TECHNICAL UNIVERSITY – SOFIA
PLOVDIV BRANCH

SIXTH INTERNATIONAL SCIENTIFIC CONFERENCE “ENGINEERING, TECHNOLOGIES AND SYSTEMS”

TECHSYS 2017

18-20 May, Plovdiv

PROCEEDINGS **СБОРНИК ДОКЛАДИ**

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ТЕХНИЧЕСКИ УНИВЕРСИТЕТ – СОФИЯ
ФИЛИАЛ ПЛОВДИВ

ШЕСТА МЕЖДУНАРОДНА НАУЧНА КОНФЕРЕНЦИЯ “ТЕХНИКА, ТЕХНОЛОГИИ И СИСТЕМИ”

ТЕХСИС 2017

18 - 20 май, Пловдив

The conference will be held within the framework of the ***Science Days of Technical University of Sofia*** under the patronage of Prof DSc Georgi Mihov - Rector of the Technical University of Sofia.

Конференцията ще се проведе в рамките на ***Дни на науката на Технически университет - София*** под патронажа на проф. дтн. Георги Михов - Ректор на Технически Унивеверситет - София.

TECHNICAL UNIVERSITY – SOFIA, PLOVDIV BRANCH

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PLENARY PAPERS • ПЛЕНАРНИ ДОКЛАДИ

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Mr Kouzou Abdellah (IEEE Senior memebr & IACSIT Senior member, IFAC,IAENG & IISRO member, IEEE-HKN Alumni Member) was born in Djelfa, Algeria in 1964. He is a collaborator researcher at Texas A&M University at Qatar. He has been the president of the Scientific council of the faculty since June 2014. He has participated in several research projects and has led several research projects. He is the founder of the Power Electronics and Power Quality research group at the Applied Automation and Industrial Diagnostic Laboratory, University of Djelfa in Algeria. He is the supervisor of many PhD Students in Algeria. He is a member of the Smart Grid Center at Qatar SGC-Q . He is a member of many editorial boards for several scientific journals and a member of the scientific and steering committees in several national and international conferences. He is the Editor-In-Chief of two journals. He is the coordinator of the Algerian IEEE Power Electronics Chapter and the chair of the sub-committee on FACTs and HVDC under the international committee PETC/IEEE-IES. He was a plenary and an invited keynote speaker and session chair in several national and international conferences and an experts in several national and international scientific activities and project evaluations.

He has published more than 160 papers, his main research interests include Active Power Filtering techniques, Power Quality issues, Power Electronics Devices, Application of Power electronics in Renewable Energies and Application of meta-heuristics optimization algorithms, Smart Grid and Smart Buildings, reliability and diagnostics in power electronics converters.

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Smart Grid and Power Electronics Integration Challenges

Abdellah Kouzou

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Abstract

Nowadays the idea of smart grid is becoming of great interest for the researchers, designers, industrial partners, the electrical energy producer, the electrical energy transporters and distributors, the consumer and the governments. Where the main objective is to provide within the existing structures of urban, electrical network and power sources, new improved quality of electrical power that can ensure several performance indicators such as the reliability, the comfort of use, the security, the safety, the privacy, the accuracy of the used technologies, the self controlling, the friendly environment interaction, the energy efficiency, the sharing of energy information within the city and the network power system for the people inside and a precise interaction among the energy producer, transporter and consumer of all levels.

Indeed, it is actually well known that the existing grid structures that are considered to be smart grid are estimated to be a complex concatenations of structures, systems and technology. Whereas; the different components used inside the considered grid have been designed, developed and improved to fulfill the requirement of the modern-day grid control. However the level reached of the grid smartness with the ensured aforementioned systems, the smart grid owners today are still having their aims passing beyond the contour of their own region and grid, indeed they want that their grid will share and interact smartly and positively with the surrounding systems, such as; the electrical power system network, the renewable energy sources, the other distributed energy systems, the communication network, the group of the buildings in the neighbor region, the city or even more, the global environment consideration etc. It can be said that to ensure the approach of interoperability between the inside systems and the outside systems many different parties are required to collaborate dynamically, accurately and seamlessly under some primordial aspects that would be achieved by smart grids, such as; the energy efficiency, the energy minimizing cost, and the energy management. On the other side, it is well obvious that the smart grids are designed initially to support many tasks based on new and advanced technologies of several domains, starting from the construction materials that can be called smart materials such as : Self-Shape-Shifting metals and Self-Healing-Materials, and other domains, especially the smart communication systems, smart meters and smart sensors.

In this context the present plenary will focus mainly on the presentation of an overview on smart grids from the traditional grid to the modernized grid, the integration of renewable energy sources and the integration of the power electronics systems, and finally the different challenges and future perspectives. The overall idea of the integration of different smart systems in smart grid will be presented in this plenary from point of view of the general research perspectives for the next generation of the smart grids based on some future perspectives, especially based on the used technologies such as smart metering, smart energy monitoring, smart power electronics devices for energy conversion and interfaces. where the main aim to give an idea to the practical researchers to go ahead for different parts of research that are giving a promising ways to obtain significant results, experimental achievement, industrial implementation and more theoretical basis.

Keywords: Smart Grid, Renewable energy, Smart meters, Smart Materials, Smart Sensors, Power electronics devices.

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CONTROL THEORY AND IT APPLICATIONS IN INFORMATION AND COMMUNICATION SYSTEMS

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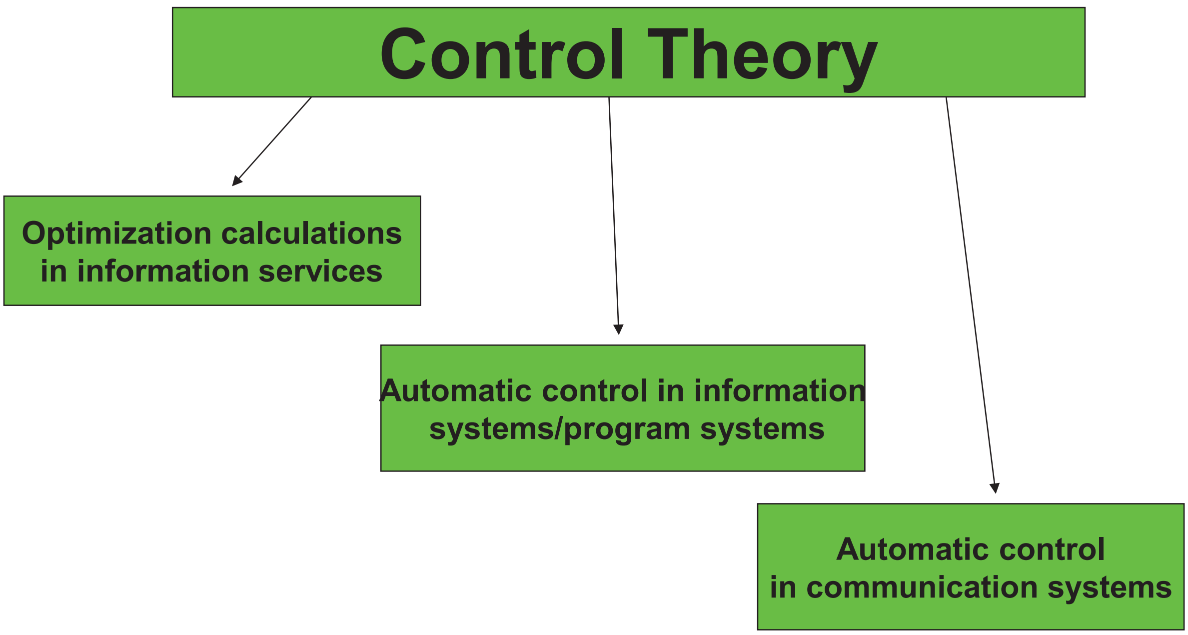
Content



SMC Industrial Automation Bulgaria
„INDUSTRY 4.0 - reality and education"

SMC International Training is the educational division of SMC Corporation, the world leader in innovation and the sales of pneumatic and electro-pneumatic components for industrial automation.

SMC International Training has a clear commitment to offer Training adapted to the needs of industry; training orientated to the development of the professional expertise required for the most diverse sectors (automotive, pharmaceutical, semi-conductors, foodstuffs, etc.)
With a global market share of 33% we are worldwide leading experts in pneumatics.
We are a strong partner to the industry and develop state-of-the-art automation solutions

- customized solutions
- innovative products
- tailor-made services

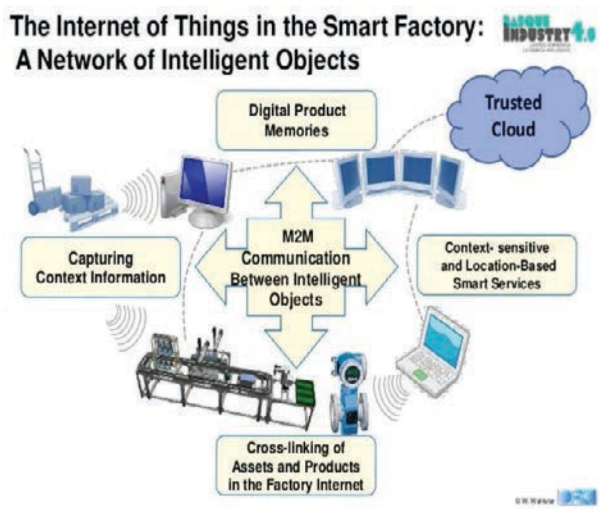
Being the world leader in pneumatics, we take pride in offering an extensive range of high quality pneumatic products; however, automation requires non-pneumatic solutions as well.
This has resulted in the development of products such as electric actuators, thermo-chillers, ionizers, ultra high purity gas and fluid control equipment, allowing SMC to offer a total solutions package
Our overall objective is to offer the highest level of support to our customers and become their sole automation supplier

SMC has a clear strategy when it comes to Industry 4.0.
We are both a leading provider and user of Industry 4.0 technologies.
We see a major need for optimization in both productivity and work schedules.

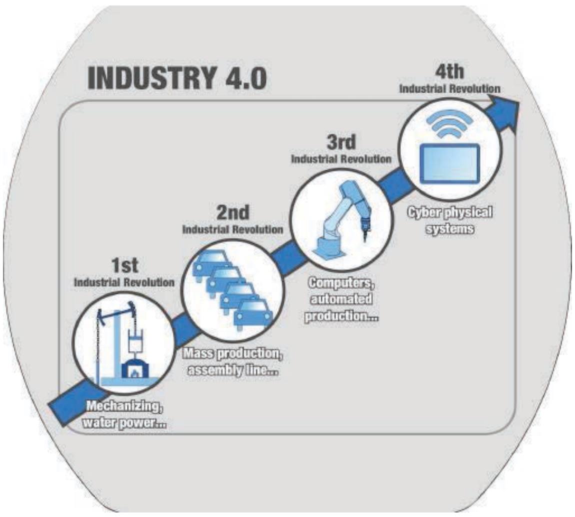
INDUSTRY 4.0 Examples

1. **MALFUNCTIONS**
   When it occurs, Malfunctions should be quickly forwarded. The system reports automatically to these responsible. The components affected are displayed in real time.
   The software assists diagnoses and provides more detailed information including details of malfunction and relevant CAD drawings, so it becomes easy to find exact faulty element and to be replaced as quick as possible
2. **PREDICTIVE MAINTENANCE**
   One of the components of Industry 4.0 is predictive maintenance with which unscheduled production stoppages can be avoided or even entirely excluded. The predictive maintenance system is capable for seeing expensive repairs or serious component failure and initiating preventive activities before greater damage occurs
3. **RAPID CHANGEOVER**
   In flexible production facilities product changeover is a rapid process. Flexible product changeover of a machine affected without setup delays by means of higher level control system such a MES or ERP.
   This means that the machine can produce various products in batches of any size.

   In the domain of Industry 4.0, SMC consistently expends its portfolio in the direction of distributed intelligence and Rapid networking. The goal here is to connect the system horizontally or vertically. We're thereby enable users to optimize their production processes constantly



The content-related drivers for the advance of Industry 4.0 solutions require interlinking of different disciplines that, even though known, have so far been viewed in isolation.
In order to be able to fulfill increasing requirements for production systems and machines, numerous generally known catchwords are known:
AUGMENTED REALITY
OPTIMIZATION,
DIGITAL COMUNICATIONS,
BIG DATA HANDLING,
SMART SERVISE,
INDIVIDUALIZATION,
COST REDUCTION,
REAL TIME REPORTING,
MALFUNCTIONS, PREDICTIVE MAINTENANCE, RAPID CHANGEOVER….



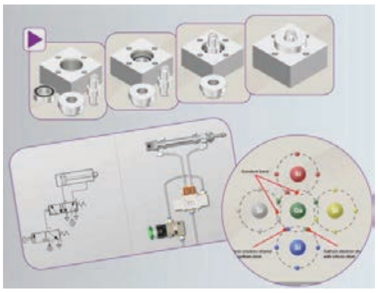
INDUSTRY 4.0 is a term generated by German Federal Government in 2011 as a High-Tech Strategy for increasing Manufacturing of German companies with focus of highly customized products.
Current usage of the term as the **4-th Industrial Revolution** has been criticized as meaningless
.
What is happened in the industry in a past 50 year is constant **EVOLUTION** and **INOVATION**, but still is not REVOLUTION.
Nevertheless, the term become popular worldwide and have been used as key target for many production companies.

Nevertheless- **Industry 4.0**, **Machine-to-Machine (M2M)**, **SMART FACTORY**, **Internet of Things (IoT)**, **Internet of Service**, **Cyber-physical systems**, **Supply-Chain-Real-Time** or whatever you like to call it, It's not just about generating business value, it's not about saving or earning money in the first place! It's much more about customization, innovation and finding (or creating) new needs!
It's about **CREATIVITY**. And let not forget – Creativity still is exceptional Human property.

And there is a **BIG Question** – How the education system should be adapted to modern requirements of the industry?
Can we create Creative People in high schools and universities?
The direct answer of this question is **"NO"** as the people a creative as they are by origin. But what the education can do with no doubt is to create an appropriate environment to develop student's creativity.
Of course, first basic knowledge of technologies and particular skills should be created and developed

Training solutions, adapted to the modern industry demands

Based on our leading position, experience and knowledge, SMC developed series of designed for Technical High Schools and Technical Universities Training solutions, adapted to the modern industry demands



eLEARNING-200 - The perfect theory companion
eLEARNING-200 is a flexible learning system where knowledge can be acquired dependant on the user's available time and requirements. Students have the option to take actual classes and additional Internet courses when this suits them best.

To be able to develop different technology skills, theoretical knowledge must be acquired first. SMC International Training presents the eLEARNING-200 course programs the perfect complement to our didactic equipment.

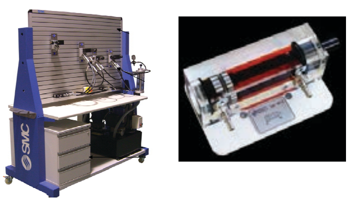
eLEARNING-200 offers a total of 13 courses based on the automation pyramid, covering technologies in automated systems.

- SMC-100 – Introduction to industrial automation
- SMC-101 – Principles of pneumatics
- SMC-102 – Introduction to electricity
- SMC-103 – DC electricity
- SMC-104 – AC electricity
- SMC-105 – Solid state
- SMC-106 – Introduction to wiring
- SMC-107 – Introduction to electric motors
- SMC-108 – Sensors technology
- SMC-109 – Programmable controllers
- SMC-110 – Process controls
- SMC-111 – Hydraulics / electrohydraulics
- SMC-113 – Robotics

A. Training systems in different technologies:

PNEUMATICS AND ELECTROPNEUMATICS and VACUUM

PNEUMATE-200, PNEUTRAINER 200, VAC 200
Small-sized, light and portable training equipment that includes extensive features which provide an enjoyable and rapid way of acquiring the fundamental concepts of pneumatics and electro-pneumatics.



HYDRAULICS

HYDROTRAINER, HYDROMODEL
Fully modular systems designed for the development of professional skills



ELECTRICAL DRIVES, SENSORS, LASER, OPTICS, ARTIFICAL VISION
ELECTRICAL PANELS, IDENTIFICATION SYSTEMS, PROGRAMMING COBTROLLERS

B. **Training systems with INTERACTIONS OF TECHNOLOGYES:**

AUTOMATION, MANIPULATION, SCADA
FMS 200

ROBOTICS, HMI, MOTION CONTROL
FAS 200

ROBOTICS, HMI, MOTION CONTROL, ERP, MES
HAS 200

C. **INDUSTRY 4.0 in education = CREATIVITY ENVIRONMENT**

We know what is Creativity – Knowledge-of-Ideas, Freedom of Thinking, Open Space in Mind, Connectivity, Smart and variable tools, Suitable environment…

Everything is providing by SiF4o0

The Connected Enterprise Reality makes all this possible. It converges plant-level and enterprise networks, and securely connects people, processes, and technologies

SiF400 has been designed to emulate Industry 4.0's automated smart factory that includes technologies, advanced manufacturing concepts and connected enterprise reality. The training system is optimized to unpack Industry 4.0, enabling organizations to – with minimal disruption – amend their factory operations.

Industry 4.0's smart factory includes cyber-physical systems that control the physical processes of the factory and make decentralized decisions. Essentially, these physical systems become Internet of Things (IoT), communicating and cooperating both with each other and with humans in real time via the wireless web
The modular features of all training equipments enable the introduction of variations in its stations so that they adapt to the different requirements of companies and training centers.

From a simple configuration of one station only (working fully autonomously) to a complex configuration with eight, ten or more stations, the possibilities are endless.

In addition, it facilitates a staggered investment, i.e. starting with an initial simple configuration which can be easily enhanced by adding workstations.

All the components in the systems **are used in industry**, so that the students can work with real elements at all times making the learning process more meaningful.

The system includes a whole series of feeding, handling, verification and loading operations etc. carried out using components from different technologies (**pneumatics, hydraulics, sensors, robotics, communications, control and HMI**).They includes the breakdown simulation system which generates up to 16 different breakdowns to be diagnosed by the students.

The combination of all these possibilities means that a lot of different assemblies can be obtained enabling the use of production management strategies.
The control panels are completely modular and can be rapidly disassembled so the students can design and integrate a new control.

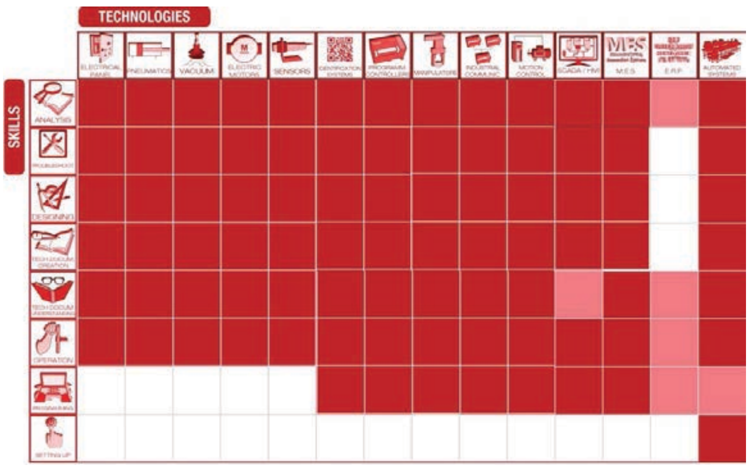
Aspects such as aesthetics, user motivation and the development of transversal skills (such as teamwork etc.) have also been taken into account in the conception and design process.

At university level, these systems represent a powerful development platform for research projects.

Every Training System includes complete documentation, oriented to the development of the professional skills. The documentation includes:

USER's MANUAL, THEORY MANUAL, EXERCISES MANUAL (STUDENT and PROFESSOR)

The acquired skills in different technologies when students use the SMC training equipments are represented in SKILLS/TECHNOLOGIES table.



18.05.2017,
Sofia, Bulgaria

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SECTION 1 • СЕКЦИЯ 1

AUTOMATION AND CONTROL SYSTEMS

АВТОМАТИКА И СИСТЕМИ ЗА УПРАВЛЕНИЕ

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FUZZY MODELING AND SIMULATION OF GAS TURBINE USING FUZZY CLUSTERING ALGORITHM

ABDELHAFID BENYOUNES [(1)], AHMED HAFAIFA [(1*)], ABDELLAH KOUZOU [(1)], MOULOUD GUEMANA [(2)]

Abstract: *Gas turbines are one of the major parts of modern industry. They have played very important role in aeronautical industry, power generation and main mechanical drivers for large pumps and compressors. This study addressed the modeling and the simulation of the Industrial Gas Turbine GE ms5001P, located in the electrcal production station of M'sila in Algeria. The used method for modeling of this gas turbine is based on fuzzy inference system with the use of Gustafson-Kessel clustering (GK) algorithm.*

Key words: *Gas turbine modeling; fuzzy modeling; fuzzyinference system; GK clustering algorithm*

1. INTRODUCTION

Currently, the development of mathematical models for the representation and approximation of complex nonlinear systems is an essential subject in several engineering disciplines. The need for a strong understanding of physical phenomena in industrial systems is a great restriction at the practical level when dealing with complex non-linear systems. Indeed, the equation of the laws governing such systems generally leads to a too complex model of knowledge and its implementation is delicate. In this case, the use of modeling techniques developed from the input / output measures collected on the system is required.

For this reason, this work relies on fuzzy logic and its tools to present a complete and integrated approach to solve all the problems encountered in the use of classical modeling and control methods. The problem of exploiting fuzzy models based on Takagi-Sugeno approach, using input / output data collected on the system being tested, for a gas turbine system application.

Indeed, Takagi-Sugeno fuzzy modeling is a universal approximation of real systems, which has shown these efficiencies in several applications in the literature [17, 24, 28, 32, 38, 81, 86]. In 1985 Takagi and Sugeno proposed the use of properties of fuzzy sets and the use of rules in a fuzzy model (TS fuzzy model). Since then, the fuzzy model of Takagi and Sugeno TS has proved its effectiveness in the study of many other nonlinear dynamic systems. Conversely, conventional approaches use a single model to describe the overall behavior of a nonlinear system, whereas fuzzy Takagi and Sugeno TS models essentially use a multi-model approach, in which the simple sub-models are linear and are combined between them, for the purpose of describing the overall non-linear system behavior.

This strong property of fuzzy models of type Takagi and Sugeno can be applied in several dynamic systems modeling applications, that can be described by differential equations. In this paper, fuzzy identification and modeling from experimental data will be presented to approximate nonlinear systems. In this framework, this work is intended for the design of an original method for the identification and modeling of industrial systems, with a view to its application to a gas turbine system. This model was trained by use of real operational data of a GE MS5001P gas turbine used for electrical energy production.

2. PROCESS DESCRIPTION

The GE MS 5001P gas turbine engine is made of three main sections [1]: the axial compressor, the

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combustion chamber and the turbine. There is a variable inlet guide vane (IGV) in the inlet of the axial compressor and a variable nozzle guide vane (NGV) in the turbine section [3]. In other part, two valves are used as the main controlling devices of the gas turbine located on the inlet fuel line of the combustion chamber, the first one is for the control of the inlet fuel pressure which called the stop ratio valve (SRV) and the second, the most important one, is used for governing the speed of the load shaft this one called the gas control valve (GCV). The figure (figure.1) represents the schematic of the gas turbine system.

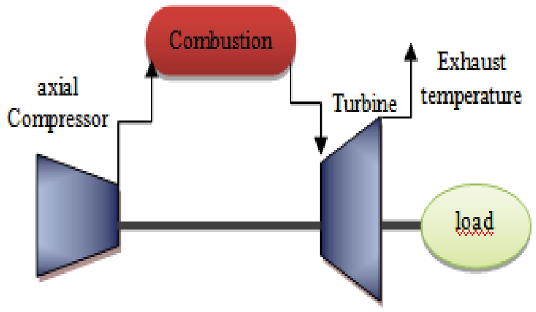

Fig. 1. Signal shaft gas turbine GE MS 5001P

The gas turbine under investigation in this work is the GE MS 5001P industrial gas turbine specifically, this turbine is designed for mechanical drive applications with a wide operating speed range to meet operating conditions of the most common driven equipment In our case it is used as an turbo generator in the M'sila electrical production station located in M'sila –Algeria (figure 2). The design point specifications of this gas turbine are presented in Table I. The detailed information can be found in the product manuals.

Fig. 2. M'sila electrical production station

***Table 1.** Examined gas turbine specifications parameters*

Quantity	Value
Compressor stage	16
Firing temperature	1.730 (F°)
Exhaust temperature	898 (F°)
Air flow	928.5 (Lb/hr)
Output	24,700 (kw)
Heat rate	12,950 (kJ/kW-h)

A. Nonlinear System Modeling

The fuzzy modeling from experimental data are effective tools to approximate a non-linear system. Among the models are widely used in the modeling techniques we find those of Takagi-Sugeno (TS) [12, 15].

A TS model uses the idea of linearization of the fuzzy regions in the state space. Based on these regions fuzzy, a non-linear system can be decomposed into a multi structure models consisting of several linear models which are not necessarily independent [2]. The fuzzy sets premises partition the input space in a number of fuzzy regions, while the functions consequences describe the behavior of the system in these regions. The fuzzy model TS is generally built in two steps:

Step 1: Determine the membership functions (MFs) antecedent of the rules;

Step 2: Estimate the parameters of the functions consequences.

One of the techniques used to achieve the first step is the fuzzy clustering, in this paper apply the Gustafson-Kessel (GK) algorithm.

B. Gustafson-Kessel algorithm

The GK algorithm constitutes a reference among the different among different methods of fuzzy classification based on minimizing the objective function of the form:

$$J_{FCM}(Z;U;V) = \sum_{i=1}^{c} \sum_{K=1}^{N} (\mu_{ik})^m D_{ikA}^2 \qquad (1)$$

Where Z is the data set, $U = [\mu_{ik}]$ is the matrix of fuzzy partition (size $C \times N$) and $V = [v_1, v_2, \ldots, v_c]$

is the vector of the center of classes to be determined with $v_i \in \Re^n$ the center of the i^{th} class $1 \prec i \prec c$, $m \in [1,+\infty]$ is a factor that denotes the degree of fuzziness of the partition.

The standard quadratic distance in space in question, which defines the distance measure between the Z_k observation and the v_i center within the meaning of the metric induced by *A*.

Gustafson and Kessel in employing a standard of adaptive distance in the purpose of detecting of classes of different geometrical shapes in a set of data. In this case, each class has its own matrix of standard, which leads to:

$$D_{ikA}^2 = \|z_k - v_i\|_A^2 = (z_k - v_i)^T A_i (z_k - v_i) \quad (2)$$
$$1 \le i \le c, 1 \le k \le N$$

It is assumed that the matrix A_i tested the hypothesis:

$$|A_i| = \rho_i \ , \ \rho_i > 0 \quad (3)$$

Where ρ_i is fixed for each class.

In this case, the optimization of (1) gives us the following expression for A_i :

$$|A_i| = [\rho_i \det(F_i)]^{\frac{1}{n}} F_i^{-1} \quad (4)$$

Where F_i is the covariance matrix blurred the i-th class given by:

$$F_i = \frac{\sum_{K=1}^{N} (\mu_{ik})^m (z_k - v_i)(z_k - v_i)^T}{\sum_{K=1}^{N} (\mu_{ik})^m} \quad (5)$$

In the equation (1), the measurement of non-similarity is expressed by of the sum of squares of distances between each data vector and the center of the corresponding class. The effect of this distance is weighted by the degree of activation μ_{ik}^m corresponding to the Z_k data vector, the value of the cost function $J_{FCM}(Z;U;V)$ can be seen as a measure of the total variance of Z_k with respect to the v_i centers. The minimization of the objective function (1) is given as flows:

$$\mu_{ik} = \frac{1}{\sum_j^c 1 \left(\frac{D_{ikA}}{D_{jkA}} \right)^{\frac{2}{m-1}}} \qquad 1 \le i \le c, 1 \le k \le N$$
$$v_i = \frac{\sum_{K=1}^{N} (\mu_{ik})^m z_k}{\sum_{K=1}^{N} (\mu_{ik})^m} \quad (6)$$

This leads to the GK algorithm given in three steps:

Step 1: Calculate the cluster centers

$$v_i^l = \frac{\sum_{K=1}^{N} (\mu_{ik}^{(l-1)})^m z_k}{\sum_{K=1}^{N} (\mu_{ik}^{(l-1)})^m} \qquad 1 \le i \le c$$

Step 3: Calculate the covariance matrix

$$F_i = \frac{\sum_{K=1}^{N} (\mu_{ik}^{(l-1)})^m (z_k - v_i^{(l)})(z_k - v_i^{(l)})^T}{\sum_{K=1}^{N} (\mu_{ik})^m}$$

Step 3: Calculate the distances

$$D_{ikA}^2 = (z_k - v_i^l)^T A (z_k - v_i^l) \qquad 1 \le i \le c, 1 \le k \le N$$

Step 3: Update the partition matrix

If $D_{ikA}{}^2 > 0$ *for* $1 \le i \le c, 1 \le k \le N$

$$\mu_{ik}^{(1)} = \frac{1}{\sum_j^c 1 \left(\frac{D_{ikA}}{D_{jkA}} \right)^{\frac{2}{m-1}}}$$

Otherwise $\mu_{ik}^{(1)} = 0$ if $D_{ikA} > 0$ and $\mu_{ik}^{(1)} \in [0,1]$

with $\sum_i^c \mu_{ik}^{(1)} = 1$ too $\|U^{(l)} - U^{(l-1)}\| < \varepsilon$.

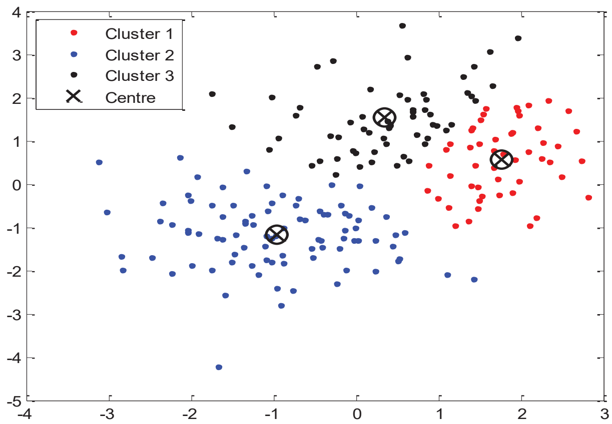

Fig. 3. *Gustafson Kessel clustering algorithm*

C. *Construction of Takagi-Sugeno models*

Consider a system described by the equation (7) :

$$y_k = f_{NL}(x_k) \qquad (7)$$

Our objective is to approximate the nonlinear function f_{NL} of equation (7) by Takagi-Sugeno model (TS):

$\mathrm{R_i}$:if x_1 is A_{i1} and x_2 is A_{i2} and … x_p is A_{ip}

Then $y_i = a_i x + d_i \quad i = 1,\ldots,r$

$a_i^T = [a_1, a_1, .a_{in}]$ With $\mathrm{R_i}$ represents the $i^{iéme}$ rule

$x = [x_1, x_1, .x_n]$ Vector of observations

A_{i1}, A_{i2},…, A_{in} : Represents the fuzzy sets,

y_i : represent the output of $i^{iéme}$ rule $a_i \in R^p$ is the vector of parameters and d_i is scalar .

The determination of f_{NL} is done in two steps:

Step1. It starts first of all by apply the clustering algorithm Gk, in order to calculate the matrix of fuzzy partition U.

Step 2. We then estimate the parameters a and b . In effect, the method of defuzzification used in the model of Takagi-Segeno, is linear in relation to the parameters. However, these parameters can be estimated by using the techniques of least-squares.

3. GAS TURBINE SYSTEM MODELING

In this study, the identification of gas turbine system is carried out in closed loop, or the control type is isochronous, the use of an open-loop procedure for identification is not preferred. The outputs inputs data have to be correlated together and generated in normal operating conditions during 5 hours and half, the inputs parameters are axial compressor discharge pressure and temperature (PCD)(TCD), Gas control valve opening (GCV), and the outputs are the speed of the turbine and Exhaust temperature (ET) Figure(4).

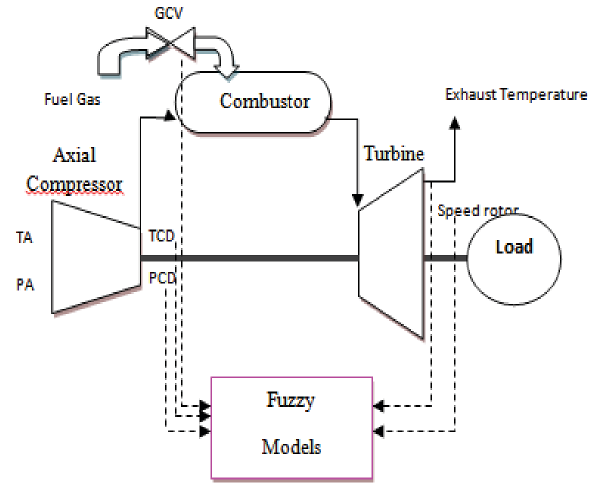

***Fig. 4.** Examined gas turbine inputs and outputs used in modeling*

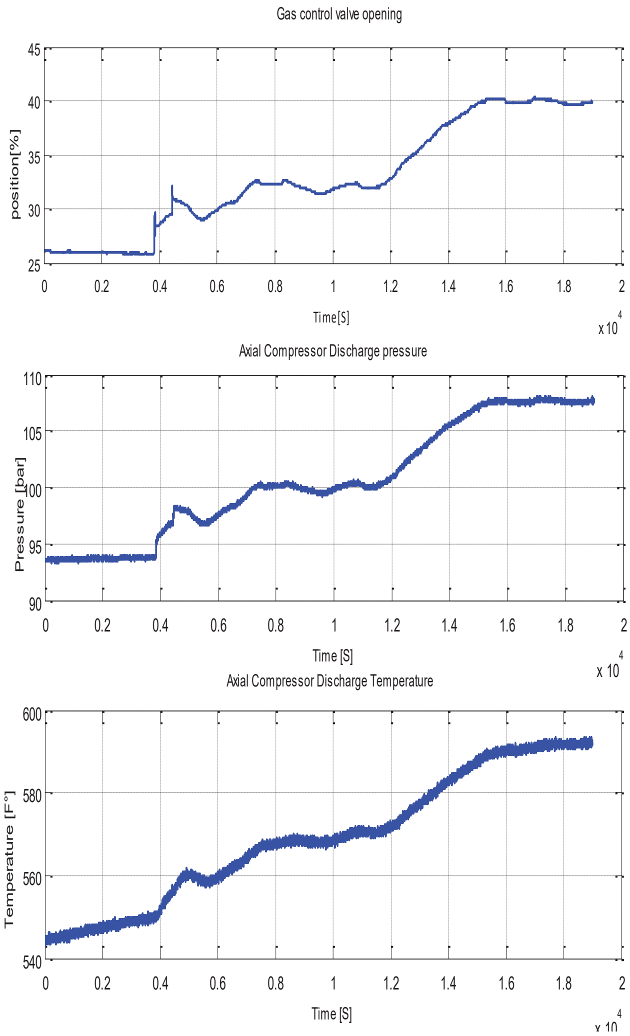

***Fig. 5.** Validation data of the examined gas turbine inputs*

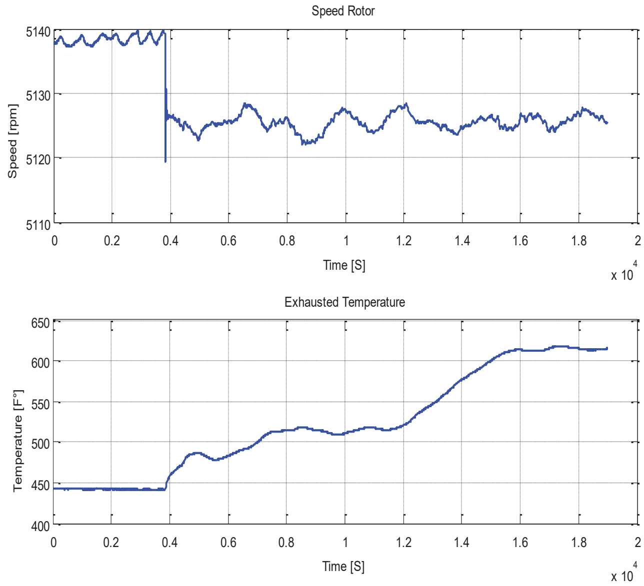

Fig. 6. Validation data of the examined gas turbine outputs

The obtained result of this simulation is shown in Figures 7 and 8 representing respectively the two main outputs of the fuzzy models ; speed turbine and exhausted temperature. Figure 9 and 10 shown the membership functions used in fuzzy models.

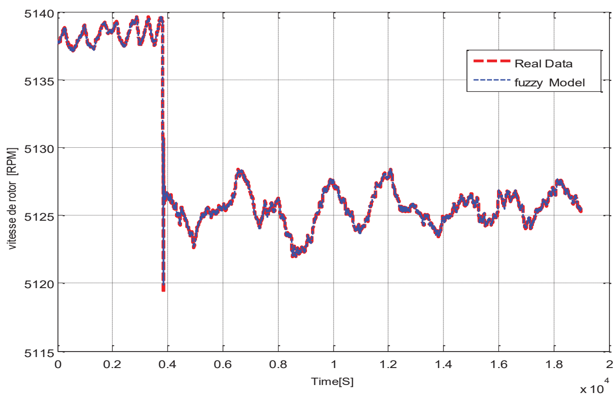

Fig. 7. Variation of obtenied model of speed rotor

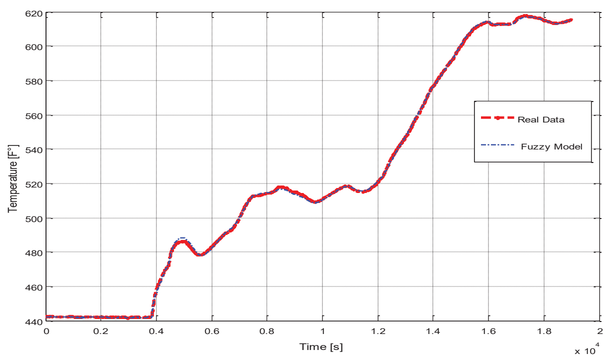

Fig. 8. Variation of obtenied model of the exhaust temperature

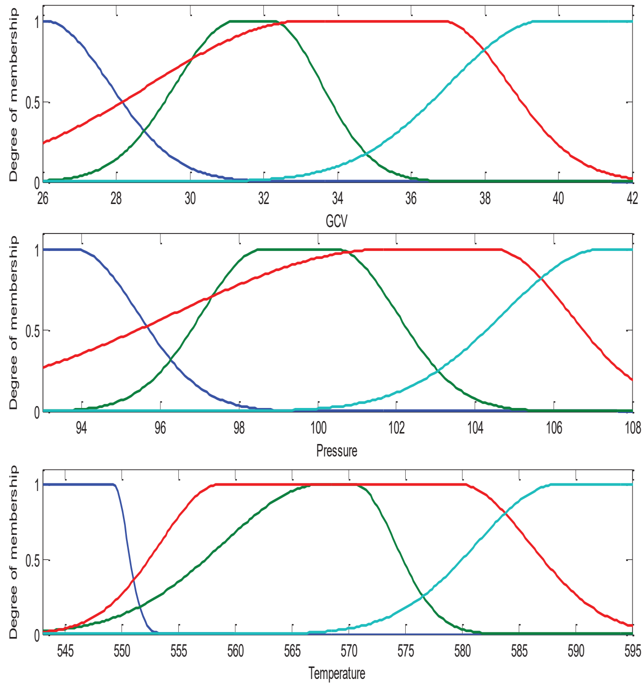

Fig. 9. Membership functions used in fuzzy models inputs

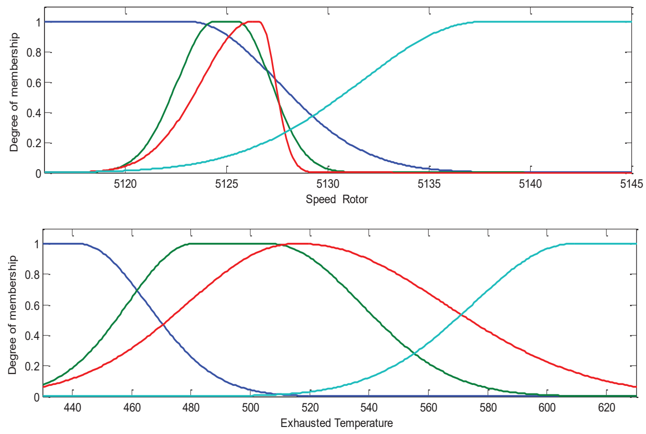

Fig. 10. Membership functions used in fuzzy models outputs

The parameter used for the numeric validation is the root-mean-square error (RMSE). and is shown in Table II.

D. Root mean square error (RMSE)

The RMSE is a frequently used measure of the difference between values predicted by a model and the values observed from the environment that is being modeled. These individual differences are also called residuals.The RMSE of a model prediction with respect to the estimated variable X model is defined as the square root of the mean squared error, given by:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}{n}} \quad (8)$$

Table 2. *Table I: RMSE comparison between the two model*

	Gas turbine parameter	
Model type	LP shaft speed	ET system
Fuzzy model	0,0076	0,011846

4. CONCLUSION

This work has addressed one of the major problems when looking for a reliable mathematical representation; the proposed Fuzzy model provides a good improvement in performance during its operation in the examined gas turbine. The use of a GK fuzzy clustering algorithm has the important advantage to allow the automatic generation of membership functions of fuzzy regions from studied data. This work, confirm that the development of digital approach is obviously More flexible to implement. The obtained results from data classification with the associated models construction offer advantageous performance in modeling of the examined gas turbine system. This approach can provide reliable models for controlling the gas turbine and system Fault diagnosis.

REFERENCES

1. Abdelhafid Benyounes, Ahmed Hafaifa and Mouloud Guemana, Fuzzy logic addresses turbine vibration on Algerian gas line. Oil & Gas Journal, 2016, vol. 114, no. 1, pp. 22-28.
2. Abdelhafid Benyounes, Ahmed Hafaifa and Mouloud Guemana, Gas turbine modelling based on fuzzy clustering algorithm using experimental data. Journal of Applied Artificial Intelligence, Taylor & Francis, 2016, vol. 30, no. 1, pp. 29-51.
3. Abdelhafid Benyounes, Ahmed Hafaifa, Abdellah Kouzou1 and Mouloud Guemana, Gas turbine modeling using adaptive fuzzy neural network approach based on measured data classification. Mathematics-in-Industry, Case Studies, vol.7, no.4, Springer 2016, DOI 10.1186/s40929-016-0006-3.
4. Ahmed Boubenia, Ahmed Hafaifa, Abdellah Kouzou, Kamal Mohammedi and Mohamed Becherif, Carbone dioxide capture and utilization in gas turbine plants via the integration of power to gas. Petroleum Journal, March 2017,
5. Ahmed Hafaifa, Guemana Mouloud, and Belhadef Rachid, Fuzzy Modeling and Control of Centrifugal Compressor Used in Gas Pipelines Systems. Multiphysics Modelling and Simulation for Systems Design and Monitoring, Book Chapter, Applied Condition Monitoring vol. 2, 2015, pp.379-389.
6. Babuška R., Verbruggen H.B., Identification of composite linear models via fuzzy clustering. Proceedings of the European Control Conference, Rome, Italy, 1995, pp. 1207–1212.
7. Babuška Robert, Fuzzy modeling for control. International Series in Intelligent Technologies, Volume 12, Kluwer Academic, Publishers Norwell, MA, USA, ISBN: 0792381548, 9780792381549, 1998.
8. Balazs Feil, Janos Abonyi, Ferenc Szeifert, Model order selection of nonlinear input–output models: A clustering based approach. Journal of Process Control, 2004, vol. 14, no. 6, pp. 593-602.
9. Berchtold M., Riedel T., Decker C. and Van Laerhoven K., Gath-Geva specification and genetic generalization of Takagi-Sugeno-Kang fuzzy models. IEEE International Conference on Systems, Man and Cybernetics. 2008, vol. SMC 2008, pp. 595 – 600.
10. Bezdek J.C. and Dunn, J.C., “Optimal Fuzzy Partitions: A Heuristic for Estimating the Parameters in a Mixture of Normal Distributions”. IEEE Transactions on Computers, 1975, vol. C-24, no. 8, pp. 835 – 838.
11. Bezdek J.C. and Dunn, J.C., Optimal fuzzy partitions: A heuristic for estimating the parameters in a mixture of normal distributions. IEEE Transactions on Computers, 1975, vol. C-24, no. 8, pp. 835 – 838.
12. Buckley J.J., Universal fuzzy controllers. Automatica, 1992, vol. 28, no. 6, pp. 1245–1248.
13. Enrique H. Ruspini, A new approach to clustering. Information and Control, 1969, vol. 15, no. 1, pp. 22–32.
14. Ford C.L., Carrotte J.F., Walker A.D., The application of porous media to simulate the upstream effects of gas turbine injector swirl vanes. Computers & Fluids, 2013, vol. 77, pp. 143-151.
15. Günyaz Ablay, A modeling and control approach to advanced nuclear power plants with gas turbines. Energy Conversion and Management, 2013, vol. 76, pp. 899-909.

16. Gustafson D.E. and Kessel W.C., Fuzzy clustering with a fuzzy covariance matrix. Proceedings of IEEE Conference on Decision and Control including the 17th Symposium on Adaptive Processes, 1978, vol. 17, Part 1, pp. 761 – 766.
17. Kulikov G.G. and Thompson H.A., Dynamic modeling of gas turbines. Book, 1st edition 2004, London, Springer.
18. Mohamed Ben Rahmoune, Ahmed Hafaifa, Mouloud Guemana, Fault Diagnosis in Gas Turbine Based on Neural Networks: Vibrations Speed Application. Book Chapter in Advances in Acoustics and Vibration, Volume 5 of the series Applied Condition Monitoring pp 1-11, on line. 02 September 2016, ISBN: 978-3-319-41458-4, 2017.
19. Nadji Hadroug, Ahmed Hafaifa, Abdellah Kouzou and Ahmed Chaibet, Faults detection in gas turbine using hybrid adaptive network based fuzzy inference systems to controlling there dynamic behavior. DIAGNOSTYKA the Journal of Polish Society of Technical Diagnostics (PSTD), 2016, vol. 17, no. 4, pp. 3-17.
20. Nadji Hadroug, Ahmed Hafaifa, Kouzou Abdellah and Ahmed Chaibet, Dynamic model linearization of two shafts gas turbine via their input / output data around the equilibrium points. Energy Elsevier Journal, 2016, DOI: http://dx.doi.org/10.1016/j.energy.2016.11.099
21. Rowen W.I., Simplified mathematical representations of heavy duty gas turbines. ASME J. Eng. Power, 1983, vol. 105, pp. 865–869.
22. Ruano, A. E., Fleming, P. J., Teixeira, C., Rodrı Guez-V azquez, K., and Fonseca, C. M., Nonlinear identification of aircraft gas turbine dynamics. Neurocomputing, 2003, vol. 55, no. 3–4, pp. 551–579.
23. Setnes M., Babuška R., Verbruggen H.B.,Complexity reduction in fuzzy modeling. Mathematics and Computers in Simulation, 1998, vol. 46, no. 5–6, pp. 507-516.
24. Takagi T. and Sugeno M., Fuzzy identification of systems and its applications to modelling and control. IEEE Transactions on Systems Man and Cybernetics, 1985, vol. SMC-15, no. 1, pp. 116 – 132.

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POWER PLANT SYSTEM IDENTIFICATION BASED ON EXTENDED LEAST SQUARE KRONECKER OPERATOR

BACHIR NAIL[1], ABDELLAH KOUZOU[1], AHMED HAFAIFA[1], AHMED CHAIBET[2]

Abstract: *This paper focuses on finding an approximate Multivariable Output-Error (MIMO OE) model of energy process (power plant) based on experimental information acquired on site. In order to obtain the parametric model, the Extended Least Square with the help of the Kronecker Operator (ELSK) and the Left Matrix Fraction Description (LMFD) theory were used. four validations criteria are used in order to select the best model order, and taking into account that the model must be left coprime (no (pole/zero) cancellation). With the objective to prove the reliability of this model and the estimator, a comparative study with recent estimation algorithm was conducted, such as: Multivariable Output Error State Space (MOESP) and with artificial intelligent model, Adaptive Neuro-fuzzy Inference System (ANFIS).*

Key words: *Multivariable model, Output-error, ELSK, LMFD, Validations criteria, MOESP, ANFIS, energy process, power plant.*

1. Introduction

The implementation of a strategy of control and regulation of an industrial engineering systems requires the use of reliable models of it which can more exploitable in control. The main aime in this work is the modelling of the dynamics behavior of a energy process, based on system identification theory using experimental data. Due to the increasing complexity of this equipment and their severe operating constraints increase with their use of added values on these supervisory strategies.

In this framework, the examined system is a Turbo-alternator (gas turbine+alternator) power plant installed in unit of production of electricity in M'sila Algeria, this plant is an internal combustion engine that uses the gaseous energy of the air, converting the chemical energy of the fuel into mechanical energy, it is designed to extract, as far as possible, the energy of the fuel. Indeed, gas turbines are also called combustion turbines, are used in a wide range of applications, including power generation, natural gas transmission, as well as various process applications..etc. However, a gas turbine is an internal combustion engine, which operates with rotary motion and reciprocation. These gas turbines are essentially composed of three main elements: the axial compressor, the combustion chamber and power turbine , and alternator drived by this gas turbine (GE MS 5001P).

MANY results have been published about the modelling of gas turbine and energetic plant using largely the artificial intelligence theory (ANFIS, Fuzzy Logic and Neural Network models), for the following grounds easy to apply and unconditioned constraints in the quality and the characterisation of the data (the convergence, the smoothing and the number of samples is not required), but there are disadvantages on these models, the difficulty of controlling, and the problem of instability, also the limitations of applying the theory of advanced control for the reason of the lack of the mathematical model, majority of the researches they have been done in recent years in this area : Gas turbine modeling based on fuzzy clustering algorithm [1], Fuzzy Modeling of Centrifugal Compressor [2], Gas turbine modelling using fuzzy logic and artificial neural networks[3], and others.

Therefore, the parametric system identification theory is used to solve the problem of approximate mathematical model which has the same characterization of the empirical model, this paper dealing with the implement the theory of left matrix fraction description (MFD) to identify the behavior of the turbo-alternator plant multivariable output-error model. In the literature many paper have been done in field of the (MFD) system identification in the left and the right among them : Identification of Turbo-compressor using (LMFD)

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[4], instrumental variable identification and extending the SRIV algorithm methods for LMFD models[5],[6] , ARMAX models identification using MFD [7], and MIMO least squares using MFD [8], and others [9],[10].

In our study, the MIMO OE model is considered to represent the dynamic behaviour of energy process (Turbo-alternator) by the extended least square kronecker operator estimator based on LMFD theory, using inputs/outputs real data, the inputs signals, GCV: gas control valve, PCD: Pressure compressor discharge and TCD: Temperature compressor discharge, and the outputs signals, ET: Exhaust Temperature, RS: Rotor Speed, and PG: Power Generation, the experimental data used in this identification acquired on site of length=10000 samples in time of 167 minutes, the selection of the final model needed to the validations criteria decision, we have using four criteria (AICs, FPEs, RMSE, and VAF) [11], in order to test the ratability of the obtained model and implemented estimator a comparative study has been done with intelligent artificial model ANFIS and MOESP algorithm introduced by Katayama [12].

The paper is organized as follow: first an introduction discussed the historical and the recent development of system identification, then it is followed by the main procedure of ELSK with application on energetic plant and a discussion of the obtained results. Finally comments, perspectives and a conclusion will finish the paper.

2. System identification

A MIMO OE (output-error) model given as:

$$A(q^{-1})y[k]=B(q^{-1})u[k]+e[k] \qquad (1)$$

Can be written in LMFD form as:

$$y[k]=A(q^{-1})^{-1}B(q^{-1})u[k]+A(q^{-1})^{-1}e[k] \qquad (2)$$

Where $u[k]\in R^m$ and $y[k]\in R^p$ are inputs and outputs vectors of the system respectively, while $e[k]\in R^p$ is a white-noise signal and the polynomial matrices $A(q^{-1})$, $B(q^{-1})$ have the following structure:

$$A(q^{-1})=I_p+A_1q^{-1}+\ldots+A_{na}q^{-na} \qquad (3)$$

$$B(q^{-1})=B_1q^{-1}+\ldots+B_{nb}q^{-nb}$$

(4)

The objective is to identify the matrix coefficients $A_i\in R^{p\times p}$ and $B_i\in R^{p\times m}$ of the matrix polynomials $A(q^{-1})$ and $B(q^{-1})$.

Expanding equation (2) yields

$$\begin{aligned} y[k]=&-A_1[k-1]\ldots-A_{na}y[k-na]+\\ &B_1u[K-1]\ldots+B_{nb}u[k-nb]+e[k] \end{aligned} \qquad (5)$$

Then using the Kronecker operator we get

$$\begin{aligned}\left[I_P\otimes y[k]^T\right]col(I_P)=&-\left[I_P\otimes y[k-1]^T\right]col(A_1^T)\\ &\ldots-\left[I_P\otimes y[k-na]^T\right]col(A_{na}^T)\\ &+\left[I_P\otimes u[k-1]^T\right]col(B_1^T)\\ &\ldots+\left[I_P\otimes u[k-nb]^T\right]col(B_{nb}^T)\\ &+e[k]\end{aligned} \qquad (6)$$

Here, the col{.} operator is one which forms a vector from a matrix by stacking its columns on top of one another.

Moreover, equation (6) can be written as

$$\begin{aligned}e[k]=\Big(&\left[I_P\otimes y[k]^T\right]col(I_P)+\left[I_P\otimes y[k-1]^T\right]\\ &\ldots+\left[I_P\otimes y[k-na]^T\right]-\left[I_P\otimes u[k-1]^T\right]\\ &\ldots-\left[I_P\otimes u[k-nb]^T\right]\Big)\begin{pmatrix}col(A_1^T)\\ \vdots\\ col(A_{na}^T)\\ col(B_1^T)\\ \vdots\\ col(B_{nb}^T)\end{pmatrix}\end{aligned} \qquad (7)$$

Or simply,

$$e[k]=\left[I_P\otimes y[k]^T\right]col(I_P)-\phi_f^T[k]\theta$$

(8)

Let's define the new signals

$$y_{ff}[k]=\left[I_P\otimes y[k]^T\right]col(I_P) \qquad (9)$$

$$y_f[k]=\left[I_P\otimes y[k]^T\right] \qquad (10)$$

$$u_f[k]=\left[I_P\otimes u[k]^T\right] \qquad (11)$$

$$\hat{\theta}=\left[\Phi_f^T\Phi_f\right]^{-1}\Phi_f^TY_f \qquad (12)$$

These signals $y_{ff}[k]$, $y_f[k]$ and $u_f[k]$ belong to $R^{p\times 1}$, $R^{p\times pp}$ and $R^{p\times pm}$ respectively

$$Y_f=\begin{pmatrix}y_{ff}[1+p\times na]\\ :\\ y_{ff}[p\times N]\end{pmatrix} \qquad (13)$$

Then θ can be estimated using least squares

$$\Phi_f=\left[\Phi_{yf}\quad \Phi_{uf}\right] \qquad (14)$$

Where

$$\Phi_{uf}=\left(\begin{bmatrix}u_f\left[1+p\times(na-1),:\right]\\ :\\ u_f\left[p\times(N-1),:\right]\end{bmatrix}\ \cdots\ \begin{bmatrix}u_f\left[1+p\times(na-nb),:\right]\\ :\\ u_f\left[p\times(N-nb),:\right]\end{bmatrix}\right)\quad(15)$$

Φ_{uf} and Φ_{yf} are constructed as follows :

$$\Phi_{yf}=\left(\begin{bmatrix}-y_f\left[1+p\times(na-1),:\right]\\ :\\ y_f\left[p\times(N-1),:\right]\end{bmatrix}\ \cdots\ \begin{bmatrix}-y_f\left[1,:\right]\\ :\\ -y_f\left[p\times(N-na),:\right]\end{bmatrix}\right)\quad(16)$$

N is the number of I/O data.

3. MOESP and ANFIS Approaches

In this paper, we have conducted a comparison between our algorithm EKLS and MOESP and ANFIS approaches, and due to the lack of ability to display all the theories related to them, cite only the sources for those wishing to learn more, for MOESP algorithm introduced by Katayama [12], ANFIS, in matlab there is a interface dedicated to identify and modelling any inputs/outputs data with ANFIS, but it is limited to give a model with single output therefore we are obliged to obtain the numbers of outputs of sub-models in our case is three [3].

Fig. 1. *GE MS 5001P Gas Turbine*

4.1. Validation of the Model

The model that have been select must have order n of (3,6,9...), because each l , $l=\dfrac{n}{p}$ matrices blocks , the blocks have a dimension of 3×3, because we have m=3 inputs and p=3 outputs . The table1 shown below clarify the change of the orders n until we stop at the best one.

The system write in linear discrete-time state space Block Observable canonical Form as follow :

Table 1. *Turbo-alternator power plant model orders n and blocks l with validations criteria values*

ELSK						MOESP				ANFIS			
l	*n*	AIC	FPE	RMSE	VAF	AIC	FPE	RMSE	VAF	AIC	FPE	RMSE	VAF
1	3	2.5483	12.7855	9.65e+27	-5.59e+51	2.5769	13.156	9.44e+28	6.89e+52	-2.43	0.08	186.25	98.16
2	6	0.0453	1.0463	1.54e+5	-1.20e+6	0.0260	1.0263	2.44e+5	2.50e+6				
3	9	0.2630	1.3008	358.1150	92.4540	0.3732	1.4524	388.1250	90.3245				
4	**12**	**0.1152**	**1.1221**	**239.6157**	**96.6654**	0.1451	1.1561	248.5187	94.9854				
5	15	0.1997	1.2212	245.3060	95.4452	0.4326	1.5412	254.4860	93.0548				

4. Application

The system under examination is power plant used in the generation of electricity in unit of Sonelgaz M'sila Algeria. It consists of two main parts, first alternator which generate the electricity and trained by the the second part is the gas turbine (GE MS5001P), Figure 1 present real show of gas turbine, and the figure 2 show the schematic block diagram of Turbo-alternator with inputs/piputs position in the Turbo-alternator model, the length of the measured inputs/outputs real data used in this identification is 10^4 samples taken during 10^4 seconds.

$$\begin{cases}x(k+1)=Ax(k)+Bu(k)\\ y(k)=Cx(k)+Du(k)\end{cases}\quad(16)$$

Where

$$A=\begin{pmatrix}O&O&O&-A_4\\ I&O&O&-A_3\\ O&I&O&-A_2\\ O&O&I&-A_1\end{pmatrix},\ B=\begin{pmatrix}B_4\\ B_3\\ B_2\\ B_1\end{pmatrix},\ C^T=\begin{pmatrix}O\\ O\\ O\\ I\end{pmatrix}$$

$$D=\begin{pmatrix}0&0&0\\0&0&0\\0&0&0\end{pmatrix},I=\begin{pmatrix}1&0&0\\0&1&0\\0&0&1\end{pmatrix},O=\begin{pmatrix}0&0&0\\0&0&0\\0&0&0\end{pmatrix}$$

From the table 1, the best model having both minimums AICs/FPEs and RMSE and maximum

VAF with no Pole/Zero cancellation is the one having order n=12 with l=4 blocks.

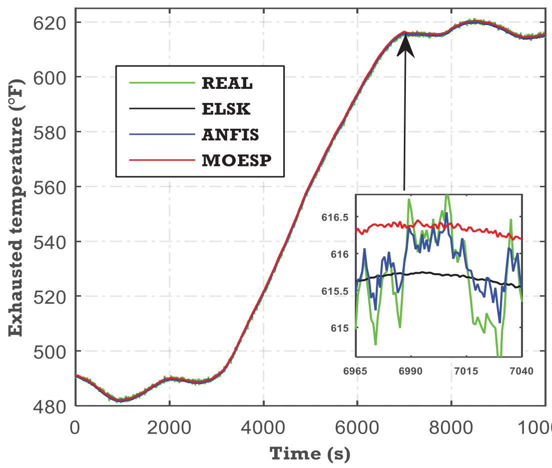

Fig. 2. Exhausted Temperature signal

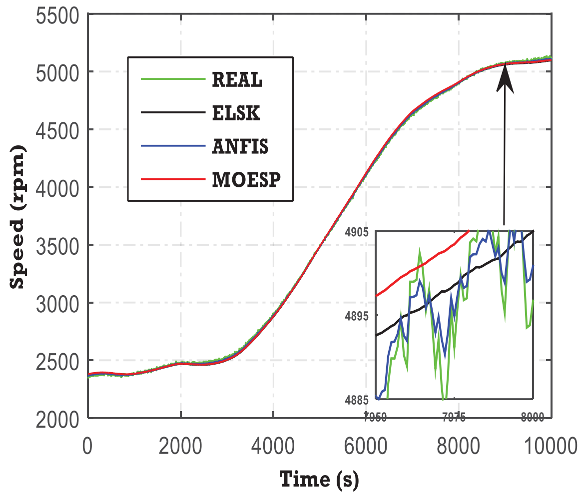

Fig. 3. Rotor Speed signal

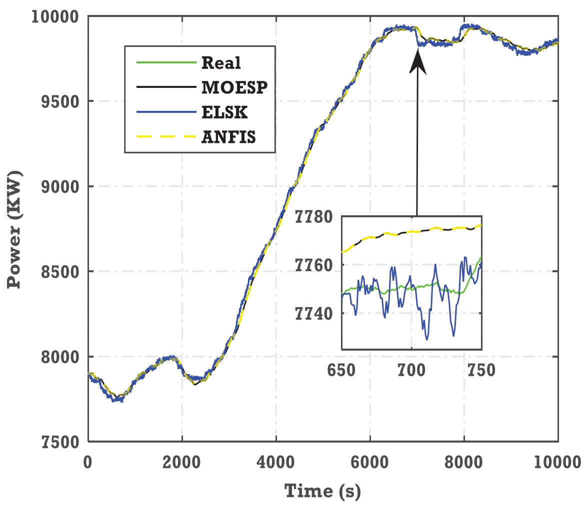

Fig. 4. Power Generation signal

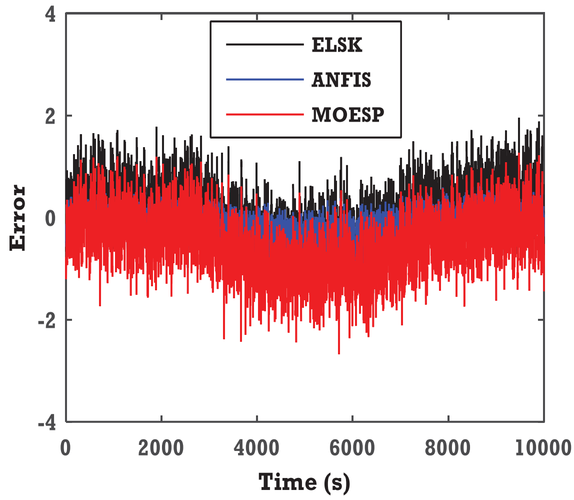

Fig. 5. Error validation of Exhausted Temperature signal

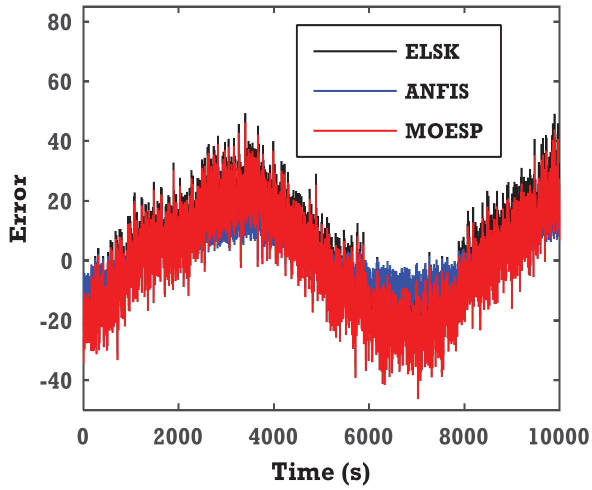

Fig. 6. Error validation of Rotor Speed signal

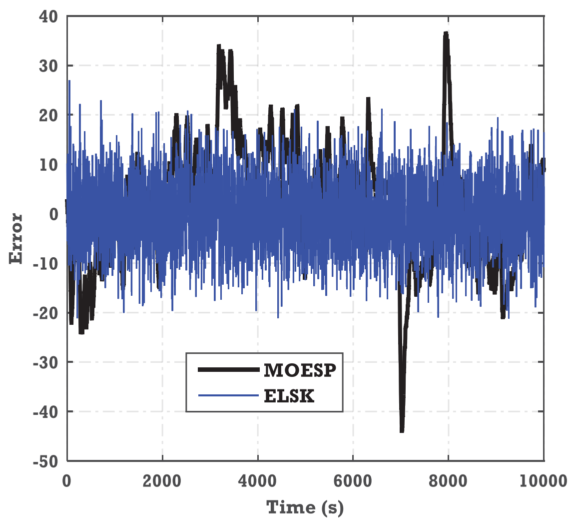

Fig. 7. Error validation of Power Generation

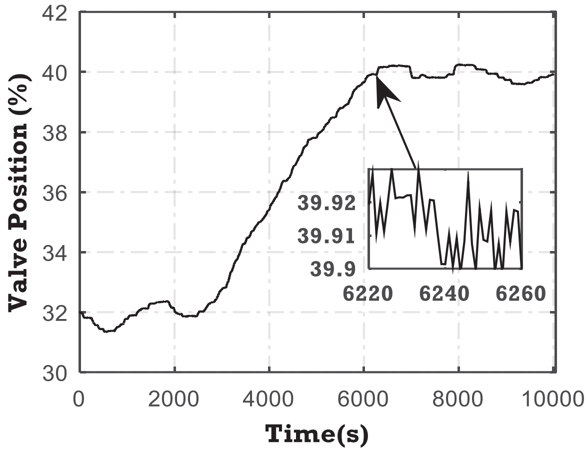

Fig. 8. *Gas Control Valve signal*

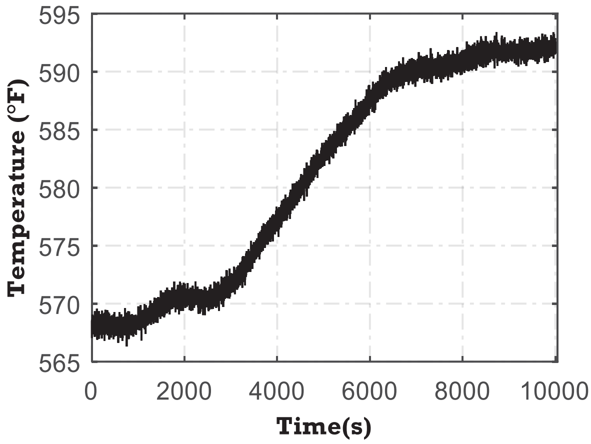

Fig. 9. *Axial Compressor Discharge Temperature signal*

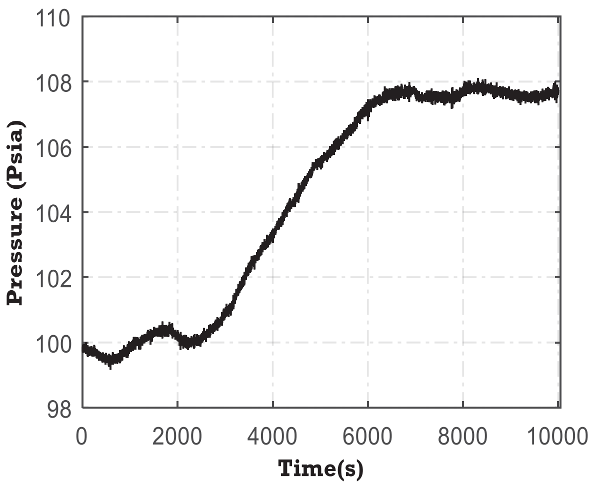

Fig. 10. *Axial Compressor Discharge Pressure*

4.1 Discussion of the obtained results

From the obtained results shown in the previous figures and due to the values numbers of the validations criteria in Table 1, can we say the obtained model is written in the block observable canonical form of index *l*=4 blocks, on the other hand by compared ELSK model with MOESP and ANFIS models, it is clear that obtained model is better than the MOESP model, and more suitable with ANFIS model, and through the figures of the outputs signals, the figures 2-4, the real signals of the exhausted temperature, rotor speed and power generation are identical with the estimated signals in all the time (0:1000) seconds and no statistical error and peak , the figures 5-7 demonstrated the convergence of the this identification (unbiased estimator), where the error converge asymptotically, the outputs signals, the figures 8-10, gas control valve, axial compressor discharge pressure, and axial compressor discharge temperature are riches with frequency which covered all the behavior of the Turbo-alternator.

Conclusion

To the best of our knowledge, this is a new contribution combined the (LMFD) theory in identification of class of MIMO OE model with the help of EKLS estimator and the first application on the energetic domain Turbo-alternator investigation, using inputs/outputs real data, based on the richest of the acquired informations with frequency about the black box (Turbo-alternator) plant, and the efficient of the kronicker product in the extended least square estimator and the flexibility of the LMFD theory all of this advantages allowed us to obtain an accurate identification and a valid and reliable model with no factors common (coprime) , this is according to the results of the validations criteria (AIC, FPE, RMSE and VAF) and the comparative study with recent MOESP algorithm which generate subspace model and with artificial intelligence model ANFIS, and recognized that they give high-fidelity models, and can say that EKLS is unbiased estimator, despite this is prejudge, due to this identification is off-line, but in our case in this work for more precision. As further works, can make this EKLS estimator in on-line system identification (recursive loop) and done a comparative study, also can applied many advanced control theory on this obtained dynamical model.

REFERENCES

1. Smith, S.E. (2004). *Name of book in italics*, page or chapter numbers if relevant. Publisher, Place of publication.
2. Brown, F., Harris, M.G., and Other, A.N. (1998). Name of paper. In Name(s) of editor(s) (ed.), *Name of book in italics*, page numbers. Publisher, Place of publication.
3. Smith, S.E. and Jones, L.Q. (2008). Name of paper. *Name of journal in italics*, volume (number), page numbers.
4. Abdelhafid Benyounes, Ahmed Hafaifa & Mouloud Guemana, Gas turbine modelling

based on fuzzy clustering algorithm using experimental data. *Journal of Applied Artificial Intelligence, Taylor & Francis*, 2016, vol. no., pp.

5. Ahmed Hafaifa, Guemana Mouloud, and Belhadef Rachid, Fuzzy Modeling and Control of Centrifugal Compressor Used in Gas Pipelines Systems. Multiphysics Modelling and Simulation for Systems Design and Monitoring, *Book Chapter, Applied Condition Monitoring*, 2015, vol. 2, pp.379-389.
6. Abdelhafid Benyounes, Ahmed Hafaifa and Mouloud Guemana, Gas turbine parameters modelling based on fuzzy logic and artificial neural networks: Solar TITAN 130N investigation. *5eme Symposium de lAssociation Algrienne de lIndustrie du Gaz AIG Sonatrach*, 16-17 Fvrier 2016, Alger.
7. Bachir Nail, Abdellah Kouzou, Ahmed Hafaifa, and Choayb Djeddi, Parametric Identification of Multivariable Industrial System Using Left Matrix Fraction Description. *J. Automation & Systems Engineering* , 10-4 (2016): 221-230.
8. Akroum, M., Hariche K., An optimal instrumental variable identification method for LMFD models, *Studies in informatics and control*, Vol 17, No.4, December 2008.
9. Akroum, M., and Hariche K., Extending the SRIV algorithm to LMFD models, *Journal of electrical engineering and technology*, Korean Instituteof electrical engineers, Vol. 4, No.1, march 2009.
10. Akroum, M., and Hariche K., A matrix fraction description-based identification algorithm for MIMO ARMAX models, submitted to *Asian journal of control*, 2008
11. R.A. de Callafon, D. de Roover, P.M.J. Van den Hof Multivariable least squares frequency domain identification using polynomial matrix fraction descriptions. Decision and Control, 1996., *Proceedings of the 36th IEEE Conference on Decision and Control*,13-13 Dec. 1996.
12. Nehorai, A., and Morf, M., Recursive identification algorithms for Right Matrix Fraction Description models . *IEEE Transactions on Automatic Control*, 29, 1103-1106, 1984.
13. R. Johansson, Multivariable system identificationvia continued-fraction approximation, *IEEE Transactions on Automatic Control*, 40(3), 507-512, 1995.
14. Ljung, L.,*System* Identification : Theory for the user (Prentice Hall),1999.
15. Katayama, T., Subspace methods for System Identification, *Springer-Verlag*, 2005.
16. Bachir Nail, Abdellah Kouzou, Ahmed Hafaifa, Belkacem Bekhiti, Parametric output feedback stabilization in MIMO systems:Application to gas turbine power plant, 8th International Conference on Modelling, Identification and Control *(ICMIC),* 971-976, November 2016.
17. L. S. Shieh and Y. T. Tsay, Transformation of a class of multivariable control systems to Block companion forms, *IEEE Truns. Autonwt. Control* 27: 199-203 (1982).
18. L. S. Shieh and Y. T. Tsay, Transformation of solvent and spectral factors of matrix polynomial, and their applications,Internat. *J. Control* 34:813-823 (1981).
19. I. Gohberg, P. Lancaster, L. Rodman, *Matrix Polynomials*,Academic Press, 1982.

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BILATERAL FILTER INTEGRATION INTO THE OPEN SOURCE SOFTWARE GELJ

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Abstract: *This paper presents the application of the computer program GelJ with additional bilateral filter implementation in the context of DNA analyses of lactic acid bacteria recombinants. The results show that GelJ could be applied for lactic acid bacteria recombinants study.*

Key words: *open source software, GelJ, DNA analyses, bilateral filter, lactic acid bacteria recombinants.*

1. Introduction

The open source software began in the late 1970s and early 1980s when the shearing of source code from a computer program and the proprietary software began to really come into conflict [1].

The term "open source software" means computer software that is made available for people to study, modify and distribute the source code to anyone and for any purpose. The copyright holder provides these rights and there is no problems for software developers to inspect, change and enhance the source code. The difference between open source software and other types of software is that the authors of open source software make its source code available to others who would like to view that code, copy it, learn from it or share it. On the other hand some software has source code that only the person or organization who created it can modify or share. Only the original authors can legally copy, inspect and alter that software.

There are different applications of open source software. In this paper is presented a computer open source program that is used for specific analyses of *Lactobacillus* recombinants in gel electrophoresis.

GelJ version *2.0* is developed by Jónathan Heras (joheras@gmail.com), César Domínguez, Eloy Mata, César Larrea, and Vico Pascual at the Department of Mathematics and Computer Science of University of La Rioja (Spain) and Mysic [2]. The program is an open source software for analyzing DNA fingerprint gel images. DNA fingerprinting is a technique for comparing DNA patterns that has applications in a wide variety of contexts [3]. There are several freely-available and commercial tools that can be used for analyzing DNA fingerprint images, but the commercial software is expensive and difficult to use in some cases. On the other hand free tools support the basic functionality for DNA analysis. So, the main advantage of GelJ is that it is free and open source software. This program is user-friendly, platform-independent and feather-weight. GelJ provides a lot of outstanding features such as digital image processing including different types of filters, mechanisms for accurate lane- and band-detection, a number of band- and curve-based similarity methods, different techniques for generating dendrograms, comparison of banding patterns from different experiments, and database support.

2. Bilateral filter

The process of filtering in terms of digital image processing is fundamental operation in the science of computer vision and image processing. The term "filtering" means that the value of the filtered image at the given location (pixel of the image) is a function of the values of the input image in a small neighborhood of the same pixel or entire image.

Bilateral filter is firstly presented by Tomasi and Manduchi in 1998 [4]. The concept of the bilateral filter has been also presented in [5] as the SUSAN filter and in [6] as the neighborhood filter.

In brief, bilateral filtering smooths images while preserving edges, by means of a non-linear combination of nearby image values. Each pixel is replaced by an average of its neighbors.

This type of filter is an effective image denoising technique and it can be used for blurring an image while respective strong edges too [4, 7]. The bilateral filter is also defined as a weighted average of nearby pixels in a manner very similar to Gaussian convolution. The difference is that the

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bilateral filter takes into consideration the difference in value with the neighbors to preserve edges while smoothing. The bilateral filter is defined by the following formula:

$$BF[I]_p = \frac{1}{W_p} \sum_{q \epsilon S} G_{\sigma_s}(\|p - q\|)\, G_{\sigma_r}(|I_p - I_q|) I_q \quad (1)$$

where I_p is notation for the gray-scale image value at pixel position p; the weight of pixel q is defined by the Gaussian $G_\sigma(\|p - q\|)$ where σ is a parameter defining the neighborhood size; s is the set of all possible image locations; r is the set of all possible pixel values. Normalization factor W_p ensures pixel weights sum to 1.0 [7]:

$$W_p = \sum_{q \epsilon S} G_{\sigma_s}(\|p - q\|)\, G_{\sigma_r}(|I_p - I_q|) \quad (2)$$

where the parameters σ_s and σ_r specify the level of filtering for the image I [7].

Median and bilateral filter are applied to an image in figure 1 (A) to yield the image in figure 1 (C).

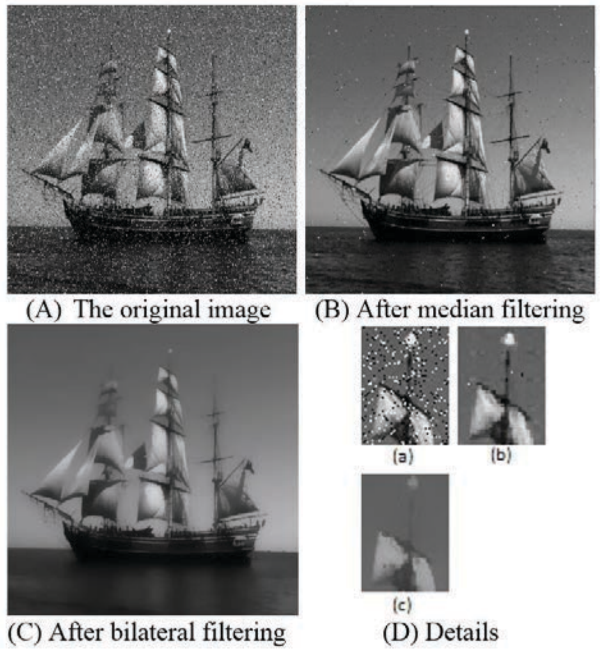

Fig. 1. *A picture before (A) and after (B) median and (C) bilateral filtering.*

The original image has salt-and-pepper noise. It can be seen that the most of the fine texture has been filtered away, and yet all contours are as crisp as in the original image. Figure 1 (d) shows a detail of figures 1 (a), 1 (b), and 1 (c).

The bilateral filter can be applied to either grayscale images and to colored images.

There are variety of applications that the bilateral filter can be used. According to the specific needs this type of filter is used for image denoising, texture and illumination separation, data fusion, 3D fairing and e.t.c. Denoising of an image is the primary goal of the bilateral filter and it is used in applications for medical image processing, tracking, movie restoration and so on [7].

3. GelJ structure and bilateral filter integration

GelJ is a software product for analyzing DNA fingerprint gel images. It is developed using the objected oriented language Java. GelJ is platform independent program because Java is platform independent language. The product provides different features for image processing using the ImageJ library [8]. On the other hand a library called Weka [9] provides variety of machine learning algorithms for data mining tasks [9, 10]. GelJ contains a special embedded database that is integrated using a library called JavaDB. GelJ has three common concepts – experiment, comparison and research. The process of making an experiment refers to analyzing the DNA fingerprints gel image provided from the biological experiment. Than the process of comparison evaluates the similarities between the samples from one or more experiments. At the end researching process collect all data from the experiments and comparisons. The main window of the GelJ program is shown in figure 2.

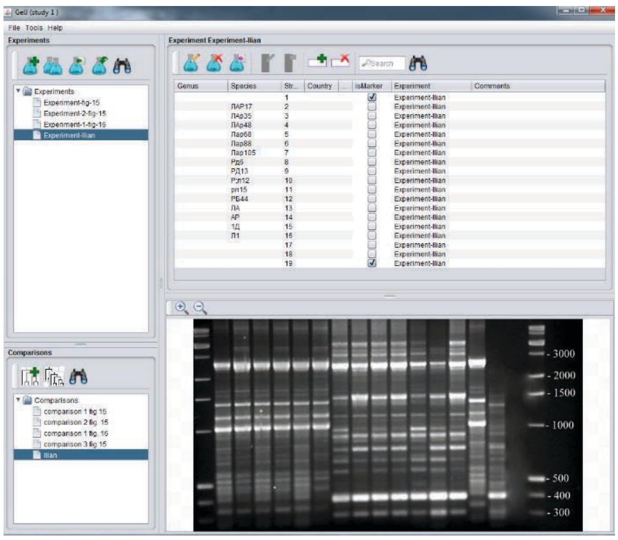

Fig. 2. *GelJ main window*

The process of making experiments consists of several steps that the user have to go through – preprocessing of the DNA fingerprint gel image, lane detection, normalization and bands detection.

Figure 3 illustrates all steps needed for gel image processing in details. On the first step the user can crop the image to cut out a specific important region. On the other hand the user can adjust brightness and contrast of the image; invert the colors and so on. The second step is lanes detection. The user have two options- automatically or manual detection. He can choose to detect the lanes automatically but after that manually editing is required. It is important to choose and mark the reference lanes. Bands detection is the third step of every analysis. First the user can automatically detect all of the bands in the entire image. For greater precision manually picking and editing the bands is required. The program provides features for adding and removing bands. The step of normalization is important for creating accurate analysis. There is a feature for adding or loading reference marker.

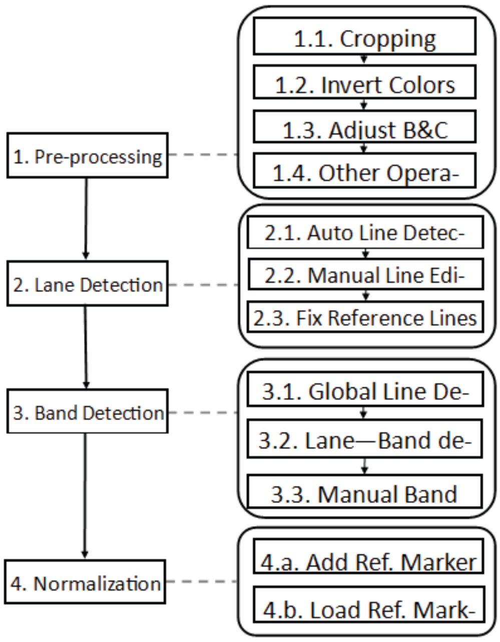

Fig. 3*. Steps needed for agarose gel image processing*

Figure 4 illustrates the user interface for selecting the bilateral filter and all of the necessary parameters.

Below are listed all of the available parameters that the user can change in order to use the bilateral filter.

Sigma Range – as the Sigma Range parameter increases the bilateral filter becomes closer to Gaussian blur.

Sigma X, Y, Z – As the spatial parameter of bilateral filter (σ_d) increases, the filter smooth larger features. In this parameter x – is the amount of pixel neighborhood in x – axis of the coordinate system; y – is the amount of pixel neighborhood in y – axis of the coordinate system; z – It is a coordinate value for smoothing 3D meshes while preserving their most prominent features [7].

Method Channels – The possible values are: 0 – Best channels; 1 – All channels; 2 – By Truncation; 3 – By Tolerance;

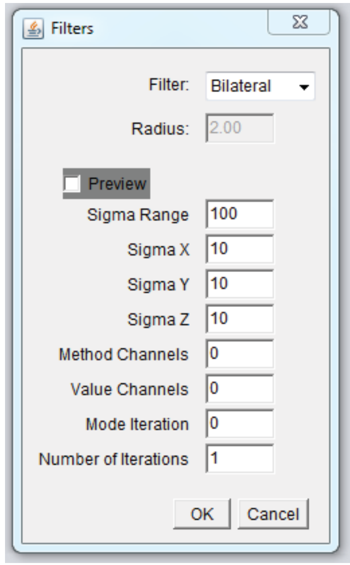

Fig. 4*. Dropdown menu for filter type selection*

Value Channels – This parameter specify the number of channels. Every image has color channels for example some colored image has 3 channels for Red, Green and Blue (RGB) components.

Mode Iteration – The bilateral filter can be iterated. The value of this field specify the iteration schema: 0 –None; 1 –Range Iteration; 2 – Space Iteration; 3 –Overall Iteration;

Number of iterations – in this field the number of iterations can be specified. Larger number of iterations leads to achieve cartoon-like renditions of images.

For integration of bilateral filter in GelJ as an additional feature *BilateralFilter_.jar* file is downloaded from:

bigwww.epfl.ch/algorithms/bilateral-filter/ [11, 12].

After that the file is included in a directory called *lib* where the external libraries are situated. In package *ij.plugin* a class named *Bilateral_Filter_Instant.java* was created. All of the necessary variables are initialized in it. They are passed to the method named *process* where the source code for implementation of bilateral filter is placed. All of the classes used in the bilateral filter library are described below.

Allocation – memory allocation for storage all intermediate result from bilateral filter.

Data – contains the input data needed for image processing.

Filter – contains the logic for image processing.

Gaussian – contains the program logic needed for the Gaussian case.

Initialization – a class responsible for initialization process of tables for *sin* and *cos*.

All of the methods that are part of the *Filter* class are listed below.

approximate() – returns three indicators on the quality of the estimate of the Gaussian function, discretized on bin items;

computeOrder() – establishing the execution order of the filter;

execute() – processing the image

selectChanels() – determines the choice of channels;

setIterativeScheme ()– determines the iterative scheme;

setLog() – specifies whether to generate a log file after treatment;

setMultithread() – determines whether the image will be processed multithreaded;

The Gaussian class implements the interface *java.lang.Runnable*. It is used following methods: *isRunning()* - to check whether it is running image processing; *run()* – for running.

4. Analyses of lactic acid bacteria recombinants

The method of agarose gel electrophoresis allows the creation of images containing valuable information for DNA analysis. Today's modern computer technologies provides variety of open source software products for creating DNA analyses easier in comparison to manual analyses.

In this research, one modern computer program for DNA analyses was used to analyze lactic acid bacteria recombinants. Randomly Amplified Polymorphic DNA (RAPD) analysis was conducted. It was used an image obtained from biological experiment. Two main primers are selected – OPP-7 and j-8 [13, 14, 15] that can work with the genomes of the couples parental strains - L. rhamnosus 1D and L. acidophilus 2; L. rhamnosus 1D and L. acidophilus Ar; L. acidophilus 2 and B. bifidum L1. The image is shown in figure 6.

After a few steps of the image pre-processing the user can continue his DNA analysis with either automatically or manually lane detection. The process of automatically lane detection often requires manually editing the height, width and position of the lanes. As a next step in the DNA analysis using GelJ takes place the procedure of bands detection. Again it can be done either manually or automatically. In the most cases the user have to do this manually for greater accuracy.

All of the bands automatically detected and after that manually processed using the software product GelJ are shown in figure 6. A band marker should be placed on every important bright peak. The groups of red colored markers determines which are the reference lanes.

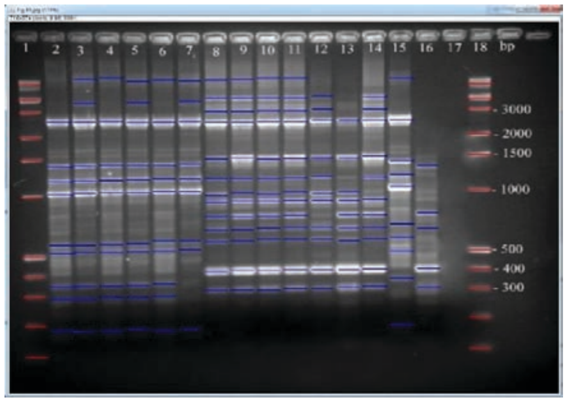

Fig. 6. *Automatically detected bands and manually processed*

As an important step in procedure of DNA analyses of lactic acid bacteria recombinants is creating a special dendrogram which is designed to illustrate the grade of similarity between couples parental strains and the recombinant clones. Such a dendrogram is shown below in figure 7. It is generated by the GelJ software using the Similarity method called Dice [16]; UPGMA linkage and the output is selected to be only dendrogram. The Dice method is also known as Dice's coefficient. It is used for comparing the similarity of two samples. The output can be dendrogram, dendrogram + images, dendrogram + images + bands. The window for creating a dendrogram is shown in figure 8.

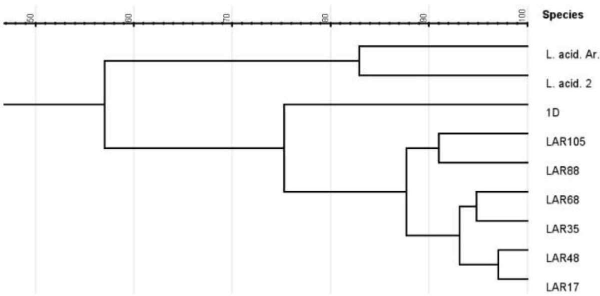

Fig. 7. *A dendrogram illustrating the grade of similarity between couples parental strains and the recombinant clones*

Creating a dendrogram follows the following iterative process: on each step the nearest two groups are combining one another in a group of higher level. Every single generated dendrogram can additionally contains information about the lanes, the original image or the image with detected bands.

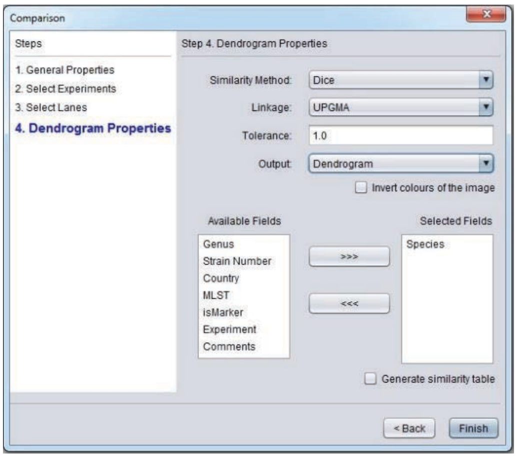

Fig. 8. *Comparison window for generating a dendrogram*

5. Conclusion

The computer program GelJ as an open source software for creating DNA analyses could be applied for lactic acid bacteria recombinants study. Using GelJ by lactic acid bacteria recombinants analysis sufficiently accurate results were received in comparison with commercial software products [13, 14, 15]. GelJ provides a lot of features thanks to which the users can easily create their analyses. In addition the open source conception of the product allows computer programmers to develop better tools and features.

REFERENCE

1. Wong, K., Sayo, P. (2004). Free/Open Source Software. A General Introduction. *United Nations Development Programme's Asia-Pacific Development Information Programme (UNDP-APDIP) Kuala Lumpur, Malaysia*, ISBN: 983-3094-00-7
2. Heras, J., Domínguez, C., Mata, E., Larrea, C., and Pascual, V. (2016). GelJ manual v.2.0, *Department of Mathematics and Computer Science of University of La Rioja (Spain) and Mysic*.
3. Heras, J., Domínguez C., Mata, E., Pascual, V., Lozano, C., Torres, C. (2015). GelJ – a tool for analyzing DNA fingerprint gel images, *BMC Bioinformatics*
4. Zhang, M. (2006), Bilateral filter in image processing, *B.S. Department of Electrical and Computer Engineering*, Beijing University of Posts and Telecommunications.
5. Smith, S. M. and Brady, J. M. (1997), Susan - a new approach to low level image processing, *Int. Journal of Computer Vision*, volume (23), pp.45–78.
6. Yaroslavsky, L. (1985). Digital Picture Processing - An Introduction, *Springer Verlag*.
7. Paris, S., Kornprobst, P., Tumblin, J. and Durand, F. (2008). Bilateral Filtering: Theory and Applications, Foundations and Trends in Computer Graphics and Vision, Vol. 4, No. 1, pp.1–73.
8. Schneider, CA, Rasband, WS, Eliceiri, KW (2012). NIH Image to ImageJ. Nat Methods; 9:671–5.
9. Markov, Z., Russell, I. (2006). An Introduction to the WEKA Data Mining System, pp. 367–368
10. Amara,l K., Netbeans IDE Tutorial for using the Weka API, University of Massachusetts Boston
11. Sage, D., Chaudhury, K.N. (2011). Constant-time bilateral filter, Biomedical Imaging Group (BIG) Ecole Polytechnique Federale de Lausanne (EPFL) Lausanne, Switzerland.
12. Chaudhury, K.N., Sage, D., Unser, M. (2010). Fast O(1) bilateral filtering using trigonometric range kernels, IEEE Transactions on Image Processing, submitted Dec.
13. Dobrev, I.N. (2011). Application of lactobacilli and bifidobacteria in the manufacture of healthy foods from goat milk, PhD thesis, University of food technology, Plovdiv.
14. Denkova, R., Dobrev, I., Denkova, Z., Yanakieva, V., Urshev, Z., Yordanova, M., Ilieva, S. (2012). Genetic, biochemical and physiological characteristics of the recombinant strain Lactobacillus RL15, obtained by intergeneric hybridization between Lactobacillus acidophilus 2 and Bifidobacterium bifidum L1. Food and Environmental Safety – Journal of Faculty of Food Engineering, Stefan cel Mare University – Suceava, Volume XI, Issue I – 2012, pp.5-14.
15. Goranov, B., Denkova, R., Teneva, D., Denkova, Z., Popova, P. (2015). Molecular-genetic identification of Lactobacillus

strains, isolated from homemade yoghurt. Ukrainian Food Journal 4 (1): pp.67-76

16. Dice, Lee R. (1945), Measures of the Amount of Ecologic Association Between Species, University of Michigon, Ecology, 26 (3): pp.297–302

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AUTOMATED SYSTEM FOR CONTROL AND MANAGEMENT OF A MACHINE FOR AUTOMATIC ASSEMBLY OF CURTAIN BRACKETS AND HOOKS

PENKO MITEV, GEORGI SHTEREV

Abstract: *The automated system for control and management is intended to assemble curtain brackets and hooks by a predefined movement sequence, registering each of the details "roll" or "bracket" with their subsequent assembly. In the work is pointed out the way of choosing of a technological scheme for control and management of the executive devices for a real automated system built and integrated in the production. The invention is implemented by "KMS Engineering" LTD - Plovdiv in "UYUT" LTD - Sankt Petersburg.*

Key Words: *fiber optic converters, logic controller, pneumatic distributors, ejector nozzle.*

1. Introduction

The target of automation is an automatic assembly machine which joins together two plastic parts - "hook" and roller". This features the following processes:

- Initial check of all default positions of actuators
- Presence of all start conditions related to the automatic mode;
- Start of automatic mode;
- Stop of automatic mode;
- Control of all mechanisms in manual mode;
- Control of each of the two vibratory bowl feeders depending on the signals from the sensors for minimal and maximal parts quantity;
- Control of the signal lamp tower with red and green lights;
- Control of the sequence of actions, which take part in the assembly process;
- Tracking of statistical parameters - "productivity", "number of errors for a period of time", etc.

The main tasks are related to the design and assembling of the described system, based on standard components, writing of control algorithm for the technological process and creation of a simulative laboratory unit demonstrating the various process activities.[1, 2, 3, 4]. The machine control system if based on a programmable logic controller which accepts signals from fiber optics sensors for detection of parts presence in assembly position and controls four pneumatic valves through relay outputs.

2. Networks of possible variants

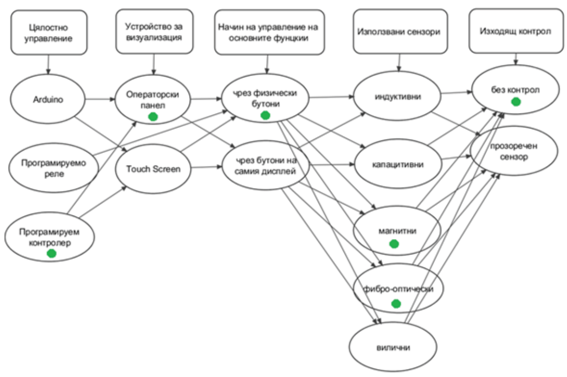

Fig. 1. Network of the possible variants for project realization

Fig. 1 shows a network of the possible variants for project realization based on the main functions which are required from the control system. An optimal solution is to be found among these variants. Some devices are

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able to do more than one operation or two fulfill two functions simultaneously. The process of decision taking is connected to a complex analysis of many factors and for each solution there are various advantages and disadvantages. Green dots mark the taken decisions for this specific task.

3. Cyclogram of the machine process

The assembly process is cycle-based where each cycle takes 1,5 seconds. Fig.2 demonstrates the time for the working stroke of every of the four pneumatic cylinders(lifting, assembly, opposing cylinders as well as a blowout nozzle). In the event of anomaly in the working cycle or in case of other emergency situation, the control system activates light and sound signals to attract attention of the site personnel.

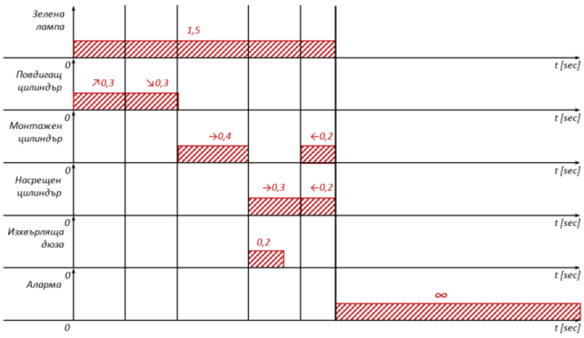

Fig. 2. Cyclogram of the machine process

4. Working algorithm

It is based on several modules - preparatory, subroutines calling module, module for delaying fiber-optic sensors' signals, control module for vibratory bowl feeders and alarms handling module. All modules are written in LADDER language and each module does not surpass 30 program steps.

5. Experimental analysis

5.1. Experimental analysis on the productivity of the vibratory bowl feeder for hooks

The vibratory bowl feeder for hooks is a critical part of the whole system. Depending on the number of arriving and properly oriented parts, the machine will either have minimal presence of parts for normal work cycles, or will need to wait until this quantity is attained. The following statistical information was acquired based on 10 trials.
(table 1):

Table 1

TESTS FOR HOOKS FEEDER PRODUCTIVITY

Parts quantity	76				
Duration for the above quantity:					
Minute	Seconds	Total: (seconds)	Parts / sec	Parts / min	Parts / hour
1	30	90	0,84	50,67	3040,00
1	40	100	0,76	45,60	2736,00
1	25	85	0,89	53,65	3218,82
1	15	75	1,01	60,80	3648,00
1	20	80	0,95	57,00	3420,00
1	32	92	0,83	49,57	2973,91
1	45	105	0,72	43,43	2605,71
1	15	75	1,01	60,80	3648,00
1	20	80	0,95	57,00	3420,00
	AVERAGE:	87	0,89	53	**3190**

Based on the results, the average feeder productivity is 3190 parts / hour. However, the assembly mechanism is able to work faster.

In case the bowl feeder could not feed enough parts, its own feeder rate is the maximum possible productivity value for the machine.

5.2. Experimental analysis on the productivity of the vibratory bowl feeder for rollers

- after 10 trials the results show that the rollers feeder has higher feed rate than the hooks feeder. This is easily explained with the smaller roller dimensions and the easier orientation in general.

The results are shown in Table 2:

Table 2

TESTS FOR ROLLERS FEEDER PRODUCTIVITY

Parts quantity	40				
Duration for the above quantity:					
Minute	Seconds	Total: (seconds)	Parts / sec	Parts / min	Parts / hour
0	38	38	1,05	63,16	3789,47
0	43	43	0,93	55,81	3348,84
0	45	45	0,89	53,33	3200,00
0	45	45	0,89	53,33	3200,00
0	40	40	1,00	60,00	3600,00
0	42	42	0,95	57,14	3428,57
0	43	43	0,93	55,81	3348,84
0	45	45	0,89	53,33	3200,00
0	45	45	0,89	53,33	3200,00
	AVERAGE:	43	0,94	56	**3368**

5.3. Experimental analysis on the PLC scan cycle

cycle - a "scan cycle" by PLCs is the time needed to execute the following sequence of operations:

- check of states on every input - logic "0" or logic "1"
- program execution
- update of output signals based on the changes in the current PLC cycle.

The PLCs from the XINJE XC3 series have a scan cycle from 1 ms to 10 ms, depending on the program complexity and the number of additional expansion modules, connected to the base PLC. During the phase of PLC program creation, the following statistical information was acquired:
(table 3):

Table 3

Number of steps inside the PLC program	PLC scan cycle (ms)
100	0
200	1
300	1
400	1
500	2
600	2
700	2
800	3
900	4

The following additional research on the scan cycle has been conducted independently from the system with a resulting scan cycle of 20 ms:

- Base PLC XC3-60PRT-C with 36 inputs and 24 outputs
- 7 additional expansion modules (a total of 140 inputs / 100 outputs)
- 5000 program steps inside the program

6. Conslusion:

1. The experience gathered from the project for automatic assembly of hooks and rollers could be applied in many other projects having similar parts. During the development of a specific manufacturing process, a detailed research activity related to industrial sensors used in industrial environment, automation components and innovations in IT and communication technologies is to be done. Additionally, analysis on the application of programmable logic controllers for industrial automation projects and other areas, based on the end user's inquiry are to be researched;
2. The design of the electrical and pneumatic diagrams is connected with the necessary number of input/output signals and parameters of the assembly process;
3. Economical parameters are to be taken into account when making decisions on the choice of automation components.

7. REFERENCES

1. Гановски В., Нешков Т., Бояджиев И., Ликов Ц., Механизация и автоматизация на монтажнитепроцеси в машиностроенето“, изд. „Техника“, София, 1986 год.
2. KrauseWerner, Geratekonstrution, VEB VerlagTechnik, Berlin, 1986.
3. Лебедовский М.С., А.И. Федотов, Автоматизация сборочныхработ, Л., Ленииздат, 1970.
4. Замятин В.К., Технология и автоматиза-циясборки, Москва, Машиностроение, 1993.

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MULTI-FUNCTION AND RECONFIGURABLE ROBUST ANALOG I/O MODULE DESIGN METHODOLOGY FOR INDUSTRIAL CONTROLLER SYSTEMS

CAGRI CANDAN, EMRE CAN DIKMEN, T. CETIN AKINCI, SERHAT SEKER

Abstract: *In this paper, applied design methodology of robust analog I/O (input and output) module of industrial controller is explained. Analog I/O modules are one of the essential part of the controller. Main aspects of the design methodology are reducing microprocessor processing complexity, selecting proper ICs (Integrated Circuits), analog signal correlation, transducer reading performance improvements, ADC (analog to digital converter) and DAC (digital to analog converter) implementation techniques. Additionally, test results and serial communication protocols also mentioned.*

Key words: *Analog module design, transducer performance improvements, noise filtering, IC selection, signal converter, signal generator.*

1. Introduction

Industrial Control Systems (ICS) is a general term covering various types of control systems and associated instruments used in industrial production, process control, machinery and critical infrastructures [1]. High capabilities and multiple functions of industrial controllers have caused widely usage and therefore have become a crucial part of the industry. As systems became more and more complex, demands of more advanced controller has gained momentum [2].

This system provides more flexible and effective measurement solutions to industry this utilizes the efficiency of overall process. System has efficient processing power and connectivity capabilities on the industrial computers thus systems. In this decade the industry which has depended on electronic design has becoming more advanced because of unique designs products. Because of these the requirement of conversion systems increased in terms of flexibility, accuracy and reliability. The previous version of the conversion systems has seen that because of their design issues the data accuracy and capacity of system is quite low.

To obtain better performance over the industrial systems several methods has been researched. In early 2000's technology a central process unit has to be connected to the all of the sensors and devices via reading or transmitting voltage [3]. The experiments showed that regarding on the process capacity, time consumption might increase exponentially. In order to decrease complexity, a modular approach has been used. To solve problem extra microprocessors has been used. Implementing microprocessor increased the speed of device furthermore it implements several benefits on device as well such as well-known communication tools (RS232-485), local algorithms which can embedded on its registers or OLED screens for notify users the status of process and device [4].

In the following level several components and their purpose has been explained. Overall system requirements process levels of methods explained.

2. Design Methodology

From the analysis of literature review, most of conversion systems has not capable of fulfilling the system requirements of industrial processes. Most of the systems are not supply current technologies demand. Therefore, our design offers low cost, low power consumption, portability, high speed and high accuracy in terms of both academic perspective and industrial demands. Our design is a compact size device. It uses 32 bit microprocessor which has the speed of up to 48 MHz Beside of this 256 Kb EEPROM. 16 Mb Internal RAM. It includes 4 channel 24 Bits A/D converters for connecting several sensors. For dominating the sensors and actuators it includes 16 bit D/A converter with both

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current and voltage options. Device has capable of supplying all industry demands such as variety of voltages (+-10V, +-5V) and for current (0-20, 4-20, 4-24 etc.).

2.1 Central Process Unit (CPU) Selection

The demand of the industrial projects has high microprocessors speed. Due to the natural environment of microprocessors this issue solved with high clock cycle, long resolution bit and smart algorithms which can able to solve big cluster of data packets and communication protocols simultaneously [5]. Almost all of the industrial processes count as nonstop processes generally the systems work on 24 hours and 7 days because of this the selected microcontroller of the systems should consume less energy from that perspective energy consumption is equal enough with processing speed. In our design we used one well known microcontrollers company's products.

To accomplish complex industrial projects a smart communication and sensor analyze algorithm required. The easiest way to solve this problem is using a fast, powerful microprocessor. In this design ARM Core based microprocessor has been used. ARM based microprocessors have supreme flexibility peripherals and cortex layers which increase our systems compatibility. The required microprocessor has to have high frequency which is up to 40 MHz or higher in order to achieve acceptable computation speed. To balance power consumption of the design, a low power consumed microprocessor required. In order to achieve process in required power level and speed the well-known company the ST is selected. Consider to GPIO requirements of the system 48 pin STM32F0xxx microprocessors series is selected.

2.2 Analog to Digital Converter (ADC) Selection and Implementation

Due to the accomplished a successful industrial project sensor communication required. Industrial devices, peripherals have different level of scale however each of which most commonly uses well known standards such as 4-20 mA or 0-10 V output. This design has capability of both 4-20 mA standards and 0-10 V standards. Design has internal jumper sets each of which for making decision of whether current or voltage uses. Receiving analog input requires a high precession and speed. To solve this, issue a four channel -24 bit delta sigma analog to digital converter has been used. The converter can able to work with 50Hz or 60 Hz analog signals. The noise resistance of integrated circuits has up to 600nB RMS [6].

2.2.1. Isolation

In this decade the design of the Analog input/output modules has been changed. All of the analog/output modules separated with the host microprocessors via some separators and controllers. There were been several methods for separating the modules from the processor. In this design we used galvanic isolation because of several advantages over the other well-known separation methods [7]. The Digital to analog converter chip has specialized for industrial projects. Selected chip especially capable of providing to 20 mA, 0 to 20mA or 0 to 24 mA current outputs or 0-5 V, 0-10 V, ±5 V or ±10 voltage outputs with a10% false supply accuracy range (0-5.5 V, 0- 11 V, ±5.5 V, or ±11 V). Because of these properties in this design our team select TI-DAC8760 model IC chip.

2.2.2. Voltage Output

The DAC chip has property of configurability. When chip is configured for voltage output, max resistivity is 1 K Ohm at 10 mA. The voltage level of output the modules output can extend up from +15V to -15V. The voltage source of the chip is supplied by power rail; therefore, the rail must be at least +- 10 V supply range in order to supply the IC chips.

2.3 Digital to Analog Converter (DAC)

As known as to accomplish an industrial project the designer of systems needs to control several sensors and peripherals. Besides of shut of/on devices any peripherals or sensors requires a wide range of input streams such as 0-10 V or 4-20 mA or 0-20mA or so. To accomplish these requirements a high precision digital to analog converter (DAC) has required. The DAC has to be work with either 0-10 V or 4-20mA or both. To accomplish this standards 16 bit dual (both V and mA output) integrated chip has been selected [8].

The DAC chip has 16 bit resolution. This range has been chosen because of the requirement of high level integration. The IC chip has max 0.1 full scale range (FSR). This range includes offset error, gain error, calibration error, scale error etc. This FSR scale range is acceptable for all of the voltage and current supply range. The maximum nonlinearity is +-1 V or +-2 mA regarding to our experiments in real-time environment. The IC chip offers a programmable interface for determining the voltage and current ranges, with using calibration register user able to program the gain error and zero error and other calibration parameters. The slew rate of output is also programmable. All of the communication between The IC chip and host processor have achieved through SPI interface. SPI is a well-known fast communication protocol which is increased the speed of the overall design. For each DAC module one microprocessor GPIO has been assigned and with full-duplex SPI communication protocol all of devices programmed separately. The calibration parameters and design information have stored in an EEPROM. The storage unit also uses the SPI buss therefore the communication speed is sufficient for obtaining all of the information from converter peripherals [9].

. In this system there has 8 blocks which represent the most important functions. The sequence of device starts with the input signal from sensors. The input determined from user side at early system execution. The user could either control the analog output by DAC or receive information from analog input by ADC peripheral. All of the communication ways handled through serial communication line [10]. Both of the information of analog input and output peripherals values stored at micro controller. After each sequence the memory part which contains the information of devices peripheral is stored on the EEPROM for providing secure information and safety to user in case of power failure. The CPU handles all of these events with using high clock frequency which is up to 42MHz. Microcontroller gather input data form ADC and generate output data which has the same parameter with input data to DAC. Thanks to that the input data remaining scaled and secured without losing information. After these processes all of the information sends to viewing module display for showing the final results.

3. Device Working Principle

Designed to comply with IEC61000-4 standards

•Selectable Voltage Output ranges from± 10V, 0 -10V, ± 5V, 0 -5V with output

•Selectable Current Outputs ranges from: 0 - 20 mA, 4 -20 mA, 0 -24mA

•Output filtering, protection up to 15kV for Electrostatic Discharge protection

•SPI interface applied with isolation which has communication speed up to 20MHz.

•High temperature protection, short circuit protection.

4. Test Results

The chip has capability of working the view of ADC on integrated circuit on 2.7 to 5 V periods. The device has been tested interns of current and voltage level and the temperature over the voltage and/or current consumption.

All of the accuracy and speed test have made with 100 sample rate with different voltage/current levels. 7 tests have been made with this device 3 of them for voltage and current test one of them for temperature test. The first test has been made 100 ms period of time. In between two following 100 ms time period the microcontroller adjusted to send a new voltage level starting from -10 V to +10 V and the devices output level measured by voltage source. As seen in Figure 1 the integrated chip cannot reach the speed level of microprocessor continuously therefore the level of voltage cannot increase sequentially. We observed that the voltage level increased like a saw-tooth wave.

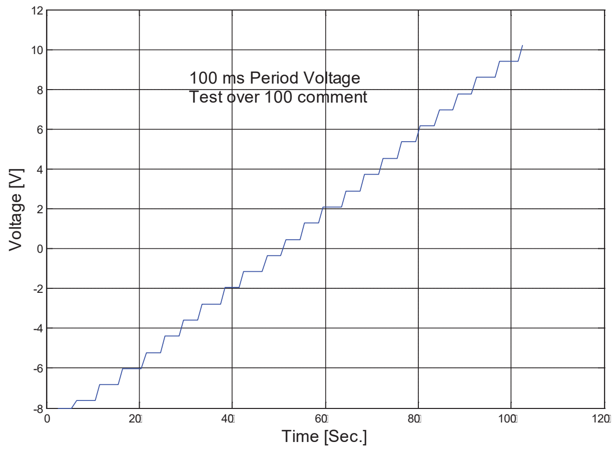

***Fig. 1.** Accuracy test +-10V level 100 ms Period for 100 samples*

Second test has been made with 250 ms time interval. To measure accuracy of the device the time interval increased by 150 ms. The results get better however instead of overall linear graph we have been seen that ripples between sequential voltages. As shown in figure two the voltage become more stable than previous test however we can clearly assume that the time period is not long enough. Third test has been made with 500 time interval. To get optimum result 500 ms have been selected. The results are get optimum as expected. As seen in figure 3 the voltage and the time period gets completely linear.

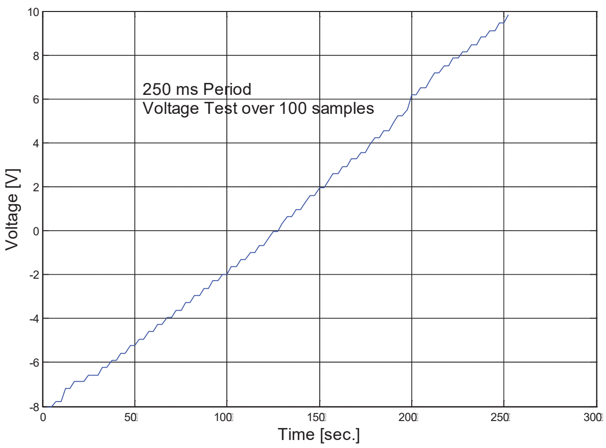

***Fig. 2**. Accuracy test +-10V level 250 ms Period for 100 samples*

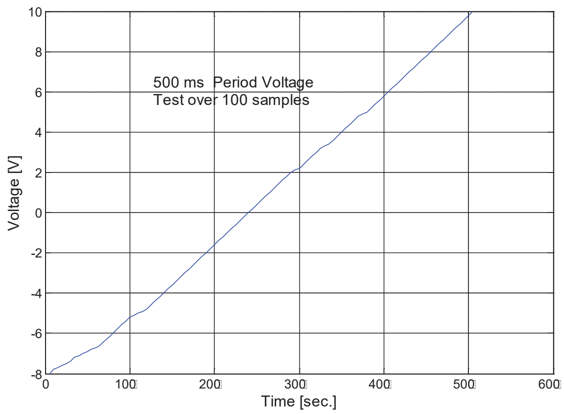

***Fig. 3.** Accuracy test +-10V level 500 ms Period for 100 samples*

After linearization of voltage test the second phase began. In second phase the level of current accuracy has been tested in the same condition with voltage tests. The first test has been made 100 ms period of time. In between two following 100 ms time period the microcontroller adjusted to send a new current level starting from 4 mA to 20mA and the devices output level measured by current source.

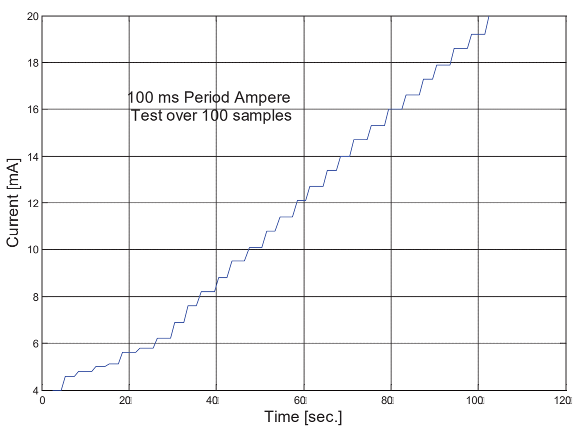

***Fig. 4.** Accuracy test 4-20 mA level 100 ms Period for 100 samples*

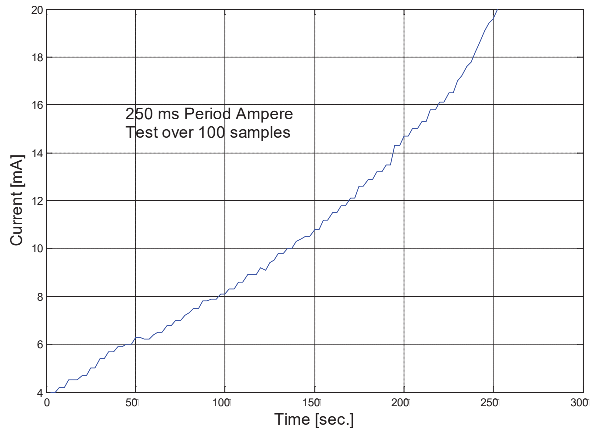

***Fig. 5.** Accuracy test 4-20 mA level 250 ms Period for 100 samples*

As seen in figure 4 we obtained a nonlinear graph in our first 30 trial we observed almost correct output however when the current level increases the chip cannot reach the level of microcontroller and some additional delays occurred. Second test has been made with 250 ms time interval. As it seen with the voltage test the result becomes sharper however as seen in figure 5 additional ripples are still disrupt the overall current signals.

Third test has been made with 500 time interval. As seen in previous test set we observed that for the optimum result the time interval must be higher than 250 in order to compere between two test sets the level adjusted to 500 ms time interval. As seen in figure 6 after adjusting the right time interval the current level become completely linear.

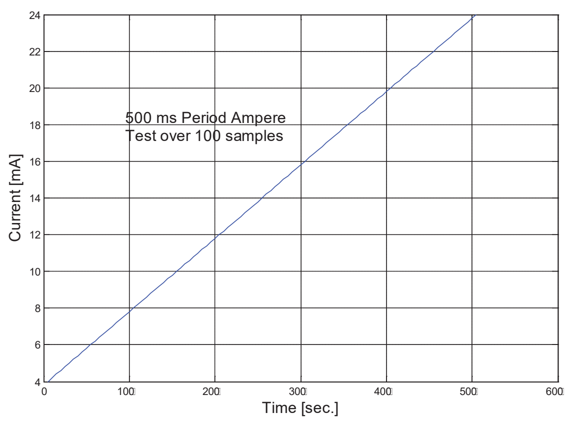

***Fig. 6.** Accuracy test 4-20 mA level 50 ms Period for 100 samples*

After finishing the accuracy test a temperature test has been started. The device applied with various level of current and voltage output and the temperature of chip measured externally. As seen in the figure 7 the level of temperature increase regarding to level of output up to a point. We observed that the device becomes stable after level of the current or voltage has been produced by the chips. The stabilization may cost because of the space between the chips on PCB as shown figure 8. The vain spaces could absorb the temperature of device which can reach over a certain range

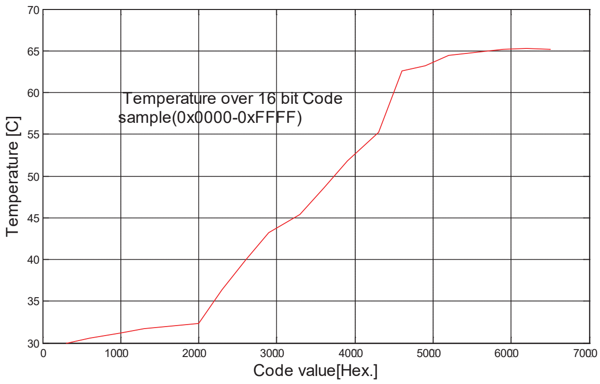

Fig. 7. *Temperature test 20 samples with the range of 16 bit data from 0 to 65535*

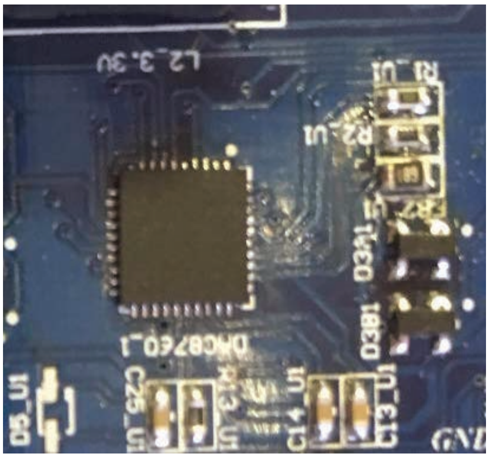

Fig. 8. *the DAC on PCB frontal seen*

5. Conclusion

In this paper an industrial sensor peripheral reader controller has been explained. The device currently in is working on with several different applications in throughout several different places and facilities. The combination between DAC&ADC enhanced the device usage thus several industrial processes has speeded up and get some extra qualifications such as combinations of analog input outputs, smart control over the process thanks to microprocessor etc. Improvement of smart devices will increase the process speed and reduce the errors.

The IC chip has capability of producing vide range of voltage and currents. The IC can also be programmed by designer in order to change the level of voltage and current. The general design of device can be seen in Figure 9.

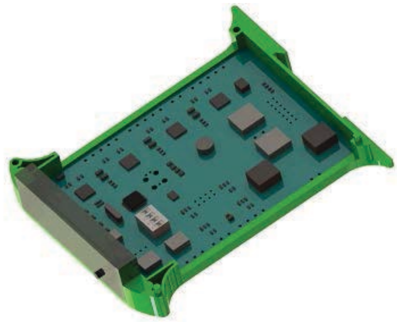

Fig. 9. *Module simulation overview*

REFERENCES

1. Hosny, A.A., Mohammed, H.A. (2015). On the Adoption of Multi-Agent Systems for the Development of Industrial Control Networks: A Case Study, ICAS 2015, Rome, Italy.
2. Balasubramanian, S., Brennan, R.W., Douglas, H., Norrie, H. (2001) An architecture for metamorphic control of holonic manufacturing systems, *Computers in Industry*, vol.46, no.1. pp.13-31.
3. Al-Zobi, Q., Al-Tawil, I., Gharaibeh, K., Al-Kofahi, I.S. (2008). Design of Power-Line Communication System (PLC) Using a PIC Microcontroller, *Journal of Active and Passive Electronic Devices*, vol. 3, pp. 331–340.
4. Almeida, E.E., Luntz, J.E., Tilbury, D.M. (2007). Event-Condition-Action Systems for Reconfigurable Logic Control, *IEEE Transactions on Automation Science and Engineering*, vol.4, no. 2. Pp.167-180.
5. Myers, G.J., Yu, A.Y.C. House, D.L. (1987). Microprocessor Technology Trends” Microelectronics Reliability, Proceedings of the IEEE, vol.74, no.12, pp.1605-1622.
6. Walden, R.H. (1999). Analog-to-digital converter survey and analysis, *IEEE Journal on Selected Areas in Communication*, vol.17, no.4, pp.539-550.
7. Inoue, S., Akagi, H. (2007). A Bidirectional Isolated DC–DC Converter as a Core Circuit of the Next-Generation Medium-Voltage Power Conversion System, *IEEE Transactions on Power Electronics*, vol.22, no.2, pp.535-542.
8. Ching-Wen Hsue, Chih-Jen Lin (1993). Built-in Current Sensor for IDDQ Test in CMOS, IEEE International Test Conference, pp.635-641.
9. Leens F. (2009). An Introduction to I2C and SPI Protocols, *IEEE Instrumentation & Measurement Magazine*, pp. 8-13.
10. Machacek, J., Drapela, J. (2008). Control of Serial Port (RS-232) Communications in LabVIEV, Modern Technique and

Technologies MTT 2008 Conference, pp.36-40.

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INDUSTRIAL NETWORK DESIGN USING LOW ENERGY PROTOCOLS

STOITCHO PENKOV, ALBENA TANEVA, MICHAIL PETROV, VASIL KALKOV

Abstract: *In this work a network development for industrial application is presented. Solutions related to the network protocols and standards for industrial applications are summarized. The main goal is focused on net operation by combining low energy protocol and transmission method. In the developed network project for industrial data exchange was use MQTT protocol and LoRaWAN. An application for security purpose is obtained. The real test and verification with sending and receiving data between the connected nodes are made. The advantages of the developed network with MQTT and LoRa are given.*

Key words: *Industrial Network, MQTT protocol, LoRa*

1. Introduction

Using network in security applications is usual, complex and sometimes dangerous tasks. There are many different ways to solve, depending of cases. An example a security in places without electricity in order to be organized, is not easy task. How to secure buildings or value staff against tiffs and there no electricity? These tasks over a long period of time are performed. It is case of highly dynamic phenomena, such as change of security status because of fire alarm or intruder, means that the results do not reflect the real value. A solution of such problem is to use low cost nodes equipped with relevant networked sensors for data collection. Several nodes can be organized and formed a grid which will bring more complexity, and we will gather all needed information. If the goal is to secure object, or to gather info under the sky, it could be use nodes with GPS to know exact location, but considering power plan that is not energy efficient. Where is needed can be used mobiles and flying robots for deploying these nodes, and at moment when nodes are deployed, it can be marked GPS position. Thus are covered large areas and different surfaces. One of the main factors for such system development is the implementation cost. In order to achieve it is appropriate to use small, low-power nodes, which are controlled and supervised by a main network grid organized by LoRaWAN.

The paper presents a WSN extension to provide communication between the nodes and the gateway over LoRaWAN, instead of IEEE 802.11 (WiFi), instead of 3,4G.

This paper is focused on configuration and development of the networked sensors for monitoring and control the environment and security system. Many articles show variety of protocols and communication networks [2, 3, 4, 5]. Generally efforts are focused on problems with network possibility and delays, packet dropouts, address channel limitations related to the packet-rates, but there is no universal solution. In the paper problems definition, development suggestions and maintenance for networked sensors are made. This work summarizes solutions related to the network protocols and standards for predefined application. Proposition of node based sensor network with specified low energy protocols are also presented.

2. Layer protocols

Regarding to the OSI model is important to discuss the way of data transmission through layers. In this point of view the transmission method will be summarized.

2.1 LoRa™ is a proprietary spread spectrum modulation scheme that is derivative of Chirp Spread Spectrum modulation (CSS). It trades data rate for sensitivity within a fixed channel bandwidth. It implements a variable data rate utilizing orthogonal spreading factors, which allows the system designer to trade data rate for range or power. Furthermore the network performance is optimized in a constant bandwidth. LoRa™ is a PHY layer implementation and is agnostic with to higher-layer implementations. This allows LoRa™ to coexist and interoperate with existing network architectures. This application note explains some of the basic concepts of LoRa™. Modulation and

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the advantages of the scheme can provide when deploying both fixed and mobile low-power real-world communications networks [6].

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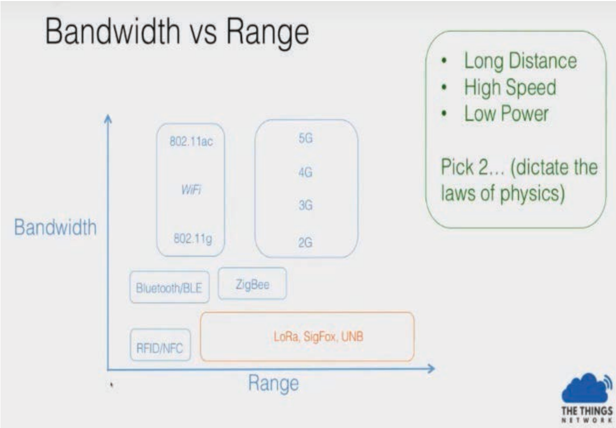


Fig. 1. *Representation of the relationship between Range and bandwidth of the signal*

Fig.1 presents relations between signal range for successful connection establishment and frequency bandwidth. In case of frequency decreasing regarding to the modulation the signal path increases with LoRa.

2.2 LoRaWAN™ /layer2/ is a Low Power Wide Area Network (LPWAN) specification intended for wireless battery operated Things in a regional, national or global network LoRaWAN would correspond to the Media access control (MAC) layer. LoRaWAN targets key requirements of Internet of Things such as secure bi-directional communication, mobility and localization services. It specification provides seamless interoperability among smart Things without the need of complex local installations and gives back the freedom to the user, developer, businesses enabling the roll out of Internet of Things.

The choice of transport protocol, when internet connectivity is need basically, is reduced to two options TCP and UDP. The Protocols allow multiple devices to communicate effectively using the Internet. However, the determination way for different data types, how are divided and stored in frames, are required. In case of a system design for collecting data in order to reduce the workload, related to the data exchange organization, it is possible to use application-layer protocols. There is variety of options. One is to use industrial automation protocols. In problem definition arises high cost of implementation.

By analyzing network protocols, extra attention should be pay to the model they use for data exchange. Many of the technologies used in modern computer systems use a data exchange model referred to as Request-Response. However, when you try to use such a model for data exchange in the sensor network you can encounter some difficulties. A possible solution is using the Publish-Subscribe method. In this method, the data publishing modules send it to a server called the broker, which then sends the data to clients subscribed to certain information. Using these methods of data exchange allows the clients to receive not all the information sent by the node, but only the data that interest. There is also no need to constantly calling the modules that generate information about the data.

2.3 MQTT protocol

Among different options described one of the most appropriate is MQTT protocol (Message Queue Telemetry Transport), details in [5]. It was designed in 1999 for transferring data from telemetry devices. The main goal of the designers was to create an efficient protocol to transfer data from devices with limited hardware resources, which is equipped with a low-performance microprocessors and a small amount of memory. Also expected to work in networks with severely limited bandwidth for data transmission. The protocol uses a publish-subscribe method and transmits the data over TCP/IP or UDP. In its implementation requires a special computer called a messages broker. The task of the broker is to collect messages and sending them to devices interested in specific information. Fig. 2 shows the organization diagram for data exchanging between Publishers and Subscribers by MQTT Broker.

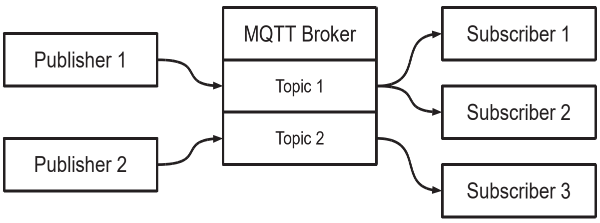


Fig. 2. *Organization of data exchange in MQTT.*

MQTT protocol messages are assigned to names that are topics. In context of the client and the broker, there is no need to configure the topic. The client sends a message to a specific topic. If there is a particular topic the broker will update its data, in the absence a new topic will be created automatically, to which will be assigned the information transmitted in the message. Topics may be organized in a hierarchical manner using the separator in the form of a forward slash (/). This allows us to organize data in a broker in a manner similar to the file system. Example topic for networked grid nodes may have the following form:

Network22/NODE11/sensor33/DATA

An important feature of the MQTT protocol is the ability to manage the quality of service by implementing QoS (Quality of Service). It allows you to manage the way to deliver a message and confirmation of its receipt.

3. System design and configuration

The developed solution for industrial network combines LoRa and MQTT protocol.

An important step in designing communication layer using MQTT protocol is to determine the structure of topics and related messages. In current system only test messages were send, which allows reading data from nodes sensors.

Therefore is achieved LPWAN based LoRaWAN, presented on fig.3. It is evident there is variety of tasks: many sensor types, devices through Gateway to the many user defined applications.

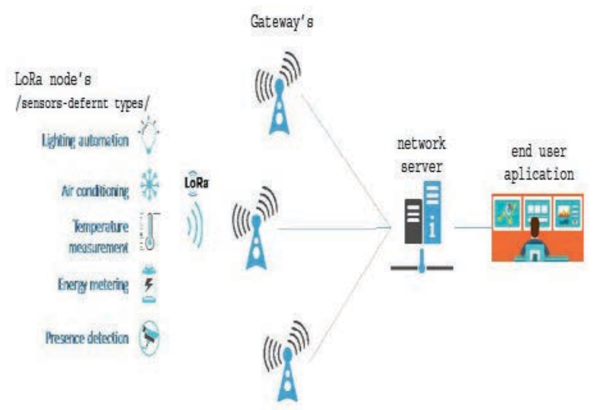


Fig. 3. Overview of the developed network with industrial applications

The network can consist of thousands nodes. In case of new LoRaWAL project is need a Gateway in case with no LoRa coverage. The proposed solution includes Gateway. This can be viewed as an advantage of the application, fig.4. LoRaWAN uses licence-free spectrum, usually ISM (Industrial, Scientific, Medical) bands to communicate over the air. In Europe, ETSI regulates the ISM band access on the 868MHz and 433MHz bands.

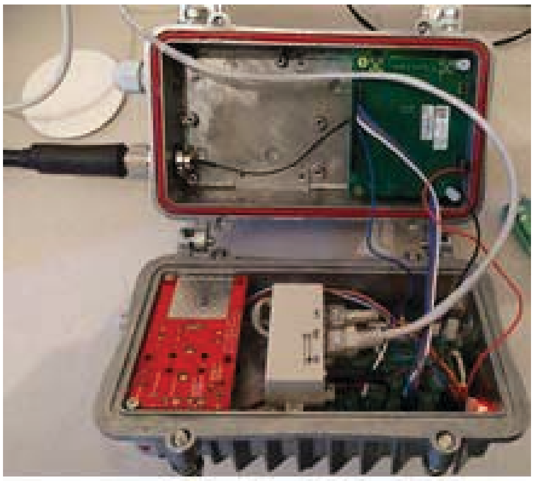


Fig. 4. Designed and Assembled Gateway included in LPWAN

The usage of these bands is submitted to limitations: The output power (EIRP) of the transmitter shall not exceed 14dBm or 25mW, and the duty cycle imposed in Europe by ETSI is limited to 1% (for devices) or 10% (for gateways) depending on the used sub-band. In this project the Gateway is placed on the laboratory roof. As an option in a startup it was assumed. The achieved signal coverage was good enough. In future work it will be improved. On the next fig. 5 are shown the used and connected LoRa nodes based on Microchip ®. In this way is developed and obtained network based on LoRAWAN.

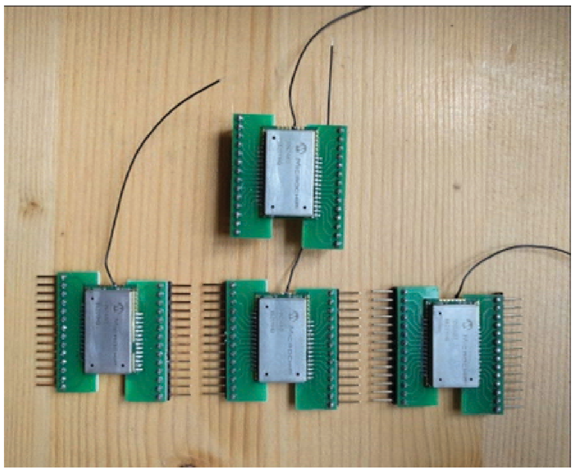
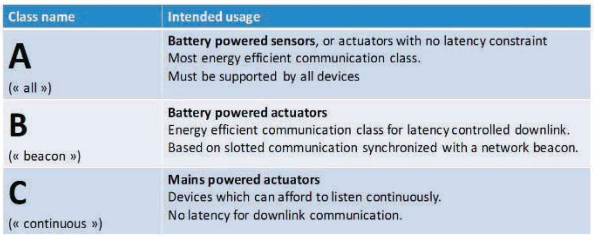


Fig. 5. Numbers of the used nodes based on Microchip in the developed network.

The architecture including three different classes (A,B,C), of communication profiles are available in LoRa networks between devices and applications, are presented on fig.6.

Fig. 6. *Typical system architecture of a LoRaWAN node*



Class name	Intended usage
A (« all »)	**Battery powered sensors**, or actuators with no latency constraint Most energy efficient communication class. Must be supported by all devices
B (« beacon »)	**Battery powered actuators** Energy efficient communication class for latency controlled downlink. Based on slotted communication synchronized with a network beacon.
C (« continuous »)	**Mains powered actuators** Devices which can afford to listen continuously. No latency for downlink communication.

Fig. 7. *Description of A,B and C profiles*

Each class serves different application needs and has optimised requirements for specific purposes. The key difference between A,B and C profiles is the trade-off made between latency and power consumption, fig.7. It is a difficult task to gather information from many and different points. In a stage of problem definition the task is related to a network design and configuration of nodes equipped with sensors. The proposed solution is based on a grid of networked nodes. If there is a lot of equipment, it is important to find a low-cost solution with low energy consumption. In order to reduce costs it is necessary to minimize the tasks of networked nodes. Therefore cable connections are not relevant or suitable. In such case of many distributed nodes cooperation, the option is to use radio communication. The solution performs the data transmission from the sensors to the gateway /one or many/. This allows using of nodes with low-cost microcontrollers. The power consumption. Easy operation and reconfiguration of the system are also given and discussed in [6].

Nowadays there are many radio communication standards, but not all are well suited to the task. The ability and widely used popular, not expensive modules with easy connection to the Internet is very important.

First one solution that comes to mind is the standard IEEE 802.11 (WiFi). It allows connecting multiple devices to the network, and easy integration with the Internet. However, it has the disadvantage of relatively high demand for energy, which is particularly important in the case of using small nodes to collect data. Among the standards for devices with low power the most interesting solution is using **LoRaWAN** network

IEEE standards are for the physical layer of the OSI model. They allow transferring data. But do not provide a convenient way to control communications and meeting the requirements of QoS (Quality of Service). Accordingly, the next step is the selection of a transport layer protocol.

Level2 Sections

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Level3 Sections

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4. Application in security area

There are many places around cities (levers, fields, car morgues, etc.) without electricity and 220V power supply. From security point of view this is a big problem and complex task. To establish and maintain the communication with such plant. The options are very less. Generally is used security system equipped with transmitters and detectors using 220V power supply. They are not applicable in such case.

It is possible to use GSM operators. We are facing with need to use special equipment with batteries. These batteries should therefore be charged. Even in this way the operability depends of the power supply. The lifecycle is not so long. This weakness is other come with the developed solution combining LoRaWAN and MQTT. In this way can be achieved promising security without 220V power supply.

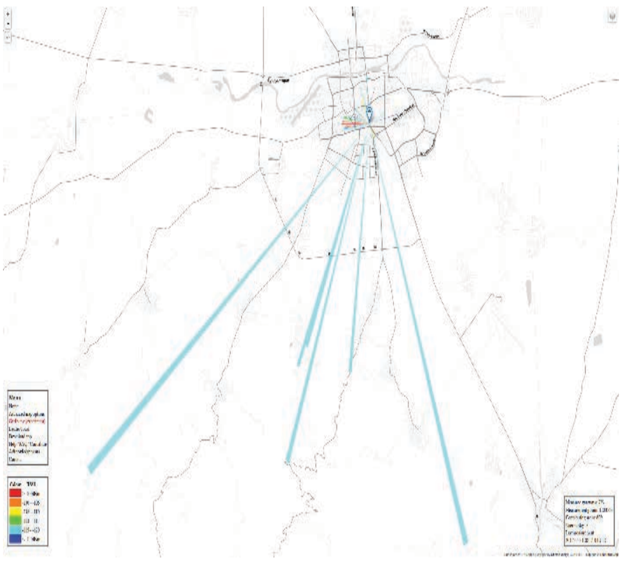

Fig. 8. *The coverage measurement with TTN mapper*

.LoRa uses low energy hence the workability is expected to be 5-10 years. To one node could be connected more than one detector and passive detectors as well.

The radio coverage of developed network, fig.8 can be viewed as an industrial solution in case with IoT implementation. The signal covers the laboratory location and connected nodes. To investigate and conduct the preliminary experiments is used software named TTN /The Things Network/ mapper, fig.9. The signal coverage and connected node was monitored. The results demonstrate the good enough signals. It shows the achieved passing of the signal at a large distance with low power.

TX- is the emitted power by the transmitter. The signal is gained by the Gateway. The signal above the dashed red line confirms the established and "good" connection.

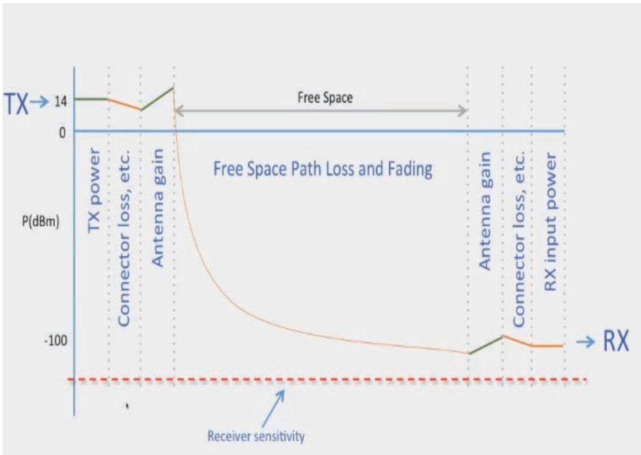

Fig. 9. *The TX and RX signals*

5. Conclusion

This work is devoted on developing, configuration and investigation of the network for security purpose in the case of missing 220V supply. A solution is found out by combination between the LoRaWAN network and MQTT protocol. All developed nodes covered IP 67 standard.

Some advantages of the system are: easy maintenance; low cost; low energy consumption; reliability and security; easy connection to the Internet, long lifecycle. The system nodes (the grid) can be enlarged with up to more than 1000 nodes connected with one gate.

In the particular test application for the industrial network development it is obtained promising results. There are eight connected nodes in this case study. Furthermore it will be possible and very easy to extend the node numbers if necessary. The idea could be associated with networked sensors for robots to perform various tasks. To industrial environment for monitoring process values like temperature, air conditioning systems and etc. Each "node" could present sensor one or many, or robot sensors, connected the main node through the Gatrway with LoRa. It is possible to use robots to spread sensors in case of hostile environment.

The paper shows an example of the use of open network protocols in networked mobile robot sensor system. MQTT protocol allowed for the use of standardized methods for data exchange in the sensor network. Also greatly simplified the integration of new nodes, the use of nodes information from other systems and integrating with the Internet.

The use of open protocols simplifies software development work, especially when it consists of a large number of independent nodes. Also simplifies the maintenance process, since it is possible to read information about the industrial values and the status of individual sensors without having to use special tools. Future work will be focused on industrial network implementation.

REFERENCES

1. Souza R., L. Agostinho, F.Teixeira, D.Rodrigues, L. Olivi, E. Guimaraes, E.Cardozo. *Control of Mobile Robots Through Wireless Sensor Networks.* XXIX Simpósio Brasileiro de Redes de Computadores e Sistemas Distribuídos, pp.805-818.
2. GreenPeak Technologies (2015), *Wireless Communication Standards for the Internet of Things,* White paper
3. Silicon Laboratories, Inc., *The Evolution of Wireless Sensor Networks*, 2015.
4. ITU-T, *Ubiquitous Sensor Networks (USN)*, ITU-T Technology Watch Briefing Report Series, No. 4, February 2008.
5. MQTT V3.1 Protocol Specification. International Business Machines Corporation, Eurotech, IBM, 2010
6. Beser, Nurettin Burcak. "Operating cable modems in a low power mode." U.S. Patent No. 7,389,528. 17 June 2008. – тва не го знам какво е
7. SEMTECH, AN1200.22 LoRa™ Modulation Basics
8. LoRa Device Developer Guide, Orange Connected Objects & Partnerships

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MACHINE VISION SYSTEMS FOR INTELLIGENT QUALITY CONTROL OF MANUFACTURING PROCESSES

BORISLAV RUSENOV, ALBENA TANEVA, IVAN GANCHEV, MICHAIL PETROV

Abstract: *An intelligent system for automated quality control of manufacturing process applications, based on machine vision is presented in this paper. The quality of many produced parts in manufacturing processes depends on dimensions and surface features. The presented automated machine vision system analyzes those geometric and surface features and decides about tile quality by utilizing statistical analysis. Refined methods for geometric and surface features extraction are presented also. The efficiency of processing algorithms and the usage of an advanced analysis as a substitution of human visual quality control are investigated and confirmed.*

Key words: *quality control, machine vision, intelligent systems*

Introduction

Many industrial processes use or require visual inspection in quality control as an integrated part of their production stages. Such processes are based on visual perception principles to successfully determine levels of product quality by quantifying its visual appearance in general and some specific visual features, respectively [1]. A visual inspection system is based on machine vision principles by using acquisition cameras and also, one or more industrial computers. The main motivation for machine vision implementation is economic factors, which constantly require less production costs.

One of processes that use machine vision for product quality control is the production in mechanical manufacturing processes [2]. The production phases are more or less automated. The exception is quality control stage with mostly human vision inspection. Some production lines still use human vision in quality control. The main reason lies in complexity of this task. Human resources are used because the visual quality control process is very complex and highly demanding and often should be on-line adaptive on changeable quality requests in classification stage of production. Because of human features limitations as controlling element in production line, man becomes one of the weakest and unreliable links. By replacing the human with machine, the whole process should have better production yield and could be more efficient [3].

Industrial control system (ICS) is a general term that encompasses several types of control systems used in industrial production, including supervisory control and data acquisition (SCADA) systems, distributed control systems (DCS), and other smaller control system configurations such as programmable logic controllers (PLC) often found in the industrial sectors and critical infrastructures. Industrial automation is a discipline that includes knowledge and expertise from various branches of engineering including electrical, electronics, chemical, mechanical, communications and more recently computer and software engineering.

In order to stay on top of a competitive market, companies have to keep their production costs as low as possible. One element of their strategy is to collect production and control data, analyze it to find improvements, and incorporate those improvements in each new plant.

The role of including quality control in other control systems may lie in control and information flow of plants, in integrating processing machines, in the Manufacturing Execution Systems (MES) [7] that monitor the processes, and in the

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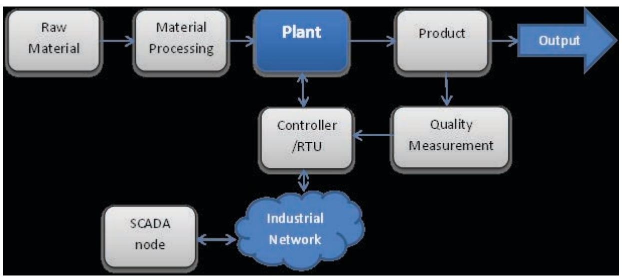
data-based Enterprise Resource Planning (ERP) [8] system that provides decision support.

Process quality control system is a novel computer-aided process quality control system, which integrates hardware and software. The system could realize quality data collection, transmission, storage, quality monitoring and quality statistical analysis for spare parts production process. It could accomplish the collection and monitoring of quality data automatically in field. Once the production process has problems, it can give an alarm and begin to analyze, providing a basis for process quality control. Furthermore, it can also carry out offline quality statistical analysis of the quality data derived from the machining field, guaranteeing after-process control of processing quality.

Quality Control System

The complete system block diagram in Figure 1 presents the role of the SCADA system; the quality measurement data is collected from the final product and stored in special registers inside the controller/ Remote Terminal Unit (RTU) which in this case is a programmable logic controller (PLC). This data is transferred to the SCADA node using industrial network which could be a local or remote network, this data is analyzed and a control decision to tune the controller if necessary to ensure that the product is within the bounds of required quality.



Quality control system block diagram

Process quality data acquisition and controlling contents include the monitoring of parameters process product quality testing. Process parameters monitoring is realized by measuring the relevant parameters on product quality characteristics. Process product quality testing is achieved by testing products' quality feature in the machining processes or machining process interval. Common processing measurement parameters for example could include cutting force, temperature, spindle motor current changes, vibration and noise signals. Process quality control should establish the correlation between process parameters and the final product quality characteristics, and ensure the quality of the final product by the adjustment to parameters.

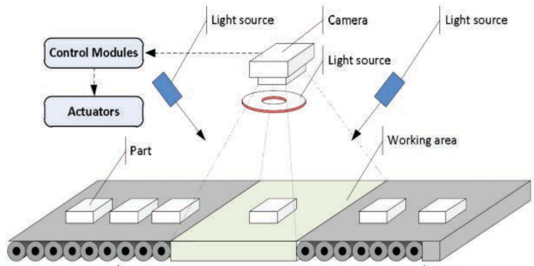
Role of SCADA in Quality Management

A production process includes the quality assurance testing of samples from each product lot. The test data is used to produce a certificate of conformance report for such a lot. The data is collected from test equipment, then sometimes manually entered into a customized database form, and then formatted to produce the certificate of conformance. Manual data entry is time-consuming, error-prone, and repetitive. Here is the challenge to introduce a supervisory control system to automate that process and integrate data collection with its other manufacturing systems. With the automation of the quality assurance process by electronically collecting data from the measurement tools, the operator does not need to write test measurements into a form and then into a computerized spreadsheet. Dozens of samples with up to hundreds of measurements are displayed; with manual work, the system can only handle a limited number of measurements. In being automated, it can be upgraded to manage much more. After data collection, a system can retrieve the expected measurement values from database for the samples of that lot.

A summary screen might he immediately displayed to the operator indicating, for each sample, whether all measurements were within control limits, within specification limits, or outside specification limits. The operator can also view details about each sample and adjust the data manually. Any data modifications are stored in an audit trail, and the initial raw data is kept for historical records. When the operator is satisfied that the data is correct, the system sends this validated data to its database, and it is possible to produce the certificate of conformance. Time saving for these procedures is significant: it could easily take an operator longer to record the measurement data than it takes the tool to create it. A supervisory control system brings the time for the whole process, from measurement to a report, down to a matter of seconds.

Description of an application system.

A typical machine vision and quality control system has the structure shown on fig.2.



Structure of a typical machine vison system

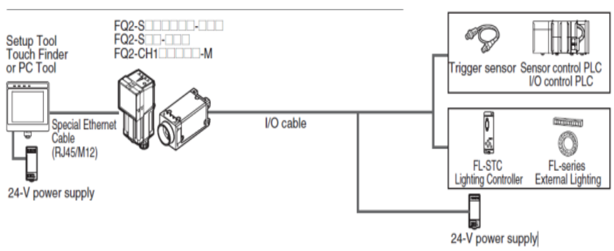
The system includes: camera, light sources, a transport system for moving the inspected products, control modules and actuators. Typically, the transport system is a part of the production process. The cameras are positioned so that the inspected parts or finished article falls into the camera's work area. In general, the control module serves to process the camera signal and to communicate with the executive actuator. If it is provided, it serves with the quality measurement system and the SCADA system of the factory as well, where the inspected product is manufactured. The light source allows accurately determine the right amount of light flux to properly capture the scene.

1.1. **Basic machine vision system of modules for temperature protection**

In the manufacture of modules for temperature protection of electric motors of compressors in refrigerators and freezers a main component which is embedded is a thermo-protector. The operating temperature of these thermal protectors is indicated by an alphanumeric code. Thermo-protectors are produced in several factories around the world. Upon entrance, each type of batch of thermo-protectors with a specified trigger temperature is "contaminated" with thermo-protectors with another trigger temperature. In addition, there are thermo-protectors with missing or incomplete alphanumeric codes. The task of identifying and separating the inappropriate incoming product from the incoming good one is accomplished by the machine vision system shown in Fig. 3.

Factory machine vision system

The system of machine vision and quality control of components for temperature protection of compressors for refrigerators and freezers with thermo-protectors is constructed schematically according to Fig. 4.



Structure of machine vision and quality control system

The smart camera model FQ [4] of the manufacturer for industrial automation company Omron was used. The equipment includes a visual inspection camera, a setup controller with predefined different quality parameters, a light source, a parallel interface for direct digital output control.

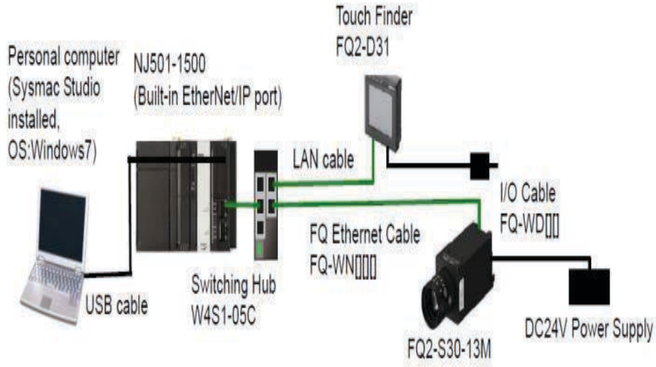
The controller of the visual inspection camera allows operation in 5 different recognition modes: in case of difference in form, difference in position, difference in width, difference in size, and color difference. For inspection of thermo-protectors, the difference in form recognition mode is used. The embedded digital outputs of the intelligent camera are used to send signal to the programmable logic controller PLC of the thermal protection module manufacturing machine. When an unsecured thermal protector is detected, the cycle stops and the actuator removes the product.

The described intelligent camera system FQ can also be seen as an intelligent sensor. Unlike conventional sensors, through camera inspection, at every stage of the production cycle of a product the quality control could be achieved. Quality control consists of separating the unsuitable product.

1.2. Smart machine vision system of modules for temperature protection

For quality management this is not enough. In order to be able to derive full information about the quantity of inferior production which is evident and what is deviation in relation to the set parameters, it is necessary to use more digital outputs. Intelligent camera FQ has a datalog function. This feature allows keeping a file with a table of values for each criterion measurement. For a modern production system, this data exchange is not fast and effective enough. It requires human intervention to be processed, which means it can not be included in the enterprise's SCADA system.

This problem is solved in the new generation of intelligent camera model FQ2. This camera already has had an EtherNet/IP^{TM} interface. A machine vision system with camera model FQ2 is shown on Fig.5.



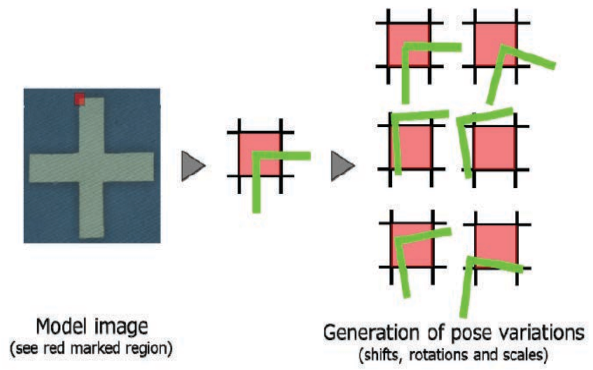
Structure of machine vision system with camera model FQ2

When using such a camera included in a SCADA system it is no longer a problem. The high-speed interface allows to be achieved the necessary data exchange. Significant improvements are also in recognition algorithms. This generation of intelligent cameras have the high-tech Shape Search III algorithm [3], [6]. It allows work with complex objects in light interference conditions and poor background. Several objects entering the camera's work area can be inspected simultaneously, even if objects are poorly or partially illuminated or rotated and overlapped. It is possible to measure distances between the outline of an object, detection of defects such as cracks, for example. There is compensation for displacement and rotation of the object. The ability to recognize text, different types of bar code and 2D code is built in. All of these features make it possible to expand the range of possible smart camera application areas. In addition to the enhanced recognition algorithms, a significant difference is also noted in the camera setup. The setting of inspection areas is dramatically simplified compared to the previous FQ equipment.

In the FQ equipment, as in previous models of Omron's cameras, an underlying search algorithm based on image outlines (dense edge) is built. It can easily be influenced by slight changes in image contours due to unevenness in conveyor systems, slight geometric differences in the inspected targets, all of which lead to a drop in measurement accuracy and sometimes resulting in unexplained behavior of the systems. One possible solution to this problem is to be performed iteratively, comparing to multiple templates, which of course leads to a drastic drop in productivity.

Experimental results and quality analysis

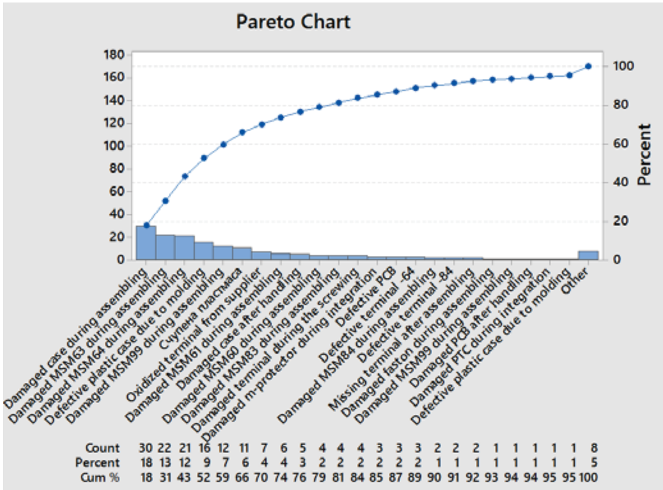
A solution to the machine vision system with camera model FQ2 is an algorithm using variation-absorbing templates. This method generates tens of thousands of possible variations for each local region to absorb the changes caused by these variations (Fig. 6)



The variation-absorbing templates method

Along with this, the generated patterns are clustered and pooled into groups based on their similarity, resulting in a reduction in the consumption of memory from 1/100 to 1/1000 compared to the amount of the generated templates. This does not lead to a drop in productivity and performance, only leads to increased accuracy and enables highly accurate recognition at high speeds. Some results of the data represent the observations of the different variations.

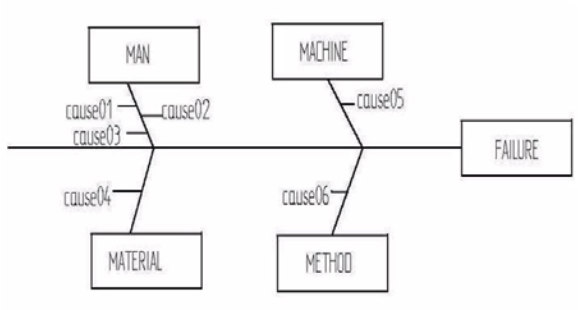
The results of the quality control of the described thermo-protector product are systematized for further processing. They are arranged in a table describing in detail: the type of defect that has occurred and number of defects of the type, change in which the defect occurred, date of occurrence, batch, operator, etc. To analyze the defects of production, first a Pareto diagram is built. The Pareto diagram for manufacturing of thermo-protectors is shown in Fig.7.



Pareto chart of inspection of thermal protectors

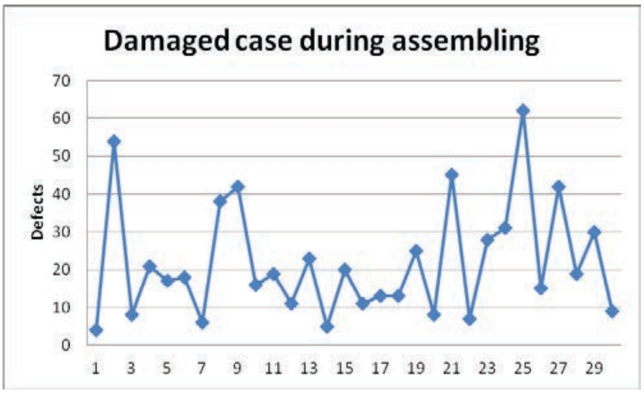
Three or five most pronounced defects/ problems are ispected. Each of them is subjected to thorough investigation using the Root cause analysis (RCA) method. RCA is a technique used to identify the conditions that initiate the occurrence of an undesired activity or state. The process of problem solving used to identify the underlying or initiating source of a nonconformance. In order to reach the cause of the defects, the so-called "Fishbone" diagram is built and shown in Fig. 8.

In the major bones or contributing to the occurrence of defects are:
Man Power (Personnel)
Machines (Equipment)
Materials (Reagents and Supplies)
Methods



Fishbone diagram

Besides the described techniques for analysis of defects and measures for their removal, a quick analysis of the condition of a defect also gives Time series plots. Time series plot can be used to visualise things that vary over time to also present in which order they occurred. A time series plot diagram can be constructed without advanced statistical software. Another advantage is that it is easy to interpret without deeper statistic knowledge and gives the possibility to see trends and process variation. A graph of the development over time of the most pronounced defect of a Pareto diagram of Fig. 7 is shown on Fig.9.



Time series plots

Thus, the accumulated and evaluated data from the quality control of the thermoprotection component can be used not only to enhance and permanently stabilize the quality. They are also to take preventative measures in servicing the machinery and equipment, involved in the production of the materials and elements involved n the final product.

Conclusion

An intelligent system for automated quality control of manufacturing process applications based on machine vision is presented in this paper. The quality of many produced parts in manufacturing processes depends on dimensions and surface features. The presented automated machine vision system analyzes those geometric and surface features and decides about tile quality by utilizing statistical analysis. Refined methods for geometric and surface features extraction are presented also. The efficiency of processing algorithms and the usage of an advanced analysis as a substitution of human visual quality control are investigated and confirmed.

The presented machine vision system has purpose to replace a human vision quality controller in the manufacture of modules for temperature protection of electric motors of compressors in refrigerators and freezers. The presented system consists of at least two cameras for image registration and one computer. After the image acquisition and trimming basic optic parameters, the geometric and surface analysis is performed. Geometric analysis relies on contour tracing method where several geometric inspection methods are united into one. Using this method, the complete time for analysis is reduced to acceptable limits suited for real time operations.

REFERENCES

[1] Batchelor B.G., Whealan P.F. (2002). *Intelligent vision systems for industry.*

[2] Forsyth D.A., Ponce J. (2003)., *Computer vision. A modern approach*. Whiliams publishing house.

[3] Gonzalez R., Woods R. (2002)., *Digital image processing*. Whiliams publishing house

[4]http://www.omron.com/technology/core/thinkAndSee/

[5] Said Ibrahim Abu Al-Roos *SCADA Online Product Quality Control*.(2013)

[6] OMRON Corporation**,** *Technology overview Pattern Matching Algorithm Shape search III*

[7] Jürgen Kletti (Ed.) Manufacturing Execution Systems – MES. *Springer-Verlag Berlin Heidelberg 2007. p.271*

[8] Monk, Ellen; Wagner, Bret (2006). *Concepts in Enterprise Resource Planning (Second ed.)*. Boston: Thomson Course Technology.

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ПРОЕКТИРАНЕ НА АСИНХРОННО ЕЛЕКТРОЗАДВИЖВАНЕ С КВАЗИРЕЗОНАНСЕН ПРЕОБРАЗУВАТЕЛ

ДИМИТЪР СПИРОВ, НИКОЛАЙ КОМИТОВ

Резюме: *Разработен е изчислителен алгоритъм за проектиране на асинхронно електрозадвижване с квазирезонансен преобразувател и управление с широчинно-импулсна модулация. Разгледана е работата на схемата по интервали и са определени напрежението и тока в постояннотоковото звено при синусоидална и простарнствено-векторна модулация. Представените сумулационни резултати потвърждават работоспособността на предложената методика.*

Ключови думи: *асинхронно електрозадвижване, квазирезонансен преобразувател*

DESIGN OF INDUCTION MOTOR DRIVE WITH QUASI-RESONANT CONVERTER

DIMITAR SPIROV, NIKOLAY KOMITOV

Abstract: *A methodology for design of induction motor drive with quasi-resonant converter and pulse width modulation control is developed. It examined the operation of the scheme in intervals and voltage and current in the DC link are calculated for sine-PWM and space vector-PWM. The simulation results confirm the performance of the proposed methodology.*

Key words: *induction motor drive, quasi-resonant converter*

1. Основни положения

Бързо намаляващите енергийни ресурси поставят въпроса за тяхното по-рационално и по-ефективно използване. Това довежда до необходимост от разработване и внедряване на енергоспестяващи производства. Като основен елемент на производствените системи се явява електрообзавеждането и електрозадвижването им. Основните елементи на електрозадвижването са двигателите и системите им за управление. Асинхронните електродвигатели са проектирани да работят с най-висока ефективност при пълно натоварване, но на практика това рядко се случва [1].

При това положение системите за управление са тези, които трябва да осигурят високоефективен режим при широк диапазон на изменение на изходните параметри и на смущаващите въздействия. Съвременните регулируеми електрозадвижвания трябва да притежават голяма точност, бързодействие, надеждност и устойчивост при стационарни и динамични режими в целия обхват на регулиране [2, 3].

Повишаването на честотата на системите, захранвани от инвертор с широчинно-импулсна модулация (ШИМ) довежда до повишаване на загубите в силовите ключове и комутационни ударни натоварвания.

Тези недостатъци могат да бъдат избегнати чрез използването на резонансни преобразуватели, осигуряващи намаляване на комутационните загуби за сметка на добавяне на пасивни, а в някои случаи и на активни компоненти. Извесни са различни видове резонансни преобразуватели, но основната идея при всеки от тях е, че превключването на силовите ключове трябва да стане при нулево напрежение върху тях или на нулев ток през тях, в резултат на което се намаляват значително комутационните загуби [2, 4].

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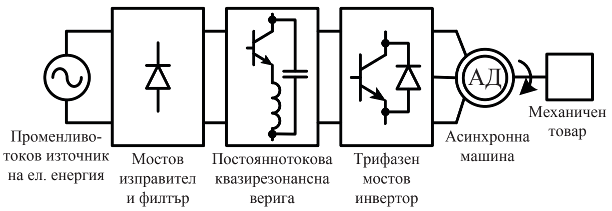
Целта на настоящия доклад е проектиране на асинхронно електрозадвижване с квазирезонансен преобразувател. Необходимо е да се изследва работоспособността на предложения алгоритъм.

2. Анализ на преобразувателя

Параметрите при проектирането на преобразувателя и на системата за управление се определят от асинхронната машина и задвижвания от нея механизъм, от техните режими на работа и товаров график. На фиг. 1. е дадена схема на регулириемо асихронно електрозадвижване с квазирезонансен преобразувател.



Фиг. 1. *Регулириемо асихронно електрозадвижване с квазирезонансен преобразувател.*

Захранването се осъществява от променливотоковата мрежа. Входното синусоидално напрежение се изправя от диодния мостов изправител и се изглажда от филтровия кондензатор. Трифазния мостов инвертор осигурява трифазното напрежение за захранване на асинхронния двигател с напрежение и честота, определени от режима на работа. За управлението на силовите ключове се използва генератор на широчинно модулиран сигнал (ШИМ генератор). Амплитудата на изходното напрежение се определя от модулационния индекс $m=U_m/U_{mp}$, където U_{mp} е амплитудата на модулиращия трионообразен сигнал, а U_m е амплитудата на модулирания синусоидален сигнал. Честотата на изходното напрежение се определя от честотата на модулирания синусоидален сигнал $f_м$.

ШИМ-генератора формира входния управляващ сигнал на системата за управление с честота f_{pwm}. Честотата на превключване на резонансната верига се определя от броя рамена на инвертора, за три фази се получава $f_c=3f_{pwm}$. Периода на превключване на резонансната верига е $T_c=1/f_c$.

Режимът на работа на постояннотоковото квазирезонансно звено зависи от входното постояннотоково напрежение U_s и от товарния ток в постояннотоковото звено i_o. Формирането на тока i_o се определя от сигнала на ШИМ-генератора и от режима на работа на товара (асинхронната машина).

Ефективната стойност на основния хармоник на изходното линейно напрежение на инвертора при синусоидална ШИМ е:

$$U_Л = \frac{1}{2}\sqrt{\frac{3}{2}}mU_s = \frac{\sqrt{3}}{2}mU_{мр}, \qquad (1)$$

А при пространствено-векторна ШИМ е:

$$U_Л = \frac{1}{\sqrt{2}}mU_s = mU_{мр}. \qquad (2)$$

Модулирания синусоидален сигнал се дефинира с изразите:

$$\begin{aligned} u_{мA}^* &= U_m^* \sin\left(\omega_s t - \psi_u\right); \\ u_{мB}^* &= U_m^* \sin\left(\omega_s t - \psi_u - 2\pi/3\right); \\ u_{мC}^* &= U_m^* \sin\left(\omega_s t - \psi_u - 4\pi/3\right), \end{aligned} \qquad (3)$$

където:

$\omega_s=2\pi f_м$ – кръгова честота на модулирания синусоидален сигнал;

U_m^* – амплитудна стойност на напрежението в относителни единици: $U_m^*=U_m/U_{mb}$, $U_{mb}=U_{mн}$;

ψ_u – начална фаза на напрежението.

Модулираните токове на трите фази се дефинират от изразите:

$$\begin{aligned} i_{мA}^* &= S_A i_A^* = S_A I_m^* \sin\left(\omega_s t - \varphi\right); \\ i_{мB}^* &= S_B i_B^* = S_B I_m^* \sin\left(\omega_s t - \varphi - 2\pi/3\right); \\ i_{мC}^* &= S_C i_C^* = S_C I_m^* \sin\left(\omega_s t - \varphi - 4\pi/3\right), \end{aligned} \qquad (4)$$

където:

I_m^* – амплитудна стойност на фазовия ток в относителни единици: $I_m^*=I_m/I_{mb}$, $I_{mb}=I_{mн}$;

$\varphi=\psi_u-\psi_i$ – фазова разлика.

Токът в постояннотоковото звено i_o се определя от израза [4]:

$$i_o = S_A i_A + S_B i_B + S_C i_C, \qquad (5)$$

където S_A, S_B и S_C са състоянията на ключовете S_1, S_3 и S_5, определени от ШИМ генератора, а i_A, i_B и i_C са моментните стойности на тока в трите фази на двигателя. Ефективната стойност на тока в постояннотоковото звено може да бъде изчислена по израза за синусоидална ШИМ [5]:

$$I_o = I_m\sqrt{\frac{m\sqrt{3}}{4\pi}\left(1+4\cos\varphi^2\right)}, \qquad (6)$$

където I_m е максималната стойност на фазовия ток на двигателя, а $cos\varphi$ е фактора на мощността.

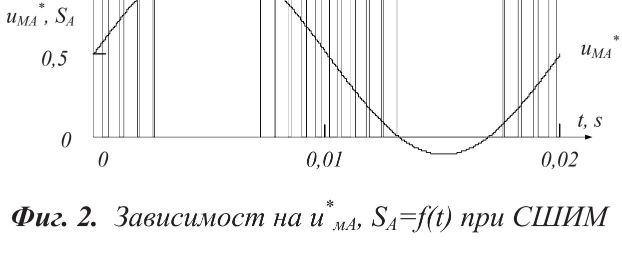
Постояннотоковото квазирезонансно звено осигурява нулиране на постоянното напрежение за превключване на силовите ключове на трифазния инвертор при нулево напрежение. При паралелните схеми това звено се състои от последователен ключ S_{a1} с обратен диод D_{a1}, един или няколко паралелни ключа и диода и пасивни елементи: резонансна бобина L_r (резонансен трансформатор с L_{r1} и L_{r2}) и резонансен кондензатор C_r.

3. Получени резултати

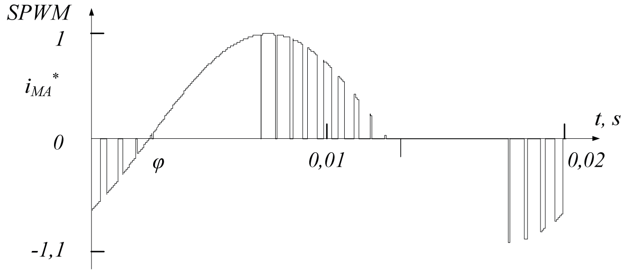
Изследвана е работата на преобразувателя при захранване на асинхронна машина 4АО 80В-4D с номинални данни, дадени в Приложение.

Захранването на схемата е трифазно с $U_{мр}$=380V. Входното напрежение на постояннотоковото звено се получава $U_s=\sqrt{2}U_{мр}$=537V. Номиналния режим на асинхронната машина се получва при захранване с $U_Л$=380V и $f_м$=50Hz и номинален товар. При синусоидална модулация номиналното захранващо напрежение се получва при модулационен индекс $m=2/\sqrt{3}\approx1{,}155$, определен по израз (1). Тъй като в режим на надмодулация (m>1) ефективната стойност на основния хармоник зависи нелинейно от m [2], то точната стойност на m се опрделя симулационно m=1,395. При пространствено-векторна модулация номиналното захранващо напрежение се получва при модулационен индекс m=1 определен по израз (2).

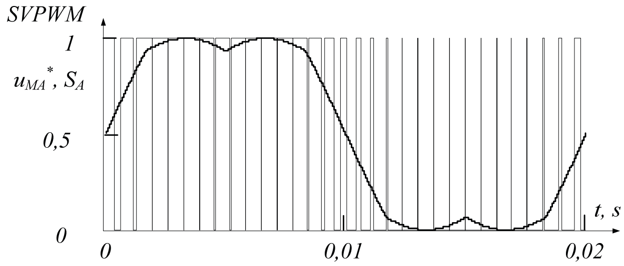
Графиките на сигнала S_A и модулираните сигнали на напрежението $u^*_{мA}$ и тока $i^*_{мA}$ за фаза A при $cos\varphi=cos\varphi_H$ (φ=43,95°), за синусоидална (СШИМ) и за пространствено-векторна (ПВШИМ) модулация са показани съответно на фиг. 2. - фиг. 5.



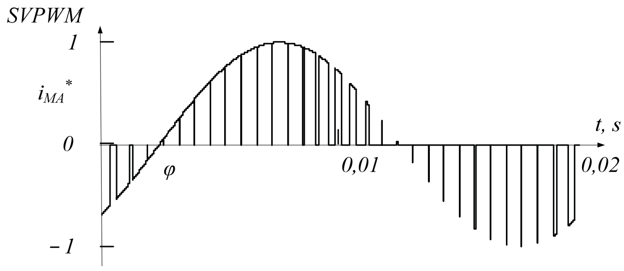
Фиг. 2. *Зависимост на $u^*_{мA}$, $S_A=f(t)$ при СШИМ*



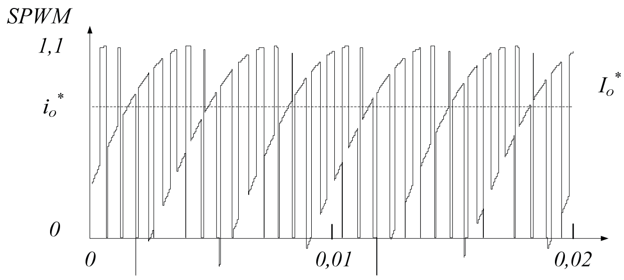
Фиг. 3. *Зависимост на $i^*_{мA}=f(t)$ при СШИМ*



Фиг. 4. *Зависимост на $u^*_{мA}$, $S_A=f(t)$ при ПВШИМ*

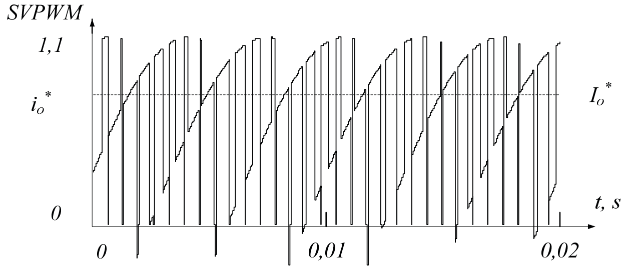


Фиг. 5. *Зависимост на $u^*_{мA}$, $S_A=f(t)$ при ПВШИМ*



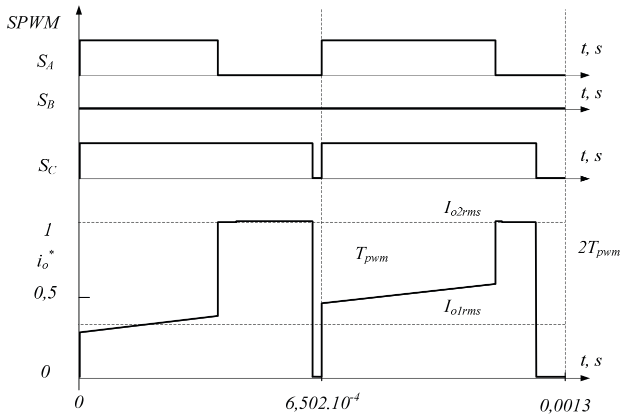
Фиг. 6. *Зависимост на $i^*_o=f(t)$ при СШИМ*

Токът в постояннотоковото звено i_o, определен по израз (5), при синусоидална и пространствено-векторна ШИМ е представен на фиг. 6 и фиг. 7.

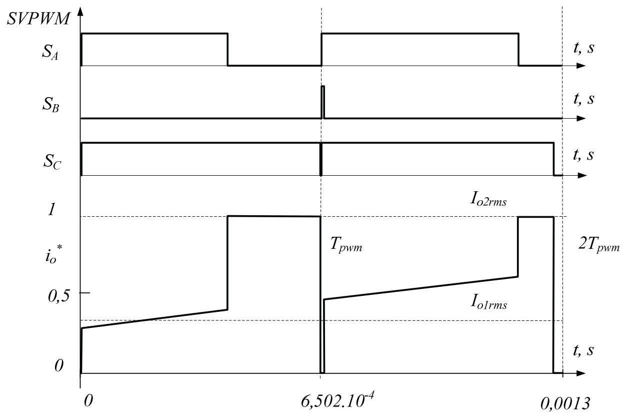


Фиг. 7. *Зависимост на $i^*_o=f(t)$ при ПВШИМ*

Анализът на работата на преобразувателя за първия интервал при $T_u=T_{pwm}$ се прави на базата на графиките, представени на фиг. 8 за синосуидална ШИМ и на фиг. 9 за пространствено-векторна ШИМ.



Фиг. 8. *Работа на преобразувателя за първия интервал при СШИМ*



Фиг. 9. *Работа на преобразувателя за първия интервал при ПВШИМ*

Ефективната стойност на тока за *x*-тия интервал I_{ox} от работата на схемата може да бъде определен с израза:

$$I_{ox}=\sqrt{\frac{1}{t_{1x}-t_{0x}}\int_{t_{0x}}^{t_{1x}} i_o(t)^2\,dt}\,. \qquad (7)$$

В Таблица 2.3 са систематизирани резултатите от изчисленията на I_o, I_{o1} и I_{o2} за първия интервал от работата на схемата, като превключтането става в момента t_0.

Таблица 1. *Резултати от изчисленията*

Модулация	I_o	I_{o1}	I_{o2}
	A	A	A
СШИМ	2,182	1,061	3,17
ПВШИМ	2,217	1,073	3,172

4. Заключение

Разработен е изчислителен алгоритъм за проектиране на асинхронно електрозадвижване с квазирезонансен преобразувател и управление с широчинно-импулсна модулация. Разгледана е работата на схемата по интервали и са определени напрежението и тока в постояннотоковото звено. Представените сумулационни резултати потвърждават работоспособността на предложената методика.

ЛИТЕРАТУРА

1. Chao, K., Liaw, C. (2001). Three-phase soft-switching inverter for induction motor drives. IEE Proc. Elect. Power Appl, Vol 148, No I, pp. 8-20.
2. Юдов, Д., и др. (1999). Повишаващ DC/DC преобразувател с подобрени енергетични показатели. Annual Journal of Electronics, TU-Sofia, стр. 120-125.
3. Dochev M. (2016). A test study stand for an adjustable asynchronous electric drive, XXV МНК „АДП 2016“, Созопол, стр.275-280.
4. Cho, J.G., Kim, H.S., and Cho, G.H. (1991). Novel soft switching PWM converter using a new parallel resonant dc-link, Proc. IEEE PESC, pp. 241-247.
5. Implementing Space Vector Modulation with the ADMCF32X, (2000). Analog Devices Inc.

ПРИЛОЖЕНИЕ

Технически данни на асинхронен електродвигател тип 4АО-80В-4D: P_N=0,75kW; U_N=380V; I_N=2,25A; n_N=1390min^{-1}; η_N=72%; $cos\varphi_N$=0,72; J_m=0,0013kgm^2.

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ОПРЕДЕЛЯНЕ НА ПАРАМЕТРИТЕ НА КВАЗИРЕЗОНАНСЕН ПРЕОБРАЗУВАТЕЛ С ДВА ПАРАЛЕЛНИ КЛЮЧА

ДИМИТЪР СПИРОВ, НИКОЛАЙ КОМИТОВ

Резюме: *Разработен е алгоритъл за определяне на параметрите на квазирезонансен преобразувател с една бобина и два паралелни ключа за захранване на асинхронна машина. Получени са аналитични изрази за работа на схемата по интервали. Формулирана е задача за оптимално определяне на параметрите на резонансните елементи. Представеното елетрозадвижване е моделирано в средата на PSpice. Симулационните резултати потвърждават достоверността на теоретичния анализ.*

Ключови думи: *асинхронно електрозадвижване, квазирезонансен преобразувател*

DETERMINATION OF THE PARAMETERS OF QUASI RESONANT DC LINK CONVERTER WITH TWO PARALLEL SWITCHES

DIMITAR SPIROV, NIKOLAY KOMITOV

Abstract: *A parallel quasi resonant DC link converter for induction motor drive application is analyzed and designed. The analytical equations and operating modes of the presented inverter are explained in details. The proposed drive system is modeled and its performance is simulated in PSpice. The design considerations are presented and the simulation results verify the theoretical analysis.*

Key words: *induction motor drive, quasi-resonant converter*

1. Основни положения

При инверторните електрозадвижвания с „твърда комутация”, силовите прибори се включват когато напрежението върху тях е ненулево и се изключват когато токът през тях има ненулева стойност [1, 2]. Всяко превключване е свързано със загуба на енергия. Използването на инвертори с „твърда комутация” за захранване на двигатели води до: електромагнитни смущения към електродвигателите и по цялата електрическа верига; при използването на дълги захранващи линии се получават пренапрежения върху клемите на двигателя; скъсяване на живота на лагетите; появат на шум и вибрации и др.

Тези недостатъци могат да бъдат избегнати чрез използването на резонансни преобразуватели, осигуряващи намаляване на комутационните загуби. Различните видове резонансни преобразуватели си приличат по това, че при всеки от тях превключването на силовите ключове трябва да стане при нулево напрежение върху тях или на нулев ток през тях, в резултат на което се намаляват значително комутационните загуби [1, 2, 3, 4].

Инверторите с квазирезонансно постояннотоково звено са получили най-широко разпространение при трифазните схеми и в частност при асинхронните задвижвания, поради редица причини [1]: възможност за „мека комутация” както при включване, така и при изключване на всички прибори на схемата; загубите в резонансните елементи извън времето за комутация са нулеви; товарът не участва в резонансния процес и др.

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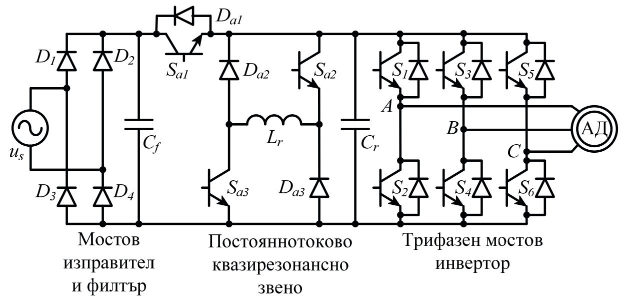
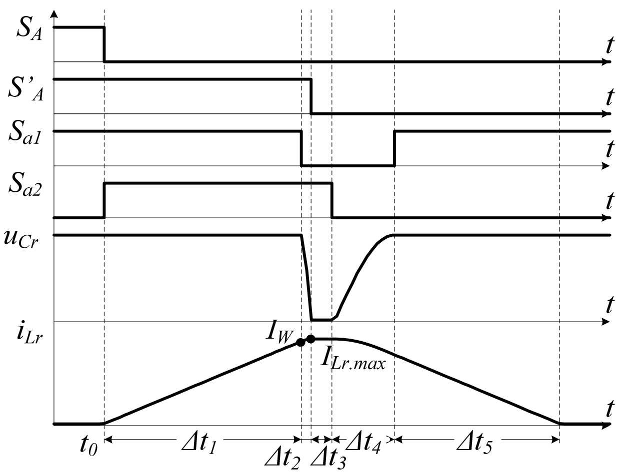
Целта на настоящия доклад е разработване на алгоритъм за определяне на параметрите на квазирезонансен преобразувател с една бобина и два паралелни ключа за захранване на асинхронна машина. Необходимо е да се изследва работоспособността на предложената методика.

2. Анализ на преобразувателя

Принципната схема на асинхронно електрозадвижване с квазирезонансен преобразувател с една бобина и два паралелни ключа в постояннотоково звено е представена на фиг.1.



Фиг. 1. *Принципна схема*



Фиг. 2. *Зависимости S_A, S'_A, S_{a1}, S_{a2}, u_{Cr}, i_{Lr} =f(t)*

Постояннотоковото квазирезонансно звено съдържа три силови ключа S_{a1}, S_{a2} и S_{a3}, три диода D_{a1}, D_{a2} и D_{a3} и резонансните бобина и кондензатор L_r и C_r.

Работата на постояннотоковото квазирезонансно звено може да бъде разделена на шест интервала (фиг. 2): установено състояние (до t_0); включване на бобината (Δt_1); резонансно разреждане на кондензатора (Δt_2); нулево напрежение на постояннотоковото звено (Δt_3); резонансно зареждане на кондензатора (Δt_4); връщане на енергия в захранващия източник (Δt_5).

На фиг. 2 е представена работата на преобразувателя по интервали.

От фигурата се вижда, че когато е необходимо превключване на някой от основните ключове на инвертора (например S_A), то се осъществява с известно закъснение $t_3=\Delta t_1+\Delta t_2$ след като напрежението в постояннотоковото звено спадне до нула чрез сигнала S'_A. Първо се включва резонансната бобина и нейния ток започва да нараства до стойност I_W. Тази стойност трябва да бъде достатъчно голяма, така че запасената енергия в бобината да гарантира резонансното зареждане на кондензатора.

От равенството на електромагнитната и електростатичната енергия при пълно преобразуване се получава:

$$W_{ем} = \frac{1}{2} L_r I_{Lr}^2 = \frac{1}{2} C_r U_{Cr}^2 \qquad (1)$$

От тук може да се определи граничната стойност на тока I_W, съответстващ на необходимата енергия, запасена в бобината:

$$I_W = U_{Cr} Z_r \qquad (2)$$

където $Z_r=\sqrt{(L_r/C_r)}$ – характеристичен импеданс на резонансния кръг.

След заместване на изразите за U_{Cr} и Z_r се получава [1]:

$$I_W = \sqrt{\left(\left(\frac{U_s}{Z_r} + I_{o1} + I_{o2}\right)^2 - \left(\frac{U_s}{Z_r}\right)^2\right)} - I_{o1}, \qquad (3)$$

където I_{o1} и I_{o2} са ефективните стойности на тока в постояннотоковото звено в интервала преди и след превключване на основните ключове.

Времето за зареждане на резонансната бобина Δt_1, времето за разреждане на кондензатора Δt_2 и общото време за преходния процес на резоанасните елементи T_W се получават [1]:

$$\begin{aligned} \Delta t_1 &= \frac{L_r I_W}{U_s}; \\ \Delta t_2 &= \frac{1}{\omega_r} a\,tan\left(\frac{U_s}{Z_r\left(I_W + I_{o1}\right)}\right); \qquad (4) \\ T_W &= \Delta t_1 + \Delta t_2. \end{aligned}$$

Входните изисквания при проектиране на преобразувателите с квазирезонансно звено са дадени в [1]:

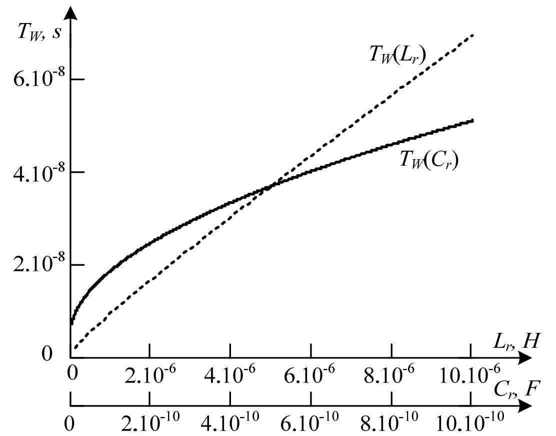
- Входното напрежение на инвертора трябва да бъде намалено до нула за превключване при нулево напрежение и отново да се повиши до напрежението на захранващия източник в рамките на резонансния цикъл;

- Токът при превключването трябва да бъде възможно най-малък, за да се намалят загубите в електрическата верига;

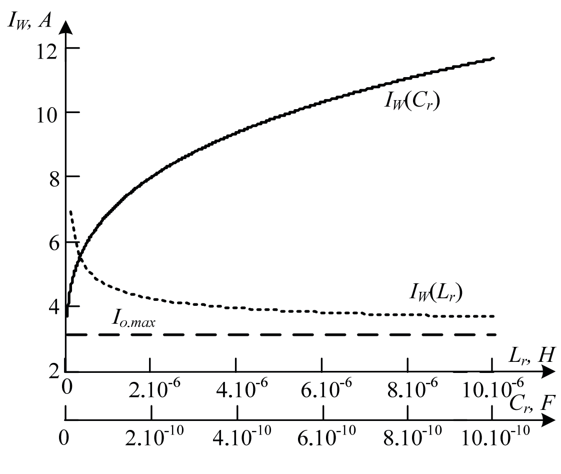
- Пиковите стойности на резонансните напрежение и ток трябва да се сведат до минимум, за да се намали претоварването на елементите във веригата;

- Скоростта на нарастване и намаляване на изходното напрежение на инвертора трябва да е ниска за електрозадвижвания със сравнително дълги кабели;

- Резонансният цикъл трябва да бъде много по-кратък от цикъла, определен от носещата честота на инвертора.



Фиг. 3. *Зависимости на $T_W=f(L_r)$ и $T_W=f(C_r)$*



Фиг. 4. *Зависимости на $I_W=f(L_r)$ и $I_W=f(C_r)$*

За удовлетворяване на входните изисквания, е необходимо времето за преходния процес на резоанасните елементи T_W и токът, осигуряващ запасяване на енергия в бобината I_W да имат минимални стойности. На фиг. 4 и фиг. 5 са представени графиките на T_W и I_W в зависимост от изменението на L_r и C_r. От графиките се вижда, че минималната стойност на T_W се получват при минимални стойности на L_r и C_r, а минималната стойност на I_W се получава при при минимална стойност на C_r и максимална стойност на L_r.

Зададчата за оптималното определяне на параметрите на резоанасните елементи можем да формулираме в следния вид: да се намерят стойностите на L_r и C_r при които времето T_W има минимална стойност, а тока I_W не надвишава максималния установен ток на товара $I_{o.max}$. Уравнението на T_W е целевата функция, а уравнвнието на I_W е ограничително условие. Следователно на функцията трябва да бъде намерен локален минимум. Целевата функция се задава с израз (6), а ограничителното условие се получава от израз (3) във вида: $I_W–k_3I_{o.max}=0$, където $k_3=1,1$ е коефициент на запаса. Като второ ограничително условие се въвежда изискването резонансния кондензатор да има стойност не по-малка от реалната, която може да се използва, т.е. не по-малка от $C_{r.min}$. За $C_{r.min}$ се приема стойността 1nF. Функцията на Лагранж приема следния вид:

$$\begin{aligned} L(L_r, C_r, \lambda_1) &= T_W(L_r, C_r) + \\ &+ \lambda_1\left(I_W(L_r, C_r) - k_3 I_{o.max}\right) + \lambda_2\left(C_r - C_{r.min}\right), \end{aligned} \tag{8}$$

където λ_1 и λ_2 са коефициенти.

Условията на Kuhn-Tucker се поучават с изразите:

$$\left| \begin{aligned} &\frac{\partial L(L_r, C_r, \lambda_1, \lambda_2)}{\partial L_r} = 0; \\ &\frac{\partial L(L_r, C_r, \lambda_1, \lambda_2)}{\partial C_r} = 0; \\ &\frac{\partial L(L_r, C_r, \lambda_1, \lambda_2)}{\partial \lambda_1} = 0; \\ &\frac{\partial L(L_r, C_r, \lambda_1, \lambda_2)}{\partial \lambda_2} = 0. \end{aligned} \right. \tag{9}$$

Получената система е от четири уравнения с четири неизвестни – L_r, C_r, λ_1 и λ_2. Оптималните стойности на резонансните елементи зависят само напрежението и токовете в постояннотоковото звено – U_s, I_{o1} и I_{o2}.

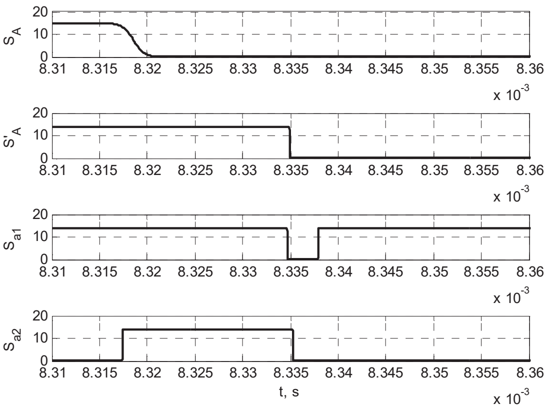
3. Получени резултати

В средата на Pspice е разработен симулационен модел на асинхронно електрозадвижване с квазирезоанасен преобразувател с една бобина и два паралелни ключа. С помощта на разработените модели е изследван трифазен асинхронен двигател тип 4AO-80B-4D с номинална мощност $P_N=0,75$kW.

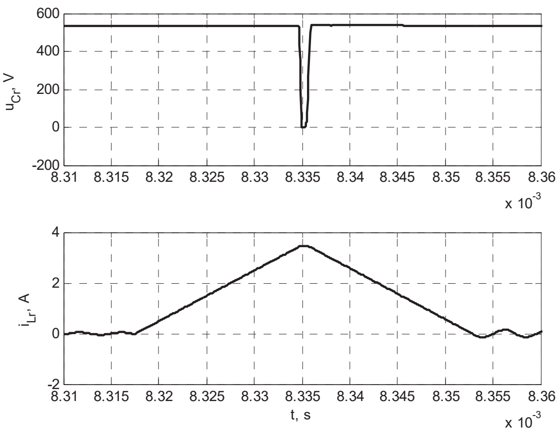
Проектирането на квазирезонансния преобразувател включва определянето на параметрите на L_r и C_r. На база на входните данни: U_s=537V; I_{o1}=1,073A; I_{o2}=3,172A, са изчислени оптимални стойности по система уравнениа (9). Резултатите са систематизирани в таблица 1. В същата таблица са дадени и минималните стойности на времето $T_{w.min}$ и тока $I_{w.min}$, получени по израз (6) и израз (3) съответно.

Таблица 1. *Оптимални стойности на резонансните елементи*

L_{ro}	mH	2,67
C_{ro}	nF	1
λ_1	-	$1{,}08.10^{-4}$
λ_2	-	$-1{,}74.10^{4}$
$T_{w.min}$	μs	0,6873
$I_{w.min}$	A	3,3285



Фиг. 5. *Зависимости S_A, ,S'_A, S_{a1}, S_{a2} =f(t)*



Фиг. 6. *Зависимости u_{Cr}, i_{Lr} =f(t)*

При генерирането на сигнал за превключване на основните ключове, допълнителните вериги трябва да се включат, така че да предизвикат резонансен преходен процес. Превключването на ключовете на инвертора става, когато захранващото напрежение се установи на нула.

Фиг. 3 и фиг. 4 представя част от получените резулатаи за един цикъл на работа на схемата. В таблица 2 са ставнени резултатите, получени от изчислителната методика с тези, получени от симулационния модел.

Таблица 2. *Резултати от изчисленията*

	Изч. методика	Сим. модел
Δt_1, μs	17,326	17,22
Δt_2, μs	0,118	0,21
Δt_3, μs	0,5	0,5
Δt_4, μs	2,567	0,57
Δt_5, μs	15,751	18,0
I_W, A	3,3285	3,45
$I_{Lr.max}$, A	3,499	3,46

От таблицата се вижда, че резулатаите, получени по изчислителната методика са близки до резултатите, получени от симулационния модел.

4. Заключение

Разработен е алгоритъм за определяне на параметрите на квазирезонансен преобразувател с една бобина и два паралелни ключа за захранване на асинхронна машина. Симулационно е изследвана работата на алгоритъма с асинхронно електрозадвижване, моделирано в средата на PSpice. От получените резултати потвърждават достоверността и работоспособността на алгоритъма.

ЛИТЕРАТУРА

1. Kedarisetti J. (2012). A Motor friendly Quasi-resonant DC-link Inverter. Ph.D. Thesis, TU-Darmstadt.
2. Юдов, Д., и др. (1999). Повишаващ DC/DC преобразувател с подобрени енергетични показатели. Annual Journal of Electronics, TU-Sofia, стр. 120-125.
3. Dochev M., G. Rashev (2013). Method and device for coil spring characteristics measurement, RaDMI 2013, pp. 777 – 782.
4. Bose B. (2001). Modern Power Electronics and AC Drives. Prentice Hall PTR, Upper Saddle River, NJ.

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СЪВРЕМЕННИ УСТРОЙСТВА ЗА КОНТРОЛ НА ДОСТЪПА

НИКОЛИНКА ЯНКОВА, ЕБРУ АДЕМ, ИБРЯМ АХМЕДОВ

Резюме: *Системите за контрол на достъп позволяват физическия достъп до сгради и помещения, като позволяват достъпа само на оторизираните лица с помощта на пълен набор от електронни методи за идентификация и електронни заключващи механизми. Функционирането им се базира на три признака на идентификация – „Какво знам?“, нещо което знаем като ПИН код, „Какво имам?“, нещо което притежаваме, като смарт карта, „Какво съм?, нещо което сме, като биометрични белези или комбинация от тях.*

Ключови думи: *биометрични данни, контрол на достъпа*

MODERN DEVICES FOR ACCESS CONTROL

NIKOLINKA YANKOVA, EBRU ADEM, IBRYAM AHMEDOV

Abstract: *Access control systems allow physical access to buildings and premises by allowing access to authorized persons only by means of a full range of electronic identification methods and electronic locking mechanisms. Their operation is based on three identifying features – “What do I know?”, Something we know as a PIN, “What do I have?”, Something we own as a smart card, “What am I?” , Which we are, like biometric marks or a combination of them.*

Key words: *access control, biometrics*

1. Увод

Съществуват много опасности, които с времето и напредването на технологиите, човечеството успява да се справи.

Защитата на обект се състои от няколко точки. Това зависи от нивото на чувствителни места. Във всички случаи е важно т. к. системата ще контролира контрол на достъпа (ACS) на обекта.

Добрата организация е използването на модерни технологии. ACS включват следното:

- противодействие на промишлен шпионаж;
- борба с кражба;
- противодействие на саботаж;
- борба с умишлено повреждане на оборудване ;
- записи на работното време;
- мониторинг на навременността на пристигането и заминаването на персонала;
- защита на неприкосновеността на личния живот;
- оценка на контрол на потока;
- контрол на влизане и излизане на транспорта.

В допълнение, ACS е бариера за „любопитни“.

С изпълнението на специфични системи за сигурност се използват различни методи за прилагането на устройства за идентификация и удостоверяване на самоличността.

Най-често се използва като ACS:

- въртящи се врати;
- турникет за преминаване в коридорите;
- шлюз кабина;
- автоматични врати;
- бариери;
- системи за паркиране;
- кръгли плъзгащи врати.

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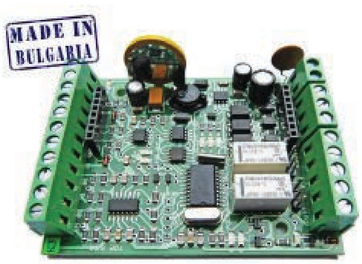
2. Динамични методи

Ръкопис и подпис динамика, гласови и речеви модели, темпо на работа на клапана. Един от известните методи е следният:

Интелигентен микропроцесорен контролер за контрол на достъп до две врати и работно време с RS485 комуникация. Този модел е подходящ за изграждане на обекти с множество контролери от серията iCON 1XX свързани в шина или самостоятелно ползване със сериен или LAN конвертор.



Фиг. 1. *iCON110*

Контролерът iCON110 от Фиг. 1 има възможност за управление на една врата двустранно или две врати еднострaнно. Разполага със стандартизирани входове за два четеца, които имат възможност за работа в режим с ПИН код, карта с работен код, биометрични четци или комбинация от тях.

Във връзка с обслужването на системата контролерът работи в два режима:

1. самостоятелен
2. серийна комуникация.

При самостоятелния режим на работа добавянето и изтриването на картите се осъществява посредством Мастер карта, която се активира първоначално чрез потребителски софтуер. В режим комуникация имаме възможност да се възползваме от удобството и бързината на серийната RS485 комуникация. Това ни дава възможност да ползваме iCON110 в самостоятелен режим с LAN или сериен конвертор или да го свържем в шина с до 253 устройства посредством RS485.

Всички настройки се извършват с помощта на платен (Andromeda Pro) или безплатен (Andromeda Tool) софтуер, които допринасят за ползване на допълнителни функции, описани във функционалността на контролера.

Трябва да се използват такива уникални статични методи, като идентификация на слой на кожата, по отношение на сканиране на пръста, динамични методи – идентификация на движението на устните при възпроизвеждане на кодова дума.

Биометричните идентификатори работят добре само когато операторът може да провери две неща:

Първо – че биометричните данни получени от даден човек са верни

Второ – че тези данни съвпадат с модела, който се съхранява в досиетата.

Биометрични характеристики са уникални идентификатори, но въпросът за тяхната надеждно съхраняване и защита срещу подслушване остава отворен.

Известно разработване ACS, въз основа на показанията и сравнението СОИ решетъчни конфигурации вените на китката, миризмата на пробите превърнати в цифров вид.

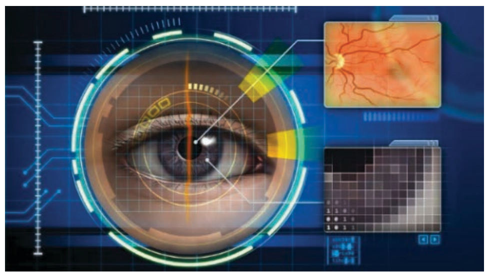
Всяка биометрична технология се прилага в следните етапи:

- сканиране обект;
- премахване на индивидуална информация;
- създаване на шаблон;
- сравняване на текущата база данни шаблон.

Потребителят адресира искане до ACS за достъп предимно идентичен, като се ратифицира с лична карта, ключ или личен идентификационен номер.

3. Идентификация с ирис

Пионер в областта на идентификацията от ирис на окото е д-р Джон Даугман. През 1994 г. той е патентовал в САЩ. Биометрично описване на структурата на ириса е подобно на баркод.



Фиг. 2. *Разпознаване по ирис*

Предимството на скенери на ириса е, че те не изискват потребителят да се концентрира върху целта, тъй като извадката пет-петна в ириса е на повърхността на окото. В действителност окото може да се сканира на разстояние по-малко от 1 m, което прави възможно използването на скенери на ириса за цели например в банкоматите. Разработване на технологии за идентификация.

Въз основа на сканиране на ириса по настоящем се използва в повече от 20 компании, включително British Telecom.

Има активна и пасивна система за разпознаване. В система от първият тип трябва да конфигурираме самата камера.

Пасивни системи – лесни за използване, тъй като камерата се настройва автоматично. Имат висока надеждност, оборудването има голямо приложение на всякакви обекти.

4. Идентификация на капилярите на ретината

При определянето на ъгловото разпределение, измерено от ретината, кръвоносните съдове в повърхността на ретината по отношение на мъртвата зона на очите и други симптоми. Моделът на капилярна система се различава от ретината дори при близнаци, и може да се използва много успешно за идентифициране на индивида.

Основното устройство за този тип система е бинокулярно. При провеждане на процедура за удостоверяване на потребителя трябва да се придържа окото към окуляра. През това време системата има време за осветяване на ретината и получава отразения сигнал. Не всеки човек ще се осмели да погледне в неизвестно нещо, което свети в очите му.

5. Идентификация по геометрията на ръката

Метод за удостоверяване на потребителя чрез формата на ръката в технологичната си структура и нивото на надеждност е сравнима с метода идентификация чрез пръстови отпечатъци. Статистическата вероятност за съществуването на две ръце е изключително малка със същата геометрия. На Фиг. 3 е примерен скенер.

Фиг. 3. *Скенер за геометрията на ръката*

Математически модел на идентификация за този параметър изисква някаква информация – само 9 байта, която ви позволява да съхранявате голямо количество записи и бързо търсене. Личните идентификационни устройства за ръчна геометрия така са широко използвани устройства в САЩ.

Най-популярното устройство сканира както вътрешната така и страничната част на дланта, с помощта на вградената видеокамера и алгоритми за компресия. Това възлиза на повече от 90 различни характеристики. Представител на тази тенденция е развитието на ACS American.

Фирмата Steller Systems, произвежда Identimat терминал. За отчитане на геометричните характеристики на ръката й с длан надолу в специалния панел. През процепите в повърхността на оптичния сензор клетка сканира четири пръстена. Тези клетки определят началната точка за два чифта пръсти – показалеца и средния, пръстен и малкия пръст. Всеки пръст е сканиран по цялата дължина, където дължината се измерва в огъване и разстоянието до „съсед“.

Резултатът на удостоверяване е положителен за потребителя. Цифровият стандарт се съхранява в база данни или в паметта на идентификационна карта. По този начин, за защита данните са криптирани.

F702 от Фиг. 4 е самостоятелен биометричен терминал за контрол на достъп и отчитане на работно време с пръстов отпечатък и парола.

Фиг. 4. *F702*

Внедрената операционна система базирана на Linux гарантира надеждността при непрекъснатата работа на терминала. Отговаря на всички световни индустриални стандарти.

Може да се използва в учреждения, където се изисква висок контрол на достъп като банки, корпоративни офиси, помещения със сървъри, помещения със складирана класифицирана информация, дори и за нужди на армията.

Биометричен терминал – контрол на достъп и работно време, базиран на лицево разпознаване, 125 kHz, ASK RFID и ПИН идентификация VF380. Общ вид на VF380 е даден на Фиг. 5.

Фиг. 5. *VF380*

Може да се използва в учреждения, където се изисква високо ниво на сигурност: банки, корпоративни офиси, помещения със сървъри, помещения за достъп до класифицирана информация. Терминалът може да се използва за отчитане на работно време, за контрол на достъп или в комбинация от двете.

Високо ниво на сигурност гарантирано от различни комбинации за идентификация: лицево разпознаване, RFID карта и парола, като всички методи могат да се комбинират.

TeraAccess – Представлява система за контрол на достъпа и отчитане на работно време, която се състои от следните компоненти:

- компютър, на който е инсталиран управляващият софтуер TeraAccess;
- контролери за достъп ACT120-O/O2;
- интерфейсен контролер, осъществяващ връзка между компютъра и контролерите (RS232/RS485);
- входни/изходни терминали за достъп (ACA1XX);
- безконтактни карти.

Новите устройства за достъп с карти са стилни и надеждни, поради което вече навлязоха и в големите хипермаркети например. Външен вид на устройството е даден на Фиг. 6.

Те са Ethernet мрежови устройства, което позволява да са много в една локална мрежа, не е необходимо да се довежда до тях допълнителен кабел, а само кабел с четири усукани двойки (например UTP или FTP). Захранващото напрежение се подава по същия кабел чрез PoE (Power over Ethernet).

Фиг. 6. *Устройство за достъп с карти*

3. Изводи:

Системата трябва да има възможност за интеграция на високо ниво с останалите системи за сигурност на един обект (основно контрол на достъп и видеонаблюдение) и графично представяне на информацията за актуалното състояние на системата и алармените събития на PC дисплей или на мобилен телефон.

Периферните устройства на системата - детекторите, трябва да могат надеждно и своевременно да реагират на всички видове атаки към обекта и същевременно процентът на фалшиви сигнали, независимо от пораждащите ги причини, трябва да е близък до нула.

Не на последно място, от значение за крайния потребител е простотата на управление на системата – колкото по-опростено е управлението, толкова по-малко са възможностите за човешки грешки по време на експлоатацията.

ЛИТЕРАТУРА

1. Ворона В., Тихонов. В. (2010). *Системы контроля и управления доступом.* М.: Горячая линия – Телеком, 272 с.
2. http://www.sectron.com/bg/grid/62/kontrol-na-dostyp-62/

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SECTION 2 • СЕКЦИЯ 2

ELECTRICAL ENGINEERING AND ELECTRONICS

ЕЛЕКТРОТЕХНИКА И ЕЛЕКТРОНИКА

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ANALYSIS OF TIME TO BREAKDOWN VOLTAGE MEASUREMENT

EMEL ONAL

Abstract: *In this paper, regression analysis of the experimental results for different gas mixtures at different pressures is done by a general purpose statistical software package called STATA. Experimental results contain breakdown times of varied gas mixtures under several pressures as nanosecond depends applied different voltage magnitudes at different polarities. Through the statistical software regression analysis done between three parameters, these are breakdown time as nanosecond, voltage magnitude as kilovolt and gas pressure as bar. After several regression analyses, gas pressure and voltage magnitude dependent breakdown time equations are obtained.*

Key words: *Impulse voltage measurement, breakdown, regression, statistics.*

1. Introduction

In practice high voltage insulation systems consist of different types of insulators such as gases, liquids, solids or any combination of them. When electric field applied to the insulator, breakdown is occurred. If insulation strength is higher than applied electric field breakdown is not occurred. This electrical breakdown phenomenon is not deterministic process, it is random. For this reason, properties of the insulator examined by statistically. To examine the electrical insulating properties of a system statistically, some experimental data are required. Therefore, to get experimental data about insulation system, under different voltage magnitudes, different insulators, different voltage polarities, some different any combination of them, measurements are obtained. Because the volt-time characteristics of the electrical breakdown of compressed gases is of practical importance in designing protection and insulation coordination for gas insulated systems, it has been studied theoretically [1-2] and experimentally [3-4].

After this data obtaining process, some statistical formulas can be obtained. In this paper using some experimental data, such as breakdown time depending on applied lightning impulse voltage magnitude and polarity and various insulating gases under different pressures, via a statistical software called STATA for each gas mixture regression analysis are done between three parameters, these are breakdown time, gas pressure and applied voltage magnitude. The theoretical predictions are examined in the light of extensive experimental results. Results are compatible with theoretical predictions.

2. Experimental results and regression analysis

In many engineering problems, two or more random variables are not statistically independent of each other during the same observation, so there is a relationship between these variables. The relationship between two variables is that one of them is influenced by the other, or that both variables are affected together by other variables. For example, the relationship between flow and rainfall in a river basin is arisen by flow is emerged after rainfall. The relationship between the flows in the two neighboring basins depends on whether they are affected by the precipitation in that area.

However, the relations are not deterministic (ie, functional), meaning that when one of the variables takes a certain value, the other will not always get the same value. This value may be slightly different in various observations due to the influence of other variables that we do not consider in a related way. For example, when one of the two adjacent river basins has a certain amount of flow, the flow in the other is not always has the same amount. Nevertheless, it is of great importance in practice to identify and determine the existence of nonfunctional relations between variables. Using this relation, it is possible to estimate the value of a variable depending on the known values of the other (or more) variables. This estimation is closest estimation of subjected variable although it is not the actual value. It can be said that the difference between the estimated value and the actual value

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(error) will also located within certain limits with a certain probability. The mathematical expression that represents a relation of the type mentioned above is called the regression equation. The purpose of regression analysis is to determine if there is a meaningful relationship between the variables considered, to obtain the regression equation expressing such a relation and to calculate the confidence intervals of the predictions to be made using this equation[5-8].

The results of the regression analysis and experimental analysis with different gas mixtures at different pressures are shown as follows.

The lightning impulse voltages used in this study are produced by a 1 MV, 50 kJ, Marx type impulse generator. The voltages are measured by means of a capacitive divider and a HIAS 743 digital oscilloscope with 12 bit real vertical resolution at 120 Mega sample / sec. All measurements of the experimental study are given in IEC standard. The present paper describes a study of breakdown strength signal analysis of Sulphurhexafluoride (SF_6) and SF_6 gas mixtures in positive impulse voltage. Sulphurhexafluoride gas due to its exceptional insulating and arc-extinguishing properties has been widely employed as insulation of high voltage power apparatus. Experimental test set-up is shown at Fig.1.

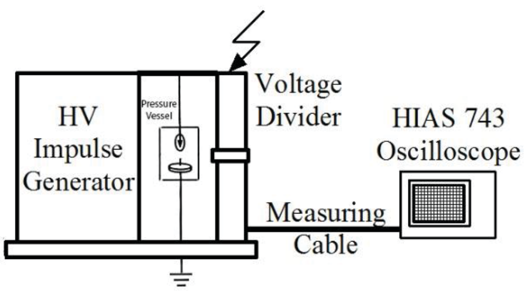

Fig. 1. *Experimental set-up*

2.1. Analysis of %100SF_6 Under Pressured Positive Polarity Lightning Impulse Voltage

First of all, breakdown time as nanosecond depended applied positively polarized lightning impulse voltage under 9 bar, 7 bar, 5 bar, 3 bar, and 1 bar pressure for 100%SF_6 gas is obtained experimentally. As an example graph of 100%SF_6 and 1 bar pressure is shown as Fig 2. As seen from Fig 2, when the breakdown time increases, the breakdown voltage decreases. Finding the time to breakdown curve is important for all equipment especially for designing insulation coordination. Basically two regimes can be distinguished, depending on whether breakdown occurs on the rise of the impulse or on its tail. The first regime occurs at much higher voltages than the latter one and it usually occurs at small electrode separations. In the first regime the time to breakdown decreases more or less regularly with increasing crest voltages while in the second one the time to breakdown shows at wide range distributions. SF_6 and SF_6 mixtures are generally used at switchgear and insulation equipment's because the breakdown voltage of this gas is very higher than that of other insulation gases.

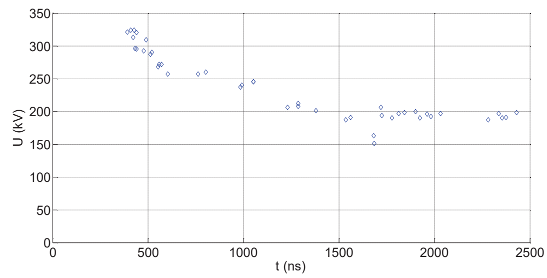

Fig. 2. *Experimental results of relationship between applied voltage magnitude U(kV) and breakdown time t(ns) for %100 SF_6 gas at the pressure of 1 bar*

If these values are transferred to the STATA environment, the values at following table 1 are obtained.

In engineering field, STATA is used to find out the breakdown time of machines. This analysis is also called reliability or failure time analysis[7-13].

Table 1. Regression analysis of %100 SF_6 gas

. reg t_ns bar U_kV

Source	SS	df	MS
Model	42366999.5	2	21183499.8
Residual	24114675.1	210	114831.786
Total	66481674.6	212	313592.805

Number of obs	= 213
F(2, 210)	= 184.47
Prob > F	= 0.0000
R-squared	= 0.6373
Adj R-squared	= 0.6338
Root MSE	= 338.87

t_ns	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
bar	-4.98655	8.184779	-0.61	0.543	-21.12141	11.14831
U_kV	-9.095287	.480204	-18.94	0.000	-10.04193	-8.148649
_cons	3442.428	126.3263	27.25	0.000	3193.398	3691.458

From here, breakdown time equation is obtained as follows;

t(ns)=3442.428-9.095287*U(kV)-4.98655*bar (1)

In equation (1), t shows the breakdown time in nanoseconds. U kV represents the peak value of applied impulse voltage. The bar in the equation takes the gas pressure between 8 and 0 bar as a bar unit.

Statistically, the value of P>|t| is 0, 543 which is inconsistent. Here is a conclusion, the effect of the gas pressures in this range is less effective than impulse voltage peak magnitude. As seen figures 2,3,4, breakdown time and voltage values are varied in large range. For this reason, it is important to know time to breakdown values.

2.2. Analysis of %50 SF_6 +%50 N_2 Under Pressured Positive Polarity Lightning Impulse Voltage

In our second model, the following regression analysis is obtained from our data, which consist of a mixture of 50% SF_6 + 50% N_2 gases and have different breakdown time due to different voltage amplitudes with positive polarity at different pressures as 9, 5, 3, 1 bar. As an example time to breakdown voltage graph of 100%SF_6 +%50 N_2 gas mixtures for the pressure of 1 bar is shown as Fig 3.

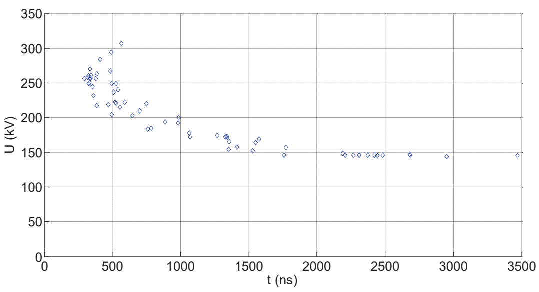

Fig. 3. Experimental results of relationship between applied voltage magnitude U(kV) and breakdown time t(ns) for %50SF_6+%50 N_2 gas mixture at the pressure of 1 bar

Regression equation for %50SF_6+%50 N_2 gas mixture is shown at equation (2).

t (ns)=3328.191-10.59744*U (kV)+4.73382*bar (2)

2.3. Analysis of %1 SF_6 +%99 N_2 Under Pressured Positive Polarity Lightning Impulse Voltage

Experimental result is shown at Fig. 4 for %1 SF_6+%99 N_2 gas mixture.

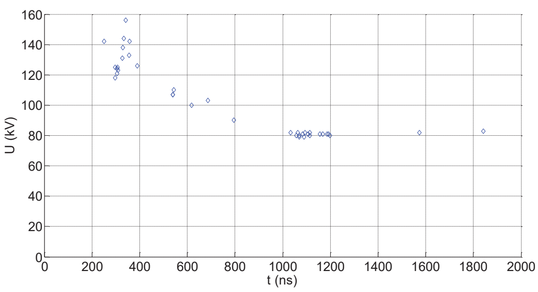

Fig. 4. Experimental results of relationship between applied voltage magnitude U(kV) and breakdown time t (ns) for %1 SF_6+% 99 N_2 gas mixture at the pressure of 1 bar

Regression equation for %1 SF_6+% 99 N_2 gas mixture is shown at equation 3.

t(ns)=1962-9.530341*U(kV)+34.51702*bar (3)

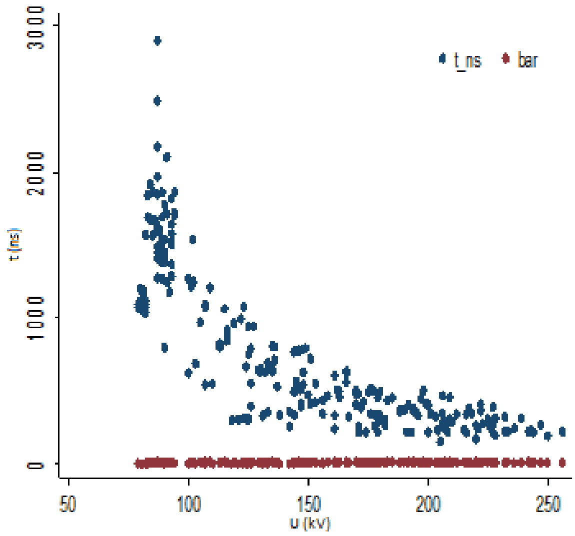

Fig. 5. Regression analysis results of relationship between applied voltage magnitude U(kV) and breakdown time t (ns) for %1 SF6+% 99 N2 gas mixture at the pressure of 1 bar

Table 2. Regression analysis of different percentage of SF_6 and SF_6 mixtures

Test environment	Standard deviation	Skewness	Kurtosis
%100 SF_6 gas at pressure of 1 bar	684.7446	0.1774	1.6092
%50 SF_6+%50 N_2 gas mixture at pressure of 1 bar	839.2957	0.8939	2.6595
%1 SF_6+%50 N_2 gas mixture at pressure of 1 bar	426.1696	0.3600	2.1473

3. Conclusion

The volt-time curves predicted by regression method with stata. The third case is presented in Fig. 5, together with the experimental results.

It can be seen that, for the three impulse waveshapes considered, the method that best fits the experimental data, which leads to a very good agreement between predicted and observed results. The greatest difference between measured and calculated times to breakdown is at %50 SF_6+%50 N_2, this case is seen at table 2 clearly. This values are insufficient to reach a definite result. It is needed to obtain more data for exact result.

For tail chopped impulses with the same time to breakdown, in principle the voltage value on the volt-time curve should be higher for waves with shorter tails. As such impulses have faster decays, higher voltage levels should be required for the breakdown to occur. The longer the time to breakdown in relation to the time to crest, the more pronounced should the differences between the curves be. As seen in fig. 5, breakdown values of experimental values are lower than that of predicted values. Because predict values are more results.

It is carried out experiments and simulation to investigate the relationship between breakdown characteristics and time parameter of applied lightning impulse voltage in this paper.

These relationships are also evident from Tables 1, 2 and fig.5. Since the tables depict that regression model among the three variables are very good fit for the considered analysis.

REFERENCES

1. Sima, W., Sun, P., Yang, M., Wu, J., Hua, J. Smith, S.E. (2016). Impact of time parameters of lightning impulse on the breakdown characteristics of oil paper insulation. *IET High Voltage*, Vol. (1), pages: 18–24.
2. Mazzetti, C., Pompili, M., (1990). Study of the Time to Breakdown in Transformer Oil under Impulse Conditions. *Transactions on Electrical Insulation,* Vol. (25), No. 6, pages: 12-26.
3. Joshi, V., Solanki, J., Solanki, S.K. (2013). Statistical method to improve voltage profile under incomplete distribution system information. *2013 North American Power Symposium (NAPS),* pages:1-5.
4. Maluckov, C.A., Mladenovic, (2016), S.A. Brakdown in low pressure Ne gas: mechanism and statistical analysis of time delay, *IEEE Transactions on Dielectrics and Electrical Insulations,* Volume (23), Issue: 1, pages: 202-210.
5. Nyanteh, Y., Srivastava, S., Edrington, S., Cartes, D., Rodrigo, H. (2015), A novel approach towards the determination of the time to breakdown of electrical machine insulating materials*, IEEE Transactions on Dielectrics and Electrical Insulation*, Vol. (22), Issue:1, pages: 232 – 240.
6. Lawless, J.F., (2003), *Statistical Models and Methods for Lifetime Data*, University of Waterloo, Wiley Interscience a john wiley & Sons Inc publication.
7. Wilson, M.P., Given, M.J., Timoshkin, V.I., MacGregor, S.J., Wang, T., Sinclair, M.A., Thomas, K.J., Lehr J.M, (2011), Weibull statistical analysis of impulse driven surface breakdown data, *2011 IEEE Pulsed Power Conference,* Pages: 218 - 222
8. Wang, Y., Wen, H., Jian, Z., Wu, Z, (2014). Steganalysis on positive and negative echo hiding based on skewness and kurtosis, *9th IEEE Conference on Industrial Electronics and Applications*, pages: 1235–1238.
9. Hayakawa, N., Yoshitake, Y., Koshino, N., Ueda, T., Okubo, H. (2005). Impulse partial discharge characteristics and their mechanisms under non-uniform electric field in N_2/SF_6 gas mixtures, *IEEE Transactions on Dielectrics and Electrical Insulation,* Vol.(12), Issue:5, pages:1035-1042.
10. Ushakov, V.Y.(2007). *Statistical Investigations of the Electrical Breakdown*, Springer Berlin Heidelberg, pages: 239-262.
11. Yuan, Z., Yu, L., Chun, D., Yi-chao, Y., Jin-liang, H., Xi, W. (2014). Experimental Study and Analysis of Insulator Breakdown Characteristics with Short-tail Lightning Impulse, *Journal of International Council on Electrical Engineering*, pages:199-203.
12. Kadir, M., Cotton, I. (2010).Application of the Insulator Coordination Gap Models and Effect of Line Design to Back flashover Studies, *Journal of Electrical Power and Energy Systems,* Vol. (32), no. 5, pages: 443-449.
13. Carrus, A., Funes, L.E. (1984). Very Short Tailed Lightning Double Exponential Wave Generation Techniques Based on Marx Circuit Standard Configurations, *IEEE Transactions on Power Apparatus and Systems*, Vol. (103), no. 4, pages: 782-787.

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SHORT TERM ELECTRICITY CONSUMPTION FORECASTING: A CASE STUDY OF ELECTRIC UTILITY AT TURKEY

EMEL ONAL

Abstract: *Energy need has been increasing day by day, and this situation makes energy management is requirement. That's why, significant rise can be seen about tending to energy management applications and different modelling in last years. This concept has a wide definition and also many subtitle. This study focus on consumption side, demand side management is explained by detail. Demand side management is the reaction of electricity price change given by consumers ranged from industrial to home. Demand switch occurs when the reaction effects the market. Demand response is entegrated via programs to market. This research is analyzed through consumption. Also demand management is defined by some resources as a whole applications for longer process. Demand response is kind of subtitle of demand management, which both of them aim the increasing of energy efficiency. At this study, the prediction is done by using daily peak electric consumption values for June 2016. The results are compared with the results of Turkey Electric Transmission Corporation. Data of Turkey Electric Transmission Corporation at maximum is % 5.94 bigger than that of found prediction values.*

Key words: Demand side management, Energy management, Electric consumption

1. Introduction

Purpose of Demand Side Participation is using more efficient and economic energy. This system has great benefits. That's why a lot of country has started to try that system many years ago. Still, there are studies about the development and using effective of this program. Even some countries issued regulations to consumers involve the system. Turkey is behind from these countries when it is compared. Fundamental of Demand Participation based on compatibility of supply and demand. Demand Participation becomes requirement in case of the harmony failures. Also, satisfying studies are not done in Turkey to entegrate demand participation into the market. Load flexibility must be provided and let the suppliers have opportunity to sale in market [1-4]. Therefore, these all prove that active demand side participation and works are needed in Turkey. While surveying why Turkey needs demand side participation, examples of this subject on foreign countries must be examined and achievements of countries whose implement that program very successfully should be analyzed. Demand side participation is important to provide flexibility to the market [5-9]. Because according to produced and purchased energy amount on all countries on world and problems of this distribution process of energy.

2. Turkey's and Other Countries Positions on Demand Side Management

Beginning of the 2000's, USA, some European countries and Australia started to operate this system successfully. Energy Efficiency Directive of European Commission put some articles to support the demand side participation for regulators in 2012. USA could be seen as more development country regarding demand side. One of the supplier companies, called ENERNOC, has come out with new projects with aggregators and conducted a survey country-wide including 4 other corporation. With this survey, 11.8 Billion Dollars energy saving is announced between 2013-2014 years. Additionally, after demand side participation is done and operated correctly, 500 Million Dollars income made is seen and announced by another research on USA since 2010. In Australia, this system is advanced level and consumers are willing to attend. Also, Canada, Japan and South Korea are the other countries whose attend in a significant level. It is possible to create more secure and clean sources by increasing the efficiency of this method.

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In our country, demand management projects are not developed and well planned. Energy is produced by natural gas on highest rate. Hence, energy interruption can be seen when the occasion that demand goes to peak point. For this reason, increasing the rate of renewable energy sources on production is very serious subject both our country and foreign countries[10-12] .

Demand participation is the system focused on consumer. When capital and small consumers entegrate into the system, providing the demand flexibility shows that how important the roles of every kind of consumers. According to research which is done by Smart Energy Demand Coalition, 2.2 Billion Dollars income was made in USA in 2013. Therefore, it was indicated that this situation prevented a large amount of investments to the wide grids and power plants just by using system. And this means huge benefit for consumers. So, all kind of consumer can take an advantage of this process and direct source can be made up through that, also productivity of this method can be measured. The direct source which is made up can launch to the market of countries local economies. In this way market could be relieved and consumers and suppliers might be encouraged for the market competition. Despite that, operating this process efficiently, whole barriers must be defined and looking for solutions to eliminate them. Likewise, entire tools, infrastructures, technological developments and projects must be examined.

3. Mapping Demand Response in Europe

Development of countries' demand response and their progress would be evaluated according to some criteria's. Also, mapping demand side response in Europe would be done based on these criteria's. These are;

*Consumer access & aggregation
*Programme requirements
*Measurement & verification
*Finance & penalties

Development of demand response of countries could be compared with each other according to these criteria's. As specified SEDC's (Smart Energy Demand Coalition) research, countries using this method efficiently do not have to make large scale investments to build power plants to produce energy. So, this source can be used their local economies. Reducing of investments for peak load back-up generators can be pointed as an example. Mapping and comparing are done in Europe according to reports which is published by SEDC for 2013, 2014 and 2015 years. When compared 2013 and 2014 years, Belgium, England and Swiss are the countries whose are active in this program in 2013, remain their activity in 2014. Besides those countries, Ireland, France and Finland become the active countries in 2014. These three countries studied partially about this program in 2013and by increasing their developments, they became an active situation in 2014. Austria, Norway and Sweden are three countries whose are in partial study for both 2013 and 2014 years as seen in fig.1. When looked at 2015 mapping, there is no country not active before 2015 and become an active after 2015. However, It can be seen that France and Swiss step forward as more active compared to countries whose status are in active in 2015. The reason for this is that participants and free aggregators, who are in market, roles and responsibilities are defined well in both country. Italy and Spain are the only the countries whose status are not in active for three years [13-14].

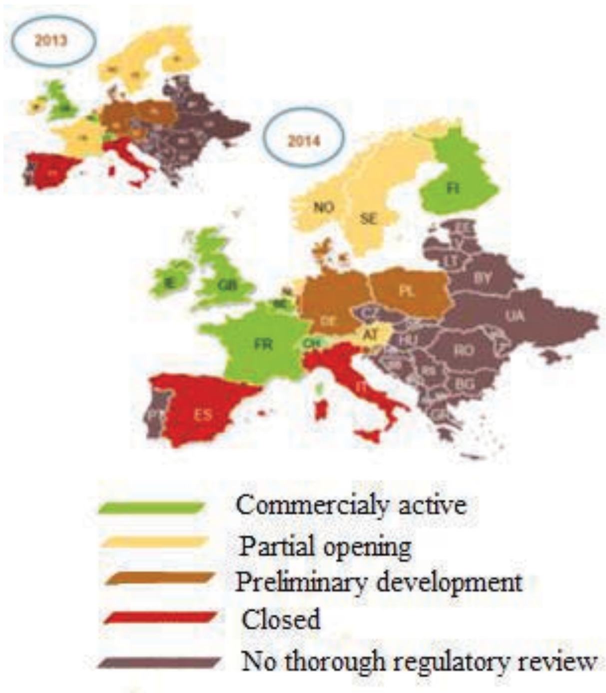

Fig. 1. *Demand Response Activity in Europe*

4. A Case Study: Prediction the consumption of next four years from daily peak load in June 2016

Peak load analyze is done in the fig. 2 at below for June 2016. The figure shows the highest and the lowest peak load values in one day in June. Load values can be seen in the figure for what time they reach highest or lowest point and how much they are. Because of the season, it could be predicted that high temperatures may lead to this situation. Also this proves that, those values are not only up to temperatures, but also terms, season or other different conditions can effect to peak load hours and their values. At here, certain days of one month are taken into the consideration.

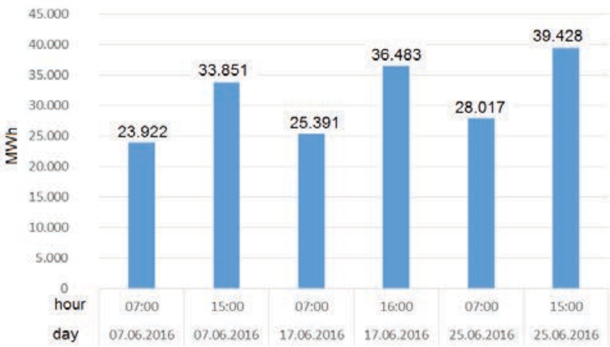

Fig. 2. *Daily highest and lowest hourly peak load*

Fig. 2 is analyzed by choosing random day in one month and examining the highest and lowest peak load in that day. This is also practiced to other random days in other months. As showed in the figure, according to values and hours when peak loads are highest and lowest level, it is possible to make some predictions. Although, these predictions could be made just based on normal circumstances, some other variables in certain time period can effect those predictions.

When considering 2016 monthly and yearly peak load analyze, the conclusion proves that why demand side management needs to be done, why focus on those projects and new modelling must be produced. Short-term demand forecasting also plays a role in the process of regulation. A precise estimate of demand is important for the purpose of setting tariffs. A detailed consumer category-wise consumption forecast helps in the determination of a just and reasonable tariff structure wherein no consumer pays less than the cost incurred by the utility for supplying the power. Also, the utility can then plan the power purchase requirements so as to meet the demand while maintaining the merit order dispatch to achieve optimization in the use of their resources.

According to reports published by TEIAS (Turkey Electric Transmission Corporation) real consumption amounts since 1970 can be seen on the fig.3. Using 3rd degree curve method, on the basis of the real consumption values between 1970-2015 years, demand prediction is made until 2020. Herewith, values found by using prediction is compared with other values which was made by TEIAS and the difference between both of them are shown in the fig. 3. Hereby, when compared with TEIAS predictions, the values at table 1 are seen.

Table 1. *Difference of predicted values of TEIAS and this study according to years*

years	difference of predicted values as percentage (%)
2016	1.43
2017	2.25
2018	3.42
2019	4.67
2020	5.94

Of course, all independent factors, occasions, financial parameters cannot known as certain on these predictions. It can be said that those differences are reasonable. The reason that the TEIAS data is high is increasing energy need.

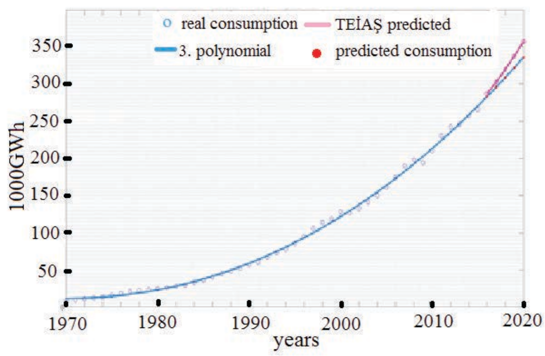

Fig. 3. *Real consumption and prediction values between 2016-2020*

5. Conclusion

In conclusion, Demand Side Response is defined, how it is operated on other countries is shown and benefits of this system are indicated. Peak load is analyzed by hourly, weekly, monthly and yearly for 2016. With all these data's, according to previous months, terms and years, prediction is practiced with consumption values. It all summarize how important the demand side management is. Because otherwise, at negative scenario different kind of problems which my lived can be estimated. As a result, nowadays, considering expanding energy needs of countries, more significant and effective planning and new modelling can point the benefits of this system.

The nature of the forecasts has also changed over the years. It is not enough to just predict the peak demand and the total energy use, say on an annual basis. Since the whole objective of demand-side management is to alter the system load shape, a load shape forecasting capability within the system is most desirable. The various methods of implementing demand-side management are time of use pricing, use of curtailable/interruptible rates, and imposition of penalties for usage beyond a predetermined level, and real time pricing. A time-of-day tariff structure to manage peaks and troughs in electricity demand, an hour-by-hour load shape forecast has become an essential prerequisite.

Further, the end-use components of the load shape must also be known in order to plan the other demand-side management activities to achieve maximum conservation, while avoiding undue demand restrictions. Another use for demand forecasting models is the assessment of the impact that a new technology might have on the energy consumption. This helps planners to evaluate the cost effectiveness of investing in the new technology and the strategy for its propagation.

REFERENCES

1. Capehart, B. L., Turner W. C., Kennedy W. J. (2012). *Guide to Energy Management*, 7th ed. Bookshub publication, pages:120-130.
2. Wang, Y.,Yang, W., Liu, T. (2017). Appliances considered demand response optimisation for smart grid, *IET Generation, Transmission & Distribution,* pages: 856-864.
3. Huang, Y., Tian, H., Wang, L. (2015). Demand response for home energy management system, *International Journal of Electrical Power Energy Systems*, Vol. (73), pages: 448–455.
4. Samadi, P., Mohsenian-Rad, A.H., Schober, R., Wong, V. W. S., Jatskevich, J. (2010). Optimal real-time pricing algorithm based on utility maximization for smart grid, *IEEE International Conference on Smart Grid Communications,* pages: 415–420.
5. Bertoldi, P., Zancanella, P., Boza-Kiss, B. (2016). Demand Response status in EU Member States, *European Commision JRC Science for policy report,* Pages:14-35.
6. Ishik, M.Y., Göze, T., Özcan, İ., Güngör, V.Ç., Aydın, Z. (2015). Short term Electricity Load Forecasting:A case study of electric utility market in Turkey, *Smart Grid Congress and Fair (ICSG), 2015 3rd International Istanbul.*
7. Albadi, M.H., El-Saadany, E.F., (2008). A summary of demand response in electricity markets, *Electric Power Systems Research*, Vol. (78), pages: 1989–1996.
8. Ikäheimo, J., Evens, C., Kärkkäinen, S. (2010). DER Aggregator business: the Finnish case, Research Report: *Technical Research Centre of Finland (VTT): Finland,* pages 39-41.
9. Türkyılmaz, O., (2015). Turkey's Energy Outlook Report. *Journal of Turkish Chamber of Mechanical Engineers*, Vol. (200), pages: 20-22.
10. Turkısh Electrical Energy 10- Year Generation Capacity Projection (2009-2018). (2009). *Turkısh Electricity Transmission Corporation Research Planning and Coordination Department,* pages:56-67.
11. International Energy Agency, (2016), *Energy Policies of IEA Countries 2016 Review Turkey,* pages:177-198.
12. Yuksel, I. (2015). South-eastern Anatolia Project (GAP) factor and energy management in Turkey, *Energy Reports*, Vol. (1), pages:151-155.
13. Yumurtaci, Z., Asmaz, E. (2004). Electric energy demand of Turkey for the year 2050, *Energy Sources*, Volume (26), Issue 12, pages:1157-1164.
14. Boiron, A.,Lo, S.,Marot, A. (2012). Predicting Future Energy Consumption, *CS229 Project Report,* pages:1-5.

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ХИБРИДНИ МРЕЖИ ИЗГРАДЕНИ ПО ТЕХНОЛОГИЯ ЗА ПЛЪТНО УПЛЪТНЕНИЕ НА КАНАЛИТЕ ЧРЕЗ ДЕЛЕНИЕ НА ДЪЛЖИНАТА НА ВЪЛНАТА

АЛЕКСАНДЪР САРАФОВ

Резюме: *Документът представя работата и принципът на действие на хибридни мрежи изградени по технология за плътно уплътнение на каналите чрез деление на дължината на вълната. Разглеждат се потенциалните проблеми при използване на метода за плътно уплътнение на каналите чрез деление на дължината на вълната, като загуби по влакното, прислушване, нелинейни ефекти, капацитет на възможните канали, които могат да бъдат уплътнени, скорост за предаване на данни и общ капацитет на хибридната мрежа. Засяга се тяхното настоящо и бъдещо приложение в съвременият бързо развиващ се свят на компютърните мрежи.*

Ключови думи: *оптични, мрежи, плътно, уплътнение, канали, светлина, дължината на вълната, капацитет, скорост, кохерентност.*

HYBRID NETWORKS USING DENSE WAVELENGTH DIVISION MULTIPLEXING (DWDM) TECHNOLOGY

ALEXANDER SARAFOV

Abstract: *The document reviews the work of the hybrid networks using dense wavelength division multiplexing (DWDM) technology. The potential problems in using the dense wavelength division multiplexing (DWDM) technology are considered. A review of their present and future usage in the fast changing technology world in the field of computer communications or data communications is given.*

Key words: *optics, networks, dense, multiplexing, channels, light, wavelength, capacity, velocity, coherent*

1. Въведение

Като начален момент в съвременната история на предаване на информацията в пространствено-времевия контур се дава периода 1887-1891 г. в който германския физик Хайнрих Рудолф Херц, успява експериментално да докаже съществуването на електромагнитната вълна предсказана теоретично от шотландския физик Джеймс Кларк Максуел през 1873 г. на базата на съставената от него динамична теория на електромагнитното поле (която от своя страна е селектирана съвкупност от емпирични и теоретични зависимости от формули и постулати на физици изследвали природата на електромагнитното поле, като той също влиза в това число с частичен принос). Още един значително важен извод от теорията на електромагнитното поле е, че светлината е също електромагнитна вълна и може да се разглежда като функция от пространствено-времевия контур. Експерименталното доказателство на Хайнрих Херц се състои в долавянето на излъчена електромагнитната енергия разпространяваща се в пространствено-времевия контур под формата на електромагнитна вълна или с други думи предаването и приемането на електромагнитото поле между два токови контура, които нямат обща галванична връзка помежду си. Няколко десетилетия по-късно след откритието на Херц става и догатката за използването на свойствата (параметрите) на

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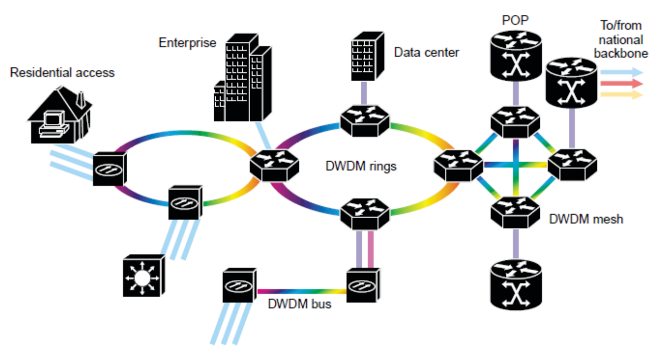
електромагнитната вълна чрез тяхната промяна за пренасянето на информация, като информацията се смята за отделна трета съставка зависима от пространствено-времевия контур, което възприемане и анализ допълва знанието/незнанието на човешки индивид за конкретно събитие в пространствено-времевия контур, като всичко случило се до момента на предаване на информация се счита за такова. След доказателството на Хайнрих Херц на труда на Джеймс Кларк Максуел динамична теория на електромагнитното поле, започва и нейното по-нататашно развитие, като от една страна параметрите на теорията на модерната електродинамика са преобразувани в по-прости димесиални такива за улеснение на инженерни цели и се съсдава науката електротехника. Тя придобива широк интерес и масовост поради леснотата си и връзката с практическите си приложения, като измервания, изследвания, анализ и др. От друга страна теорията за електромагнитното поле продължава да се развива с непроменени параметри и така се създават науките, като микровълнова техника още позната и като свръхвисокочестотна техника, поради познатата връзка между дължината на вълната и честотата, както и науки свързани с теоретични познания за разпространението на електромагнитните вълни в различни веществени материални среди и ефектите, които настъпват в тях. Тази наука поражда теоретичния анализ на предавателните линии, като различни видове вълноводи, обемни резонатори и микровълнови елементи и устройства, но добива приложение една след 1940 г.. Теорията на връзковите уравнения в предавателните линии, като телеграфните уравнения, коаксиалния кабел и други видове проводници се основава на комплексни принципи между електродинамиката и електротехниката. Използването на тази теоретична база, както и на множество експериментални тестове на редица учени в периода от 1920-1970 г. води и до създаването на модерното оптичното влакно познато днес. Информацията е основен градивен елемент подържащ общуването или комуникацията, като обменен процес в съвремените комуникации между индивиди с разнообразни цели.

2. Хибридни мрежи изградени по технология за плътно уплътнение на каналите чрез деление на дължината на вълната

Технологията за плътно уплътнение на каналите чрез разделяне на дължината на вълната позната с английската абривиатюра DWDM (Dense Wavelength Division Multiplexing) се използва за изграждане на основни кръгово топологични мрежи познати и като (token ring) в английската литература при съвременните оператори и доставчици на интернет. Именно от тези мрежи обхващащи големи територии доставчика на услугата успява да снабди крайният потребител директно или използвайки друг поддоставчик по известен като (Tier 3 provider). Основната кръгова топология минава през големи градове или населени райони, като съответно за точката, където има разположено DWDM оборудване е прието и наименованието точка на присъствие PoP (Point of Presence). Кръговите мрежи изградени на принципна за плътно уплътнение на каналите чрез разделяне на дължината на вълната се налагат поради огромното количество от трафик, което мрежата трябва да поеме. Също така с тяхното използване се изпълнява едно от важните за клиентите изискване, а именно резервираността на услугата. Т.к. топологията е кръгова, ако възникне повреда между две точки на присъствие от мрежата е възможно пренасочване на трафика в обратна посока, така че той отново да стигне до дестинацията. Това неименуемо води до повишаване на трафика, който се носи от кръговата топология, като реално трафика който е пренасочен се наслагва сумира с трафика в обратна посока т.к. техните посоки съвпадат след пренасочването. По този начин общият сумарен капацитет на мрежата нараства драстично и е важно тя да е така проектирана да няма възможност за надхвърляне на нейния капацитет. Мрежи по технологията DWDM се използват още и за връзка между държави, а именно между две точки на присъствие разположени в две страни, почти винаги управлявани от два различни доставчика на услуга.

3. Симулации и експериментални резултати

Развитието на мрежите изградени по DWDM технологията отива още по-далеч, като започва изпозлването на хибридни мрежи изградени от DWDM оборудване, включвайки кръгови топологични мрежи, мрежи от точка до точка, както и смесени мрежи. Една такава хибридна мрежа е показана на Фиг. 1, като същата може да обхваща територии на цели континенти. Важен аспект е да се отбележи, че такива мрежи имат възможност за свързване на информационни центрове познати под английското наименование, като Data Centers.



Фиг. 1. *Топология на хибридна мрежа изградена от оборудване за плътно уплътнение на каналите чрез разделяне на дължината на вълната [2]*

Потенциални проблеми на мрежите изградени от оборудване за плътно уплътнение на каналите чрез разделяне на дължината на вълната:

- неефективно при малък брой мултиплексирани канали
- загуби по влакното; освен това спектрална зависимост на загубите
- прислушване
- нелинейни ефекти
- с увеличаването на броя на каналите предавани по едно влакно се увеличава и общата (сумарната) енергия на разпространяващото се ОЛ-е. Достига се до ниво, при което се проявяват нелинейни ефекти. Те зависят и от вълновото разстояние $\Delta\lambda$ между отделните канали
- четиривълново смесване – появяват се допълнителни компонентио
- стимулирано раманово разсейване – появяват се допълнителни компоненти
- изисква използването на оптични усилватели [4]

4. Заключение

Хибридните мрежи изградени по технология за плътно уплътнение на каналите чрез деление на дължината на вълната са бъдещето за свързване на най-големите доставчици на интернет в света (Tier-1) с мрежите на техните корпоративни клиенти, а именно по-малки разпространители на услугата интернет (Tier-2) и т.н. по топологията до достигане на крайните потребители с информационни центрове Data Centers в които има колокирано оборудване на корпоративни клиенти било то фирми или частни лица и точки на обмен на мрежови префикси по известни с английското наименование Internet exchange point (IXP или IX).

ЛИТЕРАТУРА

1. J. G. Proakis, *Digital Communications, 4th Ed*., McGraw-Hill, 2000.
2. Cisco Systems, Inc. Introduction to DWDM Technology.
3. Ultimate Spectral Efficiency Limits in DWDM Systems Joseph M. Kahn and Keang-Po Ho.
4. Лекции по Оптоелектроника и оптични комуникации на Техническия Университет-София

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DIPOLE ANTENNA OVER EBG STRUCTURE FOR UHF RFID APPLICATIONS

ANGEL SLAVOV, PETER Z. PETKOV, STOYAN ILIEV

Abstract*—This paper examines the possibility of designing a low profile antenna with high gain for RFID identification in the frequency range 865 to 868MHz. The advantages of the suggested structure are high gain and low profile compared to traditional antennas.*

Key Words**:** *EBG, antenna, dipole, gain, RFID*

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1. Introduction

Modern antenna technologies have evolved extremely and rapidly last years. One of the driving reason for that evolution is so-called metamaterials. In this paper we will focus on a specific part of metamaterials namely Electromag- netic Band Gap structures (EBG). These metamatirials exhibit electromagnetic features which may not exist in nature. These materials have simultaneously < 0 and $\mu < 0$. [1] This type of structure is applicable to a wide range of applications in antenna and propagation fields. For instance it can be used as a spiral and curl antenna to achieve low profile design. [2] One of the most interesting properties of metamaterials is the reflection phase. It is defined as the phase of the reflected electric field at the reflecting surface compared to the incident one. [3] It is known that a perfect electric conductor (PEC) has 180 ◦ reflection phase for a normal incident plane wave. A perfect magnetic conductor (PMC) has the reflection phase 0 ◦ but does not exist in nature. [1], [3]

However, EBG structures are more than the PMC surface. The reflection phase of the EBG surface varies from 180 ◦ to−180 ◦ versus frequency, not only 180 ◦ for the PEC surface or 0 ◦ for the PMC surface. This reflection phase feature makes EBG unique. For example one possible application of that surface it is usage as a ground plane of wire or patch antennas for low profile design which is desirable in many wireless communications systems. [3]

A basic question here is: How effective is the EBG struc- tures for low profile antenna applications? Mushroom-like is known to have effective bandgap for a surface-wave propa- gation. It can be used to improve antenna radiation patterns. When the incident wave is a plane wave (kx 2 + ky 2 ≤ k0 2 , kz has a real value), the reflection phase of the EBG structures varies with frequency. At certain frequency the reflection phase is zero degree, which resemble the perfect magnetic conductor that does not exist in nature. [1]

To understand how the EBG improves antenna parameters, a vector dipole antenna is used. The antenna consists of two orthogonal dipoles. The advantage of the suggested construction is that the antenna can realize circular polarization which is

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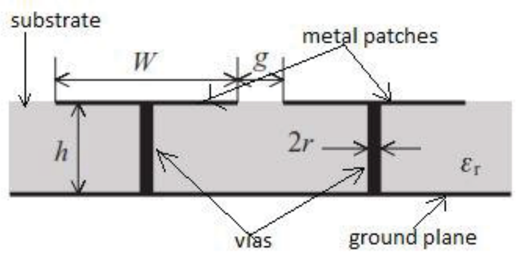
important for the RFID communications if both dipoles are used. Here only one dipole is used as radiator, for the sake of construction simplification.

The paper focuses on mushroom-like EBG structures in- vented by Sievenpiper et al. [4]. The structure studied here has a feature of compactness and can be integrated into printed circuit boards, which is very critical in handheld devices. To prove that it is necessary to be used the vector dipole antenna, the conventional ground plane and the EBG structure. Consequently three comparisons on antenna gain are presented: the vector dipole antenna, the dipole antenna with metal reflector and the dipole antenna with EBG structure.

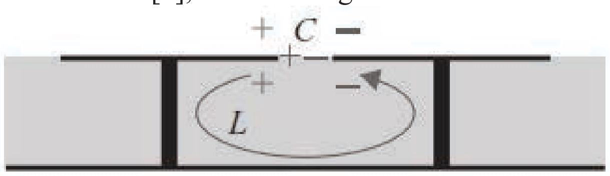
2. The EBG Structure

The mushroom-like EBG structure displayed here consisted of four elements: metal patches, a substrate, a ground plane and vias, which connected metal patches and the ground plane. This is illustrated in Fig. 1.



Фиг. 1. *Schematic diagram of the EBG structure*

The parameters in Fig. 1 are: w - width of the patch; g - patch distance; h - substrate height; r - radius via; r = 4, 3. The functionality of the EBG structure can be explained by a LC equivalent circuit model [1], shown in Fig. 2.



Фиг. 2. *Equivalent scheme of the EBG structure*

The inductance in that model comes from the current flowing along adjacent patches and connecting vias. The ca- pacitance result comes from the fringing electric field between adjacent metallic patches. The equivalent circuit model is able to predict the reflection phase as well as some surface wave properties. The capacitance and inductance in the equivalent circuit can be approximated by following formulas [5].

$$L = \mu_0 \mu_r h \qquad (1)$$

$$C = \frac{\omega \varepsilon_0 (1+\varepsilon_r)}{\pi} \cosh^{-1}\left(\frac{\omega + g}{g}\right) \qquad (2)$$

The fractional bandwidth (BW) ±90 ◦ of the reflection phase is received by the following formulas [5].

$$\omega_0 = \frac{1}{\sqrt{LC}} \qquad (1)$$

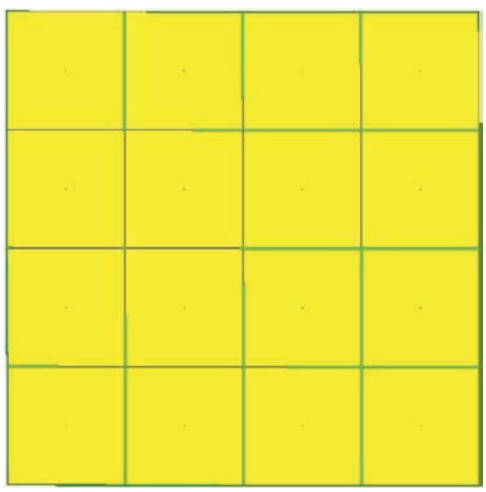
$$BW = \frac{\Delta\omega}{\omega_0} = \frac{1}{Z_0}\sqrt{\frac{L}{C}} \qquad (2)$$

3. Results

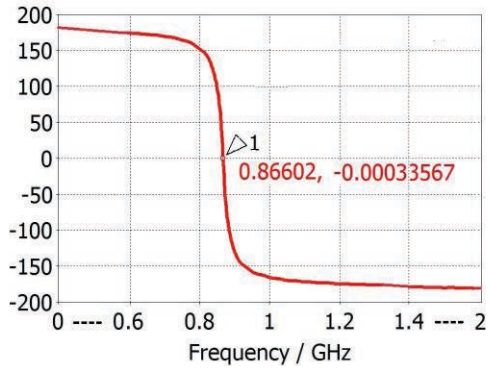
3.1. EBG Structure

For the RFID frequency range 865 MHz to 868 MHz the EBG structure is made with finite dimensions 300×300mm. The substrate material is FR-4 with thickness 2, 4mm. Accord- ing to formulas 1, 2 and 3 patch width is approximately w = 70 mm. Consequently the structure consists of 16 patches - 4×4. To simulate radiation structure described above commercial software CST Microwave Studio is used. The final dimensions after fine tuning are: patch width - 74, 24 mm; gap width - 0, 76 mm and via radius - 0, 25 mm. The EBG surface is shown in Fig. 3.

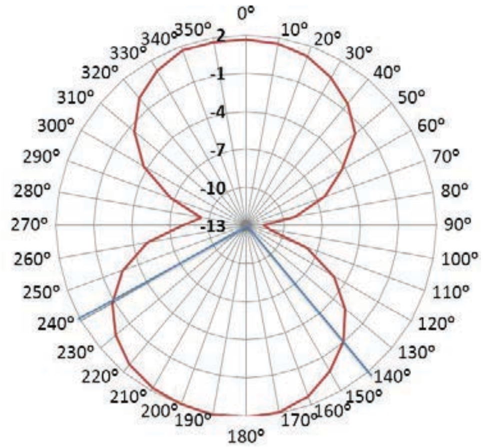
The reflection phase of the structure is determined by CST and presented in Fig. 4. As one can see from Fig. 4 the surface has reflection phase 0 ◦ at 866 MHz which is in desire bandwidth between 865 -868 MHz. In ±90 ◦ the construction has 30 MHz bandwidth from 850 to 880 MHz.



Фиг. 3. *The finite EBG structure*



Фиг. 4. *The Reflection phase of the EBG structure*



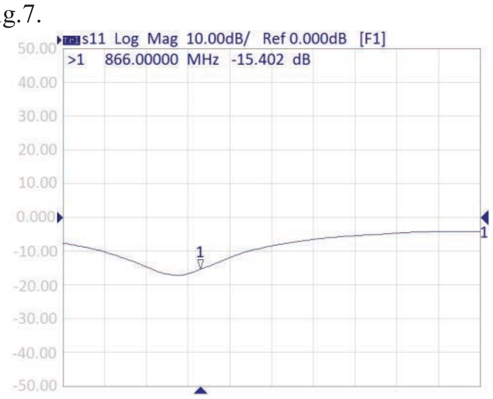
Фиг. 5. *The Radiation pattern of the dipole antenna (no reflector is employed)*

3.2. The Dipole antenna

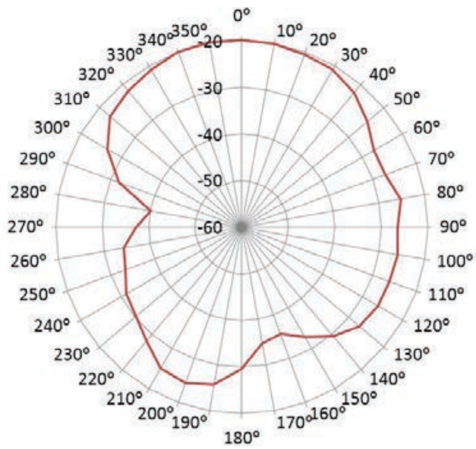
In this subsection the measurement results of the dipole antenna are presented. The antenna dimensions are: width – 104 mm, length – 104 mm, height – 2, 4 mm and substrate – FR-4. For feeding of the antenna a coaxial cable (50Ω) and balun mounted on a small PCB circuit in the middle of the antenna are used. The radiation pattern of proposed dipole is displayed in Fig. 5, resulting in gain of 2 dBi. The input return loss is displayed in Fig. 6.

3.3. The Dipole antenna with metal reflector

In this subsection the results from the dipole antenna over a plain sheet reflector are presented. The distance between the antenna and metal reflector is 1 mm. Later will be shown why a gap is chosen exactly 1 mm. For feeding of the antenna is selected again balun and coaxial cable (50Ω). There is a small hole on the metal reflector used to pass thru the coax feed cable. The dipole is fixed to the reflector with double sided adhesive tape with exact thickness of 1 mm. The measured radiation pattern of the dipole reflector struc- ture is displayed in Fig.7.



Фиг. 6. *Return loss of the dipole antenna (no reflector)*



Фиг. 7. *The Radiation pattern of the dipole antenna over a metal reflector*

Фиг. 8. *The Return loss of the dipole antenna over ground plain sheet metal reflector*

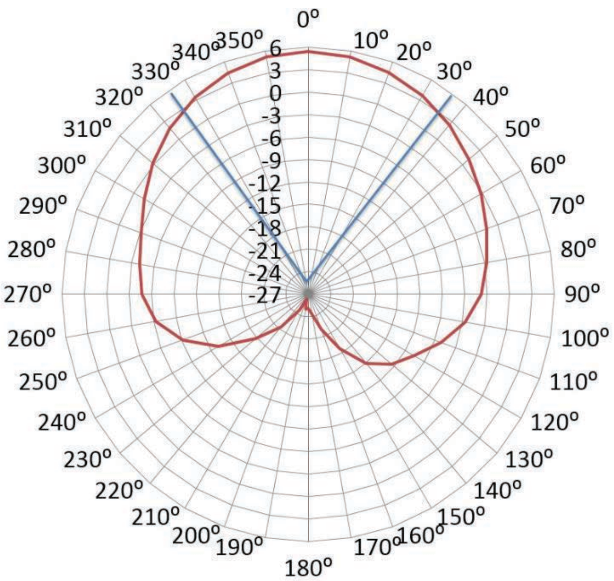
3.4. D. Dipole antenna with EBG reflector

A driving reason for researching the low-profile (closely spaced reflector) antenna is the necessity of compact systems for handheld applications. To achieve high gain and low profile at the same time, a parametric analysis is performed. The results are shown in table I.

From table I it can be concluded that a reasonable com- promise between high gain and low profile antenna can be achieved at 1 mm reflector distance from the radiating element. When the distance becomes over 15 mm the efficiency of the EBG surface significantly decreases.

The real construction is shown in Fig. 9. The final dimen- sions are: width – 300 mm, length – 300 mm and height – 5, 8 mm. For feeding of the antenna here also are used coaxial cable (50Ω) and balun which is mounted on a small PCB circuit in the middle of the antenna. Also on the EBG reflector there is a small pass-thru hole. The dipole and the EBG reflector are connected with double sided adhesive tape which has 1 mm thickness such as on the previous model with plain reflector.

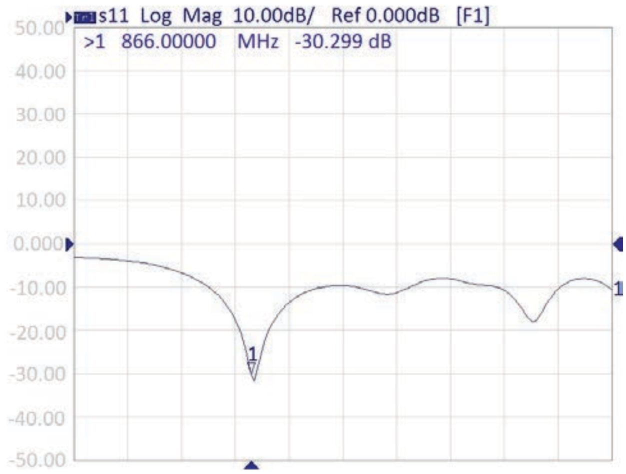
Фиг. 9. *The Real model of the antenna*



Фиг. 10. *The Measured radiation pattern of the dipole antenna over EBG structure*

Figure 10 shows the radiation pattern of the antenna with EBG structure. Also figure 10 shows gain of the antenna is G = 5, 7 dBi. The width of the main lobe is 70 ◦ which is a typical angle for RFID-application antennas. The return loss of the antenna is displayed in Fig. 11.

According to Fig. 11 the antenna has good impedance matching with reasonable bandwidth which makes antenna insensitive to manufacturing tolerances.



Фиг. 11. *The Impedance matching of the dipole antenna over EBG structure*

4. Conclusion

This paper introduced possible design of dipole antenna with EBG surface. EBG surfaces are used to increase antenna gain and decrease the antenna thickness compared with tra- ditional air gap antennas. All this features give the antenna possibility for mass production. It is intended mainly for RFID communications.

REFERENCES

1. F Yang and Y Rahmat-Sami, *Electromagnetic Band Gap Structures in Antenna Engineering*, Cambrigde University Press, 2009.
2. T.H. Liu, W.X. Zhang, M. Zhang and K.F.Tsang, ”Low profile spiral antenna with PBG substrate*”,* *Electron Lett*., vol.36, no.9, 2000, pp. 779 – 780
3. F Yang and Y Rahmat-Sami, ”Reflection Phase Characterizations of the EBG Ground Plane for Low Profile Wire Antenna Applications”, *IEEE Transactions on Antennas and Propagation*, Vol. 51. 10, October 2003, pp. 2691 - 2703
4. D Sievenpiper, L. Zhang, R. F. J Broas, G. Alexopolus and E. Yablonovich ”High-impedance electromagnetic surface with a forbidden frequency band”, *IEEE Trans. Microwave Theory Tech*., vol. 47., November 1999, pp. 2059 - 2074
5. T.T. Nguyen, D. Kim, S. Kim and J. Jang, ”Design of a wide- band mushroom-like electromagnetic bandgap structure with magneto- dielectric substrate”, *ICITA*, 2000.

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A REVIEW ON RECENT ANTENNA DESIGNING TECHNIQUES FOR ELECTROMAGNETIC COMPATIBILITY(EMC) TEST

MR.SARANG M. PATIL, PROF.PETER Z. PETKOV, PROF.BONCHO G. BONEV

Abstract: *All devices from electronics category must meet EMC requirement. In this article presents a review summary of various antenna structure designed for EM signal radiated emission and susceptibility measurements currently used for evaluating the electromagnetic compatibility/interference (EMC/EMI) characteristics of electronics systems and devices. For accurate EMC/EMI test require to capture of unknown electromagnetic radiation from an equipment using suitably calibrated EMI sensor. The response of sensors is analyzed in terms of the antenna factor-which is the ratio of the incident electric field on the antenna surface to the detected voltage at load. At the end comparison is done of all antennas specifications and new idea is proposed for improvement in EMC measurement*

Key words: *Antenna Factor, Electromagnetic compatibility, Electromagnetic Interference sensor, Immunity.*

1. Introduction

All the electronics devices and appliances are important part of our day today life, like kitchen tools to satellite, because of the more demands for wireless devices, the electromagnetic territory has becomes polluted. Electromagnetic interference (EMI) both inter- and intra- device is the well-known "pollutant".

Electromagnetic compatibility is the member of electrical science which deals with unintentional propagation, reception and generation of electromagnetic energy with reference to the unwanted reaction that such energy may induce. Electromagnetic compatibility testing of electronics equipment Necessitate to measurement of field strength radiated form devices [1].Radiated emission from equipment are measured and calibrate the field level for immunity test. Ordinarily, antennas with large bandwidth are used for emission measurement and diode based field sensors are widely used for calibrating field level for immunity test [2].The definition of EMC/EMI as per IEEE dictionary as follows [3].

Efficient EMC measurement, observes and determines the behaviour of electrical apparatus from the prospect of EM radiation with electronic circuits [4].In communication system various electronics equipments are used, at side of transmitter are designed to radiate a specific radio-frequency, power at selected frequencies to antenna, antenna radiated signal intentionally but along with that another uninitiated signal also transmitted, it is form of EMI. Another non-radiators devices is also present in surrounding like computers, ideally computer performs task and during the computation time its generate some signals internally because of electronic circuits within the system will be contained and not be radiated, however some signals are radiated as EMI because of internal signals are not contained totally [5].

Electromagnetic pre-compliance measurement applications antenna is not used widely used because of large in size and are sensitive to nearby reflections and interact with surrounding metal objects .If EMC testing is carried out during the design phase of product it provides following advantages,

- Passing rate of final compliance test is increased.
- Retest count is decreased at EMC test laboratory.
- Eliminates surprises late in the design.
- Conform that EMC considerations are part of the original.

As per the data received for EMC test laboratory, 50% submitted products are fail in compliance testing at first attempt. To reduce this statistic and improve the percentage of passing form 50% to 90% need to use EMC measurement antenna /Probe at designers/Manufacturers end [6].

A variety of antennas have been designed to help the EMC engineer test quickly over the range from 30MHz to 1GHz, and they can have quite interesting shapes [7]. A very significant concept about all antennas is that they required calibrating, and their calibration factors must be taken into consideration in any measurement of

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radiated emissions [8]. Test field calibration is described and analyzed in [9].

2. Common Antennas Used for EMC Testing

Now a day various antenna types and geometry are present, some of them are commonly used for EMC test, they are as below:

2.1. Tunable Dipole Antenna

Electrical field measurement purpose tunable antenna is widely used, this antenna support for the range of frequency over 25-1000 MHz Tunable dipole having two types- the resonant dipoles and half-wavelength dipoles.

2.2. Biconical Antenna

This antenna is called broadband dipoles that consist of two conical conductors having a common axis and vertex. The receiver is connected at vertex. Biconical antenna operates in the range of 30-300 MHz, this antenna is best for vertical polarization measurement because of smaller in size.

2.3. Log-Periodic Antenna

This antenna is called log-periodic because of structural geometry that its impedance and radiation characteristics repeat periodically as logarithm of frequency. It's operating range of frequency from 200-1000MHz

2.4. Bilog Antenna

This antenna is called log-periodic because of structural geometry that its impedance and radiation characteristics repeat periodically as logarithm of frequency. It's operating range of frequency from 200-1000MHz

2.5. Loop Antenna

The shape of this antenna is like coil and is highly sensitive for magnetic field but shielded against electric field. Measurement of electromagnetic field takes place with electrically small loop for the range of frequency approximately 20Hz-30MHz.

2.6. Horn Antenna

This antenna is specially used for high range frequency measurement of electromagnetic signals. This measure frequency above the 1GHz. Range of frequency is 1-40MHz.

3. literature survey

A number of researchers work on antenna designing for electromagnetic compatibility test. In this session consider some recants important and efficient antenna designs with specifications.

N.Narang et el.[10]. Present A Coplanar Microstrip Antenna as a Dosimetric E-field Probe for GSM /UMTS Applications. Co-planar Microstrip antenna used as E-field sensor. This probe is specifically used for Specific Absorption Rate (SAR) measurement in mobile communication. In this probe used antenna is dual band Microstrip, its support for the frequency band i.e. 915MHz and 2.10GHz in Global System for Mobile communication frequency. Over all dimensions of antenna is 30mm*100mm in size. The Microstrip design is made on a low dielectric substrate, FR4 epoxy of er = 4.4 and thickness t = 1.6 mm. structure of antenna is see in figure 1.

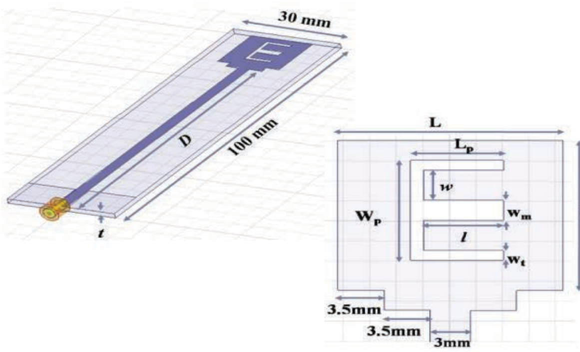

Fig. 1. *Proposed E-field probe [10].*

Mohammed Siddeqet el. [11], A New Printed Monopole Antenna as EMI Sensor is proposed, structure of proposed antenna is shown in figure 2, Tthis antenna operates in triple band resonating frequency i.e. 2.6, 3.5, 5.7 GHz. Proposed antenna overall size of 33.06mm*25mm*1.6, etched on FR-4 epoxy substrate, testing result observed like the percentage bandwidth of 6.9% and 12.2% is observed in the structure at 2.6GHz and 5.7GHz.

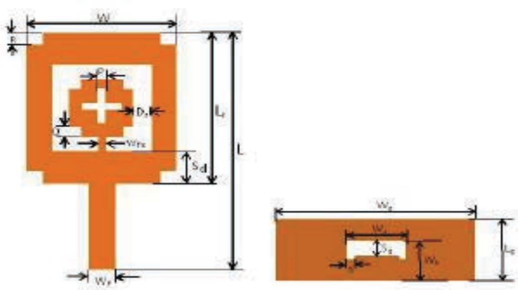

Fig. 2. *Proposed E-field probe [10].*

Zdenek Kubík et el [12], see in fig.3, has developed Optimization of electrical properties of parallel plate antenna for EMC testing, this parallel plate antenna is also called as Strip line antenna or TEM cell antenna, for the measurement device under test is kept within the uniform EM field region.

Fig. 3. Proposed parallel plate antenna [12]

Parallel plate antenna designed specifications are: W = 0.3m, H = 0.4 m, and thickness of plate's t = 0.0012m, this design support for the range of frequency from 9KHz to 30MHz.

Amit Kumar Srivastava et el. [13], , first proposed design of patch antenna is simulated on HFSS. After the simulation simulated module is fabricated, with substrate 'FR4' having electric permittivity, εr=4.3 with the height, h= 1.588mm is used. This antenna operates the 2.45GHz to 3.00GHz.so circular patch is act as good EMI sensor is concluded. Observe dimensions of proposed antenna in figure 4.

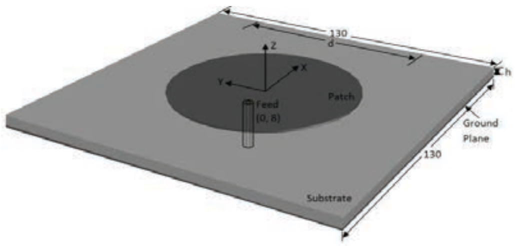

Fig. 4. Proposed circular patch antenna [13]

S. Capdevila, J. Romeu et el. [14], design of an Modulated Scatterer Technique (MST) probe antenna to be used in sensing applications, antenna designed with substrate RO4003C with a thickness of 1.52mm, has been scaled down to accommodate the new frequency range (from 868MHz to 2.45GHz). Figure 5 indicate proposed structure of MST antenna with dimensions in mm.

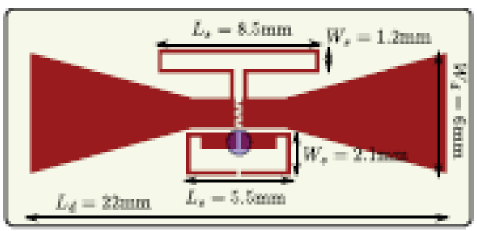

Fig. 5. Proposed MST Probe antenna [14]

Surbhi Mittal et el. [15], approach to electrically small loop electrically short field probe to obtain a flat frequency response using the combination with active oscilloscope probe. Proposed design supports to operate up to 5GHz.loop dimensions are 3*3mil and it is very small. Measurement results agree very well with the expectations from 0. 1 GHz to 3 GHz. Figure 6 is small loop field probe.

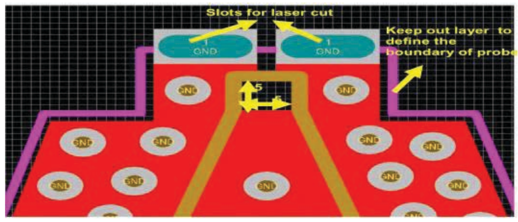

Fig. 6. Proposed Design of Flex Circuit Probe [15]

M. F. P. Tartaglia1 et el. [16], discussed the Metamaterial-based Probe for EMC Measurements, in this antenna author try to improve the gain, bandwidth and resonance with the supports of metamaterials. In this work planer probe used with square format along with 5mm of track width with 35 mm of thickness on the o ROGERS R3003 substrate with 1.5mm of thickness with a full ground plane shown in figure 7. EMC measurement can be performed with low cost planer probe is concluded.

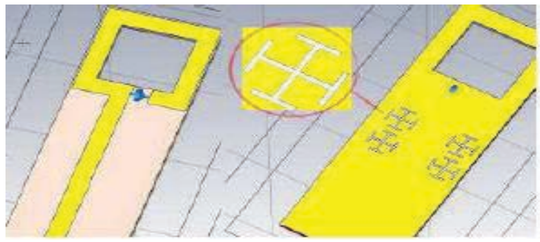

Fig. 7. Proposed Design of Flex Circuit Probe [15]

H. Lv et el.[17] , see Fig. 8 is the Indoor Electromagnetic Testing Antenna Design with Better Standing Wave Ratio and Gain is proposed, this covers frequency range between 0.14GHz and 6.3GHz so relatively bandwidth is 191.3% proposed. The antenna is constructed with dielectric constant of 2.55 and 0. 8 mm thickness of the dielectric substrate of polytetrafluoroethylene.

Fig. 8. Prototype antenna module. [17]

Xingyu Zhang et el. [18],this article present highly sensitive integrated photonic electromagnetic field sensor based on a silicon-organic hybrid modulator driven by a bowtie antenna shown in figure 9, fabrication and characterization of this compact antenna is analyze. Device capable to measure electromagnetic power density of 8.4mW/m2, corresponding to a minimum detectable electric field of 2.5V/m. at 8.4GHZ.

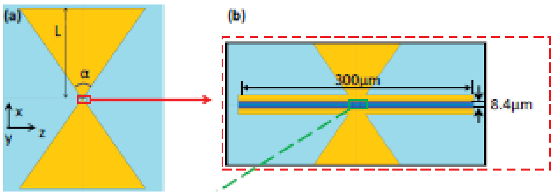

Fig. 9. *(a) Schematic top view (b) Magnified image of the feed gap region in (a). [18]*

F. H. Wee et el.[19] ,electromagnetic wave detection based on multiband antenna design proposed, antenna design is shown in figure 10 to solve the hazard electromagnetic wave detection problem a multi-band Microstrip is designed. Antenna is simulated and analyzed the results like, efficiency, VSWR, return loss, radiation pattern etc. Antenna radiates for multiple frequency like ,2.3, 4.5, 4.68, and 5.2GHz.overall dimensions of antenna is 80mm*70mm with patch 30mm*60.32mm.For mentions dimensions antenna return loss below -10dB and input impedance equal to 50Ω .

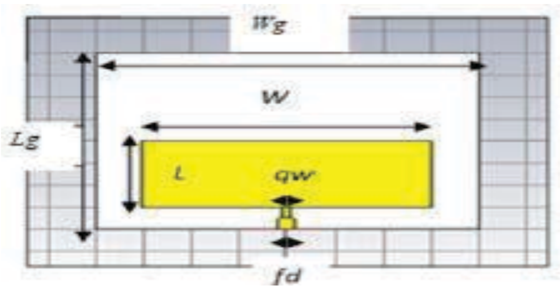

Fig. 10. *Proposed Design of Detector antenna [19]*

Nisha Gupta et el. [20] has Design of Printed Log Periodic EMI Sensor, this printed log-periodic dipoles called array with linear polarization with desired frequency range. Antenna is printed on FR-4 substrate with dielectric constant 4.4 and thickness 1.6mm, printed pattern separated by dielectric and named as element1 to 5. This 5 element dipole array supports the frequencies of 720 MHz, 1.344 GHz. and 2.64 GHz. Proposed dipole array is shown in figure 11.

Fenghan Lin et el.[21], invented 0.7–20-GHz Dual-Polarized Bilateral Tapered Slot Antenna for EMC Measurements. DBTSA in constructed with bilateral tapered slot antenna, this maintain wide operating frequency range from 700MHz to 20GHz. Figure 12 indicate Antenna structure,

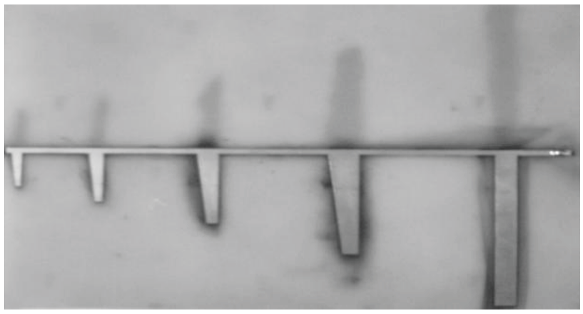

Fig. 11. *Proposed antenna Top view [20]*

The constructed of two-layer printed circuit board, substrate material is Rogers RT6002, relative dielectric constant *εr* of 2.94 and a thickness *t* of 0.762 mm (overall 1.524 mm), After result analysis of DBTSA, concluded that it is a good candidate for a dual-polarized sensor antenna for applications in wireless EMC measurement.

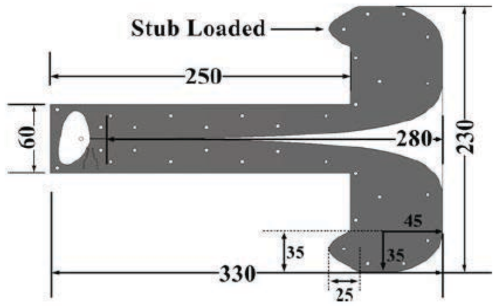

Fig. 12. *Proposed BTSA antenna [21]*

4. Important parameters for EMC/EMI Antenna Selection

The most common fundamental parameters of technical tools, the EMC antenna is used. The review of the basic parameters and related antenna parameters are discussed below:

4.1. Antenna Factor

In Electromagnetic, AF is the ratio of the electric field strength to the voltage V induced across the terminal of an antenna. This is linear definition expressed in volt per meter (V/m)

4.2. Frequency Response

Frequency response is most crucial parameter in probe characteristics, is defined as the range the probe will respond to. Probe should provide flat frequency response over all frequency range

4.3. Sensitivity

Sensitivity is defined as the how small and RF signal a probe can respond to accurately. Sensitivity is most important when small RF field should be measure. It is measured in V/m.

Table 1. *Comparative analysis of 3 -vector Probe*

Ref. Paper No.	Frequency Range.		Simulator Used	Over all antenna size.	Sensitivity	Antenna Factor (AF)dB/m	Applications
	From	To					
Ref.10	915MHz	2.10GHz	HFSS 13.0	30mm*100mm	1mV/m	50 dB/m	SAR Measurement
Ref.11	2.5 to 2.68 ,3.1 to 4.1	5.3 to 6GHz	HFSS 13.0	33.06mm × 25mm ×1. 6mmm	-	-	EMI sensor
Ref.12	9KHz	30MHz	-	W=0.3m, H=0.4m	-	-	EMC,EMI Testing of GSM cell phones, radio and TV Transmitters
Ref.13	2.45GHz	3GHz	CST Microwave Studio	130*130mm	-1.8930 to 2.4728V/m	41.7375 to 19.6dB/m	EMI sensor
Ref.14	868MHz	2.45GHz	-	22*6mm	-	-	EMC measurement
Ref.15	0.1GHz	3GHz	-	3x3 mil	3.3mV	-	EMC measurement
Ref.16	-	-	-	6cm*5cm	-	-	EMC measurement
Ref.17	0.14GHz	6.3GHz	HFSS	220*111mm	-	-	electromagnetic detection
Ref.18	8.4GHz	10GHz		12*6mm	2.5V/m.	-	electromagnetic field sensor
Ref.19	2.3GHz	5.2GHz	CST microwave studio 2014.	80*70mm	-	-	electromagnetic Wave detection
Ref.20	625MHz	2.6GHz	IE3D	Array Length=206mm		13.08-24.24dB/m	EMI Sensor
Ref.21	700MHz	20GHz	CST microwave studio	320*230mm	-	-	wireless EMC measurements

4.4. Dynamic Range

Dynamic range is the total range of RF field coverage a probe will respond to. The greater the Dynamic range the better a probe is suited to address test applications that span the gamut from low to high field strengths

5. Proposed Module

In this proposed solution for EMC/EMI measurement system, antenna constructed for three axial field measurements, designed antenna has wide bandwidth, Good antenna Factor, sensitivity should be measured in V/m ,small in size along with multiple polarization capability. Features of proposed module shown in Fig.21.

1. Conclusion

In this survey paper describes and reviews the various antenna designing techniques/ methods with different antenna geometries, Nevertheless, useful solution are still less and suffer from different problems like, Improvement in antenna factor, complexity of structure, gain, sensitivity etc, whatever antenna's currently used as EMI sensor are only detect one or two axial components, but accurate measurement of electromagnetic compatibility the three vector antenna must.

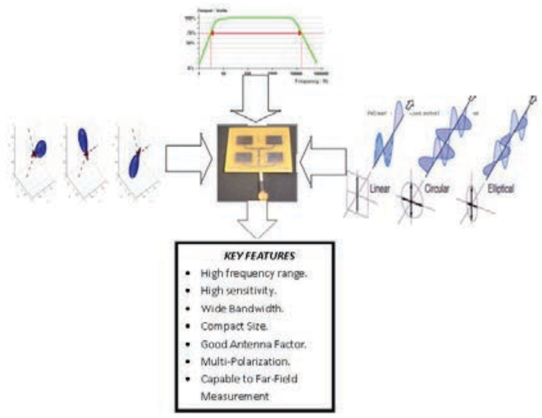

Fig. 13. *Proposed Antenna Features*

Hence, we have proposed three axial antenna geometry for calculating the average 3-axisal vector field for EMC measurement.

REFERENCES

1. Suk-Hwan Choi and Dong-Seok Kim, "*Three Axis Isotropic Field Strength Measuring Antenna*,"the journal of korean institute of electromagnetic engineering and science. 2014 sep.; 25(9), 879-885
2. Benjamin Loader and Martin Alexander, "*development of optical electric field sensor for EMC measurement*,"www.ieice.org/ proceedings/EMC14.
3. IEEE standard dictionary of electrical and electronics terms,ANS/IEEE Std 100-1977, 2nd ed.,Jay, ed, New yorl:wiley 1977.
4. J. Leutcher, V. Stekly, E. Blasch, "*Invetsigation of Avionics Power Switch Loading versus Aircraft Electromagnetic Compatibility*," IEEE AESS Magazine, Vol. 30, Issue 9, pp. 24-34, Sept. 2015
5. Mark T.MA,and Motohisa Kanda," *A review of electromagnetic compatibility/interference measurement methodologies*," procedding of the IEEE,Volume:73,Issue:3, page 388-411,yeat-1985.
6. Mark T.MA, Motohisa Kanda and Myron L.Crawford, "*A review of Electromagnetic compatibility/Interference Measurement Methodologies*," Proceeding of the IEEE, Vol 73, No3, March1985.
7. Tim Williams, "*What to look for in an EMC antenna*," Compliance Engineering European.
8. M J Alexander, "*Calibration and use of EMC antennas*, "Measurement good practice guide No. 4 from the National Physical Laboratory
9. E. L. Bronaugh, J. D. M. Osburn, " *Whole-vehicle radiated EMI immunity tests in automotive EMC: establishing and calibrating the test field*," Electromagnetic Compatibility, 1992., Eighth International Conference on, 21-24 Sep 1992, Edinburgh, pp. 39-42, 1992.
10. Narang, N., Dubey, S.K., Negi, P.S. et al., "*A Coplanar Microstrip ntenna as a Dosimetric E-field Probe for GSM Frequencies*,"MAPAN journal of metrology society of india,pp 1-5,jan 2017.
11. Mohammed Siddeq and Dr M. Satyanarayana, " *A new printed monopole antenna as EMI sensor*," International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 2 Issue 10, October – 2013.
12. Zdeněk Kubík , Denys Nikolayev et el, "*Optimization of electrical properties of parallel plate antenna for EMC testing*," Journal of omputational and Applied Mathematics 270, May 2014.
13. Amit Kumar Srivastava," *Analysis of Circular Patch Antenna as an Electromagnetic Interference Sensor*," Conference on Electrical, Electronics and Computer Science, March 2012 IEEE Students.
14. S. Capdevila, "*Design of a Small MST Probe for EM-Field Measurements and Sensing Applications*," Antennas and Propagation Society International Symposium (APSURSI), 2012 IEEE, 8-14 July 2012.
15. Surbhi Mittal, "*Active Probes for Creating H-Field Probes for Flat Frequency Response*," Electromagnetic Compatibility, 2009. EMC 2009. IEEE International Symposium , 17-21 Aug. 2009.
16. M. F. P. Tartaglia1 et el, "*A Metamaterial-based Probe for EMC Measurements*," PIERS Proceedings, Guangzhou, China, August 25{28, 2014.
17. H. Lv, X. S. Xia, Y. L. Yu, Z. X. Hua, "*An Indoor Electromagnetic Testing Antenna Design with Better Standing Wave Ratio and Gain*," International Conference on Artificial Intelligence and Industrial Engineering (AIIE 2015), Published by Atlantis Press,May 2015.
18. Xingyu Zhang, Amir Hosseini,, "*Integrated Photonic Electromagnetic Field Sensor Based on Broadband Bowtie Antenna Coupled Silicon Organic Hybrid Modulator*," Journal of Lightwave Technology, Volume: 32, Issue: 20, oct.15, 15 2014.
19. F. H.Wee, F. Maleke et el., "*electromagnetic wave detection based on multiband antenna design*, ARPN Journal of Engineering and Applied Sciences, ISSN 1819-6608, VOL. 11, NO. 8, APRIL 2016.
20. Nisha Gupta and Md. Anjarul Haque, "*Design of Printed Log Periodic EMI Sensor*," international journal of microwave and optical technology,vol.4 no.4 july 2009.
21. Fenghan Lin et el ," *0.7–20-GHz Dual-Polarized Bilateral Tapered Slot Antenna for EMC Measurements*," IEEE transactions on electromagnetic compatibility, Page -1271 - 1275, Volume: 56 Issue: 6,Dec 2014.

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ОПТИМИЗАЦИЯ НА ПРОЦЕСА ЕЛЕКТРОННОЛЪЧЕВА ЛИТОГРАФИЯ ЧРЕЗ РОБАСТНО ИНЖЕНЕРНО ПРОЕКТИРАНЕ

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Резюме: *В работата е разгледан процесът електроннолъчева литография на експонирани и проявени профили на резисти от полиметил метакрилат (ПММА) при производствени условия и наличие на грешки във факторните нива. Приложен е подход за робастно инженерно проектиране и са оценени модели за средните стойности и дисперсиите на геометричните характеристики на профилите на резистите в зависимост от вариациите на ускоряващото напрежение, дозата на експониране, първоначалната дебелина на резистите и времето за проявяване. Направена е параметрична оптимизация при конкретни изисквания за показателите на качеството.*

Ключови думи: *електроннолъчева литография, резисти ПММА, регресионни модели, робастно управление, толерансни граници, параметрична оптимизация*

OPTIMIZATION OF ELECTRON BEAM LITHOGRAPHY PROCESS THROUGH ROBUST ENGINEERING APPROACH

LILYANA KOLEVA[1], ELENA KOLEVA[1,2], VENTZISLAV TZOTCHEV[1]

Abstract: *This work considers the electron beam lithography process of exposed and developed polymethyl methacrylate (PMMA) resist profiles under production conditions and in presence of errors in process parameter values. Robust engineering approach is applied and models for the mean values and the variances of the resist profile geometric characteristics depending on variation of acceleration voltage, exposure dose, initial resist thickness and development time are estimated. Parameter optimization with specific requirements for the quality characteristics is performed.*

Key words: *electron beam lithography, resist PMMA, regression models, robust control, tolerance range, parameter optimization*

1. Въведение

Литографията е основна технология в микроструктурирането. При този процес като първа стъпка на микрогравирането се прави "записване" (на микроструктурни латентни образи) в чувствителен тънък слой, наричан резист. Втората стъпка на литографският процес е проявяване на латентния образ чрез разтваряне на облъчените или на необлъчените участъци на резиста (записаните микрообрази), което превръща латентния образ в релефна картина на структурата в резиста [1].

При производствени условия отклоненията в изходните характеристики на продукта могат да се дължат на различни причини [2]:

- производствени причини - човешки грешки, вариации в характеристиките на суровините, настройката на машините и изменението на производствените параметри с времето, измервателни грешки и др.;

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- влияние на околната среда - както по време на производството, така и по време на използване на продуктите;
- влошаване на изходните характеристики с времето. Вариациите на изходните характеристики имат случаен характер и най-често са с нормално разпределение.

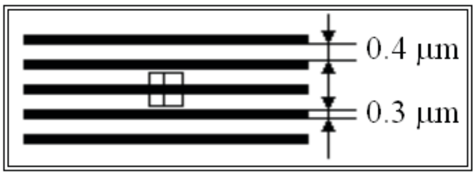
При реални условия отклоненията в настройките на параметрите на процеса, както и промените в околната среда, са по-значителни в сравнение с производството в лабораторни условия и се предават към изходните характеристики на продукта, причинявайки нарастване на разсейването им. Повишаването на качеството, определено като намаляване на разсейването на изходните характеристики, дължащо се на грешки във факторните нива или промяна в стойностите на неуправляеми фактори, може да стане чрез избор на подходящи оптимални параметри на процеса. По този начин се постига робастност по отношение на грешки във факторните нива и други шумове, т.е. повишава се качеството на продукта [2 - 7].

2. Описание на експеримента

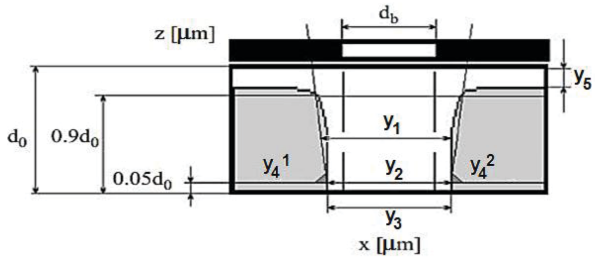
В настоящият експеримент е разгледано експониране с електронен лъч и проявяване с метил-изобутил кетон (МИБК) на структура от 5 паралелни линии с ширина 0.3 μm, разположени на разстояние 0.4 μm една от друга и размерите на профила, получени в средата на централната линия на положителен резист полиметил метакрилат (ПММА) върху силициева подложка (Фиг. 1). Параметрите на процеса електроннолъчева литография (ЕЛЛ), които варират по време на експеримента, са: ускоряващо напрежение (z_1, keV), първоначална дебелина на резиста (z_2, μm – d_0 на Фиг. 2), време на проявяване (z_3, s) и доза на експониране (z_4, μC/cm^2), като диапазоните им на изменение са показани в Таблица 1.

Таблица 1. *Диапазони на изменение на процеса електроннолъчева литография*

Фактор	Размер-ност	Кодирани фактори	z_{MIN}	z_{MAX}	z_0
z_1	keV	x_1	20	24	22
z_2	μm	x_2	0.3	0.5	0.4
z_3	s	x_3	240	360	300
z_4	μC/cm^2	x_4	900	1300	1100



Фиг. 1. *Структура на експонирания резист*



Фиг. 2. *Геометрия на напречното сечение на проявения резист ПММА*

Изследвани са следните геометрични характеристики на напречното сечение на проявения резист ПММА (Фиг. 2):

- Ширина на повърхността – y_1 [μm] – ширината на височина 55% от първоначалната дебелина на резиста, измерена от силициевата подложка;
- Ширина на дъното – y_2 [μm] – ширина на височина 5% от първоначалната дебелина на резиста, измерена от силициевата подложка;
- Ширина при подложката – y_3 [μm];
- Ъгъл на стените на резиста – y_4 [°] – среден ъгъл, получен чрез усредняване на ъглите на стените на резиста (y_4^1 и y_4^2);
- Загуба на дебелина на резиста – y_5 [%].

От гледна точка на качеството на получения профил, стремежът е към получаване на паралелни стени на напречното сечение на проявения резист, както и минимални загуби на дебелина на резиста. Тези изисквания са свързани, както с функционалните характеристики на получаваните изделия, поради малките им размери, така и с минималните загуби на материал от обработка.

3. Регресионен анализ

Проведен е планиран числен експеримент, при който е изпълнен оптимален композиционен план от 24 опита. Стойностите на параметрите на процеса (z_i) са кодирани (x_i) в диапазон от -1 до 1 по следната формула:

$$x_i = (z_i - z_{i0}) / \lambda_i , \qquad (1)$$

Таблица 2. *Регресионни модели на геометричните характеристики на резиста*

Парам.	***Регресионни модели***	R^2	$R^2_{(adj)}$
y_1	$0.45138952 - 0.01838889x_1 - 0.00047879x_2 + 0.02983199x_3 + 0.02349321x_4 + 0.00416232x_1^2 + 0.00156668x_2^2 - 0.0029375x_1x_3 - 0.00131986x_2x_3x_4 + 0.00342362x_3x_4 - 0.0021875x_1x_2 - 0.0015625x_1x_4 + 0.00373136x_3x_4^2 + 0.00118014x_2x_4 - 0.0010625x_1x_3x_4 + 0.0009375x_1x_2x_4+0.0008125x_1x_2x_3+0.00061852x_2x_3+0.00144429x_1^2x_4$	0.98956	0.98666
y_2	$0.46907754 - 0.02694444x_1 + 0.01303117x_2 + 0.04180783x_3 + 0.03204235x_4 + 0.00664468x_1^2 – 0.007875x_1x_2 + 0.00933453x_2x_3 + 0.00737965x_2x_4 – 0.00624535x_2x_3x_4 + 0.003875x_1x_2x_4 + 0.00375x_1x_2x_3 - 0.00375x_1x_3x_4$	0.98035	0.96988
y_3	$0.48520985 – 0.03244444x_1 + 0.01423087x_2 + 0.04898345x_3 + 0.03770034x_4 – 0.01075x_1x_2 + 0.01453905x_2x_3 -0.0063078x_3x_4 + 0.01267754x_2x_4 – 0.00994746x_2x_3x_4 + 0.007125x_1x_2x_3 + 0,006875x_1x_2x_4 – 0.0065x_1x_3x_4 + 0.005375x_1x_4$	0.95362	0.92889
y_4	$95.905 – 2.2433333x_1 + 1.6697343x_2 + 1.7374913x_3 + 1.7243059x_4 - 1.558653x_3^2 + 0.904375x_1x_3 + 1.4720837x_2x_3 – 1.2247872x_3x_4 + 0.93971598x_2x_4 + 0.899375x_1x_4 – 0.68903402x_2x_3x_4$	0.94822	0.90075
y_5	$15.2 – 1.3444444x_1 – 3.7697674x_2 + 3.0252907x_3 + 2.1453488x_4 + 1.7430233x_2^2 – 0.4252907x_3^2 – 0.45625x_1x_4 – 1.0447674x_2x_3 + 0.49476744x_3x_4 – 0.74273256x_2x_4 – 0.30625x_1x_3 + 0.28125x_1x_2 + 0.61744186x_2^2x_3 – 0.9x_2x_4^2 – 0.16773256x_2x_3x_4$	0.99949	0.99852

където λ_i е интервал на вариране, изчислен за съответните нива на фактора, а z_{i0} е средата на интервала на границите на вариране, които са показани в Таблица 1. Получените модели са дадени в Таблица 2, където са показани и коефициентите им на детерминация (R^2), както и коригираните коефициенти на детерминация (R^2_{adj}). Направеният анализ показва, че получените модели са достатъчно точни, за да се използват за предсказване и оптимизация на геометричните характеристики, на профилите, получени при експониране на положителен ПММА резист с електронен лъч.

4. Робастно проектиране

На базата на проверените регресионни модели са оценени и модели за средните стойности и дисперсиите на изследваните показатели на качеството при производствени условия и грешки във факторните нива. Използваните толерансните интервали на входните параметри са показани в Таблица 3.

Таблица 3. *Толерансни граници за параметрите на ЕЛЛ*

Величина	Означение, кодирани	Толерансна граница
z_1 [keV]	p_1	$p_1 \pm 0.02\ p_1$
z_2 [μm]	p_2	$p_2 \pm 0.05\ p_2$
z_3 [s]	p_3	$p_3 \pm 0.0006$
z_4 [μC/cm^2]	p_4	$p_4 \pm 0.03\ p_4$

Разглеждането на преноса на грешките във факторните нива към изходната характеристика позволява намирането на режими, които са нечувствителни по отношение на тези грешки. За целта се оценяват два модела, описващи средната стойност и дисперсията на изходните характеристики при производствени условия.

Моделът за средната стойност на изходната характеристика е [2, 3, 6]:

$$\tilde{y}(p) = E[y(z)] = \eta_m(p) + \Theta^T E(g) \qquad (2)$$

където $\eta_m(p)$ е модел на изходната характеристика, $E(g)$ е математическото очакване на g. Вторият член взима предвид отклонението, предизвикано от грешки, предадени от параметрите на процеса p към изходната характеристика (p), Θ^T е вектора на коефициентите на регресионния модел ($\eta_m(p)=\Theta^T F$), F - матрица от известни функции f на параметрите на процеса p, определени чрез регресионния модел (z), g = h – f, h е вектор на регресорите в регресионния модел, разгледани като съдържащи грешки e (за всеки параметър на процеса - $z_i = p_i + e_i$).

Моделът за дисперсията е:

$$\tilde{s}^2 = E(\Theta^T \psi \psi^T \Theta) + \sigma_\varepsilon^2 = \Theta^T \Psi \Theta + \sigma_\varepsilon^2 \qquad (3)$$

където $\psi = g – E(g)$, е определена на основа на дисперсиите на всеки параметър на процеса p, което може да бъде изчислено с помощта на толерансните граници на параметрите на процеса, ковариационната матрица на грешките, при наличие на грешки във факторните нива, $\Psi=E(\psi\psi^T)$ зависи от структурата на

Таблица 4. *Оптимални работни параметри*

Параметър	p_1	p_2	p_3	p_4	min.
$\tilde{s}^2(y_1)$	0.9429	-0.9984	-0.9980	-0.9992	$1.658*10^{-6}$
$\tilde{s}^2(y_2)$	0.0000	0.0000	0.0000	0.0000	$4.915*10^{-5}$
$\tilde{s}^2(y_3)$	0.0219	0.0219	0.0219	0.0926	0.0001571
$\tilde{s}^2(y_4)$	-0.1728	-0.3608	1.0000	-0.7194	1.698
$\tilde{s}^2(y_5)$	1.0000	1.0000	-1.0000	-1.0000	0.02953

регресионния модел и от плана на експеримента, е случайната грешка на изходната характеристика.

Изчисляването на ковариационната матрица на грешките, $\Psi = E(\psi\psi^T)$ се базира на някои предположения за математическото очакване на грешките e, а именно: $E(e_i)=0$, $E(e_i^2) = \sigma_i^2$, които могат да бъдат определени чрез толерансните граници.

Определянето на дисперсиите от толерансните граници зависи от начина, по който са зададени границите. Ако толерансните граници са дадени като процент от номиналната стойност на параметъра на процеса:

$$\left(p'_i - \frac{\delta_i p'_i}{100}, p'_i + \frac{\delta_i p'_i}{100} \right), \qquad (4)$$

следната формула може да бъде използвана за изчисляването на кодираната дисперсия:

$$\sigma_i^2 = \left[\delta_i p'_i / (300\,\omega_i)\right]^2, \qquad (5)$$

където $\omega_i = \lambda_i$ за всеки от параметрите на процеса, то за кодираната стойност на дисперсията се получава:

$$\sigma_i^2 = \vartheta_{0i} + \vartheta_{1i} p_i + \vartheta_{2i} p_i^2, \qquad (6)$$

където:

$$\vartheta_{0i} = \left(\frac{\delta_i p'_{io}}{300\omega_i} \right)^2, \quad \vartheta_{1i} = \frac{2\delta_i^2 p'_{io}}{300^2 \omega_i}, \quad \vartheta_{2i} = \left(\frac{\delta_i}{300} \right)^2 \qquad (7)$$

Ако толерансните граници са дадени чрез постоянни стойности $(p'_i - \varsigma_i, p'_i + \varsigma_i)$, които не зависят от номиналните стойности на параметрите на процеса, кодираната стойност на дисперсията е:

$$\sigma_i^2 = \sigma^2(p_i) = \sigma_i^2(p'_i)/\omega_i^2 = \sigma'^2_i / \omega_i^2 = \varsigma_i^2 / 9\omega_i^2 \quad (8)$$

Управлението на производствените процеси (статиката) е свързано с избор на подходящи оптимални режими на процесите, които се реализират. При задаване на работни стойности на параметрите на процеса могат да се отчетат редица оптимизационни критерии, свързани с показателите на качеството на получавания продукт, както и отчитането на шумовите фактори и вариациите на параметрите на процеса при производствени условия.

5. Оптимизация

Изборът на метод за оптимизация е важна предпоставка за решение на оптимизационната задача, тъй като той осъществява процеса на търсене на най-добрия резултат.

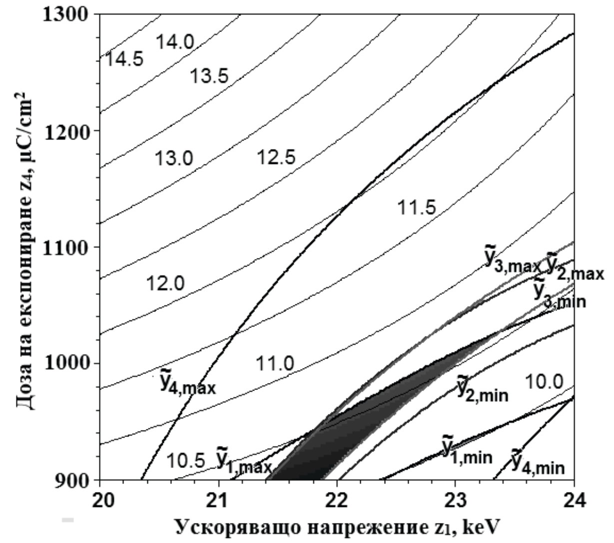
За целите на проучването е проведена еднокритериална оптимизация на дисперсиите на изследваните показатели на качеството. Намерените минимални стойности на дисперсиите, както и кодираните стойности на параметрите на процеса, при които те са получени, са показани в Таблица 4. Вижда се, че дисперсията е най-голяма при средните ъглите на стените на профила на резистите.

В задачите на многокритериалната оптимизация едновременно се оптимизират няколко критерия (целеви функции) в допустимо множество от решения (алтернативи). В общия случай не съществува едно решение, което да оптимизира всички критерии. В зависимост от вида на критериите и ограниченията, както и от типа на променливите, задачите на многокритериалната оптимизация могат да се разделят на линейни, нелинейни, целочислени, мрежови и др. задачи.

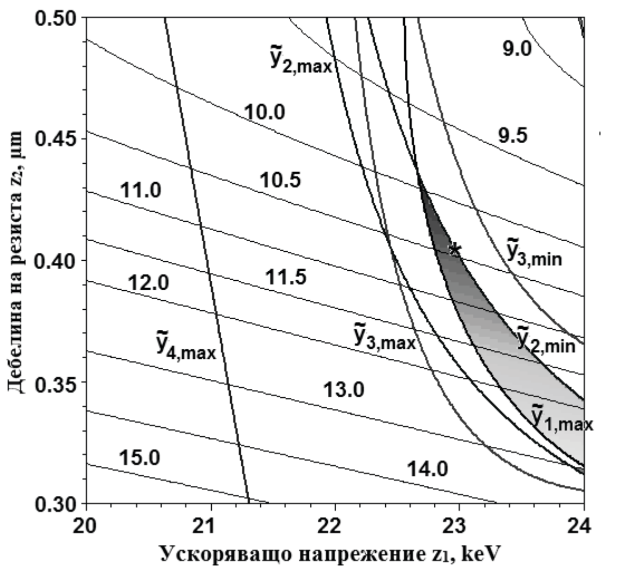
При производството на резисти ПММА с размер на ширината 0.400 μm, с цел постигане на паралелни стени на напречните сечения на профилите на резистите са поставени изисквания, свързани със средните стойности на ширините на напречните сечения на профилите на резистите на различна височина и на ъгъла на стените на проявените резисти:

- $0.395 \leq \widetilde{y_1}(p) \leq 0.405$
- $0.395 \leq \widetilde{y_2}(p) \leq 0.405$
- $0.395 \leq \widetilde{y_3}(p) \leq 0.405$
- $87 \leq \widetilde{y_4}(p) \leq 93$

На Фиг. 3 е представена оптимална област на параметрите на процеса ускоряващо напрежение z_1 и доза на експониране z_4 при дебелина на резиста z_2 = 0.4 μm и време на проявяване z_3 = 240 s, където защрихованата област е тази, в която са спазени и четирите ограничения.



Фиг. 3. *Графична оптимизация – средна стойност на загубата на дебелина на резиста* $\widetilde{y_5}(\mathrm{p})$ *при* $z_2 = 0.4$ *µm и* $z_3 = 240$ *s*



Фиг. 4. *Графична оптимизация – средна стойност на загубата на дебелина на резиста* $\widetilde{y_5}(\mathrm{p})$ *при* $z_3 = 240.06$ *s и* $z_4 = 1000.84$ *µC/cm*^{2}*;*

Получена е и минималната стойност за средната стойност на загубата на дебелина на резиста $\widetilde{y_5}(p)_{min}$ =10.45% при изпълнение на поставените ограничения при оптимални стойности на параметрите на процеса: z_{1opt} = 22.9428 keV, z_{2opt} = 0.4041 µm, z_{3opt} = 240.06 s и z_{4opt} = 1000.84 µC/cm^2.

На Фиг. 4 е представена контурна графика на средната стойност на загубата на дебелина на резиста $\widetilde{y_5}(p)$ в зависимост от ускоряващото напрежение z_1 и дебелината на резиста z_2 при постоянни стойности на другите два параметъра и равни на техните оптимални стойности - времето за проявяване z_{3opt} = 240.06 s и дозата на експониране z_{4opt} = 1000.84 µC/cm^2. На фигурата със символ "*" е означен полученият оптимален режим, като защрихованата зона съответства на областта на параметри на процеса, при които се изпълняват ограниченията за геометричните характеристики на профила на експонирания и проявен резист. Стойностите на другите два параметъра на процеса са постоянни и равни на техните оптимални стойности (z_{1opt} и z_{4opt}).

При многокритериалната оптимизация едновременно се оптимизират няколко критерия едновременно. В общия случай не съществува едно решение, което да оптимизира всички критерии. Съществува, обаче, множество от недоминирани алтернативи, наречено Парето оптимално множество, всеки елемент от което може да бъде решение на многокритериалната задача от математическа гледна точка. В практиката, обаче, е необходимо да бъде избрана една алтернатива за крайно решение на задачата. За нейния избор е нужна допълнителна информация. Всички Парето-оптимални решения притежават следното свойство: всяко отклонение от някое от тях с цел подобряване на един или на няколко критерия води до влошаване на поне един или на няколко от останалите критерии. Затова Парето-оптималните решения са ефективни, недоминиращи, неподобряващи се, компромисни или приемливи.

В конкретния случай заданието е да се минимизират едновременно средната стойност на загубата на дебелина на резиста $\widetilde{y_5}(p)$ и дисперсиите на всичките пет геометрични характеристики на профила на резиста. Получен е Парето фронт (Парето оптимални решения) с помощта на генетичен алгоритъм и продукта QstatLab [8]. Десет от тях са представени в Таблица 5, заедно със стойностите на параметрите на процеса, при които те са получени. Вижда се, че дисперсиите на ширините на повърхността, на дъното и при подложката не се изменят (до 4 десетичен знак). В рамките на зададените областни ограничения за параметрите на процеса и получените средни стойности на останалите геометрични характеристики варират в много малки граници.

Таблица 5. *Парето оптимални решения*

No.	p_1	p_2	p_3	p_4	$\widetilde{y_5}(p)$	$\tilde{s}^2(y_1)$	$\tilde{s}^2(y_2)$	$\tilde{s}^2(y_3)$	$\tilde{s}^2(y_4)$	$\tilde{s}^2(y_5)$
1	-0.1271	-0.3492	-0.9992	-0.9993	11.3918	0.0000	0.0000	0.0002	1.6984	0.0301
2	-0.2525	0.3614	-0.9949	-0.9996	9.2823	0.0000	0.0000	0.0002	1.6986	0.0297
3	-0.2933	0.7609	-0.9766	-0.9723	8.6865	0.0000	0.0000	0.0002	1.6988	0.0295
4	-0.2647	0.3985	-0.9985	-0.9994	9.1930	0.0000	0.0000	0.0002	1.6986	0.0296
5	-0.2753	0.5974	-0.9965	-0.9959	8.8138	0.0000	0.0000	0.0002	1.6987	0.0295
6	-0.3123	0.7264	-1.0000	-1.0000	8.5954	0.0000	0.0000	0.0002	1.6987	0.0295
7	-0.3157	0.4983	-0.9849	-0.9985	9.0499	0.0000	0.0000	0.0002	1.6986	0.0296
8	-0.1492	-0.0029	-0.9998	-0.9996	10.1961	0.0000	0.0000	0.0002	1.6985	0.0299
9	-0.2865	0.6322	-0.9944	-0.9999	8.7540	0.0000	0.0000	0.0002	1.6987	0.0295
10	-0.3689	0.6338	-0.9996	-0.9999	8.7684	0.0000	0.0000	0.0002	1.6987	0.0295

Решението на многокритериалната задача определя множество ефективни (недоминирани) решения, образуващи фронта на Парето. В този случай изборът на оценъчна система от критерии и тяхното аранжиране по степен на важност е трудно формализуем проблем, който няма еднозначно тълкуване и неизбежно поражда субективни решения.

6. Заключение

Чрез прилагане на робастно инженерно проектиране са оценени модели за средните стойности и дисперсиите на качествените показатели, характеризиращи геометрията на профила на положителен резист ПММА, след експониране с електронен лъч и проявяване при процеса електроннолъчева литография. Получените модели дават възможност за параметрична оптимизация при производствени условия и наличия на грешки във факторните нива за получаване на резисти с високо качество и възпроизводими характеристики. Получените чрез многокритериална оптимизация решения са робастни (нечувствителни) към неизбежните грешки в стойностите на параметрите на процеса при производствени условия.

Прилагането на този подход ще повиши качеството на произвежданата продукция при изпълнение на поставените технологични изисквания.

ЛИТЕРАТУРА

1. Младенов Г., (2009) *Електронни и йонни технологии*, изд. „Птоф. Марин Дринов”.
2. Vuchkov I.N. and Boyadjieva L.N. (2001). *Quality improvement with design of experiments*, Kluwer Academic Publishers, The Netherlands.
3. Koleva E.G. and Vuchkov I.N. (2005). Model-based approach for quality improvement of EBW applications in mass production, *Vacuum*, Vol. 77, pp. 423-428.
4. Koleva E., Mladenov G., Vuchkov I., Velev K., Lamond B. and Petrova D. (2009). Program tool EBMR-MREDO for robust engineering quality optimization of EBMR of titanium. *E+E*, 5-6, 264-269.
5. Koleva E., Vuchkov I. and Velev K. (2009). Multiresponse Robust Engineering: Case with Errors in Factor Levels. *PLISKA Studia Mathematica Bulgarica*, 19, 193-206.
6. Koleva E.G. and Vuchkov I.N. (2010). Multiresponse robust engineering: industrial experiment parameter estimation. Advances in Data Analysis: Theory and Applications to Reliability and Inference, Data Mining,Bioinformatics, Lifetime Data, and Neural Networks, Ed. C. H. Skiadas, Birkhäuser Boston, a part of *Springer Science+Business Media*, LLC 2010, 337-344.
7. Petrova D., Koleva E. and Voutchkov I. (2012). *Model-Based Robust Parametric Design of Automatic Cleaning Process. Journal of Pharmaceutical Innovation*, March 2012, Volume 7, Issue 1, Publisher Springer US. 30-37.
8. http://qstat.dir.bg/

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ЕКСПЕРИМЕНТАЛНО И ЧИСЛЕНО ОПРЕДЕЛЯНЕ НА КОЕФИЦИЕНТА НА ДОПЪЛНИТЕЛНИ ЗАГУБИ МЕЖДУ ШИНИ

ИВАН ХАДЖИЕВ, ДИАН МАЛАМОВ, ВАСИЛ СПАСОВ

Резюме: *В тази работа са проведени експериментални и числени изследвания на влиянието на скин ефекта и ефекта близост на паралелно разположени тоководещи шини. Експерименталните изследвания са направени чрез разработената за тази цел експериментална уредба. Числените изследвания са извършени чрез разработени компютърни модели в средата на програмния продукт Comsol. Направено е сравнение между получените експериментални и числени данни за коефициента на допълнителни загуби между тоководещи шини.*

Ключови думи: *коефициент на допълнителни загуби, тоководещи шини, МКЕ*

DEFINING THE COEFFICIENT OF ADDITIONAL LOSSES BETWEEN BUSBARS EXPERIMENTALLY AND NUMERICALLY

IVAN HADZHIEV, DIAN MALAMOV, VASIL SPASOV

Abstract: *Experimental tests and numerical study of the influence of both skin and proximity effects on parallel current-carrying busbars have been carried out and the results have been described in this paper. The experiments have been conducted by means of an experimental installation, specially developed for the purpose. The numerical study has been performed with the help of computer models, developed in the software product Comsol. A comparison has been made between the obtained experimental and numerical data of the coefficient of additional losses between current-carrying busbars.*

Key words: *coefficient of additional losses, current-carrying busbars, FEM*

1. Introduction

It is known that when alternative current flows through current-carrying elements, additional losses occur due to skin and proximity effects [1]. These losses depend in a complex way on the dimensions of the current-carrying elements, on the frequency of the current, on the properties of the material, etc. It makes their direct calculation quite difficult. The skin effect is described by differential equations [2], [3], [4]. Analytical solution is only possible for simpler cases, such as the ones, presented in [5]. Papers [3] and [4] consider the skin effect in a massive busbar and give an approximate analytical solution. An electric device has been shown in [2] for measuring the flux density, while in [6] the skin effect has been discussed and the magnetic field in the conductors has been calculated by the finite element method. The numerical results have been presented in a graphical format and compared with analytical ones. Paper [7] presents a study of the skin and proximity effects in case of using U-shaped busbars in terms of their dimensions and location, as well as vs. the frequency.

This paper describes both experimental tests and a numerical study of the coefficient of additional losses between current-carrying busbars. A comparison between the obtained experimental and numerical results has been made.

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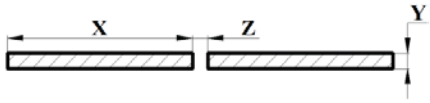
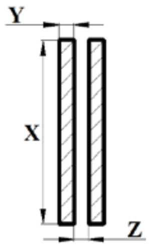
2. Busbar location variants

Table 1 presents the variants of location of the busbars, for which the coefficient of additional losses has been studied.

Table 1. *Types of location of the investigated busbars*

Variant 1 
Variant 2 

3. Studying the coefficient of additional losses between current-carrying busbars experimentally

A special experimental installation has been developed for the purpose of studying the coefficient of additional losses experimentally, as shown in Fig. 1.

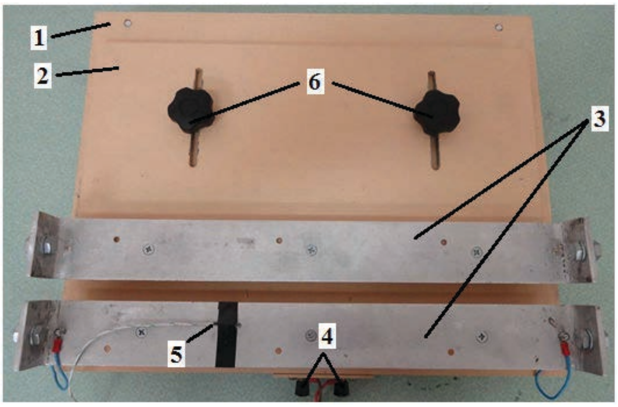
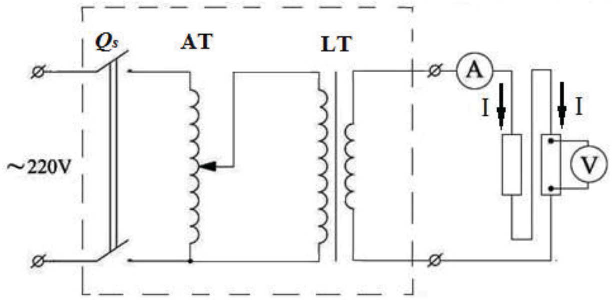
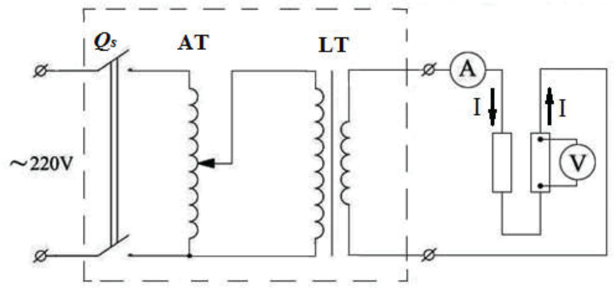


Fig. 1. *Experimental installation for studying the coefficient of additional losses:* ***1*** *- stationary part;* ***2*** *- movable part;* ***3*** *- aluminium busbars with dimensions [60x6]mm;* ***4*** *- terminals for measuring the voltage drop;* ***5*** *- K type thermocouple;* ***6*** *– fixer.*

The electrical circuit of the experimental installation is shown in Fig. 2.



a)



b)

Fig. 2. *Electric circuit of the experimental installation for studying of the coefficient of additional losses at: a) – currents in the same direction; b) – currents in opposite directions;* Q_s *– circuit breaker; AT – autotransformer; LT – load transformer; A – ammeter; V – voltmeter.*

The coefficient of additional losses is defined according to the formula:

$$k = \frac{P_{\sim}}{P_{=}} = \frac{I^2.R_{\sim}}{I^2.R_{=}} = \frac{R_{\sim}}{R_{=}}, \tag{1}$$

where: $P_{\sim}$ are the losses per unit of length at alternating current with r.m.s. value I; $P_{=}$ are the losses per unit of length at direct current I of the same magnitude; $R_{\sim}$ and $R_{=}$ are the resistances of the busbars at alternating and direct current respectively.

The resistances of the busbars $R_{\sim}$ and $R_{=}$ are defined according to the following formulae:

$$R_{\sim} = \frac{\Delta U}{I_{\sim}}; \tag{2}$$

$$R_{=} = \frac{\Delta U}{I_{=}}. \tag{3}$$

Here ΔU is the voltage drop of the busbars.

3.1. Experimental results for the coefficient of additional losses

The coefficient of additional losses has been defined by means of the experimental installation described above. Fig. 3 and Fig. 4 illustrate the dependence of the coefficient of additional losses on the distance between the busbars for variant 1 in case of currents in the same direction and in opposite directions.

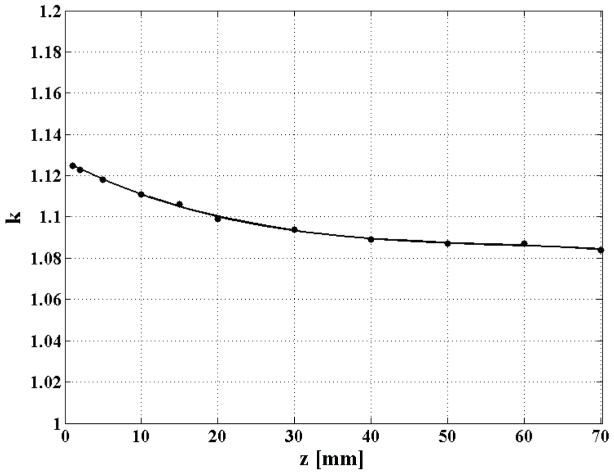


Fig. 3. Dependence of the coefficient of additional losses on the distance between the busbars for variant 1 and currents in the same direction.

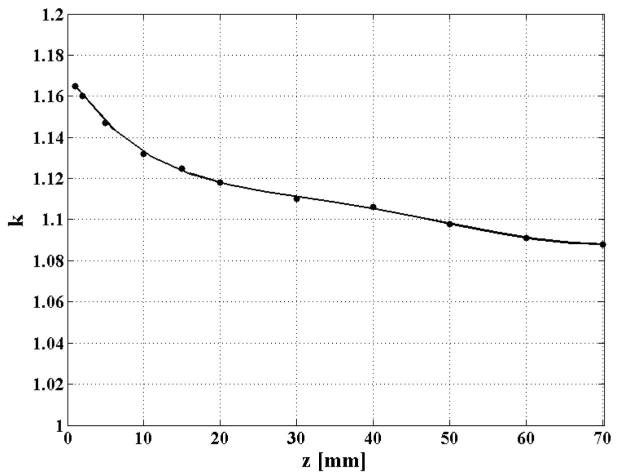


Fig. 4. Dependence of the coefficient of additional losses on the distance between the busbars for variant 1 and currents in opposite directions.

Fig. 5 and Fig. 6 show the dependence of the coefficient of additional losses on the distance between the busbars for variant 2 in case of currents in the same direction and opposite directions.

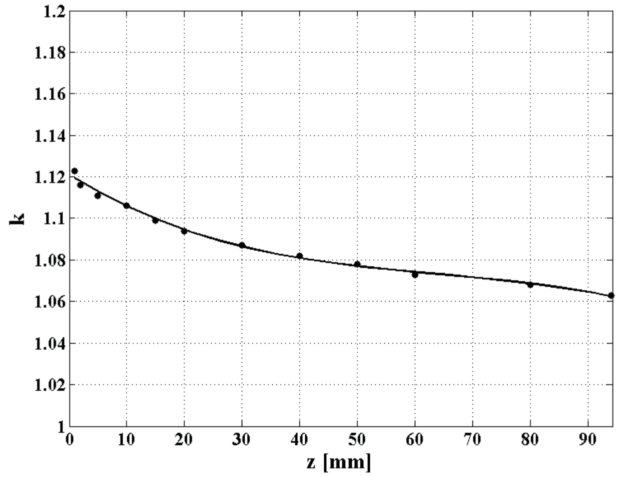


Fig. 5. Dependence of the coefficient of additional losses on the distance between the busbars for variant 2 and currents in the same direction.

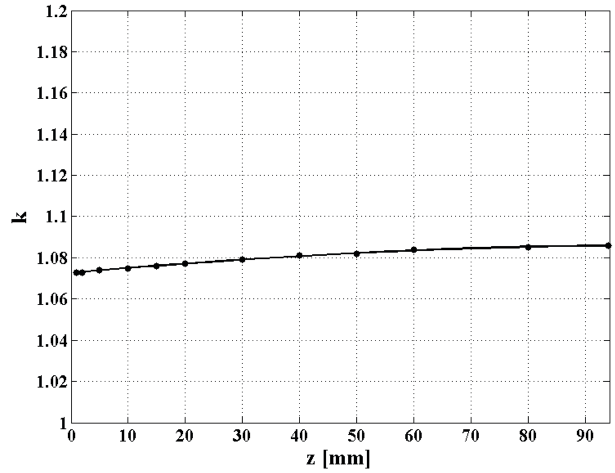


Fig. 6. Dependence of the coefficient of additional losses on the distance between the busbars for variant 2 and currents in opposite directions.

4. Numerical study of the coefficient of additional losses between current-carrying busbars

4.1. Mathematical model

The mathematical model of a quasi-stationary electromagnetic field is described by the Helmholtz equation in a complex type [8]:

$$\nabla^2 \dot{\mathbf{A}} - j\omega\mu\sigma \dot{\mathbf{A}} = -\mu \dot{\mathbf{J}}_e, \tag{4}$$

where: $\mathbf{A}$ is the magnetic vector potential; ω is the angular frequency; μ is the magnetic permeability; σ is the specific electrical conductivity; $\mathbf{J}_e$ is the current density of external sources. The second member of the equation reflects the eddy currents.

The solution of the electromagnetic problem is given at a predetermined boundary condition along the border of the buffer zone of the type:

$$\mathbf{n}\mathrm{x}\mathbf{A} = 0. \qquad (5)$$

The losses per unit of length at alternating current are obtained from the electromagnetic field problem solution according to the formula:

$$P_{\sim} = \iint_{S} \mathbf{J}.\mathbf{E}dS. \qquad (6)$$

The losses per unit of length at direct current are calculated by the formula:

$$P_{=} = \frac{I^2}{\sigma S}, \qquad (7)$$

where I is the current through the busbar; S is the cross-section of the busbar.

The coefficient of additional losses is defined by the formula:

$$k = \frac{P_{\sim}}{P_{=}}. \qquad (8)$$

4.2. Analysis by the finite element method

Numerical models for defining the characteristics of the electromagnetic field for the variants presented in Table 1 at frequency of 50 Hz have been created by the software product COMSOL [9].

Fig. 7 shows the mesh of finite elements.

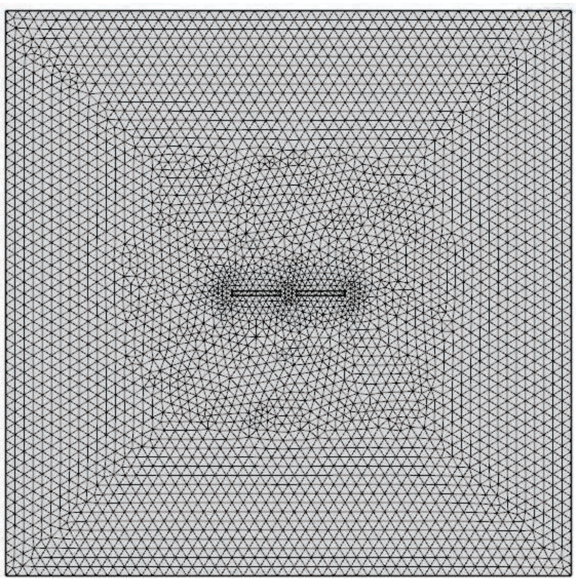


Fig. 7. *Mesh of finite elements.*

Fig. 8, Fig. 9, Fig. 10 and Fig. 11 illustrate the distribution of the magnetic flux density for variant 1 and variant 2 at dimensions x = 60mm, y = 6mm and z = 20mm.

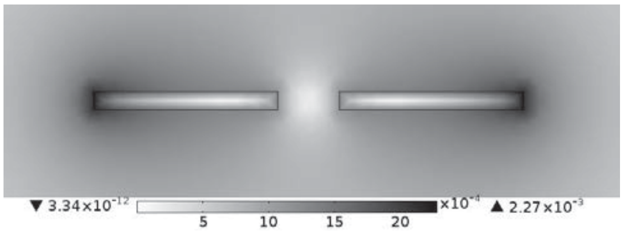


Fig. 8. *Distribution of the magnetic flux density B[T] for variant 1 and currents in the same direction.*

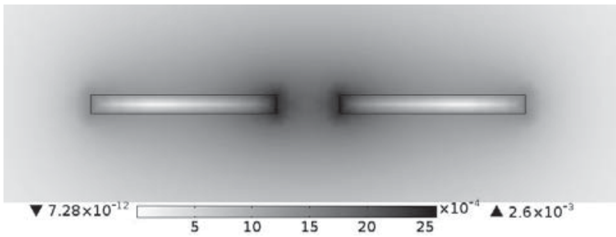


Fig. 9. *Distribution of the magnetic flux density B[T] for variant 1 and currents in opposite directions.*

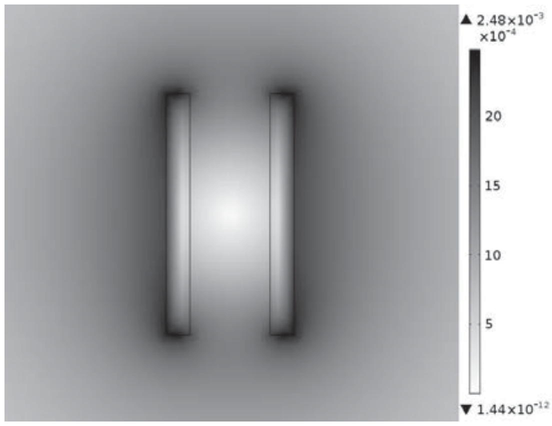


Fig. 10. *Distribution of the magnetic flux density B[T] for variant 2 and currents in the same direction.*

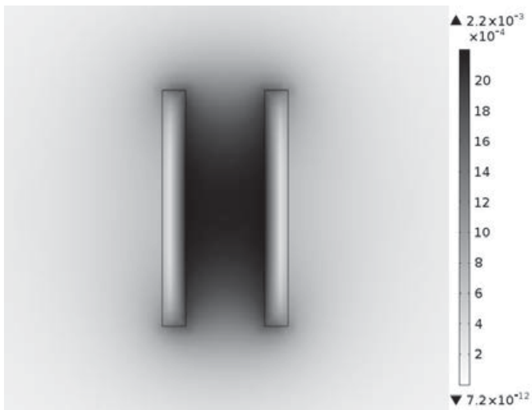
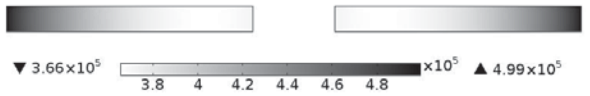
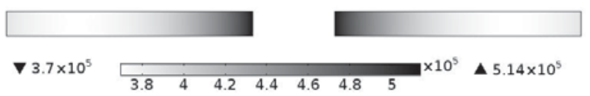


Fig. 11. *Distribution of the magnetic flux density B[T] for variant 2 and currents in opposite directions.*

The obtained distribution of the current density in the busbars for variant 1 and variant 2 at dimensions x = 60mm, y = 6mm and z = 20mm is shown in Fig. 12 and Fig. 13.

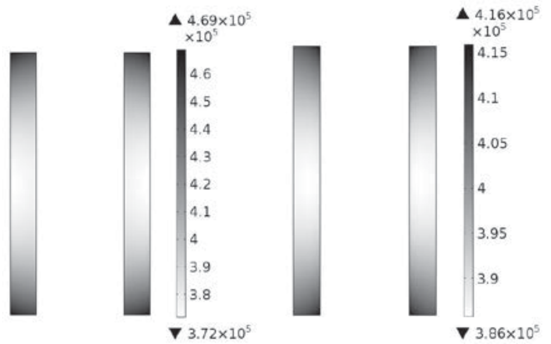


a)



b)

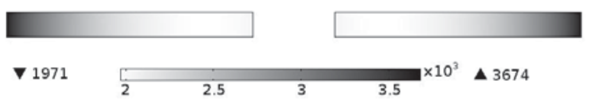
Fig. 12. *Distribution of current density [A/m^2] for variant 1 at: a) - currents in the same direction; b) - currents in opposite directions.*



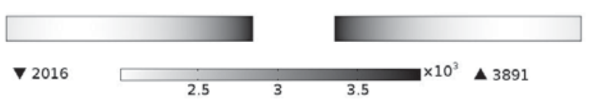
a) *b)*

Fig. 13. *Distribution of current density [A/m^2] for variant 2 at: a) - currents in the same direction; b) - currents in opposite directions.*

The obtained distribution of the specific losses in the busbars for the different variants at dimensions x = 60mm, y = 6mm and z = 20mm is shown in Fig. 14 and Fig. 15.

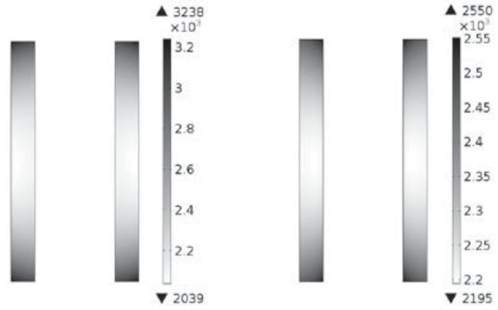


a)



b)

Fig. 14. *Distribution of the specific losses [W/m^3] for variant 1 at: a) - currents in the same direction; b) - currents in opposite directions.*



a) *b)*

Fig. 15. *Distribution of the specific losses [W/m^3] for variant 2 at: a) - currents in the same direction; b) - currents in opposite directions.*

5. Comparison between the obtained numerical and experimental results

Fig. 16, Fig. 17, Fig. 18, and Fig. 19 show the graphic dependencies of the coefficient of additional losses on the distance between the busbars obtained from both the experimental tests (curve 1) and the numerical study (curve 2).

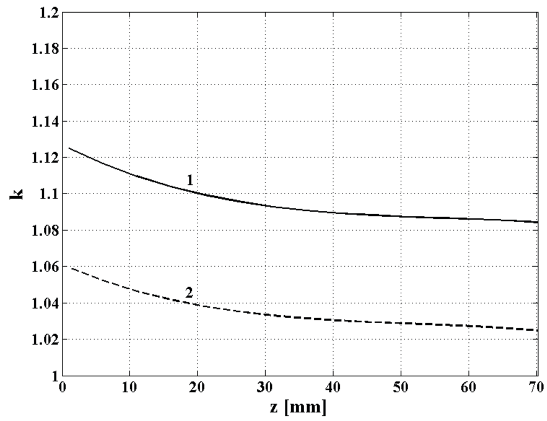


Fig. 16. *Dependence of the coefficient of additional losses on the distance between the busbars for variant 1 and currents in the same direction.*

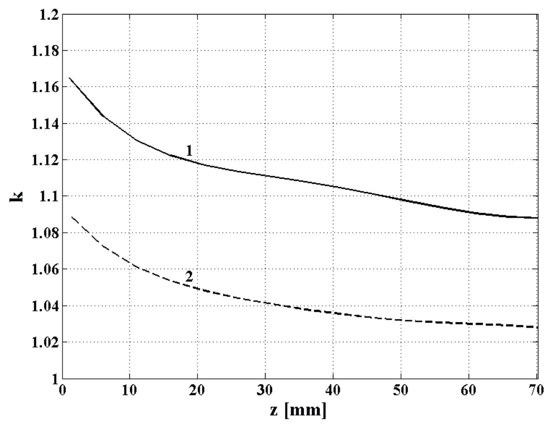


Fig. 17. *Dependence of the coefficient of additional losses on the distance between the busbars for variant 1 and currents in opposite directions.*

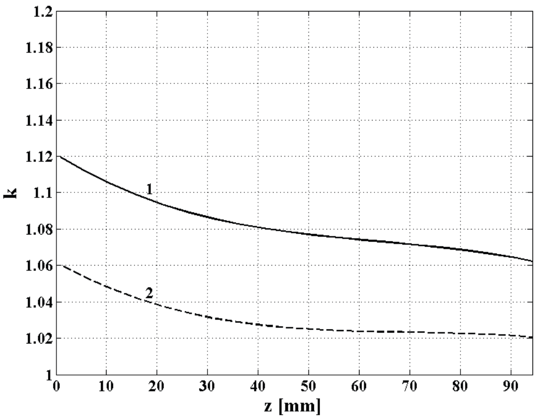


Fig. 18. Dependence of the coefficient of additional losses on the distance between the busbars for variant 2 and currents in the same direction.

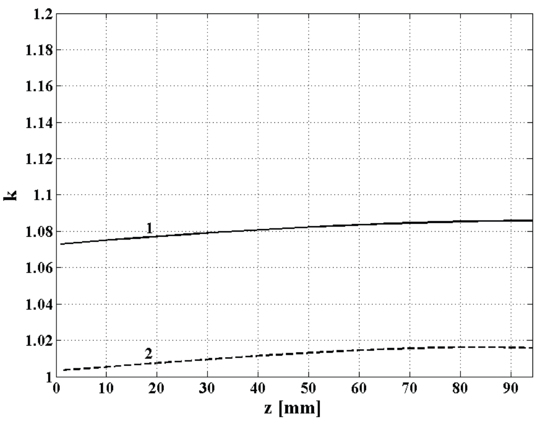


Fig. 19. Dependence of the coefficient of additional losses on the distance between the busbars for variant 2 and currents in opposite directions.

6. Conclusion

Based on the results from the numerical study and the experimental tests carried out, the following conclusions can be made:

- the pattern of change of the coefficient of additional losses considerably depends on the distance between the busbars;
- the coefficient of additional losses for variant 1 decreases with the increase in the distance between the busbars, regardless of the direction of the current;
- the coefficient of additional losses for variant 2 decreases with the increase in the distance between the busbars at currents in the same direction, while at currents in different directions the situation is just the opposite;
- the coefficient of additional losses has the highest value when the busbars are positioned as in variant 1 and in case of currents in opposite directions.

The difference between the obtained numerical and experimental results is 7%. It allows for studying the coefficient of additional losses numerically and obtaining arrays of data in order to be able to define this coefficient directly.

REFERENCES

1. Alexandrov, A. (2002). *Electrical apparatuses - part I (Electromagnetic and thermal problems),* Heron press, Sofia (in Bulgarian).
2. Kosek, M., Truhlar, M., Richter, A. (2011). Skin-effect in massive conductors at technical frequencies, *Przeglad Elektrotechniczny (Electrical Review),* ISSN 0033-2097, R. 87 NR 5.
3. Kosek, M., Truhlar, M., Richter, A. (2012). Skin-effect in conductor of rectangular cross-section – approximate solution, *Przeglad Elektrotechniczny (Electrical Review),* ISSN 0033-2097, R. 88 NR 7a.
4. Gerling, D., Approximate analytical calculation of the skin effect in rectangular wires, *University of Federal Defense Munich, 85579 Neubiberg,* Germany.
5. Hanka, L. (1975). *Theory of electromagnetic field*, SNTL, Prague. (in Czech).
6. Greconici, M., Madescu, G., Mot, M. (2010). Skin effect analysis in a free space conductor, *Elec. Energ*. vol. 23, No. 2, pp. 207-215, Serbia.
7. Lažetic, K., Prša, M., Đuric, N. (2009). Proximity effect against skin effect in two coupled U–shaped busbars, *Elec. Energ*. vol. 22, no. 3, pp. 293-303, Serbia.
8. Yatchev I., Marinova, I. (2011). *Numerical methods and modeling of circuits and fields*, *Part one*, Sofia. (in Bulgarian).
9. *COMSOL Version 4.2 User'guide*. (2011).

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STUDY OF TWO TYPES OF SENSORS OF STATIC FORCES - A PIEZOELECTRIC SENSOR AND A PIEZOELECTRIC ELASTOMER SENSOR

NIKOLA GEORGIEV

Abstract: *The present paper studies a piezoelectric sensor (PS) and a combined piezoelectric elastomer sensor (CPES), consisting of a piezoelectric sensor and an electro-conductive elastomer sensor, both sensors measuring static and slowly changing forces. The piezoelectric sensor works in a resonance mode, since higher level of sensitivity is thus achieved. Both sensors have been modeled and the influence of the measured static force on the mechanical resistance of the piezoelectric sensor has been defined, as well as on its output voltage. Thence the influence of the measured static force on the resistance of the electro-conductive elastomer sensor has also been determined. Models have been obtained for both sensors in Simulink in MATLAB environment. The models have been experimentally tested.*

Key words: *combined sensors, piezoelectric, elastomer, Matlab, Simulink model, static force*

1. Introduction

A great number of mechanical quantities such as mass, force, acceleration, momentum, deformation and angular velocity are measured by means of piezoelectric transformers [1, 2, 3]. They work both in static and dynamic modes. Usually by means of this type of sensors static or slowly changing forces are measured and the measured force is applied to the piezoelectric transformer itself or to a metal element, to which piezoelectric elements are attached [2].

Piezoelectric resonant sensors are also used in robotics to measure distances, touch, and static or dynamic forces in resonance mode [2].

Electrically conductive elastomer sensors are a special class of tactile sensors of force, marked by their compactness and low cost.

The most frequently used construction of tactile sensors with electro-conductive rubbers (elastomers) is the sandwich type (fig.1). The elastomer material in it 5 is placed between two metal (brass) electrodes 1 and 6. The measured static force is applied perpendicular to the sensor, and the volume resistance of the electro-conductive rubber changes in result [4].

This paper studies a piezoelectric sensor and a combined sensor, which, in turn, consists of a piezoelectric sensor and a sensor with an electro-conductive elastomer. The considered sensors measure static and slowly changing forces, and the piezoelectric sensor works in a resonant mode. The electro-conductive elastomer sensor is represented by a resistor $R_{r,,}$ by means of which its volume resistance is expressed. Modeling of the PS and CPES is carried out and the influence of the measured static force on the mechanical resistance of the metal rod of the piezoelectric sensor and thence on its output voltage is defined. The influence of the measured static forces on the resistance of the electro-conductive elastomer sensor is registered.

2. Exposition

The piezoelectric sensor (PS) of force, studied here, is composed of two piezoelectric plates 2 and 3, stuck on a metal (brass) rod 1, fig 1. The measured static force is applied to the metal rod and this allows for increasing the range of the measured forces considerably.

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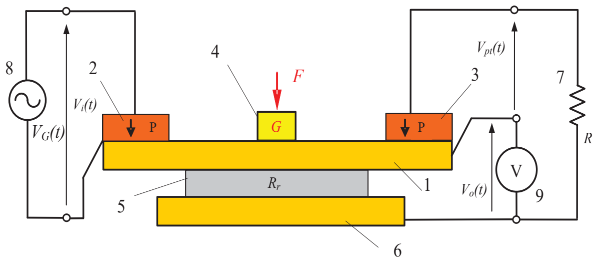

Fig.1. *Experimental installation of the CPES*

The applied static force F can be expressed by the concentrated mass M-4. The sinusoidal generator 5 supplies electrical energy to the input of the piezoelectric plate of the PS-2, where it is converted into mechanical oscillations due to the reverse piezoelectric effect. Since the generator is set up for resonant frequency ω_0 for PS, the mechanical oscillations reach their maximum and are in the form of standing waves in the metal rod 1. The mechanical oscillations are converted again into electrical signal due to the forward piezoelectric effect in the output piezoelectric plate 3. The sensor with the electro-conductive elastomer consists of two brass electrodes 1 and 6 and an electro-conductive rubber 5 between them. The measured static force changes the volume resistance of the rubber R_r, and this is registered by means of the voltmeter 9.

3.Modeling

Fig. 2 shows the electro-mechanical circuit of the PS, containing electrical input and output parts, presented by its capacitors C_{e1}, C_{e2}. A mechanical part is located between them, which comprises the mechanical resistances of the piezoelectric plates R_p, L_p, C_p, as well as those of the metal rod R_m, L_m, C_m. Energy transformation from electrical to mechanical and vice versa is presented by the ideal transformers Tr_1 и Tr_2. Similar electro-mechanical circuit for a PS is considered in [2]. The active resistance R together with the resistance, presenting the sensor with the electro-conductive elastomer R_r are connected to the output of the piezoelectric transformer. Thus the measured static force changes: the mechanical resistance of the metal resonator and thence the output resistance of the piezoelectric transformer $V_{pt}(t)$; the electrical resistance of the electro-conductive sensor R_r and thence the voltage of the output voltage divider $V_0(t)$. Thus the measured static force influences both sensors, first reducing the output voltage of the piezoelectric senor, and then reducing the voltage on the electro-conductive sensor. This allows for increasing the level of sensitivity of the combined piezoelectric elastomer sensor significantly.

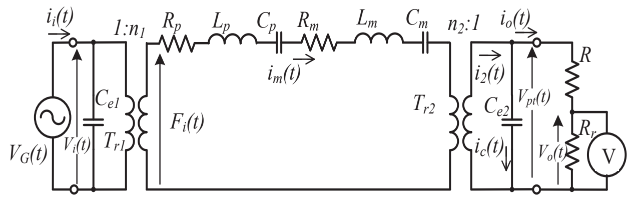

Fig.2. *Equivalent electro-mechanical circuit of the CPES*

Fig. 2 presents an electro-mechanical circuit of the CPES in which the equivalent electrical and mechanical quantities are denoted as follows:

$V_i(t)$, $V_{pt}(t)$ - input and output electrical voltages on the PS;
$V_o(t)$ - output electrical voltage for the CPES;
$i_o(t)$ - output electric current of the PS;
n_1, n_2 - coefficients of electro-mechanical conversion at the input and output of the PS;
$F_1(t)$ - input mechanical force for the PS;
$i_m(t)$ - mechanical current (oscillatory speed).

The piezoelectric plates, used both for the purposes of modeling and for the experimental tests, are rectangular in shape, with dimensions: length $L_p=8.10^{-3}$ m, width $W_p=15.10^{-3}$ m and thickness $T_p=1.10^{-3}$ m and are made of piezoelectric ceramic material PZT4m having the following parameters: piezoelectric module $d_{31}=123.10^{-12}$ $C.N^{-1}$, Young's modulus Y^E_{1p} $=0,83.10^{11}$ $N.m^{-2}$, density $\rho_p=7600$ $kg.m^{-3}$, permittivity $\varepsilon^T_{33}=11,5.10^{-9}$ $F.m^{-1}$, elastic constant $S^E_{11}=11,7.10^{-12}$ $m^2.N^{-1}$, longitudinal frequency constant N=1600 Hz.m and quality factor of the piezoelectric ceramics $Q_{Mp}=500$. The metal rod is made of brass with Young's modulus Y^E_{1m} $=0,98.10^{11}$ $N.m^{-2}$, density $\rho_m=8500$ $kg.m^{-3}$ and the following dimensions: $L_m=7.10^{-2}$ m, $W_m=15.10^{-3}$ m и $T_m=1.10^{-3}$ m.

The sinusoidal generator $V(t)$ is with amplitude $V_m=7$ V and circular frequency $\omega_0=660991$ s^{-1} equal to the frequency of the PS.

Since the sinusoidal generator is assumed ideal, it can be presented in Fig. 3 by means of the input voltage of the PS

$$V_G(t) = V_1(t) \quad . \tag{1}$$

Thus the input voltage $V_1(t)$ is also sinusoidal and, due to the reverse piezoelectric effect, expressed by the coefficient of electro-mechanical transformation n_1, it is converted into a sinusoidally changing mechanical force $F_1(t)$ in the simplified equivalent circuit of the CPES, fig. 3

$$F_1(t) = n_1 V_1(t) \quad . \tag{2}$$

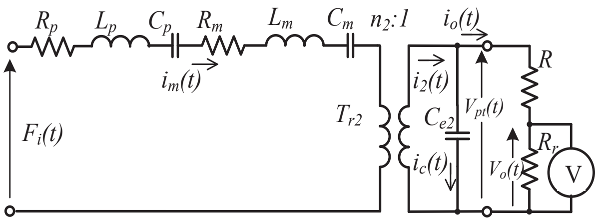

Fig. 3. *Simplified equivalent electro-mechanical circuit of the CPES*

The mechanical resistances and coefficients of ideal transformations for the piezoelectric ceramic plates are equal to [3]

$$n_1 = n_2 = W_p d_{31} Y_{1p}^E \quad , \quad R_p = \frac{\pi T_p W_p \sqrt{\rho_p Y_{1p}^E}}{2Q_{Mp}} \quad ,$$

$$L_p = 2T_p W_p L_p \rho_p \quad , \quad C_p = \frac{L_p}{2\pi^2 T_p W_p Y_{1p}^E} \quad . \tag{3}$$

The mechanical resistances of the metal rod are found in the same way

$$R_m = \frac{\pi T_m W_m \sqrt{\rho_{m1} Y_{1m}^E}}{4Q_M} \quad , \quad L_m = T_m W_m L_m \rho_m \quad ,$$

$$C_m = \frac{L_m}{\pi^2 T_m W_m Y_{1m}^E} \quad . \tag{4}$$

Metal rod density ρ_{m1} can be expressed by means of the concentrated mass M, as well as by the mass G and the density ρ_m of the brass metal rod

$$\rho_{m1} = \rho_m \left(1 + \frac{M}{G}\right) \quad . \tag{5}$$

The concentrated mass can be presented by the concentrated force F and the acceleration of gravity

$$M = \frac{F}{g} \quad . \tag{6}$$

Thus the density of the metal rod ρ_{m1} can be expressed by the measured concentrated force

$$\rho_{m1} = \rho_m \left(1 + \frac{F}{gG}\right) \tag{7}$$

After substituting (7) into (4) for the mechanical resistance, presenting the losses in the metal rod, it is obtained

$$R_m = \frac{\pi T_m W_m \sqrt{Y_{1m}^E \rho_m \left(1 + \frac{F}{gG}\right)}}{4Q_{M0}} \tag{8}$$

By means of the derived expression the influence of the measured static force on the mechanical loss resistance is taken into account for the PS.

The mechanical quality factor Q_M of the metal rod of the PS can be obtained from the damping ratio of the mechanical waves in α, and the circular resonant frequency ω_0 of the PS

$$Q_M = \frac{\omega_0}{2\alpha} \quad . \tag{9}$$

The dependence between the volume resistance of the electro-conductive elastomer and the measured force $R_r = f(F)$ is non-linear. The theory of the elastic properties of bodies [5] is used for its analytical derivation.

With the help of the Hooke's law the measured force can be presented as follows

$$F = \sigma S = Y_r \varepsilon S = Y_r S \frac{\Delta h}{h} \quad , \tag{10}$$

where:

S is the cross-section of the electro-conductive elastomer;

Y_r - Young's modulus of the electrically conductive elastomer;

ε - relative deformation ;

h - thickness of the electrically conductive elastomer.

From (10) for the relative deformation of the electro-conductive elastomer it is obtained

$$\varepsilon = \frac{F}{Y_r S} \,, \qquad (11)$$

Taking into account the relative deformation ε and introducing a corrective coefficient β for the resistance of the electro-conductive elastomer it is obtained

$$R_r = R_{ro}\, e^{-\frac{\beta}{Y_r S}F} \,, \qquad (12)$$

By R_{ro} the resistance of the electro-conductive elastomer is denoted at zero static force F.

With the help of the second law of Kirchhoff for the mechanical part of the PS, fig.3, the following expression is obtained

$$F_1(t) = \left(R_p + R_m\right) i_m(t) + \left(L_p + L_m\right)\frac{di_m(t)}{dt} + \left(\frac{1}{C_p} + \frac{1}{C_m}\right)\int i_m(t)\,dt \qquad (13)$$

After integrating both members of the equation and certain transformations, for the mechanical current of the PS it is obtained

$$i_m(t) = \frac{1}{\left(L_p + L_m\right)}\int F_1(t)\,dt - \frac{\left(R_p + R_m\right)}{\left(L_p + L_m\right)}\int i_m(t)\,dt + \frac{\left(\frac{1}{C_p} + \frac{1}{C_m}\right)}{\left(L_p + L_m\right)}\iint i_m(t)\,dtdt \qquad (14)$$

The output electric current through the capacitor can be obtained from the mechanical current and the electro-mechanical transformation for the output of the PS

$$i_c(t) = \frac{1}{n_2} i_m(t) \,. \qquad (15)$$

Thus the output voltage of the PS can be found

$$V_{pt}(t) = V_c(t) = \frac{1}{C_{e2}}\int i_c(t)\,dt \,. \qquad (16)$$

This output voltage is supplied to the resistive divider, consisting of R and R_r, whereas for the output voltage of the combined piezoelectric elastomer sensor it is obtained

$$V_o(t) = \frac{V_{pt}(t)}{1 + \dfrac{R}{R_r}} \,. \qquad (17)$$

With the help of the expressions (8), (14) and (16) a Simulink model of the piezoelectric sensor in MATLAB environment is developed, fig. 4.

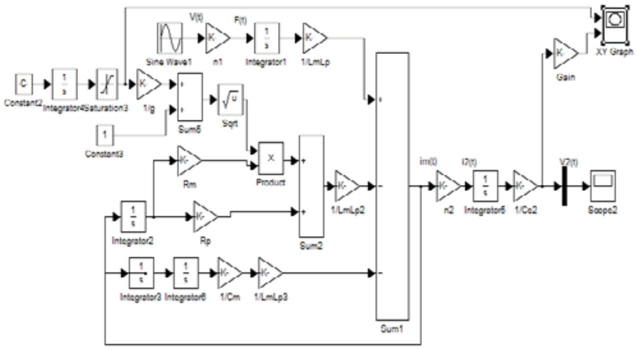

Fig. 4.

Fig. 5 presents the change of the simulated r.m.s. output voltage V_{pt} of the piezoelectric sensor in case of changing the measured concentrated force F within the range from 0 to 10N.

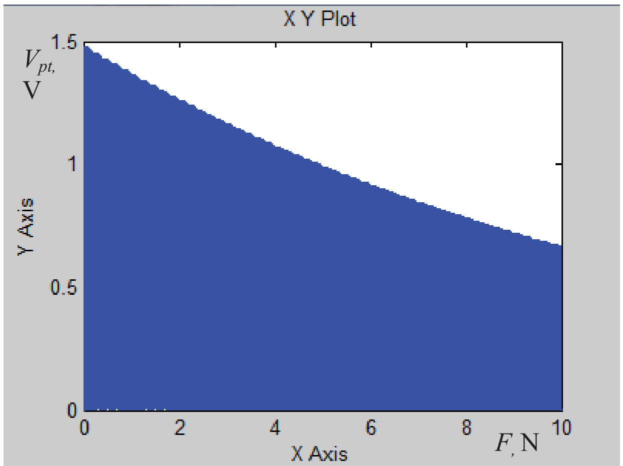

Fig. 5.

With the help of the expressions (8), (14), (16) and (17) a model of the combined piezoelectric elastomer sensor can be developed in Simulink (MATLAB environment), fig. 6.

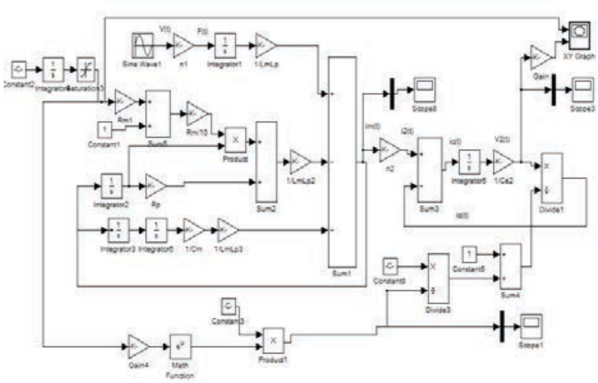

Fig. 6.

Fig. 7 presents the change of the simulated r.m.s. output voltage V_o of the combined piezoelectric elastomer sensor for the measured concentrated force F within the studied range.

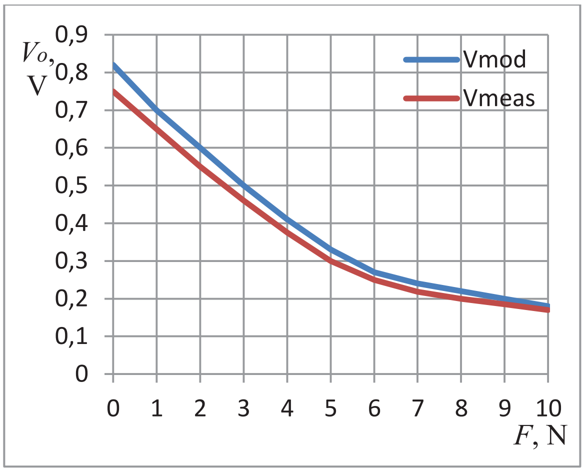

Fig. 7.

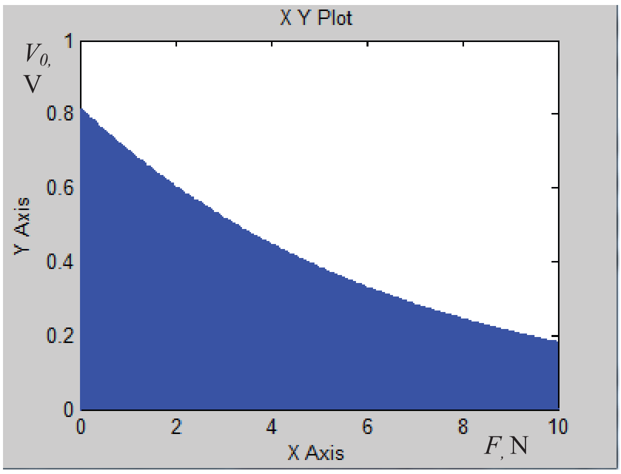

Fig. 8.

The presented model of the piezoelectric sensor in Simulink is experimentally tested by means of the circuit in fig. 1. The change of the effective values of the output voltages V_{pt} obtained by the model and from the experiment in function from the measured concentrated force F is shown in fig. 8.

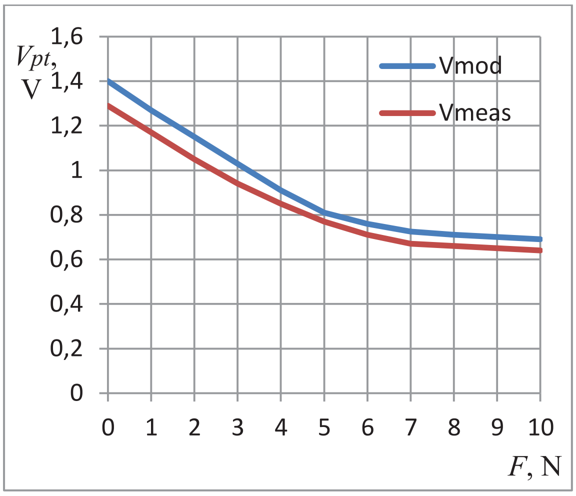

Fig. 9.

The model in Simulink of the combined piezoelectric elastomer sensor is also experimentally tested by means of the circuit in fig. 1. The change of the effective values of the output voltages V_o obtained both by the model and from experiments as a function of the measured concentrated force F is shown in fig. 9.

The voltages obtained in the simulation are higher both for the piezoelectric sensor and for the combined piezoelectric elastomer sensor, since the sinusoidal generator is assumed ideal, fig. 1.

The maximum relative error for the piezoelectric sensor is δ_{max}=8,53%, and this shows that the Simulink model well describes the behavior of the studied sensor for static forces.

For the combined piezoelectric elastomer sensor the maximum relative error is δ_{max}=9,33%, which means that the Simulink model well describes its behavior as well.

The relative levels of sensitivity measured within the studied range of the concentrated force F, are: S_F=51% for the piezoelectric sensor; S_F=77% for the piezoelectric elastomer sensor. Consequently the relative level of sensitivity of the combined piezoelectric elastomer sensor considerably exceeds the one, of the standard piezoelectric sensor. This is due to the fact that the measured force acts on both parts of this sensor – the piezoelectric and the elastomer.

5.Conclusion

Two types of sensors have been studied: a piezoelectric sensor and a combined piezoelectric elastomer sensor, consisting of a piezoelectric sensor and an electro-conductive elastomer sensor, both sensors measuring static and slowly changing forces.

Both sensors have been modeled and the influence of the measured static force over their output voltages has been defined.

The models have been tested experimentally and it has been established that they define well the behavior of the sensors while measuring static forces.

The relative level of sensitivity of the combined piezoelectric elastomer sensor considerably exceeds the one, of the standard piezoelectric sensor and it suggests the possibility to use it for measuring static and slowly changing forces.

References

[1] Lavrinenko, V. (1975). *Piezoelektricheskie transformatori.* Energia, Moscow.

[2] Trofimov A. I. (1979). *Measuring transducer static loads.* 32-45. “Machine building” Moscow.

[3] Kartashev, I. and Marchenko, N. (1978). *Piezoelektricheskie transformatori toka*, Tehnika, Kiev.

[4] Kostova, M. (1993). *Electrically Conductive Elastomeric Composition for Rubber Electrodes*. Copyright Certificate, №2603, RB.

[5] Harper, C. A. and Edward M. P. (2003). *Plastics Materials and Processes*. John Wiley & Sons.

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STUDY OF THE INFLUENCE OF THE PIEZOELECTRIC CERAMICS PARAMETERS ON THE OUTPUT CURRENT OF A PIEZOELECTRIC TRANSFORMER, POWERING A SUPER-CAPACITOR

NIKOLA GEORGIEV

Abstract: *A piezoelectric transformer, working in three-resonance mode with two parallel electric resonances at the input and the output and one mechanical resonance in series has been considered in this paper. The influence of the parameters of the piezoelectric ceramics on the magnitude of the output current of a piezoelectric transformer of current in short-circuit mode has been studied. The obtained expression can serve as informational output parameter of this type of transformers. The basic output electrical parameters of a number of piezoelectric ceramic materials (used in practice) have been compared. The times for charging the super-capacitor, connected to the output of the piezoelectric transformers have been calculated. Experimental tests have been conducted, confirming the validity of the obtained expression for the output current in short-circuit mode.*

Key words: *piezoelectric transformer of current, three-resonance mode, short-circuit current, super-capacitor*

1. Introduction

Traditionally, on-off control of semiconductor devices (thyristors and triacs) is accomplished by means of optrons and pulse inductive transformers. There is a need for additional power supply with the optrons, and the pulse transformers are characterized by low workability and a high extent of dissipation. One of the promising directions for eliminating these shortcomings is the use of piezoelectric transformers of current (PTC). [1].They have the following basic advantages: compactness, high workability, temporal and temperature stability, resistance both to electrical and mechanical overloads, and capability to work in short-circuit mode.

The aim of this paper is to study the influence of the parameters of the piezoelectric ceramic materials over the output short-circuit current, which is one of the main electrical parameters of the piezoelectric transformers of current.

2. Exposition

It follows from the name of the piezoelectric transformers of current that the most essential parameter for this type of piezoelectric transformers is the output current, obtained from the generator section.

The principle of operation of a transverse-transverse type of a PTC is explained by fig. 1:

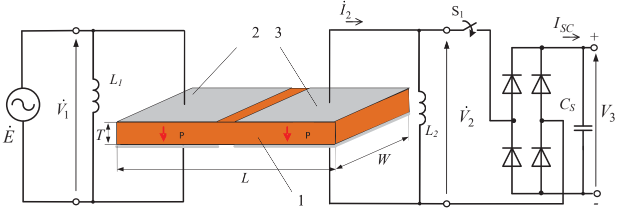

Fig.1. *Equivalent electro-mechanical circuit of a PTC*

Two pairs of silver electrodes 2 and 3 have been laid on a piezoelectric ceramic plate 1, i.e., a PTC has been constructed [2]. In the excitation section 2 of the PTC electrical energy is converted into mechanical, while in the generation section 3, mechanical energy is converted into electrical. The electric resistance of the piezoelectric ceramic plate is of the order of tens of GΩ and determines the excellent separation of the two electrical parts of the PTC.

The voltage of the sinusoidal generator is supplied to the excitation section and the electrical

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energy is converted into mechanical oscillations. They propagate into the piezoelectric ceramic plate and when they reach the generator section, they are converted into an electrical signal, which, after being rectified, charges the super-capacitor C_S.

If the sinusoidal generator is set at some of the resonant frequencies of the PTC, then standing mechanical waves arise in it and the output electric voltage has a maximum value.

Inductances L_1 and L_2 are connected in parallel both to the input and the output with values, allowing for obtaining two parallel (current) resonance circles with the electrical capacitances C_e of the excitation and the generator sections – fig. 2. These parallel resonance circles are with frequency, coinciding with the resonant frequency of the mechanical part of the PTC. Thus three resonance circles are obtained: two parallel electrical and one in series (mechanical), with the same resonant frequency – fig. 2.

Both sections – the excitation and the generator one – are expressed by their electrical capacitances *Ce,* while the electro-mechanical conversion is expressed by the ideal transformers Tr.1 and Tr.2. The mechanical part of the PTC is shown by its connected in parallel concentrated mechanical parameters: active resistance R_M – taking into account the losses in the PTC; inductance L_M – defining the mass; and capacitance C_M - taking into consideration the elasticity of the PTC [3].

Before the switch S_1 is turned on, the PTC works in idle-run mode; when it is turned on, the PTC works in a mode, close to a short-circuit mode, since the super-capacitor is not charged.

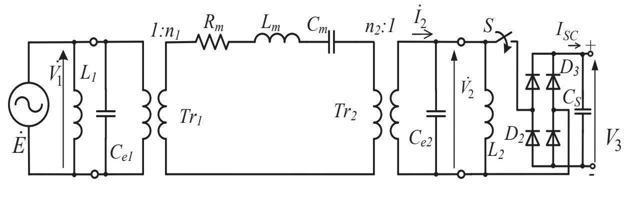

Fig.2. *Equivalent electro-mechanical circuit of the PTC*

When the excitation and generator sections are with the same length, the coefficients of ideal transformation are the same $n_1= n_2=n$.

Because of the resonance mode in the mechanical part of the PTC

$$\left(\omega L_M - \frac{1}{\omega C_M}\right) = 0 \quad . \qquad (1)$$

Consequently, the total mechanical resistance of the PTC is equal to the mechanical loss resistance

$$Z_M = R_M \quad . \qquad (2)$$

Since the input and the output electrical parts of the PTC have two parallel resonance circles, then the two equivalent reactive conductivities are equal to

$$B_1 = \left(\frac{1}{\omega L_1} - \omega C_1\right) = 0 \quad , \quad B_2 = \left(\frac{1}{\omega L_2} - \omega C_2\right) = 0 \quad . \qquad (3)$$

After reducing the mechanical part of the circuit to the electric part for a three-resonance mode [3] it has the form (fig.3):

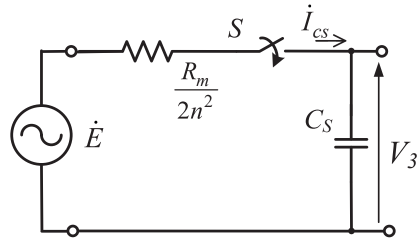

Fig.3. *Reduced electrical circuit of the PTC for three-resonance mode*

The mechanical loss resistance R_M can be expressed in the following way:

$$R_M = \frac{\pi Z_0}{4Q_M} \quad , \quad Z_0 = T\,W\sqrt{\rho\,Y} \quad , \qquad (4)$$

$$n = n_1 = n_2 = W d_{31} Y \quad ,$$

where:

$W,\ T$ are the width and the thickness of the PTC;

d_{31}, Y, ρ - the piezoelectric module, Young's modulus and density of the PTC;

Q_M - the mechanical quality factor;

Z_0 - the mechanical characteristic resistance of the PTC;

n_1, n_2 - the coefficients of ideal transformation.

By using the reduced electric circuit of the PTC for three-resonance mode (fig. 3), for the r.m.s. value of the output short-circuit current of the PTC it is obtained

$$\dot{I}_{SC} = \frac{2n^2\,\dot{E}}{R_M} \quad . \qquad (5)$$

The coefficient of ideal transformation n and the mechanical resistance $R_м$ in (5) are expressed by the parameters of the piezoelectric ceramics and the geometric dimensions of the PTC (4) and it is obtained

$$\dot{I}_{SC} = \frac{8W\,Q_M\,d_{31}^2\,Y\;\dot{E}}{\pi\,T} \quad . \qquad (6)$$

From [2], Young's modulus and the velocity of the sound in the piezoelectric ceramics c_1 are equal to

$$Y = \frac{k_{31}^2 \varepsilon_{33}^T}{d_{31}^2} \quad , \qquad c_1 = \sqrt{\frac{Y}{\rho}} \quad . \qquad (7)$$

After substituting by (7) into (6), for the r.m.s. value of the output short-circuit current is finally obtained

$$I_{SC} = \frac{8W\,Q_M\,k_{31}^2\,c_1\,\varepsilon_{33}^2\,E}{\pi\,T} \quad . \qquad (8)$$

The obtained expression (8) shows the dependence of the r.m.s value of the output short-circuit current on the parameters of the piezoelectric ceramics ($Q_м$, k_{31}, ε_{33}, c_1), geometric dimensions (W,T) and the r.m.s. value of the input electromotive force (E). This expression shows in perceivable form which of the parameters of the piezoelectric ceramics exert significant influence and this facilitates the right choice of the needed piezoelectric material; it also illustrates how the output current in short-circuit mode can be increased by changing the geometric dimensions of the PTC.

The coefficient of transformation in idle-run mode k_{U0} gives additional information about the output electric parameters of the PTC. It has to be taken into account since in some of the electronic control circuits the PTC initially works in idle run mode and then it switches into a mode, close to short circuit. The time for charging the super-capacitor t can be calculated in the following way [4]

$$t = \frac{C_S\left(V_{31} - V_{30}\right)}{I} \quad , \qquad (9)$$

$$I = \frac{I_{CS}}{2} \quad , \qquad (10)$$

where:

V_{31} is the voltage of the charged super-capacitor;

V_{30} - the initial voltage value of the super-capacitor before charging;

I_{CS} - the short-circuit current in case of a depleted super-capacitor.

Based on the obtained expression for the short-circuit current, the coefficient of transformation in idle run mode k_{U0} and the charging time of the super-capacitor t, several types of piezoelectric ceramics have been analyzed and their parameters presented in Table 1. The main purpose in this case is to determine the most appropriate among them for producing a PTC. Table 2 illustrates both the calculated by (8) the output short-circuit current and by (9) the charging time of the super-capacitor t and the corresponding measured quantities. The calculations, as well as the measurements, are for a super-capacitor with capacity of 300 F and E =3V, W=25 mm, T=0,5mm.

The coefficient of transformation in idle-run mode k_{U0} is calculated in the following way [3]

$$k_{U0} = \frac{4\,Q_M\,k_{31}^2}{\pi^2\left(1 - k_{31}^2\right)} \quad . \qquad (11)$$

Table 1.

Piezo ceramics	Q_M	k_{31}	ε^T_{33} x10^{-9} F/m	c_1 m/s
PZT-4	500	0,33	11,5	4560
PZT-5A	75	0,34	15	3860
PZT-4H	65	0,38	30	3900
PZT-7A	600	0,3	4	4800
PZT-8	1000	0,3	9	4600

Table 2.

Piezo ceramics	k_{U0}	I_{sc}. mA calc.	I_{sc}. mA meas	*t*, s calc.	*t*,s meas.
PZT-4	25	658	645	2 181	2 245
PZT-5A	4	124	121	1 161	1 231
PZT-4H	4,5	268	257	5 373	5 448
PZT-7A	24	254	241	5 669	5 809
PZT-8	40	918	899	1 760	1 817

The maximum relative error for the output short-circuit currents is δ_{max}=2,1%, while for the charging times of the super-capacitor it is δ_{max}=3,1%.

From the results, given in Table 2 the following conclusions can be drawn:

- The most appropriate piezoelectric ceramic materials for producing PTCs are PZT-4, PZT-8, since the highest short-circuit currents are obtained with them.

- With these two types of material the shortest charging times for the super-capacitors are obtained, which is crucial for their practical application.
- The calculated short-circuit current values are always higher than the measured ones, since the sinusoidal generator is assumed ideal;
- The lower short-circuit currents in comparison to the calculated ones lead to longer charging times of the super-capacitors than the calculated times.

3.Conclusion

A piezoelectric transverse-transverse transformer, working in three-resonance mode with two parallel electrical resonances at its input and a mechanical resonance in series at its output has been considered in this paper.

An expression has been obtained, which takes into account the influence of the parameters of the piezoelectric ceramics, the dimensions of the PTC and the input electromotive force on the magnitude of the output current of the piezoelectric transformer of current in a short-circuit mode.

The main output electrical parameters of practically used piezoelectric ceramic materials have been compared.

The times for charging the super-capacitor, connected at the output of the considered piezoelectric transformers have been calculated.

Experimental studies have been carried out, which confirm the validity of the obtained expression for the output current in short-circuit mode.

References:

[1] Magori, V. (1982). *Piezo-Zndkoppler. Eektronik N6,* 85-90.

[2] Катц, Г.В. (1964). *Магнитые и диэлектрческие приборы.* , Energia, Moscow.

[3] Lavrinenko, V. (1975). *Piezoelektricheskie transformatori.* Energia, Moscow.

[4] http://www.illinoiscapacitor.com/

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LOAD AND CONTROL CHARACTERISTICS OF A SERIES RESONANT DC-DC CONVERTER WITH A SYMMETRICAL CONTROLLED RECTIFIER

ANGEL LICHEV, ALEKSANDAR VUCHEV, NIKOLAY BANKOV, YASEN MADANKOV

Abstract: *A series resonant DC-DC converter operating at frequency higher than the resonant one is examined. A symmetrical controlled rectifier is used, which allows a phase shift control. On the base of a first harmonic analysis, the processes in the converter are studied. As a result, expressions for basic parameters are obtained and the load characteristics are built.*

Key words: *series resonant dc-dc converter, controlled rectifier, ZVS, phase-shift control*

1. Introduction

The well-known series resonant DC-DC converter operating at frequency higher than the resonant one has a number of advantages: zero voltage switching (ZVS), small size and low weight, natural short circuit protection and so on [1, 2, 3]. However, it does not allow a bidirectional power transfer between the power supply source and the load to be achieved. This disadvantage can be avoided by using a symmetrical controlled rectifier [1, 4, 5] combined with a phase shift control method [2, 3, 6]. Thereby, the output power varies from zero to the maximum value.

Even though, resonant DC-DC converters with unidirectional power flow are thoroughly described in literature, only very few is found on bidirectional resonant converters. The reasons might be the higher converter complexity and the additional components needed [7].

In [8], a first harmonic analysis of a bidirectional series resonant DC-DC converter operating above resonant frequency is presented and controlled by the conduction time of the output stage transistors. As a result, expressions for basic parameters of the converter are obtained.

The current paper presents sequel of the theoretical examinations achieved in [8]. Its purpose is both the load and control characteristics of the bidirectional series resonant DC-DC converter to be obtained with phase-shift control and operation at constant frequency above the resonant one.

2. Principle of the Converter Operation

The circuit of the examined bidirectional converter is presented in Fig. 1. It consists of two identical bridge inverter stages, resonant tank circuit (L, C), matching transformer Tr, capacitive input and output filters (C_d and C_0), snubber capacitors $C_1 \div C_8$ by which a ZVS is obtained.

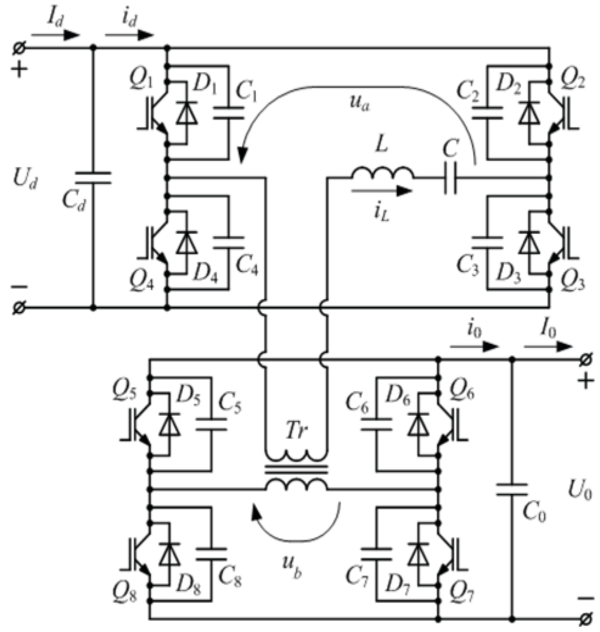

Fig. 1. *Circuit of the Examined Resonant DC/DC Converter*

The „input" stage (transistors Q1÷Q4 with freewheeling diodes D1÷D4) operate as an inverter and the „output" stage (transistors Q5÷Q8 with freewheeling diodes D5÷D8) – as a rectifier. Voltages U_d and U_0 are applied to the input and the output terminals, respectively.

The operation of the converter is illustrated by the waveforms, presented in Fig. 2. Two operating modes are known – DIRECT MODE and

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REVERCE MODE. In the first mode, it is assumed that energy flows from the "inverter" to the "rectifier" (from the source of voltage U_d to the one of voltage U_0). In the second mode (which is possible because of the converter is reversible) – the energy flows from the "rectifier" to the "inverter" (from U_0 to U_d).

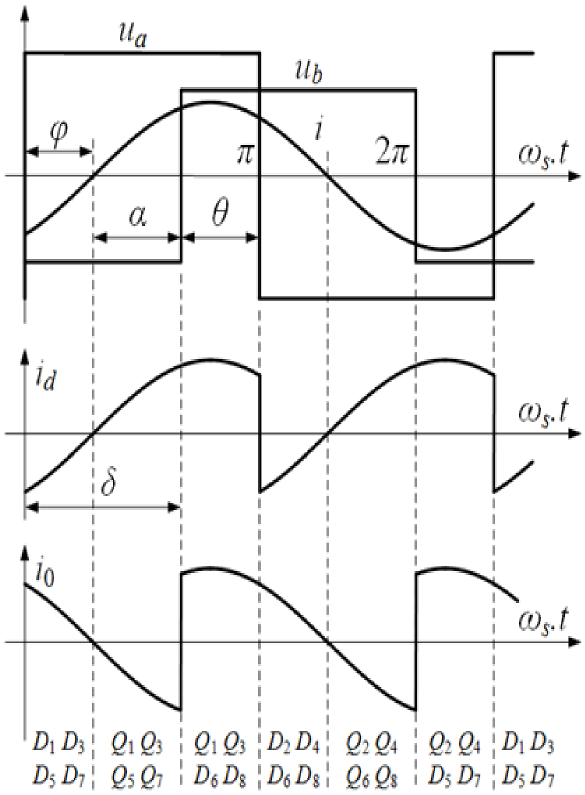

Fig. 2. *Waveforms of the Basic Voltages and Currents*

The converter operates at constant frequency ω_s which is higher than the resonant ω_0. Therefore, the transistors pairs of the "inverter" Q_1, Q_3 and Q_2, Q_4 operate at ZVS. The transistors of the "rectifier" also operate at ZVS. When the current i_L passes through zero, Q_5 and Q_7 or Q_6 and Q_8 begin to conduct. This pair switches off after time, corresponding to an angle α (as described in [8]). As a result, the voltage u_b is shifted in time from u_a.

In this way, the control of the output power is obtained by the variation of angle α

When $\varphi > \pi/2$, than the conduction time of the inverter reverse diodes D_1, D_3 (D_2, D_4) is more than that of the transistors Q_1, Q_3 (Q_2, Q_4). In this case, the energy transferred back to the power supply is more than the consumed one and the average value of the current I_d is negative.

The output voltage U_0 cannot change its sign. This is due to the rectifier diodes operation. As a result, when $\alpha > \pi/2$, the energy transferred back from the load is more than the consumed for the rectifier and the average value of the current I_0 is negative. This means that the rectifier transistors Q_5, Q_7 (Q_6, Q_8) conduct longer than its diodes D_5, D_7 (D_6, D_8).

3. Results of the Converter Operation Analysis

The examination of the converter is carried out with harmonic analysis. The impact of an only the first harmonic is taken into account.

For the purposes of the analysis, the following assumptions are made: the matching transformer is ideal with a transformation ratio k, all the circuit elements are ideal, the influence of the snubber capacitors and the pulsation of the supply voltage U_d and the output voltage U_0 are neglected, i.e. the voltages u_a and u_b have rectangular shape.

On the basis of the assumptions made, the resonant frequency, the characteristic impedance and frequency detuning of the resonant circuit are:

$$\omega_0 = 1/\sqrt{LC}\,;\ \rho_0 = \sqrt{L/C};\ \ \nu = \omega_S/\omega_0$$

In accordance with the chosen method of analysis, it is assumed that only the first harmonics of the current i_L and the voltages u_a and u_b have impact in the examined circuit. This gives the opportunity the processes in the converter to be illustrated by means of vector charts. (Fig. 3). The aforementioned operating modes are realized by the variation of the angle α. In DIRECT MODE, it is assumed that α varies in the range $0 \le \alpha \le \pi/2$, (Fig.3a). In REVERCE MODE, the control parameters vary in the range $\pi/2 \le \alpha \le \pi$ (Fig.3b).

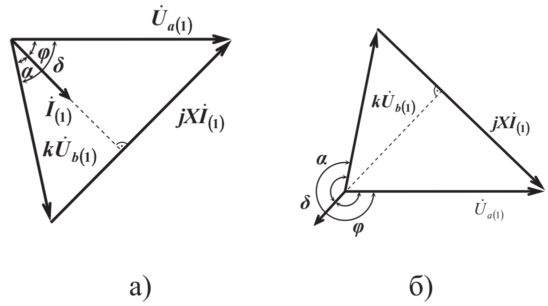

Fig. 3. *Vector Diagrams of the Basic Voltages and Currents*

The normalized values of the output voltage U_0' and the output current I_0' are determined as follows:

$$U_0' = kU_0/U_d \ \text{ и } \ I_0' = \frac{I_0/k}{U_d/\rho_0} \tag{1}$$

The output characteristic $U_0' = f(I_0';\alpha)$ of the converter is:

$$U_0' = cI_0' tg\alpha \pm \sqrt{1 - c^2 I_0'^2} \qquad (2)$$

When $I_0' > 0$, the sign is positive and the energy is transferred to the load. When $I_0' < 0$, the sign is negative and the energy is transferred back to the power supply source.

According to (2), the output current can vary in range, defined by a minimum and a maximum value:

$$-1/c \le I_0' \le +1/c \qquad (3)$$

From the expression it is observed that, the possible extreme values of the output current dependent only on the frequency detuning of the resonant circuit.

On the basis of (2) the control characteristics of the converter are obtained. It is derived that:

$$U_0' = \frac{R_0'}{\sqrt{c^2 + \left(c \cdot tg\alpha - R_0'\right)^2}}, \qquad (4)$$

where $R_0' = U_0' / I_0'$ is the normalized value of the load resistor.

The direction of the output voltage U_0 is uniquely determined. Therefore the above equation does not give enough information about the possible operation modes of the converter. So, it is more convenient the following expression to be used:

$$I_0' = \pm \frac{1}{\sqrt{c^2 + \left(c \cdot tg\alpha - R_0'\right)^2}} \qquad (5)$$

On the basis of the first harmonic analysis presented above the following expression for the normalized current through the "inverter" transistors is obtained:

$$I_{QI}' = \frac{\left(\dfrac{\pi I_0'}{2\cos\alpha}\right)}{2\pi\left(1 + \cos(\varphi)\right)} \qquad (6)$$

For the normalized average values of the currents through the "inverter" diodes is derived that:

$$I_{DI}' = \frac{\left(\dfrac{\pi I_0'}{2\cos\alpha}\right)}{2\pi\left(1 - \cos(\varphi)\right)} \qquad (7)$$

Expression for the normalized average current through the "rectifier" transistors is obtained as follows:

$$I_{QR}' = \frac{\left(\dfrac{\pi I_0'}{2\cos\alpha}\right)}{2\pi\left(1 - \cos(\alpha)\right)} \qquad (8)$$

The normalized current through the "rectifiers" diodes is:

$$I_{DR}' = \frac{\left(\dfrac{\pi I_0'}{2\cos\alpha}\right)}{2\pi\left(1 + \cos(\alpha)\right)} \qquad (9)$$

The expression for the normalized capacitor peak voltage is:

$$U'_{CM} = \pm \frac{\pi I_0'}{2\nu\cos\alpha} \qquad (10)$$

The normalized RMS value of the current through the inductor is:

$$I'_{EFF} = \frac{\pi I_0'}{2\sqrt{2}\cos\alpha} \qquad (11)$$

4. Load and Control Characteristics

For the purposes of the design of the converter, its load and control characteristics have to be known.

Fig. 4 presents the output characteristic of the converter. They are obtained (on the basis of equation (2)) at frequency detuning ν = 1,15 and transformation ratio k = 1.

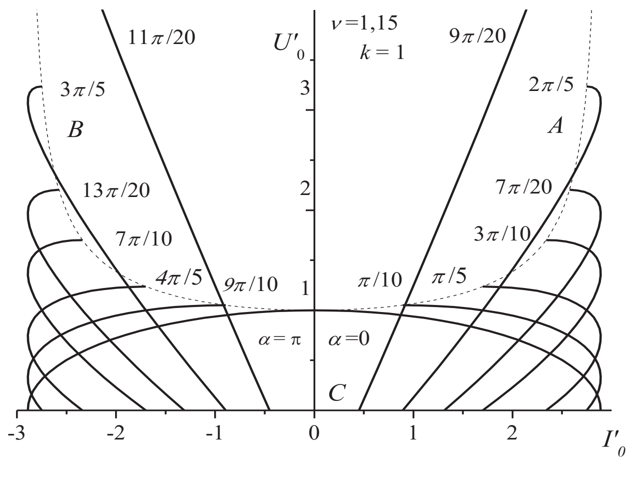

Fig. 4. *Normalized output characteristics at 0≤α≤π*

The output characteristics present the normalized dependencies of the output voltage U_0 from the output current I_0. They are obtained when the converter operates at a constant frequency with different values of the control angle α.

The output characteristics situated in the first quadrant correspond to the DIRECT MODE ($0 \le \alpha \le \pi/2$), and the others in the second quadrant – to the REVERCE MODE ($\pi/2 \le \alpha \le \pi$). The ordinate is the boundary between the two modes. The characteristics are arranged symmetrically with respect to it.

From Fig. 4 it is observed that the output voltage does not change its polarity and, independently from the energy transfer direction, can significantly exceed the input one. Moreover, the output current I_0 cannot exceed the value at the output short circuit for $\alpha = 0$ or $\alpha = \pi$ respectively.

The ZVS operating range boundaries are pointed out in dotted lines. These are the curves A (for $\varphi = 0$), B (for $\varphi = \pi$) and C (for $\varphi = \pi/2$). The values of the control angle are chosen in a way to be couples symmetrical to $\pi/2$.

The dependencies of the average value of the current I'_{QI} through the „inverter" stage transistors from the output current I'_0 (based on (6)) are shown in Fig. 5.

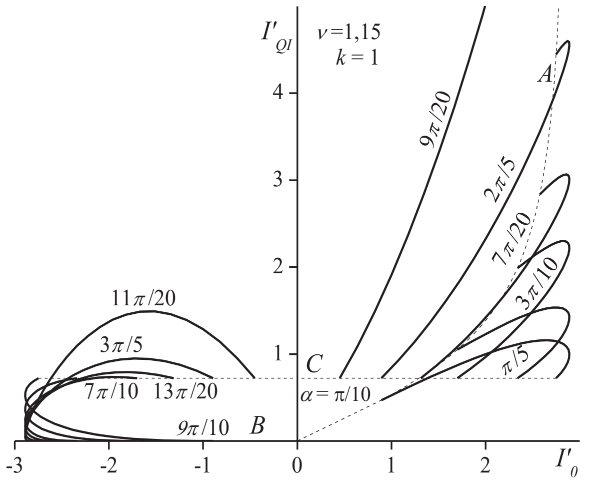

Fig. 5. *Normalized average current through the "inverter" transistors - I_{QI}*

On this figure the boundary *B* falls with the abscise axis and other boundary *C* is parallel to that. The conducted analyses show that the characteristics of the average value of the "inverter" reverse diodes current I'_{DI} (built on the basis of (7)) have the same form as those from Fig. 5, but they are mirrored with respect to the ordinate. This results in the conclusion that at DIRECT MODE the stress is mainly on the "inverter" transistors, and at REVERCE MODE – on its reverse diodes.

Fig.6 presents the normalized dependencies (drawn on the basis of (8)) of the average value of the current I'_{QR} through the „rectifier" stage transistors from the output current I'_0. This is another case when the characteristics for the average value of the "rectifier" reverse diodes current I'_{DR} (based on (9)) have the same form as those from Fig. 6 but are mirrored with respect to the ordinate. This results in the conclusion that obtaining higher output voltage leads to an increase in all the "rectifier" devices stress.

The calculations show that, I'_0 and I'_{QR} increase to a certain value, then decrease to the limit. However, it is not noticeable on the characteristics.

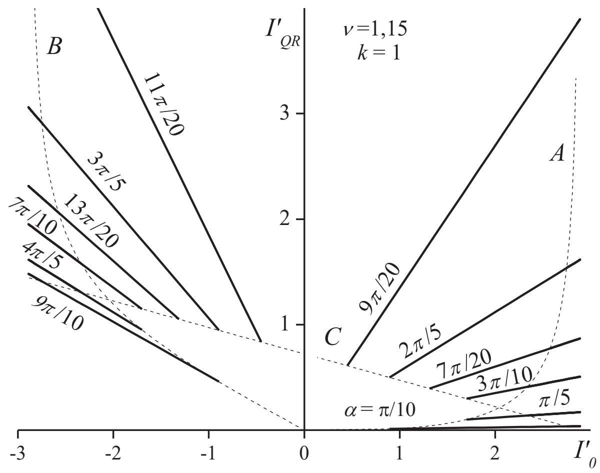

Fig. 6. *Normalized average current through the "rectifier" transistors - I_{QR}*

Fig. 7 presents the normalized dependencies of the peak value of the capacitor voltage U'_{CM} (based on (10)) from the output current I'_0. Like the output characteristics, these are also symmetrical with respect to the ordinate. Therefore, independently from the energy flow direction, the resonant tank elements are similarly loaded for the same energy quantity. Moreover, it can be observed that for a random characteristic the capacitor voltage is always greater than the output one.

Here, like in Fig. 5, the variations of I'_0 and U'_{CM} about the limit values are not noticeable on the characteristics.

The dependencies of the effective value of the current through the inductor I'_{EFF} (drawn on the basis of (11)) from the output current are shown in

Fig. 8. It is easy to be seen that the characteristics are symmetrical with respect to the ordinate and again, independently from the energy flow direction, the resonant tank elements are similarly loaded for the same energy quantity. When the output current $I'_0 = 0$ (for $\alpha=\pi/2$) the RMS current can reach very high values. Here, again, the variations of I'_0 and U'_{CM} about the limit values are not noticeable on the characteristics.

It could be seen, that the characteristic in Fig. 7 are similar to these in Fig. 8.

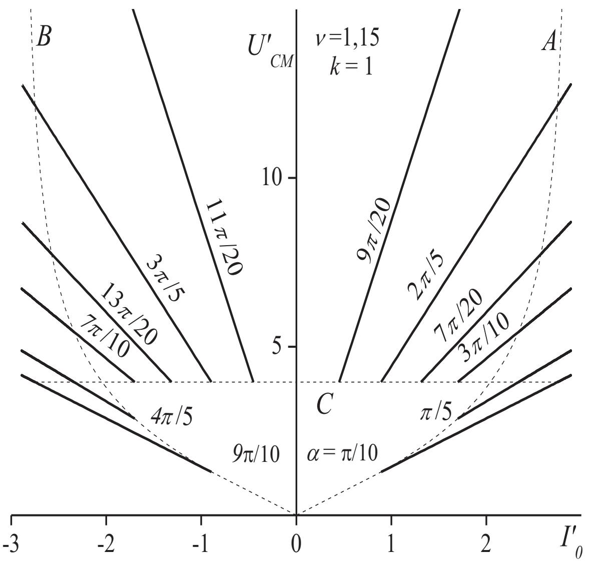

***Fig.** 7. Normalized resonant capacitor peak voltage - U_{CM}*

Normalized control characteristics for the output current I'_0 as a function of the control angle α.are presented in Fig. 9. They are built on the basis of equation (5), at frequency detuning ν = 1,15 when the converter operates at several different values of the load resistor R'_0 = 0,1; 0,3; 0,5; 1,0; 2,0.

In this case, the abscissa appears to be the boundary between the two modes of energy transfer. From the figure, it is observed that independently from the value of the load resistor these characteristics have two extreme values. The output current gains same values for these points, which can be determined by expression (3).

Fig. 9 shows that from the point of view of the converter output power control, the most appropriate interval of variation of the angle α is the one limited by the two extreme values. Moreover, the control characteristics can be assumed as linear for a comparatively wide range.

With increase of the value of the load resistor the range of change of the control parameter decreases. As a result the characteristics become largely nonlinear.

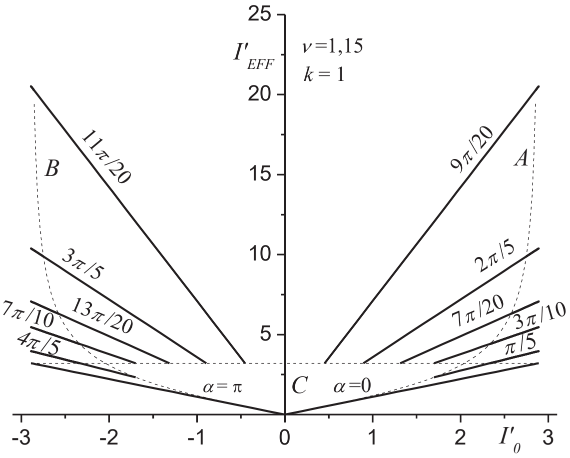

***Fig. 8**. Normalized RMS current - I_{EFF}*

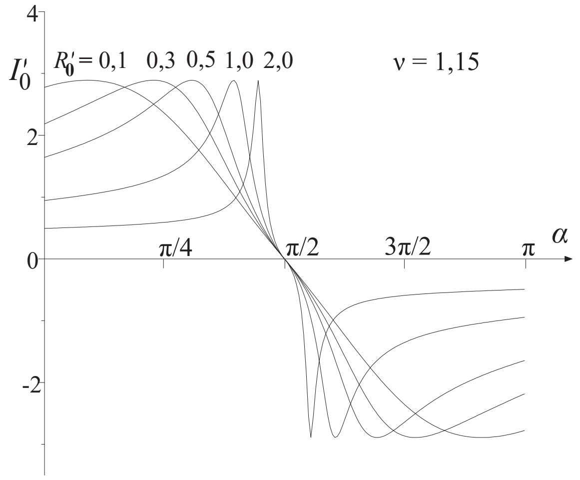

***Fig. 9**. Control Characteristics of the Converter*

5. Conclusion

A series resonant DC-DC converter, operating above the resonant frequency, is examined. A symmetrical controlled rectifier is used. As a result of the first harmonic analysis, normalized load and control characteristics of the converter are built. Based on the research, it can be concluded that the considered converter is bidirectional and it can operate without violation of the ZVS conditions in wide range of variation of the control parameter. It is proven that the converter output voltage can exceed the input one independently from the energy transfer direction. It is found that the converter power devices stress grows up with the output power increase.

The obtained results can be used for further examination and design of such converters.

REFERENCES

1. Cheron, Y., Foch, H. and Roux, J. (1986) Power Transfer Control Methods in High Frequency Resonant Converters. In: *PCI Proceedings, June 1986, Munich*, pp. 92-103.
2. Liu, Y. and Sen, P. C. (1996) Source Reactance Lossless Switch (SRLS) for Soft-Switching Converters with Constant Switching Frequency. In: *IEEE Transaction on Circuits and Systems, 1. Fundamental Theory and Applications, 1996*, Vol. 43, pp. 301-312.
3. Rossetto, L. and G. Sipazzi, G. (1988) Series Resonant Converter with Wide Load Range. In: *Industry Applications Conference, Thirty-Third IAS Annual Meeting*, *1998*. IEEE. Vol. 2, pp. 1326-1331.
4. Dixneuf, D. (1988) *Etud d'un variateur de vitesse à résonance pour machine asynchrone triphasée*. Thèse.
5. Patent № 4717990, U.S. H04M 7/00; H02J 3/38: Cheron Y., P. Jacob, J. Salesse; *Static Device for Control of Energy-Exchange between Electrical Generating and/or Receiving Systems*
6. Grigorova, Tsv. and Bankov, N. (2008) Investigation of the Series Resonant Converter with Secondary-Side Transistor Bridge Rectifier, *Elektrotechnika & Elektronica*, №3-4, pp. 9-14
7. Krismer, F. (2010) Modeling and optimization of bidirectional dual active bridge DC-DC converter topologies. PhD thesis, ETH Zurich
8. Bankov, N., Vuchev, A. (2015) An Analysis of a bidirectional resonant DC/DC Converter. *: National Forum "ELECTRONICS 2015", 14-15 May 2015, Sofia*, pp. 110 – 115

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LOAD AND CONTROL CHARACTERISTICS OF A PHASE-SHIFT CONTROLED BIDIRECTIONAL SERIES RESONANT DC/DC CONVERTER

ANGEL LICHEV, ALEKSANDAR VUCHEV, NIKOLAY BANKOV, YASEN MADANKOV

Abstract: *A phase-shift-controlled bidirectional series resonant DC-DC converter operating at frequency higher than the resonant one is examined. On the base of a first harmonic analysis, the processes in the converter are studied. As a result, expressions for basic parameters are obtained and both load and control characteristics are drawn.*

Key words: *series resonant dc-dc converter, controlled rectifier, operation above resonant frequency*

1. Introduction

The trend of increasing the share of green energy is remains stable [1]. Therefore, the issues related to the conversion and accumulation of this energy gain popularity.

For this purpose, bidirectional resonant DC-DC converters are used, which can operate at zero voltage switching (ZVS) [2, 3, 4].

In [5], a bidirectional series resonant DC-DC converter operating above the resonant frequency is presented with a phase-shift control. An examination is carried out with harmonic analysis. Expressions for the basic parameters of the converter are obtained.

This paper presents sequel of the theoretical examinations achieved in [5]. Its purpose is load and control characteristics of the bidirectional series resonant DC-DC converter to be obtained with phase-shift control and operation at constant frequency above the resonant one.

2. Principle of the Converter Operation

The circuit of the examined converter is presented in Fig. 1. It consists of two identical bridge inverter stages, resonant tank circuit (L, C), matching transformer Tr, capacitive input and output filters (C_d и C_0). Fig. 1 also presents the snubber capacitors $C_1 \div C_8$ by which a zero voltage switching is obtained.

A voltage U_d is applied to the DC terminals of the „input” inverter stage (transistors $Q_1 \div Q_4$ with freewheeling diodes $D_1 \div D_4$), and a voltage U_0 – to those of the „output” stage (transistors $Q_5 \div Q_8$ with freewheeling diodes $D_5 \div D_8$).

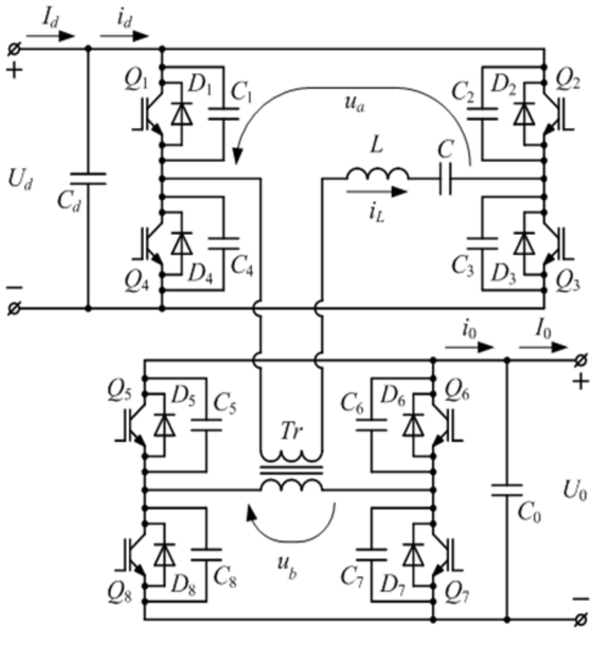

Fig. 1. *Circuit of the Bidirectional Resonant DC/DC Converter*

The operation of the converter is illustrated by the waveforms, presented in Fig. 2. Two operating modes are possible. The first of them is DIRECT MODE. In this mode, it is assumed that energy is transferred from the source of voltage U_d to the one of voltage U_0 (from the “inverter” to the “rectifier”). In the second mode – REVERCE MODE, (which is possible because of the converter is reversible), the energy flows in reverse direction – from U_0 to U_d.

The “input” stage generates a voltage u_a. The converter operates at constant frequency ω_S, which is higher than the resonant one ω_0. For that reason, the current i_L falls behind the voltage u_a at an angle φ.

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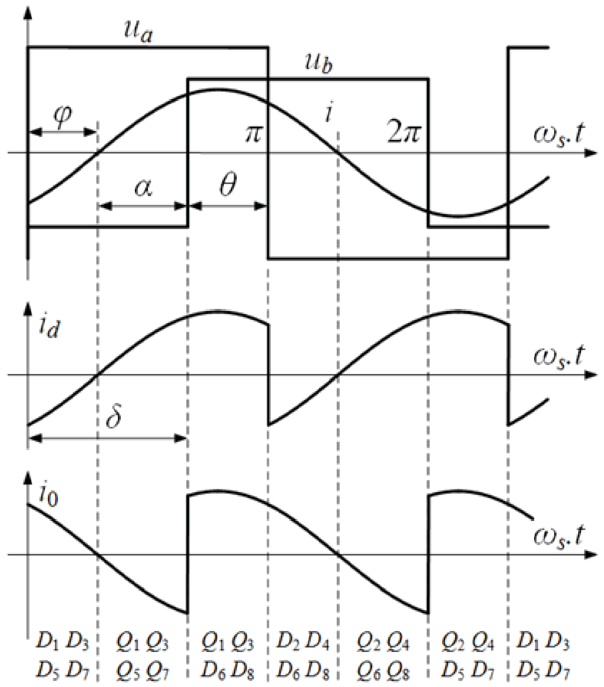

Fig. 2. *Waveforms of the Basic Voltages and Currents*

The "output" stage generates a voltage u_b. This voltage is shifted from u_a at an angle δ (δ= α+φ).

Angle φ corresponds to the conduction time of the „input" stage freewheeling diodes, and angle α – to the conduction time of the „output" stage transistors.

When $\varphi > \pi/2$, the energy transferred back to the power supply source is more than the consumed one and the average value of the current I_d is negative. In this case the conduction time of the inverter reverse diodes D_1, D_3 (D_2, D_4) is more than that of the transistors Q_1, Q_3 (Q_2, Q_4).

Because of the rectifier diodes operation, the output voltage U_0 cannot change its sign. Therefore when $\alpha > \pi/2$, the energy transferred back to the load is more than the consumed for the rectifier and the average value of the current I_0 becomes negative. That means that the rectifier transistors Q_5, Q_7 (Q_6, Q_8) conduct longer than its diodes D_5, D_7 (D_6, D_8).

3. Results of the Converter Operation Analysis

The examination of the converter is carried out with harmonic analysis. The impact of only the first harmonic is taken into account. The results of the analysis can be used for engineering calculations because they are accurate enough.

For the purposes of the analysis, the following assumptions are made: the matching transformer is ideal with a transformation ratio k, all the circuit elements are ideal, the influence of the snubber capacitors and the pulsation of the supply voltage U_d and the output voltage U_0 are neglected, i.e. the voltages u_a and u_b have rectangular shape.

On the basis of the assumptions made, the resonant frequency, the characteristic impedance and frequency detuning of the resonant circuit are:

$$\omega_0 = 1/\sqrt{LC}\,;\ \rho_0 = \sqrt{L/C};\ \ \nu = \omega_S/\omega_0$$

In accordance with the chosen method of analysis, it is assumed that only the first harmonics of the current i_L and the voltages u_a and u_b have impact in the examined circuit. This gives the opportunity the processes in the converter to be illustrated with vector charts (Fig. 3). The aforementioned operating modes are realized by the variation of the angle δ. In DIRECT MODE, it is assumed that δ varies in the range $0 \le \delta \le \pi$, (Fig.3a), and in REVERCE MODE - $\pi \le \delta \le 2\pi$ (Fig.3b).

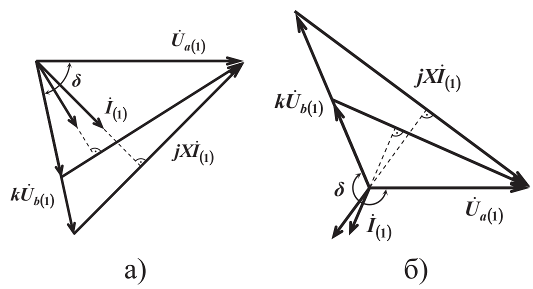

Fig. 3. *Vector Diagrams of the Basic Voltages and Currents*

The normalized values of the output voltage U_0' and the output current I_0' are determined as follows:

$$U_0' = kU_0/U_d \ \text{ и } \ I_0' = \frac{I_0/k}{U_d/\rho_0} \tag{1}$$

After relevant calculations it is obtained that:

$$I_0' = \frac{\sin\delta}{c}, \tag{2}$$

where: $c = \dfrac{\pi^2}{8}\left(\nu - 1/\nu\right)$.

The normalized output voltage is:

$$U_0' = \frac{\cos\varphi}{\cos\alpha} \tag{3}$$

According to the expression the boundaries of the ZVS operating mode are obtained for the "inverter" transistors (at φ = 0 and φ = π) and for the "rectifier" transistors (at α = 0 and α = π).

For ($\pi/2 \le \delta \le 3\pi/2$), the transistors in both stages operate at ZVS.

On the basis of the first harmonic analysis presented above the following expression for the normalized current through the "inverter" transistors is obtained - (4):

$$I'_{QI} = \frac{\left(\dfrac{\pi I'_0}{2\cos\alpha}\right)}{2\pi(1+\cos(\varphi))} \qquad (4)$$

For the normalized average values of the currents through the "inverter" diodes is derived that:

$$I'_{DI} = \frac{\left(\dfrac{\pi I'_0}{2\cos\alpha}\right)}{2\pi(1-\cos(\varphi))} \qquad (5)$$

The expression for the normalized average current through the "rectifier" transistors is:

$$I'_{QR} = \frac{\left(\dfrac{\pi I'_0}{2\cos\alpha}\right)}{2\pi(1-\cos(\alpha))} \qquad (6)$$

The normalized current through the "rectifier" diodes is:

$$I'_{DR} = \frac{\left(\dfrac{\pi I'_0}{2\cos\alpha}\right)}{2\pi(1+\cos(\alpha))} \qquad (7)$$

The expression for the normalized capacitor peak voltage is:

$$U'_{CM} = \pm \frac{\pi I'_0}{2\nu\cos\alpha} \qquad (8)$$

The normalized values of the RMS current through the inductor are:

$$I'_{EFF} = \frac{\pi I'_0}{2\sqrt{2}\cos\alpha} \qquad (9)$$

4. Load and Control Characteristics

Detailed information of the examined series resonant DC-DC converter design can be obtained from its load characteristics.

On the basis of (2), the normalized dependencies of the output voltage U'_0 from the output current I'_0 are obtained (Fig. 4) when the converter operates at a constant frequency (ν = 1,15). The output characteristics situated in the first quadrant for $0 \le \delta \le \pi/2$ correspond to DIRECT MODE, and the others in the second quadrant when $-\pi/2 \le \delta \le 0$ – to REVERSE MODE. In the area of the output characteristics, the boundaries of ZVS mode are shown with dotted line. The analysis of the dependencies shows that in this case the converter operation is very limited and practically no-load mode is not possible. Apparently, this range of variation of the control parameter δ is not recommended for operation of the converter.

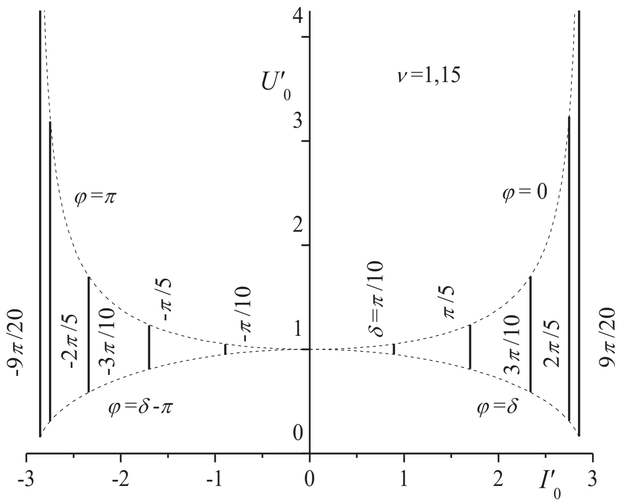

Fig. 4. *Normalized output characteristics at $-\pi/2 \le \delta \le +\pi/2$*

Fig. 5 presents the normalized output characteristics of the converter for value of the control parameter in the range $\pi/2 \le \delta \le 3\pi/2$. The ones situated in the first quadrant for $\pi/2 \le \delta \le \pi$ correspond to the energy transfer to the load, and the others in the second quadrant for $\pi \le \delta \le 3\pi/2$ – to the mode of energy return back to the power source respectively. The ordinate appears to be the boundary between the two modes. Referring to it, the characteristics for the equally distanced from π control angles are situated symmetrically. Obviously, limitations for the converter operation at ZVS are not observed.

The output characteristics (Fig. 4 and Fig 5) show that, independently from the range of variation of the control parameter, the output voltage does not depend on the output current, i. e. the examined converter behaves as an ideal current source. Moreover, the output voltage does not change its polarity and, independently from the energy transfer direction, can significantly exceed the input one.

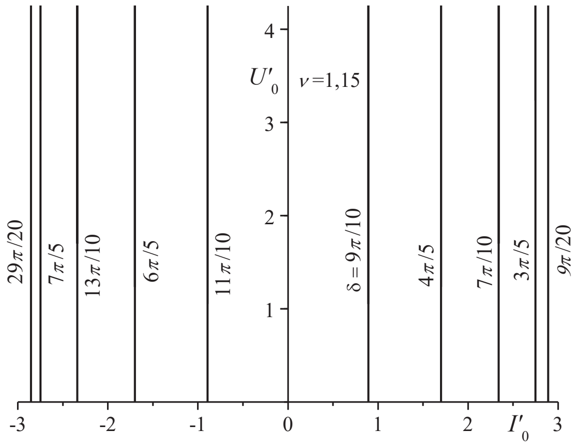

Fig. 5. *Normalized output characteristics at* $\pi/2 \leq \delta \leq 3\pi/2$

In Fig. 6 the normalized dependencies of the average value of the current I'_{QI} (drawn on the basis of (3) and (4)) through the "input" stage transistors from the output voltage U'_0 are presented. They are obtained for variation of the control parameter in the range $\pi/2 \leq \delta \leq 3\pi/2$.

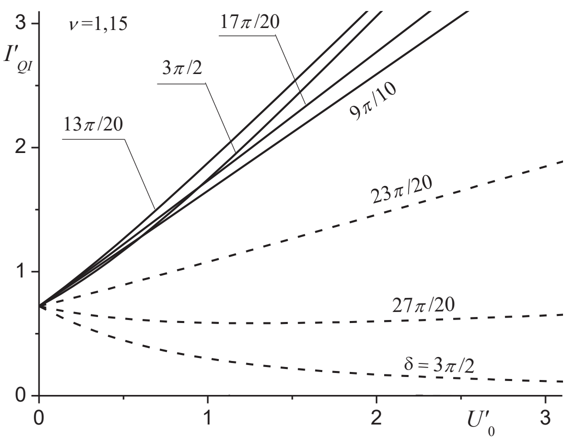

Fig. 6. *Normalized average current through the "input" stage tranzistors -* I'_{QI}

The characteristics corresponding to the DIRECT MODE are presented with thick lines, and those to the REVERCE MODE – with dotted lines. For a wide range of variation of angle δ, monotonous rise of the current is observed with the increase of the voltage. In this range, the converter power devices stress is bigger for greater values of the output voltage. However in REVERCE MODE, this is not valid for all values of the control parameter.

The normalized dependencies of the average value of the current I'_{DI} (drawn on the basis of (3) and (5)) through the "input" stage freewheeling diodes from the output voltage U_0 are shown in Fig. 7.

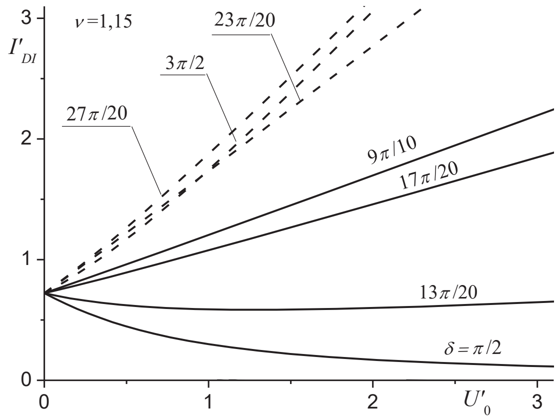

Fig. 7. *„input" stage freewheeling diodes –* I'_{DI} *Normalized average current through the*

The variation of angle δ is in the range $\pi/2 \leq \delta \leq 3\pi/2$. The characteristics corresponding to the DIRECT MODE are presented with thick lines, and those to the REVERCE MODE – with dotted lines. Here like in Fig. 6, for a wide range of variation of angle δ, both the current and the voltage increases. In this range, the converter power devices stress is bigger for greater values of the output voltage. In DIRECT MODE, this is not valid for all values of the control parameter.

The analysis of the characteristics in Fig 6 and Fig. 7 shows that the current through the devices has significant value in no-load mode, fact that is not of minor importance.

Fig. 8 presents the normalized dependencies of the average value of the current I'_{QR} (based on (3) and (6)) through the „output" inverter stage transistors from the output voltage U'_0. Similar dependencies of the average value of the current I'_{DR} (built on the base of (3) and (7)) through the „output" inverter stage freewheeling diodes are shown in Fig. 9.

The characteristics corresponding to the DIRECT MODE are presented with thick lines, and those to the REVERCE MODE – with dotted lines. They are obtained for variation of the control parameter in the range $\pi/2 \leq \delta \leq 3\pi/2$. For both modes, monotonous rise of the currents I'_{QR} and I'_{DR} is observed with the increase of U'_0. This shows that, independently from the energy transfer direction, the converter power devices stress is bigger for greater values of the output voltage.

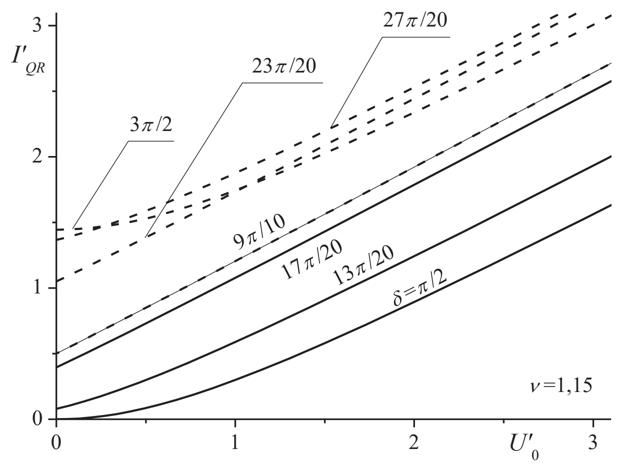

Fig. 8. *Normalized average current through the „output" stage transistors – I'_{QR}*

The normalized dependencies (based on (3) and (8)) of the peak value of the capacitor voltage U'_{CM} from the output voltage U'_0 are presented in Fig. 10. It could be seen that obtaining higher output voltage leads to an increase of the capacitor peak voltage. Moreover, for a random characteristic U'_{CM} is always greater than the output one.

Fig. 10 shows that in no-load mode the capacitor peak voltage has maximal value which is significant.

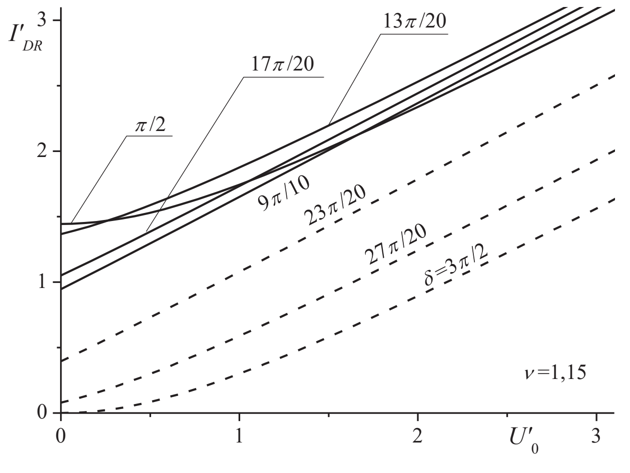

Fig. 9. *Normalized average current through the „output" stage freewheeling diodes – I'_{DR}*

Fig. 11 presents the dependencies of the normalized RMS value of the current through the inductor I'_{EFF} (built on the basis of (3) and (9)) from the output voltage U'_0. It is possible to see that the RMS current value increases at the output voltage increasing.

Likewise as the capacitor peak voltage in no-load mode the inductor current has maximal value which is significant. Moreover, the characteristic in Fig. 11 are similar to these in Fig. 10.

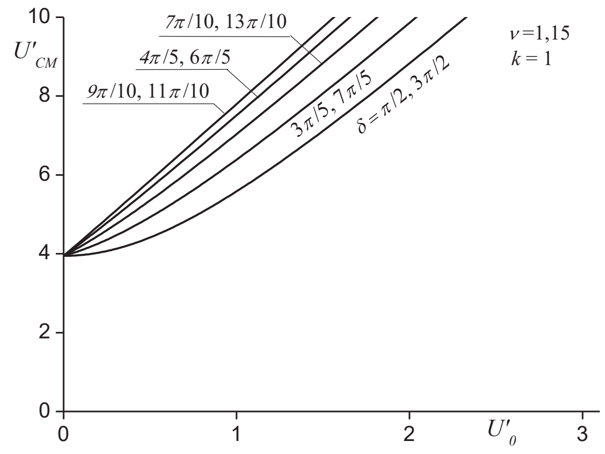

Fig. 10. *Normalized resonant capacitor peak voltage – U'_{CM}*

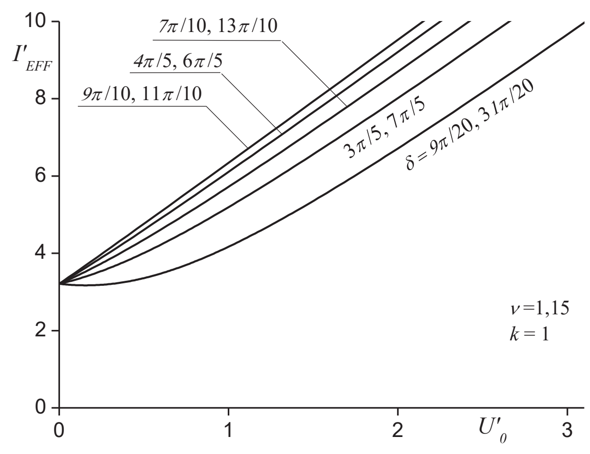

Fig. 11. *Normalized RMS current – I'_{EF}*

Fig. 12 presents normalized control characteristics of the examined converter for several values of the frequency detuning (ν = 1,08; 1,10; 1,15; 1,20; 1,30). According to the fact that the output voltage does not depend on the output current, they are easily obtained with the substitution $\varphi = \delta/2$ ($U'_0 = 0$). In the range $\pi/2 \leq \delta \leq 3\pi/2$, the dependencies variate monotonously, and a significant linear section can be observed. This is the recommended control interval. There are not limitations for ZVS in this case.

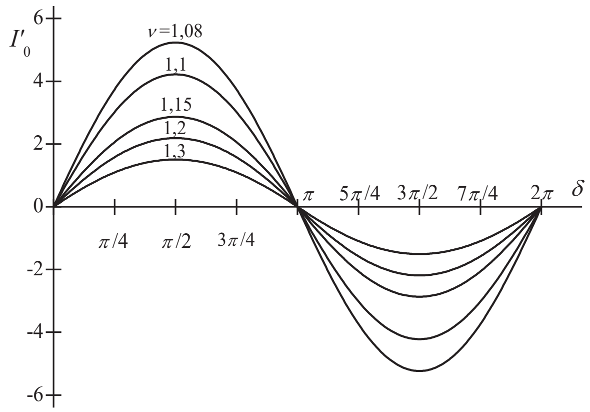

Fig. 12. *Normalized control characteristics*

5. Conclusion

The presented output and control characteristics show that the bidirectional series resonant DC-DC converter can operate without violation of the ZVS conditions in wide range of variation of the control parameter. It is proven that the converter behaves such as an ideal current source. The converter output voltage can exceed the input one independently from the energy transfer direction. It is found that the converter power devices stress grows up with the output power increase.

With regard to the “inverter”, this is not valid. For some values of the control parameter – with the increase of the output voltage, the converter power devices stress decreases.

The obtained results can be used for design of resonant DC-DC converters.

REFERENCES

1. Kramer, W. et al. (2008) *Advanced Power Electronic Interfaces for Distributed Energy Systems*. Colorado: National Renewable Energy Laboratory
2. Alhaddad, K., Cheron, Y., Foch, H. and Rajagopalan, V. (1986) Static and Dynamic Analysis of a Series-Resonant Converter Operating above its Resonant Frequency, *PCI Proceedings*, Boston, October 1986, pp. 55-68
3. Cheron, Y., Foch, H. and Roux, J. (1986) Power Transfer Control Methods in High Frequency Resonant Converters. In: *PCI Proceedings,* June 1986, Munich, pp. 92-103.
4. Sivachandran, P., Gomathy, D. and Priyadarshini, G. (2016) A Reviw of Bidirectional Resonant Converter, *Middle-East Journal of Scientific Research*, 24 (3), pp. 877-886
5. Bankov, N., Vuchev, A. and Vuchev, S. (2015) An Analysis of a Bidirectional Series Resonant DC/DC Converter, *Annual journal of electronics,* Sofia, pp. 228-231

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EXPERIMENTAL ANALYSIS OF THE SUPPLY VOLTAGE QUALITY OF INDUCTION MOTORS WITH PWM CONVERTERS

IVAN KOSTOV, BOJIL MIHAYLOV, VASIL SPASOV

Abstract: *This paper presents an experimental analysis of the harmonic content of the supply voltage in induction motor electric drives. The drives are fed by voltage and frequency converters with autonomous voltage inverters with sinusoidal Pulse Width Modulation. For the purpose of analysis a laboratory stand is developed for measuring non-sinusoidal periodic signals. The stand consists of an induction motor, frequency converter, digital storage osciloscope and harmonics analyzer. The quantitative integral evaluations of non-sinusoidal periodic voltages are obtained based on the V/f=const and V=var; f=const control law. The analysis is carried out in Simulink environment by the fast Fourier transform Analysis Tool in SimPowerSystems Toolbox for Matlab. Conclusions are drawn about the supply voltage quality and the possible application of converters for the supply of induction motors in operation modes.*

Key words: *electromagnetic compatibility, induction motor electric drives, harmonic spectrum, fast Fourier transform*

1. Introduction

Presently induction motor electric drives based on non-linear semiconductor converters are widely used in various industrial areas. While offering enhanced opportunities for the control of technological processes, these drives also create problems. They generate current and voltage harmonics that can reduce the rated torque and efficiency, increase heating and magnetic noise of motors [1, 2]. For this reason, it is necessary to determine the supply voltage quality.

The induction motor drives use variable voltage converters (VVC) and variable frequency converters (VFC) with a DC link. Such converters have numerous capabilities regarding the forming of the output voltage and its harmonics toward high carrier frequencies due to the implementation of fast switching elements. One of the most commonly used methods for modulating the VFC output voltage is through Pulse Width Modulation (PWM).

The aim of this paper is to determine the supply voltage quality of induction motors fed by static frequency and voltage converters using PWM. For that purpose a laboratory stand of induction motor electric drive is developed and the voltage harmonic spectrum indicators of the PWM equipment are determined. The experimental analysis is carried out by the fast Fourier transform Analysis Tool in SimPowerSystems Toolbox for Matlab. On obtaining the quantitative indicators of the supply voltage quality, their impact on the electrical drive characteristics is evaluated.

The paper is organized as follows. Section 2 outlines the harmonic spectrum indicators of the supply voltage of the motor. Section 3 focuses on the mathematical analysis of the modulated periodic signals. The developed laboratory stand and research methodology are given in Section 4. In Section 5 the results from the experimental analysis are presented. Finally, conclusions are drawn in Section 6.

2. Harmonic spectrum indicators

The phase voltage of the motor in an induction motor (IM) electric drive controlled by a semiconductor converter is analysed. The latter is set to operate as frequency converter and voltage converter. To evaluate the IM periodic non-sinusoidal supply voltage, the following coefficients are used [3, 4]: total harmonic distortion coefficient (k_{THD}), coefficient of deformation (k_D), form coefficient (k_f) and weighted harmonic voltage factor (k_{HVF}).

In addition, the rms values of the stator phase voltage (U) and of its first harmonic (U_1) are also evaluated.

The above coefficients are determined by the formulae [5, 6]:

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$$k_{THD}=\frac{\sqrt{\sum_{\nu=2}^{\infty}U_{\nu}^{2}}}{U_{1}};\; k_{HVF}=\frac{\sqrt{\sum_{\nu=5}^{\infty}\frac{U_{\nu}^{2}}{\nu}}}{U_{1}}. \tag{1}$$

$$k_{D}=\frac{U_{1}}{U};\quad k_{f}=\frac{U}{U_{AV}}. \tag{2}$$

All odd harmonics not multiple of 3 are included in k_{HVF} in (1).

It should be taken into account that for induction motors, fed by sinusoidal voltage with harmonic components, the standard determines the ability for loading within the range from 1 to 0.7 of the rated power with k_{HVF} varying from 0.030 to 0.115 [7]. Implementation of static PWM converters increases the steel losses by about 12% [5]. The total increase in the motor losses is by another 3%, 0.5% of wich is in the stator coil, 2% in the rotor coil and 0.5% are additional losses. This leads to a decrease in efficiency of the general-purpose motors by about 0.7% (95.3%-94.6%) at rated speed and load for 3kHz modulation signal.

3. Mathematical analysis of modulated periodic signals

The output voltage formed by the PWM is given by [8, 9]:

$$u_{a}=0{,}5mU_{d}\,sin(\omega t+\psi)+F(M\omega_{c}\pm N\omega). \tag{3}$$

Here m is the index of modulation; $\omega=2\pi f$ is the angular frequency of the modulated signal; ψ is its phase angle; $\omega_c=2\pi f_c$ is the carrier angular frequency; U_d is the rectified voltage by the DC-link unit and the residual function $F(M\omega_c \pm N\omega)$ equals the sum of all high-frequency harmonics.

Expression (3) contains harmonics that depend on the carrier frequency. They are concentrated around the multiples of M (both even and odd) of the carrier frequency. As shown in Table 1, the sum M+N is a positive odd integer.

The most commonly used techniques for evaluating the measured signals include Fast Fourier Transform (FFT) and specialized software.

Table 1. Harmonic spectrum of sinusoidal PWM voltage

N(M)		M		
Odd M	Even M	1	2	....
0	±1	$1\omega_c$	$2\omega_c \pm 1\omega$	.....
±2	±3	$1\omega_c \pm 2\omega$	$2\omega_c \pm 3\omega$	.....
±4	±5	$1\omega_c \pm 4\omega$	$2\omega_c \pm 5\omega$	.....
±6	±7	$1\omega_c \pm 6\omega$	$2\omega_c \pm 7\omega$	.....
±8	±9	$1\omega_c \pm 8\omega$	$2\omega_c \pm 9\omega$	.....
......	......	.....	.....	.....

4. Laboratory stand and research methodology

Based on the analysis, a laboratory stand of induction motor electric drive is developed. It consists of a static AC to DC converter capable of working as VFC and VVC, digital oscilloscope and personal computer. The stand is shown in Fig. 1. Here UR stands for uncontrolled rectifier and C_F for DC-link capacitor. The rms value of the supply voltage is U=220 V and the frequency is f=50 Hz.

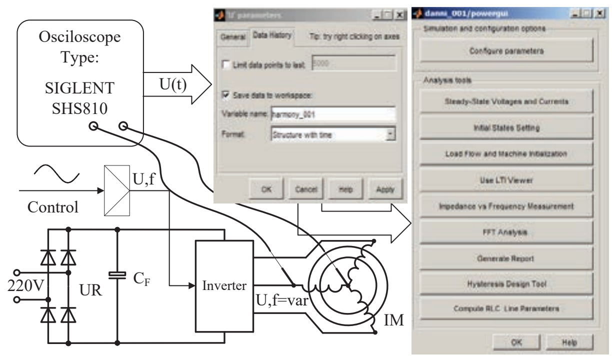

Fig. 1. *Schematic of the laboratory stand*

A full wave bridge rectifier and DC-link are used. The power inverter operates with sinusoidal PWM and carrier frequency f_c=5(2.5) kHz. The DC voltage maximum value is $V_{DC}=220\sqrt{2}$ V. The induction motor model has the folowing rated parameters: active power P_r=180 W; speed n_r=1366 rpm; line voltage V_r=380 V; frequency f_r=50 Hz; number of pole pairs z_p=2; efficiency η=64 % and power factor cosφ=0.64.

The T-shaped equivalent circuit parameters are: stator resistance R_s=55.8 Ω; stator leakage reactance L_s=0.089 H; rotor resistance R_r=46.6 Ω; rotor leakage reactance L_r=0.157 H and magnetizing reactance L_m=1.367 H.

The FFT Analysis Tool from the SimPowerSystems ToolBox in Simulink uses Structure with Time format for the measured values of the voltage V(t). The values are stored in the Workspace. The discretization time t_k is between 2μs and 20μs depending on the modulated signal frequency. The induction motor operates at no-load. The supply voltage is varied based on the V/f=const control law for the VFC mode and V=var; f=50 Hz=const for the VVC mode. A Siglent 1810 digital oscilloscope with 2GB memory is used.

5. Results from the experimental analysis

Fig. 2 shows the induction motor phase voltage at 30 Hz when supplied by VFC. The values of the first 33 harmonics are also displayed as a percentage of the first hamonic peak value (V_{1max}). Here V_{1max}=124.2 V and k_{THD}=91.22 %.

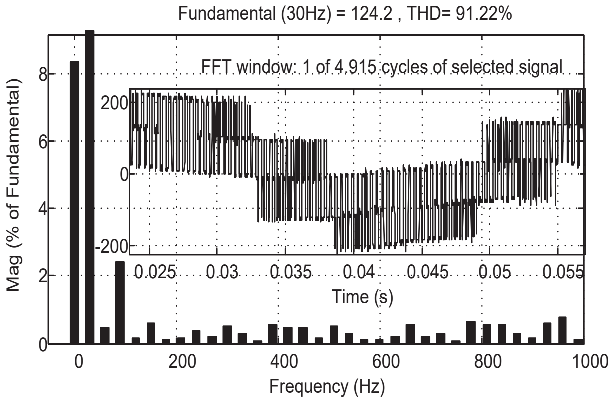

Fig. 2. *VFC output voltage form and values of the first 33 voltage harmonics at f_c=2500 Hz, f=30 Hz*

The shape of the motor phase voltage at 50 Hz, minimum voltage amplitude V_{1max} = 27.83 V and VVC converter mode is shown in Fig. 3. The values of the first 20 harmonics expressed as a percentage of the first harmonic peak value are also displayed. Here k_{THD} = 266.45%.

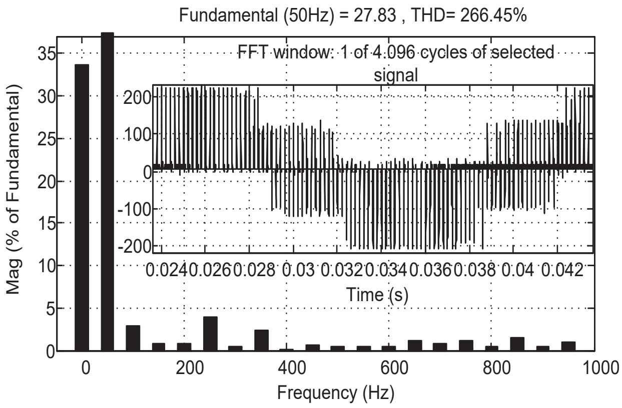

Fig. 3. *VVC output voltage shape and values of the first 20 voltage harmonics at f_c=2500 Hz, f=50 Hz*

The phase voltage harmonic spectrum at 30 Hz and VFC mode is shown in Fig. 4. The analysis is carried out up to f_{max}=15 kHz. It can be seen that that harmonics tend to group around the multiples of M of the carrier frequency.

The phase voltage harmonic spectrum at 50 Hz, V_{1max}= 27.92 V and VVC mode is shown in Fig. 5. The analysis is also carried out up to f_{max}=15 kHz. There is again grouping of harmonics around the carrier frequency multiples of M.

To determine the quantitative indicators by means of formulae (1) to (2), a set of experiments is carried out. Six modulated frequencies (10, 20, 30, 40, 50 and 100 Hz) are analyzed for the VFC mode. Tables 2 and 3 show the obtained results for the harmonics spectrum indicators of the voltage when the motor follows the V/f=const control law.

Five voltages (20, 48, 77, 106 and 133 V) at f=50 Hz and two carrier frequencies (2.5 kHz and 5 kHz) are analyzed for the VVC mode. Tables 4 and 5 show the obtained results for the harmonic spectrum indicators of the voltage at no-load.

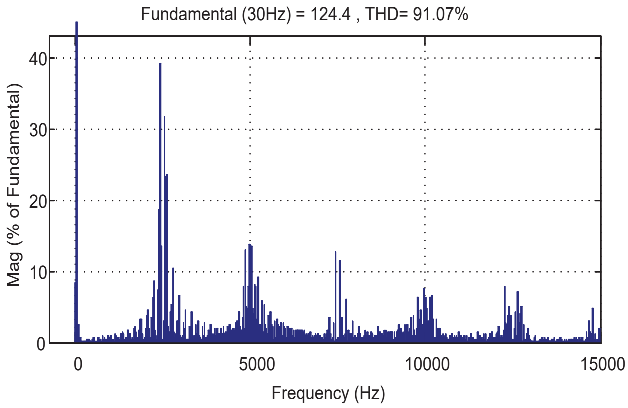

Fig. 4. *VFC output voltage harmonic spectrum at f_c=2500 Hz, f=30 Hz*

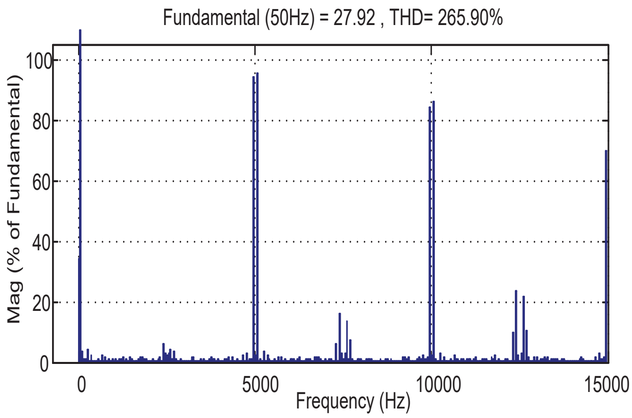

Fig. 5. *VVC output voltage harmonic spectrum at f_c=2500 Hz, f=50 Hz*

Table 2. VFC output voltage harmonic spectrum indicators at f_c=2500 Hz, no-load

f [Hz]	U [V]	U_1 [V]	k_f	k_{THD}	k_d	t_k [μs]
10	71	30	1.92	2.11	0.43	20
20	96	58	1.51	1.33	0.60	8
30	118	88	1.32	0.91	0.74	8
40	139	118	1.19	0.62	0.85	8
50	150	136	1.12	0.46	0.91	8
100	153	140	1.11	0.45	0.91	8

Table 3. VFC output voltage harmonic spectrum indicators at f_c=5000 Hz, no-load

f [Hz]	U [V]	U_1 [V]	k_f	k_{THD}	k_d	t_k [μs]
10	73	30	1.97	2.18	0.42	20
20	96	58	1.51	1.33	0.60	8
30	118	88	1.32	0.91	0.74	8
40	139	118	1.19	0.62	0.85	4
50	150	136	1.12	0.46	0.91	4
100	153	139	1.13	0.46	0.91	2

Table 4. VVC output voltage harmonic spectrum indicators at f_c=5000 Hz, no-load

f [Hz]	U [V]	U_1 [V]	k_f	k_{THD}	k_d	t_k [μs]
50	57	20	2.08	2.66	0.35	4
50	87	48	1.62	1.50	0.55	4
50	112	77	1.44	1.05	0.69	4
50	133	106	1.25	0.74	0.80	4
50	148	133	1.18	0.49	0.90	4

Table 5. VVC output voltage harmonic spectrum indicators at f_c=2500 Hz, no-load

f [Hz]	U [V]	U_1 [V]	k_f	k_{THD}	k_d	t_k [μs]
50	57	20	2.08	2.66	0.35	4
50	88	49	1.62	1.50	0.55	4
50	111	77	1.44	1.03	0.70	4
50	133	106	1.25	0.74	0.80	4
50	148	133	1.18	0.49	0.90	4

Tables 6 and 7 present the k_{HVF} values, calculated from the experimental data. The first value takes into account all harmonics with magnitude greater than 5% of the main harmonic. The second value is obtained by (1). Table 6 is for VFC at two carrier frequencies. Table 7 presents the k_{HVF} values for the VVC at one carrier frequency.

Table 6. Weighted k_{HVF} coefficient for the VFC converter

f_c [kHz]	f [Hz]					
	10	20	30	40	50	100
	k_{HVF} [%]					
2.5	4.9 8.5	6.9 10.0	5.4 8.5	4.4 6.4	3.7 8.0	5.1 7.6
5	4.3 15.9	4.6 7.4	4.3 6.1	0.8 4.5	2.5 4.1	3.1 5.3

Table 7. Weighted k_{HVF} coefficient for the VVC converter

f_c [kHz]	U_1 [V]				
	20	48	77	106	133
	k_{HVF} [%]				
2.5	11.5 17.1	5.5 17.5	9.0 12.3	5.6 8.5	3.8 5.8

6. Conclusion

This paper evaluates the supply voltage quality and its impact on induction motors, fed by static frequency and voltage converters using PWM. A series of experiments are conducted on a specially developed laboratory stand. The voltage from the converters is examined by FFT-analyser in SimPowerSystems Toolbox of Simulink.

Based on the results, it can be concluded, that harmonics tend to group around the multiples of M of the carrier frequency for both the VFC and VVC mode. Despite shifting of the harmonics towards high carrier frequencies, the weighted harmonic voltage factor exceeds the limit, set by the Standard IEC 60034-1. To improve the quality of the supply voltage, sinusoidal filters can be implemented on converters outputs.

The obtained results show that the total harmonics distortion coefficient and the distortion coefficient do not significantly vary with the carrier frequency, but strongly depend on the voltage. The values of k_{THD}, however, are well above the limit, recommended by the IEEE Std 519-1992.

The developed laboratory stand and the experiments carried out can be used as a foundation for future research of other types of modulation.

REFERENCES

1. Bose B. (2002). *Modern power electronics and a.c. drives*, 711 p. Prentice Hall.
2. Rizov, Pl., Sotirov, D., Batashki, St., and Spasov, R. (2010). Analysys of the harmonic content of e.m.f. in induction generators by FEM. *Proceedings of the Technical University of Sofia*, Vol. 60, Issue 2, pp. 225-234.
3. Bose B. (2006). *Power electronics and motor drives - advances and trends*, 915 p. A.Press.
4. Rizov Pl., Spasov, R., et al. (2015). The application of finite element method for determining the THD in the electromotive force in a synchronous machine with permanent magnets under different loads. *Proceedings of the 14-th International Conference ELMA 2015*, pp. 171–180.
5. IEC 60034-17:2002 *Cage induction motors when fed from converters – appl. guide*, 44 p., 3Ed.
6. IEC 60034-25:2007 *Guidance for the design and performance of a.c. motors specifically designed for converter supply*, 74 p., 2Ed.
7. NEMA MG 1-2009: *Motors and Generators*, Section IV, Part 30, 575 p.
8. Krishnan R. (2003). *Electric motor drives - modeling, analysis, and control*, 650 p. Singapore.
9. Kazmierkowski, M., et al. (2002). *Control in power electronics*, 518 p. Elsevier Science.

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INVESTIGATION OF ONE LOOP ELECTRIC CIRCUIT FOR CONTROL OF FLASH LAMP

YANKA IVANOVA, SVETOSLAV IVANOV, ROSSEN BOJILOV

Abstract: *This article provides a transient analysis in discharge flash lamp operated by one-loop high-voltage electric circuit. Lamp is designed to emit a strong non- coherent exciting radiation for management of Solid Nd: YAG, ruby, or Er: YAG lasers. It is designed a scheme for impulse control of Xenon flash lamp. For simulation research in program environment is proposed replacement scheme. The results of simulation studies are presented.*

Key words: *impulse control, xenon gas discharge lamp, one-loop electric circuit*

1. Introduction

Modern laser technology is a combination of the physical principle of the laser, the selection of suitable active environments in combination with electrical and electronic devices for excitation of these environments and receiving laser radiation. Basic for practical applications in industry, science, in medicine are lasers with condensed active substances (liquid and solid), in particular solid-state Nd: YAG, ruby, Er: YAG and the like lasers, as well as its unique ability to adjustment dye lasers and lasers with F - centers. The dye lasers in the range of $0,57 \mu m$ to $0,62 \mu m$ are currently the main tunable sources widely used in lidar technology for remote monitoring of the composition and atmospheric pollution. They also find important applications in systems for the separation of isotopes, as well as medical applications for the treatment of serious illnesses. Typical of them is that to obtain sufficient output power and energy required highly specialized non - coherent - Lamp excitation requiring very steep front of excitation radiation $(\sim \mu s)$. Obtaining of such exciting radiation massively available and widely used discharge lamps is not easy technical task. This requires discharge across the lamp to be induced by a capacitor or a capacitor battery with a significant capacity ($\sim \mu F$) charged to a very high voltage ($\sim 10kV$). It is thus possible the formation of fast rising edge ($1 \div 3 \mu s$) pulse with a very high intensity respectively received in a powerful pulse of current through the lamp. The result is a sharp increasing to several times of the output generated power.

This article presents a practical implementation of the scheme with a single loop automatically synchronized formation of a discharge in discharge xenon flash lamp. Composed is a model for transient analysis of the scheme and engineering design of this type of driver circuits.

2. Driver management scheme for xenon flash lamp

In common pulsed lasers, solid-state and the dye lasers, the optical pumping is carried out with flash lamps, [1] having infinitely large initial resistance, and negative dynamic resistance. The power of this type lamps usually consists of a capacitor for accumulating energy and for the discharge, the coil forming the pulse, high-voltage DC power supply and the ignition circuit for the ionization of the lamp. The length of the resulting high-energy ($\sim 100 \div 300\ J$) pulse with a steep edge ($\sim 1\ \mu s$) is determined by the type of the controlled laser.

2.1. Principal scheme for control of flash lamp

Principal electrical control circuit of flash lamp is shown in Figure 1. In the researched circuit is used a gas discharge flash lamp filled with xenon at a relatively low gas pressure of a few thousand Pascals. To provide the necessary electrical charge in parallel to the power source is switched storage capacitor C_1. In order to trigger discharge between electrodes by an additional ignition device connected to the lamp is fed to pulse which ionizes the gas in advance [2].

The resistance of the lamp decreases and the accumulating capacitor C1 discharges through it [3,4]. As a result of the discharge a powerful pulse is emitted with duration determined by the

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capacitance of the storage capacitor C_1 and the inductance of the discharge circuit L_1.

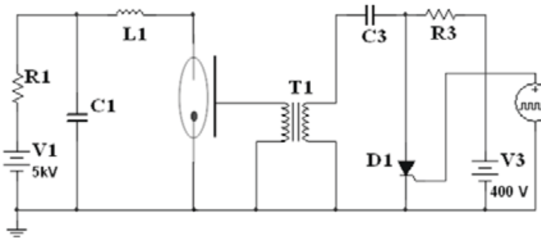

Fig. 1. *Electrical scheme for control of flash lamp*

The electrical schematic diagram of an ignition device includes the following elements: a transformer T_1, capacitor C_3, a resistor R_3, thyristor D_1, DC power source V_3 and a generator of control pulses V_4. The source of DC voltage $V_3 = 400\ V$ is charging capacitor C_3. Upon receipt of a control pulse from the control system thyristor D_1 turns ona result of which the capacitor C_3 discharges through the primary winding of the transformer. Thus arises the initial ionization of the gas in the lamp and it is ready to be incorporated into the basic power supply from the capacitor C_1, charged with a voltage $V_1 = 5kV$. In the scheme in question generator pulses V_4 generates pulses with *TTL* - levels. Duration of generated pulse is *26µs*. The repetition period is *2ms,* which duration corresponds to the frequency *500 Hz*. Because the scheme under consideration comprising a gas discharge flash lamp, the inductance of the discharge circuit L_1 and the accumulation capacitor C_1 is one-loop, ignoring all active losses, excluding the lamp the transients processes can be described with the following integro-differential equation:

$$U_{C1}(0) = L_1 \frac{di_{L1}}{dt} + K_0 \sqrt{i_{L1}} + \frac{1}{C_1} \int i_{L1} dt, \quad (1)$$

where:

i_{L1} is the current in the lamp as a function of time;

$U_{C1}(0)$ is the voltage to which the capacitor C_1 is charged in the initial moment $t = 0$;

K_0 is the impedance of the lamp, which depends on the geometry of the lamp, as well as the gas pressure in it.

2.2. Replacement circuit for simulation research

For the study of transients the control scheme of the flash lamp it is made a replacement circuit for simulations in programming environment NI Multisim. Constructed scheme is presented in Figure 2. In the scheme the trigger device is represented by the impulse generator V_4 and switch S_2.With the aim of producing a replacement circuit diagram for carrying out simulation research a theoretical analysis of voltamper characteristic of the impulse control of a xenon discharge lamp is done[5].

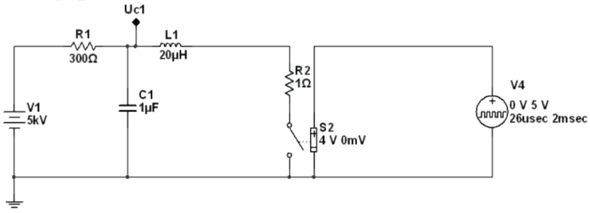

Fig. 2. *Substitution scheme for the study of transients in the programming environment NI Multisim*

It is established that the variation of current as a function of applied voltage on the lamp can be experimentally received from the equivalent electric circuit including a parallel combination of a capacitor and an active resistance and inductance in series included, figure 3. The active resistance *R* is defined as the real part of the total resistance of the lamp.

The established value of the current in the switching power supply of the lamp has been expressed by the inclusion of a consistent inductance *L*.

During the arc discharge in the lamp positive and negative electric charges are generated. Their amount related to a the applied voltage on the lamp determines the value of the capacity *C* in the equivalent circuit of the lamp. This replacement scheme can be used for a maximum duration of control pulses *40µs*.

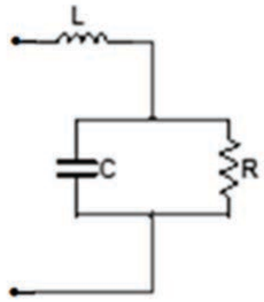

Fig.3. *Equivalent substituting scheme of the lamp*

For the present research of transient processes in one-loop power control scheme of the flash lamp is sufficiently the lamp to be furnished by the included resistor R_2 (Fig. 2)

It is known that the active resistance of the lamp according to the duration of the control pulses can be determined from the formula:

$$R_2(t) = \frac{\rho(t).l}{A} \quad (2)$$

where: A is the cross-section of the lamp (cm^2);

l is length of the lamp (cm);

t is 1/3 of the pulse duration (ms);

$\rho(t)$ is the impedance of the plasma (Ω.cm), which depends on the impulse duration in time.

With R_1 is referred to the internal resistance of the voltage source V_1. Pulse duration of the source V_4, indispensable to ignite the lamp is $26\mu s$. Key used (relay) S_2 is a controlled by voltage switching level $4V$, making it possible to control of the circuitry of source signals with *TTL* levels.

3. Results

Simulation researches have been done in the Multisim environment. The graph of change of a current I_{L2} through the flash lamp obtained by simulation researches with the set values of the passive components in the control circuit, is shown in Figure 4. The current through the lamp is variable, reaching a maximum value of *956A* for $7\mu s$. The change of the current represents a fading transition process.

Figure 5 shows the shape of the voltage on the capacitor C_1, switched in parallel to the power source U_{C1}. The supply voltage V_1 is $5kV$. Figure 6 illustrates the transient process of charge the capacitor C_1 with the high voltage of the power source, after the excitation of the lamp.

From the graph of the transient processes in the one-loop electric circuit it is established that the process charge has a duration of *2ms*, like this time interval affixes restriction on the maximum frequency of the control impulses.

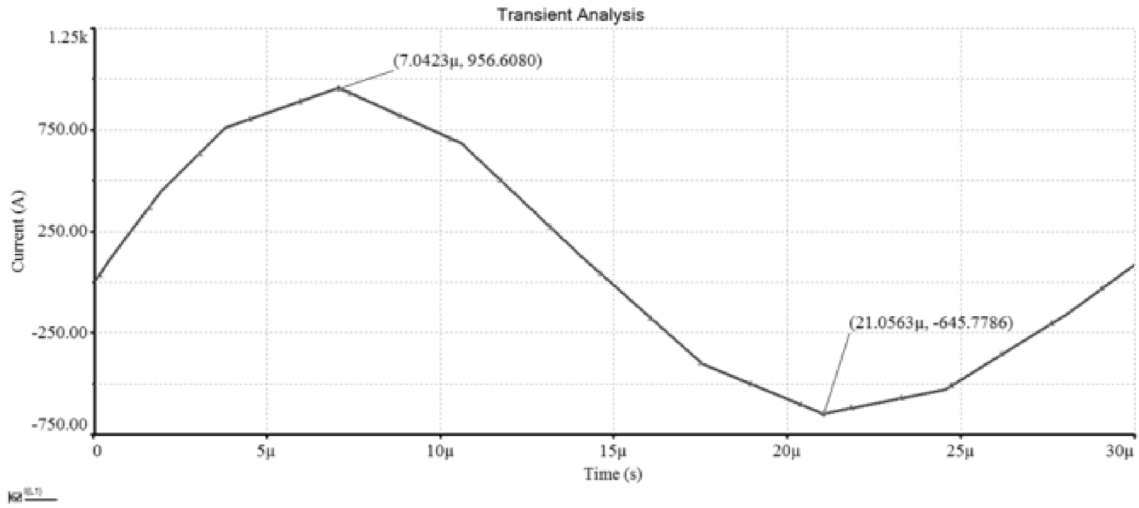

Fig. 4. *Graph of change of the current I_{L2} through the flash lamp*

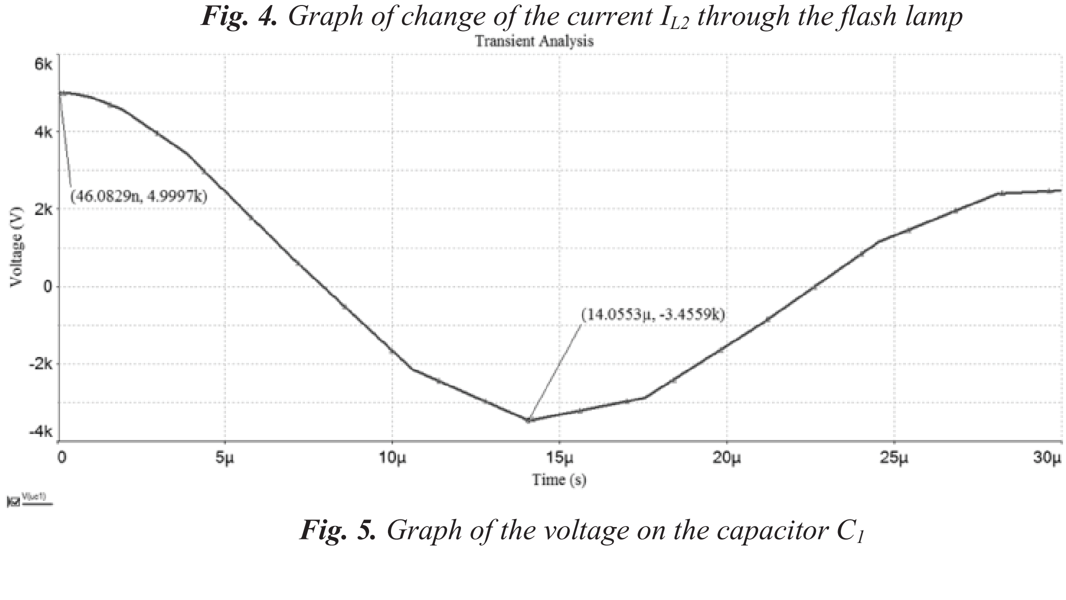

Fig. 5. *Graph of the voltage on the capacitor C_1*

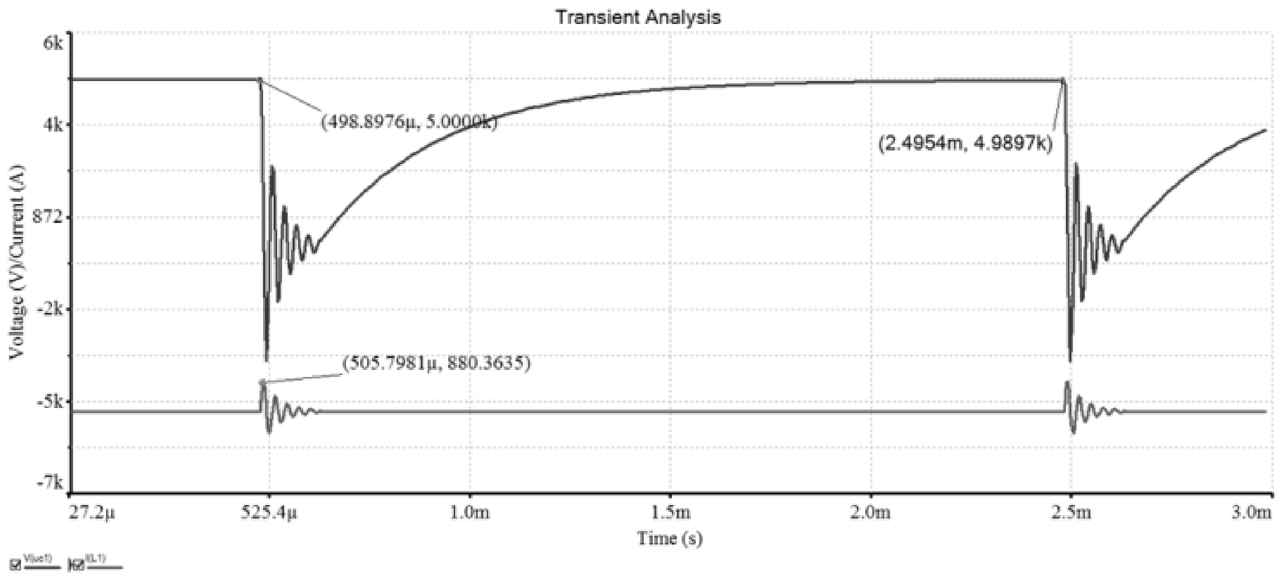

***Fig. 6.** Graph of the transient process of charge the capacitor C_1*

4. Conclusion

This paper examines a classical solution for impulse control of xenon lamp in programming environment Multisim, as the results are approaching with sufficient accuracy to practical researches of the scheme. The substitution scheme allows optimization of transient processes in the flash lamp by changing the values of passive elements included. The results of the simulation researches allow the evaluation of energy and frequency characteristics of the control circuit. The substitution circuit assembly does not include the excitation lamps of the lamp, such as the impulse transformer, the thyristor and the passive elements. This is not necessary because this schematic solution is often applicable in practice, and ready impulse transformers for different circuit solutions are available on the market.

LITERATURE:

1. Beggar R., Louhibi D., Almabouada F., Noukaz A. (2008). "Caractérisation expérimentale d'une lampe flash utilisée pour le pompage d'un laser à solide ", the 4 th National Seminary on Laser and Applications, SENALAP'2008, Tizi-Ouzou from 10 to 11 May 2008.

2. Браун М. *Токозахранващи устройства. Техника*, София, 1997.

3. Almabouada F.,Louhibi D., Hamici M., Hammoum Y., Haddouche A. (2011). Power supply for xenon flashlamp. SIPP'2011 / UKM Ouargla / 13 - 15 February/Février 2011.

4. Dondon P., Lequertier J. (2001) An integrated pedagogical approach for a switching power supply design: example of fly back. Electronics, the 8th IEEE International Conference, Page(s):1615-1618 Vol.3, 2-5, Sept. 2001.

5. Yanca Kissova, Svetoslav Ivanov. (2014) Analysis and simulation research of scheme for obtaining high energy pulse excitation of laser with a discharge lamp. *Машиностроене и машинознание*. Година IX, книга 3. ISSN 1312-8612, Издателство на технически университет-Варна, стр. 50-53.

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ULTRASONIC SENSOR FOR MEASURING WATER SPEED

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Abstract: *In the proposed article, an ultrasonic receiver and an ultrasonic transmitter are designed and tested to measure the rate of water flow in a cylindrical tube. A device running on time - impulse method of speed measurement, has been investigated. An analysis of the frequency and selectivity of the receiver has been made. A methodology has been developed to select the pulse frequency and the frequency of the low frequency modulation signal. The proposed schematics of the transmitter and the receiver were studied.*

Key words: *Ultrasonic flowmetering, signal processing, transit-time flowmeter*

1. Introduction

The phenomena arising from ultrasound propagation in a moving environment are used in sensors to measure velocity and fluid flow. The sound velocity c which is a material property value is the propagation velocity of a sound wave in a medium. It changes with the density of the measuring medium. Therefore it is temperature dependent in liquids and pressure and temperature dependent in gases [1, 2]. The time changes when the sound carrier is also in motion, in fact, it is the sum of the sound velocity in the measuring medium and the measuring medium velocity. This effect is utilized in an ultrasonic flowmeter. The advantages of ultrasonic sensors are high performance, allowing determining short-term speed fluctuations, and lack of additional impedances along the way of supplying the liquid with external placement of transmitters and receivers of ultrasonic waves, possibility of control of reversal streams. The disadvantage that makes it difficult to use ultrasonic sensors to measure velocity and cost is the significant difference in ultrasound speed (1000-2000m/s) and medium (1-10m/s). Differences in velocity and flow rate sensors are based on measuring the velocity of the ultrasound wave going upstream and downstream. The main attributes for which they are classified are: the number of channels, the nature of the acoustic channel, the location of the emitters and the receivers, the mode of operation, the method of processing the signals. According to the number of channels, acoustic sensors can be single channel (fig.1) and multichannel (fig. 2) [3].

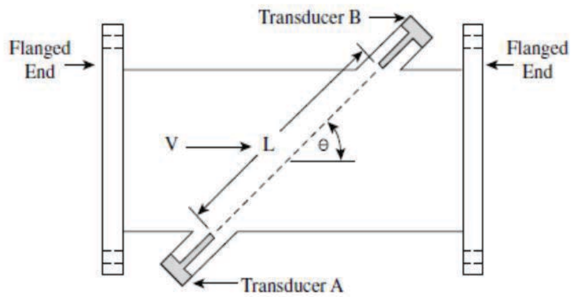

Fig.1. *One-channel ultrasonic sensor*

According to the character of the acoustic channel, the sensors are without refraction of the ultrasound beam and by refraction by means of special elements. In some ultrasonic sensors, the emitters and receivers are located in the stream, and other ultrasonic sensors are located outside the flow. The acoustic channels of these sensors may be parallel to each other but may also be crossed. Virtually all ultrasonic sensors can operate in time-pulse, frequency-pulse and phase mode [1].

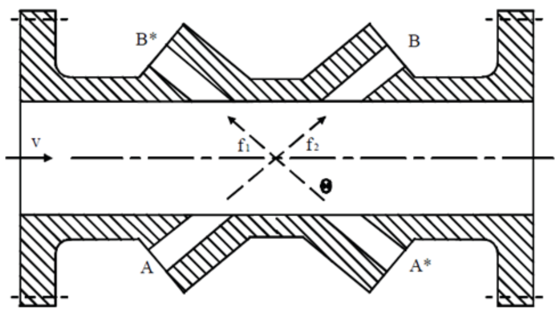

Fig. 2*. Two-channel ultrasonic sensor*

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When working in time-impulse mode, the principle of operation of ultrasonic sensors is based on measuring the propagation time of the ultrasound pulses along the flow and against the flow in the pipe (fig. 1). The time for passing the ultrasound pulse from the transmitter A to the receiver B is given by the expression:

$$t_{AB} = \frac{L}{(C + V.\cos\theta)} \qquad (1)$$

The time for passing the ultrasound pulse from the transmitter B to the receiver A is given by the expression [4]:

$$t_{BA} = \frac{L}{(C - V.\cos\theta)}, \qquad (2)$$

where: C is the ultrasound rate in the water;

θ is the angle of propagation of the ultrasound to the pipe axis;

V is the speed of the water;

L is the distance between the ultrasonic transmitter and receiver (transducers A and B).

According to equations (1) and (2), since $V << C$, it can be shown that

$$\Delta t = t_{BA} - t_{AB} = \frac{2.L.V.\cos\theta}{C^2} \qquad (3)$$

Therefore, the velocity of the fluid V can be determined by the formula:

$$V = \frac{C^2.\Delta t}{2.L.\cos\theta} \qquad (4)$$

The main disadvantage of this method of determining the velocity of the fluid is the discrepancy between the speed averaged in the direction of ultrasound and the velocity averaged over the cross section of the pipeline. It is possible to introduce an empirical coefficient that allows error exclusion at the expense of this factor only in narrow range of medium viscosity variations as well as a slight change in the number of Reynolds *Re* [5]. Changing the speed of ultrasound in the environment, for example, when changing the temperature, also gives rise to a measurement error.

2. Transit Time Flow meter

The principle schematic of the speed sensor is shown in fig. 3.

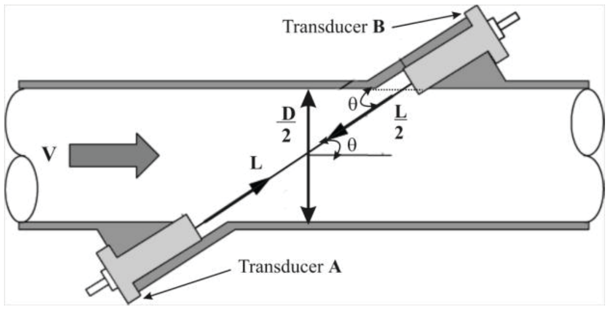

Fig. 3. *Construction of the ultrasonic sensor*

The velocity of the fluid as a consequence of equation 4 can be determined by the formula:

$$V = \frac{\Delta T.2.L}{\cos\theta.(T_{AB} + T_{BA})^2} \qquad (5)$$

The magnitude of the angle θ can be determined by the rectangular triangle formed by the diameter of the tube D and the direction of the sensors L.

$$\theta = \arcsin\frac{D}{L} = \sin^{-1}\frac{D}{L} \qquad (6)$$

Therefore, the water velocity in the pipe V can be definitively determined by the equation:

$$V = \frac{\Delta T.2.L}{\cos\left(\sin^{-1}\frac{D}{L}\right).(T_{AB} + T_{BA})^2} \qquad (7)$$

When designing the ultrasonic sensor, it is necessary to determine the length of the ultrasound wave λ which is distributed in the water as a function of the selected frequency f by the formula:

$$\lambda = \frac{C}{f} \qquad (8)$$

where: C is the velocity of the ultrasound wave in the water [6].

The time for transmitting the ultrasound wave from the emitter to the receiver at the distance labeled L is determined by the formula:

$$t = \frac{L}{c} \qquad (9)$$

The coefficient k, which shows the relationship between the distance L and the length of the ultrasonic wave λ can be determined by the formula:

$$k = \frac{L}{\lambda} \tag{10}$$

Therefore, the reference frequency with which the radiated high frequency oscillations are repeated is determined by the formula:

$$f_{rep} = \frac{f}{k} \tag{11}$$

With a pre-selected duty cycle of the reference pulses D, the number of cycles containing the ultrasound wave is determined by the formula:

$$N_{cycle} = \frac{f.D}{f_{rep}} \tag{12}$$

The duration of the packet of ultrasonic pulses has a value that is determined by the formula:

$$PW = \frac{N_{cycle}}{f} \tag{13}$$

The aim of the research is to design and test an ultrasonic transmitter and an ultrasonic receiver to measure the water velocity in a pipeline by the direct measurement of the transition time. The pipeline diameter D is *100mm* and the distance between the sensors L is *150mm*. Schematics of the designed and investigated ultrasonic receiver and transmitter are shown in Figures 4 and 5.

2.1. Ultrasonic transmitter

The transmitter includes a rectangular pulse generator with a frequency of *1MHz*, implemented with a Schmitt trigger (*DD U3A*), fig. 4. The *Frep* repercussion pulses that determine the duration of the broadcast packet of high frequency pulses are at a frequency of *10 kHz* with duty cycle *D = 50%.* With the operational amplifier *U2*, the pulses are amplified to an amplitude of *10V*. For transmitters and receivers, double ultrasonic receivers and WC75 - 1 transmitters can be used. Figure 5 shows the high frequency pulses emitted by the emitter *f*, modulated by the duration of the *Frep* reference pulse. The duration of the *PW* packet is *50 µs*.

Figure 5a shows the packet of impulses generated by the ultrasonic transmitter. The duration of this packet is determined by the duration of the reference pulse shown in figure 5b.

2.2. Ultrasonic Receiver

The scheme of the ultrasonic receiver is shown in fig. 6. The generated signal from piezo sensor *U5* is amplified sequentially by two operational amplifiers powered by a single-pole voltage. The resistor divider *R1, R3* creates the so-called virtual zero without changing the amplitude of the input signal. In this case, a virtual zero value equal to ½ of the supply voltage for the operational amplifiers is selected. The scheme is designed to amplify frequencies *1MHz*. With the *D2* diode and with the capacitor *C5* an amplitude detector is realized for the received high frequency pulses. The voltage at the detector output goes to the input of the analog comparator with a digital output *U3A*. With the logic elements *U7C* and *U6B* a $\overline{R} - \overline{S}$ trigger is realized. When the impulse with response frequency F_{rep} reaches, after logging in. „1" at the output of the comparator, the digital output of the trigger *RX1* detects a registered ultrasonic signal from the receiver. Figure 7a shows a graph of the output voltage of the detector when receiving the ultrasonic signal with frequency *1MHz*.

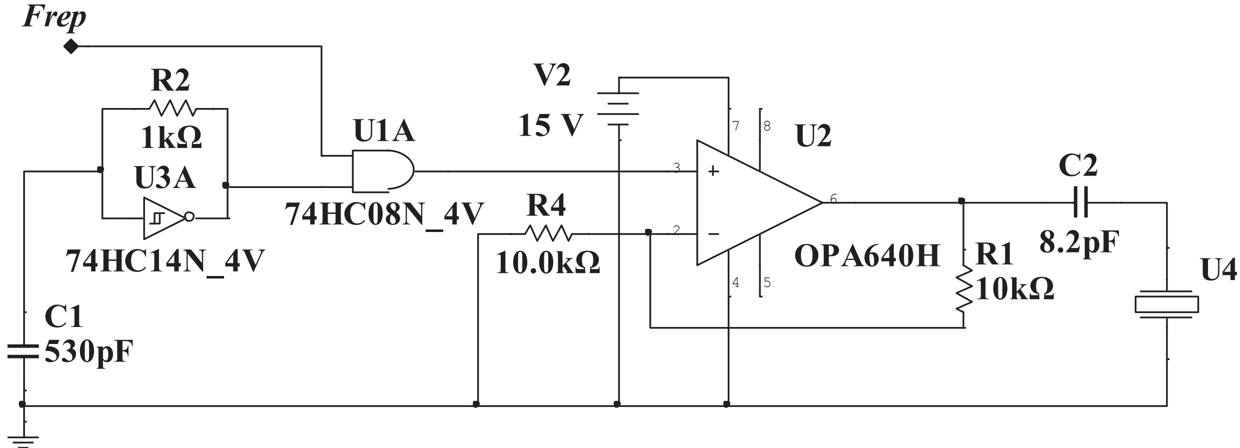

Fig. 4. *Scheme of the ultrasonic transmitter*

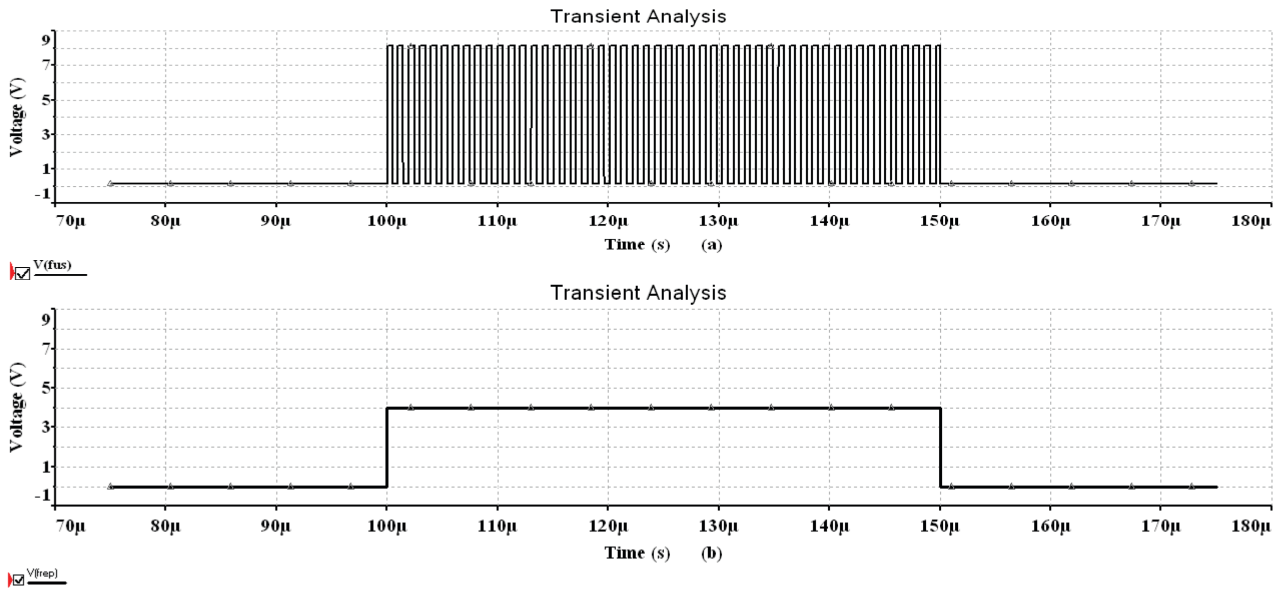

Fig. 5. *Graphs of the generated high frequency ultrasound pulses (a) and the reference pulse defining the duration of radiation (b).*

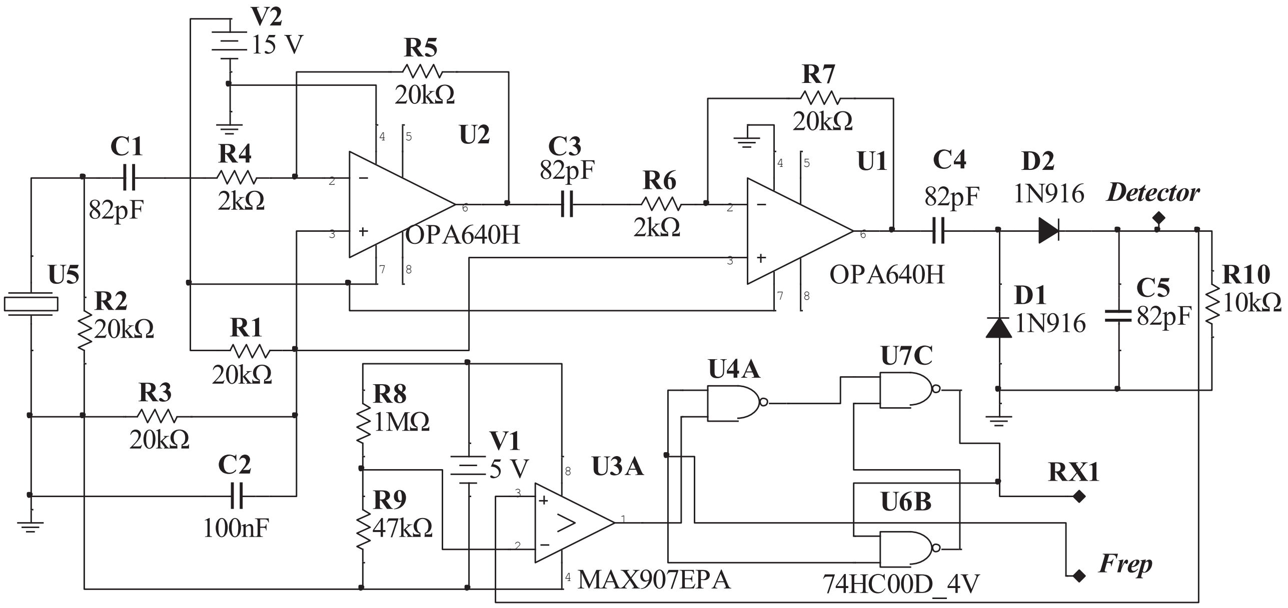

Fig. 6. *Scheme of the ultrasonic receiver*

In Fig. 7b shows the reference frequency pulses F_{rep} that start the emission of ultrasound pulses from the transmitter, as well as inputs to the logic element of the receiver *U4A*, which allows switching of the trigger to the output of the receiver.

In Fig. 7c shows the graph of the output impulses of the receiver *RX1*, which allow for the calculation of the delay time T_{AB}.

These calculations can be made from a microprocessor control system. Another fundamental task of the ultrasound sensor management system is to generate pulses with the reference frequency determining the start and end of the ultrasound pulses.

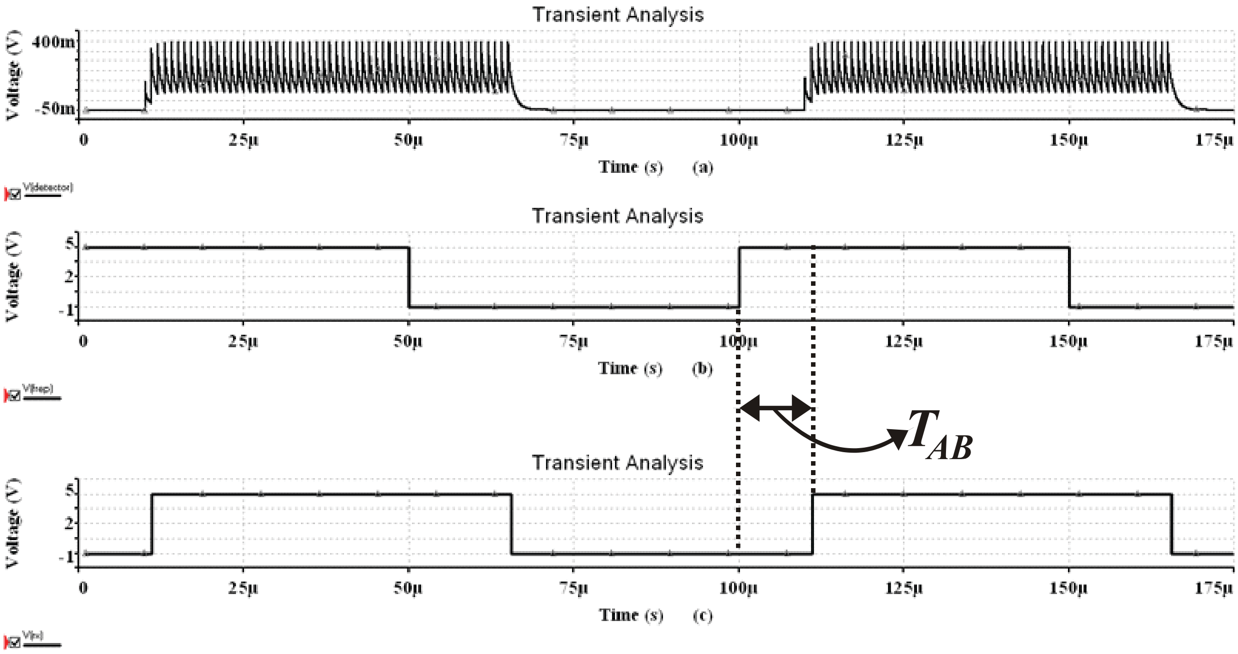

Fig. 7. *Graphics of the amplitude detector output signals (a), the reference pulses entering the receiver (b) and the output pulses of the receiver (c).*

3. Results and discussion

The ultrasonic receiver is designed to receive *1MHz* signals. Figure 8 shows the amplitude-frequency characteristic of the analogue part of the receiver. Research has been done in "Multisim" software. The gain coefficient for the received signal frequency is *51* (*34dB*) and is kept almost constant for frequencies up to *9 MHz*.

Analog amplifiers are designed to amplify high-frequency signals, with low frequency capability being achieved by the transfer capacitors at their inputs.

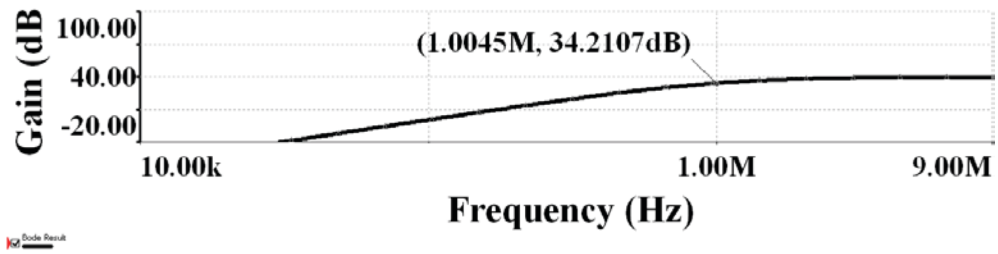

Fig. 8. *Amplitude-frequency characteristic of the ultrasonic receiver.*

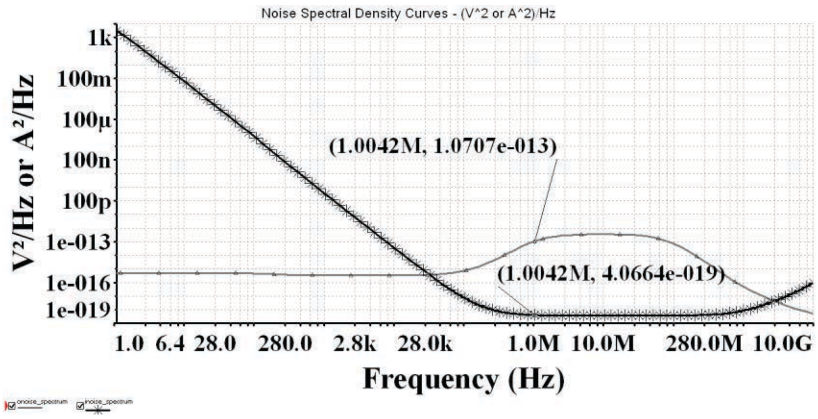

***Fig. 9**. Graphs of the spectral density of the noise input at the input of the amplifier and the output after amplification of the signal*

It is made a study of the spectral density of the noise generated by the elements in the amplifier of the ultrasound receiver (fig. 9). The sources of this noise are: heat noise, contact noise, lungs (Schottky noise) and pulse noise. The graph shows that the input noise at *1 MHz* has a value 4.10^{-19} V^2/Hz, and after signal gain there is value 1.10^{-13} V^2/Hz.

Therefore, the analog amplifier circuit suppresses signals with a frequency lower than *1MHz*. With the arrival of each reference impulse at the input of the ultrasonic receiver the output signal of the $\overline{R}-\overline{S}$ trigger is reset and it is prepared to read the delay time of the ultrasound signal passing through the water T_{AB}.

4. Conclusion

The selected mode for measuring the water velocity in a pipeline is the time - impulse method. This method allows measurement of the velocity of fluids in tubes up to *6m* in diameter. Designed are ultrasound transmitter and receiver models with good resistance to low frequency sound signals.Generation of high frequency pulses and reference frequency is realized with the appropriate choice of microprocessor control system. The microprocessor control system can determine the water velocity in the pipeline by solving equation (5).

Schematics of receivers and transmitters need to be connected to both piezoelectric converters (transducers), *A* and *B*, figure 3. Accordingly, the emission sequence of the ultrasound pulses must be against the direction of fluid movement to determine the time T_{BA} and in the direction of movement of the fluid T_{AB}.

REFERENCES

1. O'Sullivan, I. and W. Wright. (2002) Ultrasonic Measurement of Gas Flow Using
2. Jan, G., D. and G. be Boer. (2001) The Manufacturing of Ultrasonic Gas Flowmeter, *Flow Measurement and Instrumentation* 12, 89-99.
3. Cannizo, M., M. Dell'Isola, M. Diritti. (1997). Measurement of high-pressure natural gas flow using ultrasonic flowmeters, *Measurement* Vol. 20 No. 2, , 75-89.
4. Gai, H., M.S. Beck and R.S. Flemons. (1989). An Integral Ultrasound Transducer/Pipe Structure for Flow Imaging, *Ultrasonics Symposium*, 1077-1082.
5. Yoder, J., B. Liptak. (2003). *Instrument engineers' handbook: Process Measurement and Analysis*, Fourth Edition, Volume I., 353-361.
6. Асенов, А. (2007). *Измерване на разход на флуиди.* София.

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ВИРТУАЛЕН ИНСТРУМЕНТ ЗА ИЗМЕРВАНЕ И ОБРАБОТКА НА ДАННИ ОТ ПРЕКИ МНОГОКРАТНИ ИЗМЕРВАНИЯ

ВАНЯ РАНГЕЛОВА, ВЕНЦЕСЛАВ ПЕЕВ, НИКОЛАЙ ПАУНКОВ

РезюмеВ работата се представя разработен виртуалния инструмент за измерване и обработка на многократни измервания в реално време. Като източник на реалния сигнал се използва функционален аналогов генератор, системата за събиране на данни е АЦП - EMANT 300. На предния панел на виртуалния инструмент могат да се видят всички параметри, свързани с измерването. Също така хистограмата, реалното наблюдение на измерения сигнал, компонентите на неопределеността и други.

Ключови думи: *използва се отново стила Abstract, не се оставят празни редове преди или след параграфите*

VIRTUAL MEASUREMENT TOOL AND DATA PROCESSING OF DIRECT REPEATED MEASUREMENTS

VANIA RANGELOVA, VENCESLAV PEEV, NIKOLAI PAUNKOV

Abstract:*This work presents the development of the virtual instrument for measuring and processing of multiple measurements in real time.As a source of the real signal is used functional analog generator, the data acquisition system is EMANT 300.On the front panel of the virtual instrumentcan be seen all parameters related to measurement. Also the hystogram, the real monitoring of the measured signal,uncertainty components and others.*

Key words:*virtual instrument. repeated measurements, statistics, uncertainty, LabView*

1. Въведение

Неопределеност на измерване е параметър [1], свързан с резултата от измерване, който характеризира дисперсията на стойностите, които могат да бъдат приписани на измерваната величина. Винаги, когато е възможно се предпочитат многократните измервания пред еднократното, съответно и достоверността на оценката е по голяма. В нашата разработка е създаден виртуален инструмент за измерване в реално време и обработка на данните в реално. За обект е взет сигнал от функционален генератор, чиято честота на сигнала ще се измерва многократно.

2. Същност на измервателната задача.

Да се измери 100 пъти честота на нискочестотен сигнал зададена с функционален генератор тип JUPITER500, f=100Hz , като се направят многократни наблюдения. Време за измерване на всеки един резултат 10 секунди.

2.1. Съставяне на спецификация на измерването.

-Анализ на условията на измерване- измерването се извършва в лабораторни условия при температура на околната среда $+35,0^{\circ}C$

- Анализ на схемата на измерване -време на цикъла за измерване с виртуалния уред *– 10 s*

-Анализ на техническите характеристики на АЦП -- работни условия на използване – температура на околната среда от $0^{\circ}C$ до $50^{\circ}C$, *80% R.H,* относителна грешка на измерваната честота на триъгълни сигнали δf .

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2.2. Съставяне на уравнението на връзката.

$$f = \overline{f^{`}} + f_{кв} + cf_{t^\circ}$$

Където:

$\overline{f^{`}}$ - непоправения резултат от измерването.

cf_{t° - поправка за изменението на честотата на опорния генератор от промяна на температурата на околната среда.

$f_{кв}$ - поправка за грешката от квантуване-методична.

Изключване на грубите грешки.

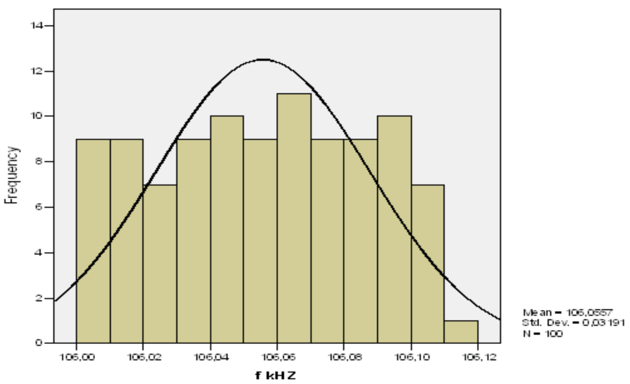
Поради естеството на експеримента, е ясно, че би трябвало да няма груби грешки, но с оглед спазване на методиката се прави и такава проверка.Използва се статистическия пакет SPSS Следвъвеждане на многократните измервания и последваща статистическа обработка на измерените данни се получават следните стойности за средноаритметичното на извадката от 100 наблюдения $\overline{f^{`}}$ и средноквадратично отклонение $S(f^{`})$:

$$N = 100 \qquad \bar{f} = \frac{1}{100}\sum_{i=1}^{100} f_i = 106.055$$

При $N > 30$, средноквадратичното отклонение на резултата се изчислява по формулата:

$$S(f^{`}) = \sqrt{\frac{\sum_{i=1}^{100}(f_i^{`} - \bar{f}^{`})^2}{100}} = 0{,}0055$$

Проверка на вида на разпределението се прави с програмата SPSS. За целта се въвеждат измерените стойности и се построява хистограмата дадена на Фиг. 1.



Фиг.1*Хистограма на резултатите.*

От фигура 1 се вижда, че разпределението на измерваната величина не е нормално (Гаусово).Затова, се използва ***критерия на Ирвин***. След проверка на критерия, се установи, че няма груби грешки. Защото за всяко $\eta_к$ получаваме, $\eta_к \le \eta$ таблично=1,0 за 100 измервания и ниво на достоверност p = 0,95, където

$$\eta_k = \frac{(f_i - f_{i-1})}{S(f)}.$$

3. Преглед и обсъждане на съставящите на неопределеността.

Неопределеността на резултата от измерването съдържа две групи съставки.

1.Неопределеност, получена чрез оценяване тип А, посредством статистическа обработка на резултатите от измерването. Към тази група се отнася неопределеността характеризираща разсейването на резултатите от многократни наблюдения.

2. Неопределеност получена въз основа на априорната информация за измерването, чрез оценявания тип Б.

Към тази група се отнасят: неопределеността, свързана с избора на броя отчети от предния панел на виртуалния инструмент, неопределеност, свързана с грешката от нелинейност на АЦП и неопределеност, свързана с изменението на честотата на опорния генератор в АЦП от промяна на температурата на околната среда.

3.1.Документиране и изчисляване на съставляващите на неопределеността.

U_1-*неопределеност*, свързана с разсейването на резултатите от многократните наблюдения (Оценяване тип А).При N>100 може да се приеме, че:

$$u_1 = S(\bar{f}) = 0{,}0055\,Hz$$

U_2- *неопределеност*, свързана с избора на броя отчети $N_{отч}$ от предния панел на виртуалния инструмент (Оценяване тип Б). Изчислява се чрез израза за абсолютна грешка:грешка от дискретизация. Стойността на големината на кванта на преобразуване се определя от измерената честота разделена на броя на избраните отчети:

$$q = \frac{\bar{f}_x}{N_{отч}} = \frac{100}{100} = 1$$

$$\sigma = \frac{q}{\sqrt{3}} = \frac{1}{\sqrt{3}} = 0{,}577Hz$$

q е големината на кванта на преобразуването.

U_3- *неопределеност* свързана с свързана с грешката от нелинейност на АЦП. Границите на абсолютната грешка от нелинейност не надхвърлят 10ppm[4], тогава при прието правоъгълно разпределение ще бъде равен на:

$$\sigma = \frac{q}{\sqrt{3}} = \frac{10.10^{-6}}{\sqrt{3}} = 0,577.10^{-5}\ \text{Hz}$$

U_4-*неопределеност*, свързана с нестабилността на честотата на опорния генератор в АЦП.Границите на абсолютната грешка не надхвърлят 122 ppm [4], тогава при прието правоъгълно разпределение ще бъде равен на:

$$\sigma = \frac{q}{\sqrt{3}} = \frac{122.10^{-6}}{\sqrt{3}} = 0,71.\ 10^{-4}\ \text{Hz}$$

Изчисляване на комбинираната средноквадратична и разширена неопределеност на резултата от измерването **Uc**:

$$u_c = \sqrt{u_1^2 + u_2^2 + u_3^2 + u_4^2} = 0,577$$

При ниво на достоверност р = 0,95, коефициентът на припокриване к е 2 и разширената неопределеност е равна на:

$$U = k.u_c = 2.0,577 = 1,15\ Hz \quad k=2$$

Обобщение на бюджета на неопределеността [2] е даден в Табл. 1.

Таблица 1.*Бюджет на неопределеността*

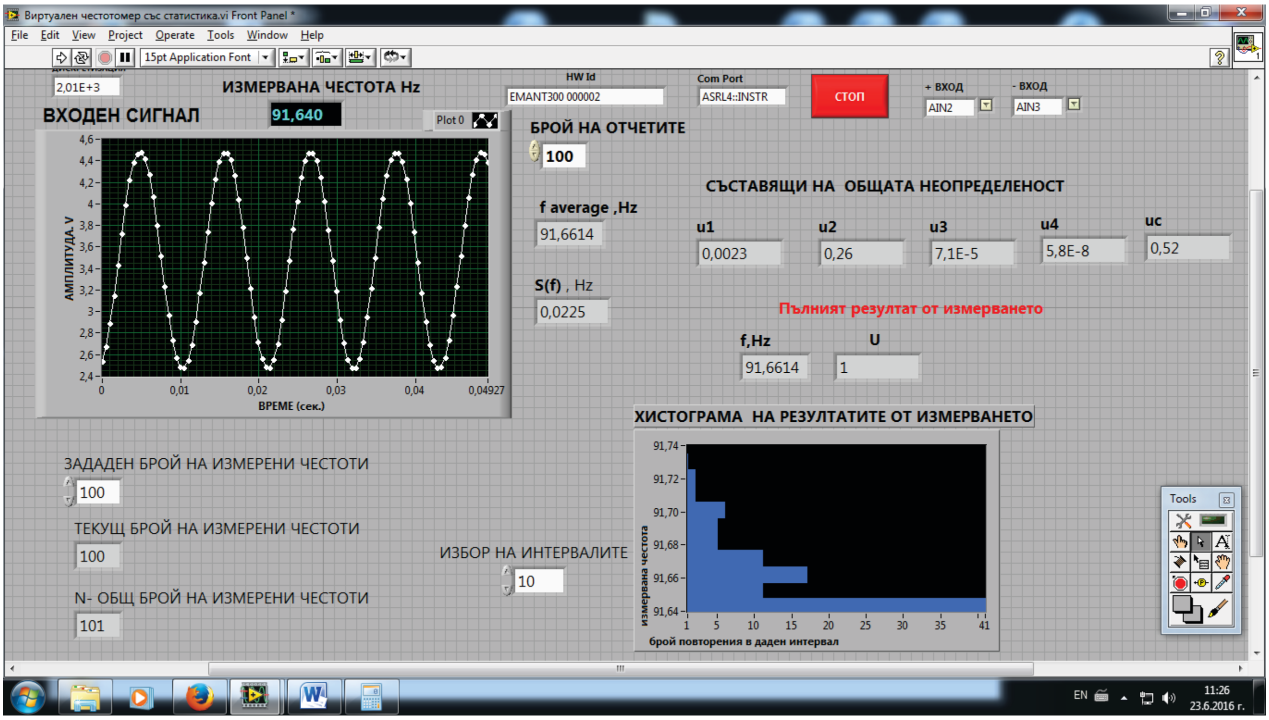
Съставляваща i	Тип оценяване	Тип разпределение	Брой измервания N	Коефициент на разпределението b	Стойност на съставляващата на неопределеността u_i, Hz
u_1	А	Правоъгълно	100	-	0,005
u_2	*Б*	Правоъгълно	-	0,6	0,577
u_3	*Б*	Правоъгълно	-	0,6	$0,577.10^{-5}$
u_4	*Б*	Правоъгълно	-	0,6	$0,71.\ 10^{-4}$

4. Разработване на виртуален инструмент за многократни измервания.

С така направената постановка се разработи и виртуален инструмент, който да реализира по горната процедура автоматизирано и контролируемо. Като аналого-цифров преобразувател се използва система за събиране на данни АЦП – EMANT 300 [3] и персонален компютърсъс заредена програмна среда LabView8.5.

На предния панел на разработения виртуален инструментпоказан на Фиг. 2, са включени следните възможности:Наблюдение на входния измервателен сигнал, цифрова индикация на измерената честота,означение на кои входни портове е сигнала,индикация на ID, време да измерване,зададения брой на цифрови отчети,зададения брой на многократното измерване на честотата на сигнала,индикатор за номера на текуща измервана честота,индикатор на общия брой измерени честотии,измеренана средна стойност на честотата,измерената средноквадратична стойност на извадката, хистограма на многократните измервания, четирите видове съставки на неопределеностите и техните стойности, разширената неопределеност,крайният резултат.

На фиг. 2 е показан един резултат от направените експерименти. А именно, както се вижда това са следните стойности на проследяваните параметри :***Стойността на измерената честота*** $f_{average}$ ***91,661Hz.,стойността на средно кв. откл*** S_f



Фиг.2. *Преден панел на разработения виртуален инструмент за обработка на преки многократни измервания в реално време.*

0,0225, избрания брой отчети - 100 , избрали сме брой измервани честоти – 100, хистограмата на разпределение на тези 100 измервания на една и съща честота,съставящите общата неопределеност :

$$U_1=0{,}0023 \quad U_2=0{,}26 \quad U_3=7{,}1 . 10^{-5}$$

$$U_4=5{,}8 . 10^{-8} \quad U_c=0{,}52$$

5. Заключение

Резултатите от проведени измерванията никога не са абсолютно еднакви и без колебания, защото зависи с колко чувствителен уред ще се проведе експеримента и при какви условия, а също и от използваната измервателната техника. Ето защо „неопределеността на измерванията” е част от резултата на измерването. Тя е необходима и допринася за установяване на прецизността в изразяването на измерената величина. Неопределеността на измерването трябва да е известна за всяко измерване. Всеки резултат от измерване е известен само в границите на своята неопределеност. Бюджетът на неопределеността обобщено представя оценяването на съставящите на неопределеността на резултата от измерването. Бюджетът включва списък на всички източници на неопределеност, свързаната с тях средноквадратична неопределеност и методите за нейното оценяване. Изхождайки от казаното до тук, разработката може да се използва навсякъде, където има потребност от такава обработка на резултати, а също и от студентите като обобщен пример на методиката по изразяване на неопределеността на измерванията. Тази методика за задаване на неопределеността на измерването се изисква в много страни и е задължителен елемент от документите за сертификация на дадено изделие.

ЛИТЕРАТУРА

1. ISO/IEC GUIDE 99:2007 (E/F)
2. Радев Х., *Метрология и измервателна техника* , том 1, Софттрейд, 2009г
3. http://emant.com
4. https://www.dataforth.com/signal-conditioning-accuracy-vs-resolution.aspx

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HIGH SENSITIVE LONG DISTANCE SCANNING FIBER-OPTICS LASER SENSOR SYSTEM

MARGARITA DENEVA, MARIN NENCHEV

Abstract: *The principle of the proposal is to use laser with long (25 m and more) resonator, composed by series of short free space parts, coupled by long optical fibers. We combine the laser with such resonator construction with spectral characteristics of the generation, which are appropriate for intra-cavity laser spectroscopy registration of expected atoms and molecules (including atmospheric non-desired pollutions – SO_2, NO_2, Na etc.). The registration on the base of the intra-cavity laser spectroscopy (ILS) method makes the laser developed extremely sensitive for atoms or molecules presence in the investigated spaces of the resonator free-space region, in principle down to single atoms. The laser spectral control includes also original solution for producing suitable controlled multi-bands spectrum for simultaneous monitoring in different spectral bands. The laser system proposed is very convenient for controlling the air purity in number of rooms in given laboratory, enterprises, where the presences of the non-desired pollutants are expected. We treat theoretically the system action and present the experimental laboratory test on the example of registration of Sodium atoms presence in the air.*

Key words: *intra-cavity spectroscopy, special laser system, long resonator, multi registration parts, theoretical treatment, experiment with Sodium atoms*

1. Introduction

Specialized laser systems are established at present as important tools for distant monitoring of air pollutions, in ecology, in industrial enterprises producing different type chemical materials, in military production, etc. [e.g. 1-4]. Here we propose high-sensitive long-distance scanning fiber optics laser sensor system for such ecological control, especially for monitoring of close working places (number of separated rooms). The principle of the proposal is to use laser with long (50 m and more) resonator, composed by series of short free space parts in each monitored place (room), coupled by long optical fibers and combined by the laser with such resonator construction with spectral characteristics of the generation that are appropriate for intra-cavity laser spectroscopy registration of expected atoms and molecules (including atmospheric non-desired pollutions – SO_2, NO_2, Na, etc.). The registration on the base of the intra-cavity laser spectroscopy method makes the laser developed extremely sensitive for atoms or molecules presence in investigated free-space resonator region, in principle down to single atoms. Except the cheapest engineering realization, the important advantage is the completely elimination of possibility for spark formation that is of essential importance for the military production specialized enterprises. We present also the experimental laboratory test of developed such system by registration of Sodium atoms presence in the air in different places.

2. Details of the principle of the proposed system

2.1. General description

The laser source, which is suitable for intra-cavity spectroscopy, is with homogeneously broadened amplification and with controlled wide-band generation. As an additional advantage in our case, the spectrum is tunable in the laser gain. The general condition for application of the laser source in intra-cavity laser spectroscopy is that the spectral band of the emission must be smooth, structure-less. The principle of the extremely high sensitive intra-cavity registration consists in this that the spectral absorption lines of the investigated atoms or molecules presented in the laser cavity make holes in the smooth laser spectrum.

The drastically increasing of the sensitivity in comparison with this one in the case of the extra-cavity registration is result of strong competition between the generation at different lines in the wide

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spectrum in the homogeneous broadened active laser medium [5,6]. The introduction of smallest losses for one line leads to strong decreasing or suppressing of the lasing at this line. The additional important factor to increase the competition and respectively - the sensibility is to use temporally long generation – long pump pulses (flashlamp-pumping with long exciting pulses or cw diode pumping) or cw operation. The condition to be avoided the typical structure in the wide-band laser spectrum is that in the resonator are precluded any parallel reflective surfaces (including low reflection), forming the resonance structure of Fabry-Perot type. As very convenient laser for intra-cavity laser spectroscopy, which is applied here, following our earlier work [7], is a waveguide type laser that naturally enables to exclude the parallel surfaces into the cavity and to obtain smooth spectrum.

The schematic of the system proposed, taking into account the given general description, is presented in Fig.1.

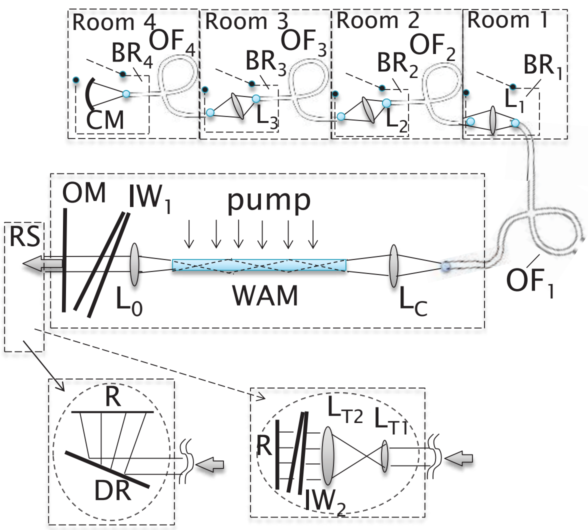

Fig. 1. *The schematic of the proposed system*

In the proposed system, the laser is composed by a capillary-tubular cuvette filled with liquid active medium (WAM) or other type waveguide realization active medium; pump source, and the special resonator. In one side of the WAM the resonator reflector is formed by output coupling using wedged mirror OM (R= 0.96), spectral selective and tuned Interference Wedge IW [8] and focusing lens L_o. The last transforms the emitted light from the output of the waveguide AM. In the other side, the resonator reflector is formed by series, numbered with *i*, (*i* = 1,2,3,4), of boxes for registration BR_i connected via long optical fibers (OF_i) that are coupled each other with the corresponding lens (L_i *; all lenses in the system are AR coated*) and at the end of fiber OF_4 with retro-reflected output by the end-concave mirror CM. The each box is disposed in the corresponding room – $Room_i$. The registration subsystem RS consists of spectrum analyzer, which in one variant is based on diffraction grating DR in near grazing incident angle, where the resolution is highest, and photograph-plate R with corresponding construction arrangement (first inset in Fig.1, details are not shown) or realized on the base of CCD matrix. In equal manner, the spectrum can be registered after expanding telescope (L_{T1}-L_{T2}) and using convenient Interference Wedge IW_2 [8, 9] second inset in Fig.1. Below, as a point of the presentation, we give general detailed description of the characteristics of the system, which leads to the reality of its expected advantageous practical functioning.

The laser is the waveguide flashlamp pumped dye laser (in other realization can also be suitable spectrally semiconductor laser and flashlamp pumped Ti:Sapphire laser). The dye active solution – 3.10^{-4} mol/l Rh6G in ethanol, flows through the cell that is cylindrical glass capillary-tube with internal diameter of 1 mm, external diameter of 10 mm and length of 100 mm. The pumping is by flashlamp in elliptical type reflector thus assuring the exciting pump energy of 10 J in 15 µs pulse (rise front 2 µs, plato 4 µs and fall front 7 µs - at half maximum). The focal length of the lens L_o is 10 cm and for the lens L_c it is 5 cm, respectively; the radius of end-concave mirror CM is 5 cm and its reflectivity is 99 %. The IW_1 and IW_2 are composed by dielectric layers and both are with thickness of 3 µm, wedge angle $5x10^{-5}$ rad and reflectivity of the composed mirrors for IW_1 – 0.8 and for IW_2 - 0.3. The mechanical construction of each box (20x20x25 cm) contains a door that can assure its prevention of the registration, i.e. the corresponding room to be out of control. The aim of such isolation is to assure possibility to monitor each room separately. The total length of the high quality connected optical fiber is with β = 7 dB/km (multimode, 125/250 µm) and the total length of the fibers is 15 m. Accepting that the loss of any connection (by lenses L_i) is (0.2-0.3) dB, the ratio (returned power/incident power) for total fiber system can be evaluated to be of order of (0.55 – 0.6), or the fiber part can be accepted as equivalent mirror with reflection of ~0.6.

2.2. Theoretical description of the system action.

A discussion of the strongly increased sensitivity obtained by applying intra-cavity spectroscopy technique will be presented.

In the consideration we will use the values of laser system discussed in the previous point. The differential rate equations system [5], adapted for description of the case under investigation described Rh6G dye solution and pumping with the system parameters described above, is:

$$\left|\begin{array}{l} \dfrac{dN_2}{dt} = R_p(t) - \left(\sum\limits_i B_i \cdot q_i\right) \cdot N_2 - \dfrac{N_2}{\tau} \\ \dfrac{dq_i}{dt} = Va \cdot B_i \cdot q_i \cdot N_2 - \dfrac{q_i}{\tau_{c_i}} \end{array}\right.$$

with $P_{out_i}(t) = (\gamma_1 \cdot c/2L') \cdot h\nu \cdot q_i(t)$

Here q_i are the generated photon number for the corresponding wavelength in the considered laser spectrum; P_{out_i} is the corresponding output power, which integration in the time (from 0 to the length pulse) gives the output energy. In the systems, with N_2 is noted the population of the upper laser level per unit volume in the WAM. The term $B_i = (\sigma_e^i \cdot l \cdot c)/(V_a \cdot L')$ [s^{-1}], where σ_e^i is the emission cross-sections for the given wavelength in the laser spectrum; V_a is the working volume (0.05 cm^3); c = 3x10^{10} cm/s is the light velocity; $L' = L + (n-1) \cdot l$ - the optical length of resonator, where $l = 10$ *cm* is the length of the active medium, n is the refractive index and L is 25 m. The time term τ of 3 ns is the lifetime of the upper laser level for the Rh6G WAM. The dumping time of a photon in the resonator is $\tau_{c_i} = L'/(c \cdot \gamma_i)$, where γ_i [5] describes the loss into the resonator for the wavelength in the considered laser gain spectrum (depending on the reflectivity of the combined end resonator mirror OM, IW_1 and Lo). The system was solved numerically by Runge-Kutta-4 method. From the solution we obtain q_i(t) and the respective output power for each wavelength in the spectrum; γ_1 characterises the output of the laser resonator. The calculations are prepared for the spectral range (588 – 591) nm, in which the Sodium D-lines are also comprised.

In the example considered we will compare the extra-cavity and intra-cavity registration of presence of Sodium vapors outside and inside of the described special resonator. We will study the behavior of the formed by the Sodium atoms absorption holes in the spectrum at the Sodium D-lines (doublet D_2 =589.0 nm and D_1=589.6 nm). Let's we accept that the same volume of Sodium atoms with the same concentration and length – path of the laser beam through the volumes, is disposed one time outside the resonator and after this - inside the resonator. Let's the Sodium atom concentration provides absorption losses for single pass at D_2 line of 1% (respectively – 0.5 % for D_1 line). Using the given above differential equation system, we obtain the spectra of laser light for the two cases.

For the extra-resonator case (simple passage) we obtain practically non-observable (or specially detected holes due to of 1 and 0.5 % absorptions at the lines). The calculated output laser spectrum for this case is shown in Fig.2, in the inset the formed hole by the absorption at D_2 line in expanded scale is given.

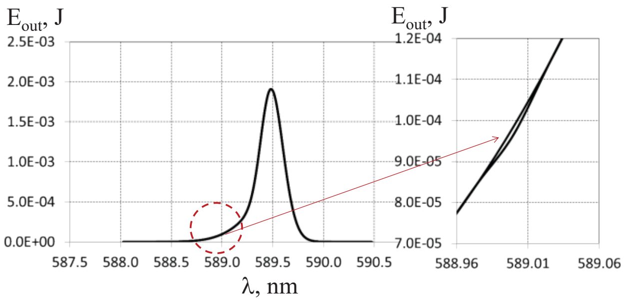

Fig.2. *The calculated output laser spectrum for the case of registration by single passage through the Sodium D-lines. In the inset is shown the formed hole by the absorption at D_2 - line (the figure is expanded).*

The calculations for the intra-cavity case of emission spectrum with the same volume of Sodium atoms, gives the picture, shown in Fig.3. The drastically increasing of the holes at the D-absorption lines can be seen. This confirms our expectations for the possibility for high sensitive registration of desired atoms presence by application of the proposed laser system and for monitoring of such presence in few rooms.

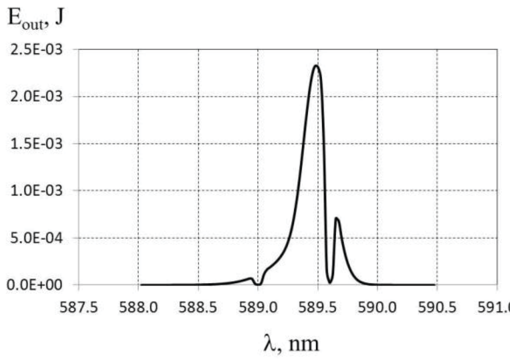

Fig.3. *The calculated output laser spectrum for the case of intra-cavity registration by single passage through the Sodium D-lines.*

Let us evaluate the concentration of the Sodium atoms that leads to 1% decreasing of the transmission – i.e. the case considered above. Following Ref. [9] we can write:

$$I/I_o = \exp(-\sigma \cdot N \cdot l_a)$$

where I_0 is the incident intensity, I – the intensity of the transmitted beam, both I_0 and I for wavelength of the absorption line, $\sigma = 6.10^{-12}$ cm^2 is the absorption cross-section for the D_2 line and l_a=5 cm is the path of the beam trough the volume with Sodium atoms. For these conditions, after a simple arithmetic, we obtain that N is of order of $(10^7 \div 10^8)$ cm^{-3}. Thus our system assures reliable registration of presence of Sodium atoms with such concentration.

3. Experimental test

In the given in the work practical test-realization (example) that clarifies the system action, we use only two structures - BR_1 and BR_4, excluding BR_2 and BR_3. Both optical fibers OF_1 and OF_4 were with length of 1 m each and damping factor β = 300 dB/km and four connections with the lenses (equivalent mirror with reflection ~ 60 %). The other used characteristics of the elements and of the construction are the given above. The volume of Sodium atoms is formed by burning of three standard matches with the flame outside the cavity near the output mirror OM (extra-cavity spectroscopy) or inside the cavity - in the space between the cell output and lens Lc.

The typical real spectra of the emission of laser system with spectrum of generation tuned at Sodium D-lines are given in Fig.4. The top spectrogram (Fig.4a) is for the case when the Sodium atoms are formed outside the cavity and the laser light passes through the space with the Sodium atoms (absorption outside the cavity). The bottom spectrogram (Fig.4b) is for the case of presence of the Sodium atoms inside the complex laser cavity.

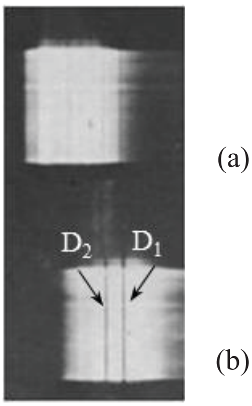

Fig.4. *Typical real spectrums of the laser system emission with spectrum of generation tuned at Sodium D-lines. The top spectrogram is for the absorption outside the cavity and the bottom - for the Sodium atoms inside the complex laser cavity. The strong increasing of the sensitivity is evident.*

In Fig.5 are shown the corresponding trace-curves for the two spectrograms – left for the given in Fig.4(a) and right – for the spectrogram in Fig.4(b).

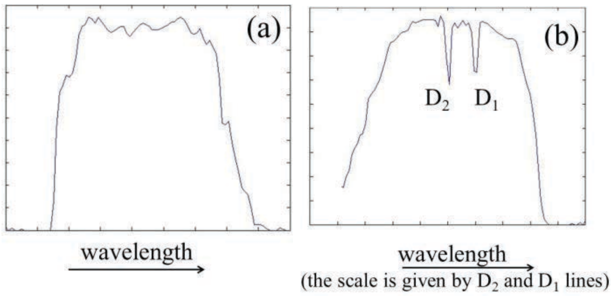

Fig.5. *The corresponding trace-curves for the two spectrograms in Fig.4 – left for case (a) – Sodium atoms are outside the cavity (practically the absorption D-lines are not observed) and right for the case (b)– the atoms are inside the cavity (real observation of the D-lines). The scale is given by the holes of D_2 and D_1 lines marked on the figure.*

Following the theoretical considerations, given above, and the obtained spectrograms, we can conclude that practical laboratory model of the system proposed is able for real registration of Sodium atoms with concentration ~ 10^7 cm^{-3}. This concentration can be accepted to correspond to the obtained one in the matches flame.

4. Discussions

Following the results from the theoretical analysis and from the carried out experiment we make in evidence the feasibility of the proposed system and its advantages for specific ecologic monitoring and survey for dangerous pollutions, accompanied the industrial production. The sensibility of such intra-cavity spectroscopy based technique is more than of order of magnitude higher than the standard extra-cavity laser technique. Very suitable laser sources are these one that avoid the flat parallel reflected (as well as partially) surfaces, what in high degree is natural property of the waveguide laser sources. With application of modern low-losses optical fibers and suitably treated elements (without parallel surfaces, there is no parallel passage of the light rays) the proposed system can be organized as very suitable technical instrumentation for extremely sensible detection of desired pollutant atoms. Note that in particular case of many rooms disposed at both sides of building corridor, the optical fiber part of the resonator can be adapted to form a ring type laser resonator. This will permit to use more effectively fiber parts of the resonator.

5. Conclusion

In the work is proposed the principle of the special laser system with an optical fiber based long (20 m and more) resonator, composed by series of short free space parts, coupled by long optical fibers. We combine the laser with such resonator construction with spectral characteristics of the generation that are appropriate for intra-cavity laser spectroscopy registration of expected atoms and molecules. As it is shown, the registration on the base of the intra-cavity laser spectroscopy (ILS) method makes the developed laser extremely sensitive for atoms or molecule presence in investigated spaces of the resonator free-space region. The laser spectral control includes also the original solution with Interference Wedge for producing suitable controlled multi-bands tunable spectrum (for monitoring in different spectral bands). The theoretical treatment of the system action and the experimental laboratory test for registration of very low concentration presence of Sodium atoms in the air confirm the feasibility of the system and its expected advantages. The laser system proposed is very convenient for controlling the air purity in number rooms of given laboratory, enterprises, where the presence of the non-desired pollutants is expected.

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REFERENCES

1. W. Demtröder *Laser spectroscopy: basic concept and instrumentation*, (2003) 3rd ed. Springer, Germany and the literature therein.
2. P. Sudhakar, P. Kalavathi, D. Ramakrishna Rao, M. Satyanarayana (2014). Design of Laser Based Monitoring Systems for Compliance Management of Odorous and Hazardous Air Pollutants in Selected Chemical Industrial Estates at Hyderabad, India. *Remote Sensing and Spatial Information Sciences*, volume XL-8, *and the literature therein* .
3. E. D. Hinkley, P. L. Kelley. Detection of Air Pollutants with Tunable Diode Lasers, *Science* 19 Feb 1971: Vol. 171, Issue 3972, pp. 635-639, DOI: 10.1126/science.171.3972.635
4. Бураков В.С., Исаевич А. В., Мисаков, П.Я., Ненчев М.Н., Патриков Т.В., Пашов А.Е., Пешев З.И., Расширение аналитических возможностей внутрирезонаторных лазерных спектрометров, *Приб. и техн. Эксперимента - ПТЭ*, No 5, 1994, 150-156, (RUSSIA, trad. and parallel ed. in USA – *Prib. Tech. Eksperimena*, (1994) Improvement analytical …, Burakov V. S. et all); M.Deneva, E.Krasteva. P.Bakardjiev, M.Nenchev (2001). Tunable laser devices with inverted spectrum for application in intracavity spectroscopy and spectral selective excitation of atoms, *Proc. of LTL Plovdiv'2001, International Symposium* (2001) 153-156.
5. O.Svelto. *Principles of lasers,* 5th ed. Springer Science-Business Media, 2008.
6. M.Deneva, P.Uzunova, M.Nenchev, Tunable subnanosecond laser pulse generation using an active mirror concept", *Opt. and Quant. Electronics*, 39 (2007) 193-212, **USA**
7. M.Nenchev, V.Stefanov, A. Gizbrekht, Study of Self frequency locking in dye laser at the Sodium D-lines. 3rd Confer. on Luminescence, Szeged, Hungary,1979, Confer. Digest,. Vol.1, 135-139 (in Russian); M.Nenchev, V.Stefanov, A.Gizbrekht, A.Bokhanov, Self frequency locking in lasers at lines of intracavity gases, Bulg. J. Phys. 7, (1981) 521-524
8. E.Stoykova, M. Nenchev, Gaussian Beam Interaction with Air-gap Fizeau Interferential wedge, *J. Opt. Soc. America A*, 27 (1), 58-68 (2010)
9. Y.H.Meyer, M.N.Nenchev, On intracavity absorption and self-frequency locking in pulsed dye laser. *Opt. Communs.*, vol.4, No5, (1982) 292-294 and the literature therein.

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THERMO-SENSITIVE PAPER APPLICATION AS METHOD FOR LASER BEAM SPOT STUDY – CASE OF Q-SWITCHED LASER PULSES

VALKO KAZAKOV

Abstract: *Recently, we have developed, as a new technique for laser spot profile investigation, a combined spot registration on appropriately chosen thermo-paper with convenient computer treatment [3]. Such technique presents some essential advantages: spectral insensitivity in very large range (from UV to IR); the registration is not affected by electromagnetic noise; as addition, it is extremely cheap and accessible. Here, on the base of our previous experience, obtained mainly with free lasing Nd:YAG laser pulses, we present results of application for Q-switched pulses of this laser. Some specific behavior of the registration under condition of more than thousand times shorter pulse influence than in free lasing are shown and the condition – power density and energy density limits of correct registration are carried out. The technique under carefully laser illumination control can give acceptable results also in the considered case.*

Key words: *laser spot study, thermo-sensitive paper, Q-switching.*

1. Introduction. General aim of the work.

The aim of the work is extension of our previous results, related with development of the practical application of **T**hermo-**S**ensitive **P**aper **R**egistration **T**echnique (TeSPeRT) for laser spot imaging. This old technique [1, 2] is used in the literature and in the laboratory practice only for visual illustration (including also successfully - for the interesting cases) of the laser spot. The base of the technique, as a rule, is the whitening in the laser beam incident area on the black thermo-sensitive paper. In previously reported applications [1, 2] are used accidentally taken sensitive materials and without conclusion about energetic characteristics of the spot. As we have shown in Ref. [3], in condition of combining the convenient chosen thermo-sensitive paper for registration and convenient computer treatment, and with correctly defined illumination, this technique can be successfully used for laser beam energetic parameter study. In the noted work we demonstrate the correct determination of the energy density distribution in the beam cross-section, as well as evaluation of the beam energy. Our previous investigation is by the use of the free lasing Nd:YAG laser light (pulse length 0.1 – 3 ms; power ~ 10 - 40 kW). The obtained results confirm the usefulness and the expected potential of the technique developed by us, especially for the condition of typical free lasing light emission. Taken into account the essential difference between the characteristics of the free lasing and Q-switched laser pulses, especially temporal (ms against ns) and power (kW against hundreds kW for comparable energies), the application of the developed by us technique for the Q-switching case needs particular treatment of the Q-pulses registration, which is the aim of the presented work. Here, we present the results of noted above study and namely concerning the energetic aspects and conditions for correct applications of the TeSPeRT for Q-switched laser pulses treatment. Note that such technique presents some essential advantages in comparison with electronic based techniques of this type: spectral insensitivity in very large range (from UV to IR); the registration is not affected by electromagnetic noise; and as addition, it is extremely cheap and accessible. The beam-profile knowledge is of essential importance in the laser manufacturing and in the scientific and practical application of the lasers [1 - 5].

2. Experimental investigations and results.

We start the proposed study using the results, given in our previous work [3], about the free laser pulse light treatment applying TeSPeRT. In the work [3] we have presented and discussed the principle and the convenient condition to obtain correct energy density distribution in the laser beam cross section. The given there results are for pulse

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energies in the range of 0.3 J to 10 J with pulse duration in the range 100 - 3000 μs – i.e. the typical free lasing operation of used in the tests Nd:YAG lasers (at 1.06 μm and 1.36 μm generation). Taken into account the well-known essential difference between the characteristics of free lasing and Q-switched laser pulses, especially temporal and pulse power characteristics [1, 2], we provide systematic study for the case of the Q-pulses registration by the TeSPeRT.

In the study of free lasing case in Ref. [3], we have shown that a very suitable material for the beam spot marking is the tracing paper, blacked at one side through the copy machine and illuminated at the non-blacked side by the laser beam. Here, following our works [3] and complementary investigations, we have used for beam spot registration the same type of tracing paper (A4 92 gr/m^2 from Sihl Digital Imaging Company), blacked one (1X), two (2X) or three (3X) times through the standard xerography type action machine - Konica Minolta Dialfa Di 5510. The blacking-out was made by copying the tracing paper at normal blacked position of the machine option. We do not observe noticeable difference comparing few tracing papers from different producers and also the blacking by different copiers of the noted before type (Sharp-MX-3500, Toshiba 2500c) for normal blacking operation. The transmission of pure tracing paper is measured to be ≈ 50 % when the paper is placed closely to the entrance of the light power meter (Thorlabs SN6050506). In this manner the measurement with flat and large entrance of 2 cm diameter accept all the diffused light. We used both He-Ne yellow (0.595 μm) laser beam with incident diameter on the paper of ~ 2 mm and power of 3.6 mW, and focalized light from standard electric bulb with tungsten filament. There is no notable difference of the measured transmissivity. The corresponding measurements of the transitivity after blacking are: for 1X - (10 ± 2) %; for 2X - (1 ± 0.1) % and for 3X ≈ 0.1 %. The transmission through marked spot by Q-switched pulse is measured to be ≈ 25 %, which is ~ 2 times more than the transmission through spot illuminated by free lasing pulse with the same energy – given in Ref. [3]. There are quite differences in 2D and 3D graphics, when the Q-switched marked spot is scanned with white cover and with black cover. The graphics of spots, scanned with black cover are with unusual form and lower height than is expected to be. Hence, in case of Q-switched pulses there is not only whitening of the blacked paper, but also cleaning at some points of the spot where is a higher power density and there the blacked paper is transparent like a pure tracing paper. The computer treatment in this work is made after scanning the spots by scanner with white cover. Thus, the cleaned/ transparent points of the spots are scanned like white points, which gives more accuracy, because the base of the method is whitening proportional to the energy/ power density. In case of free lasing, there is no notable difference between scanning with white or black scanner cover, because there is only whitening without cleaning of the blacked layer.

As a laser beam source for the investigation we used passively Q-switched Nd:YAG laser. The study was performed at laser parameters: generally for the energy between 0.1 J to 1.5 J and pulse length 1 μs ± 0.2 μs; repetition rate – single pulse (to 1 Hz); emitting at line 1.06 μm. In most of the experiments the energy of the beam, illuminating the studied material, was equal to the laser output energy, except the case where fine plate filters were used. The energy was measured with FIELDMAX energy meter, Coherent (USA), the pulse duration - with two-channel 200 MHz storage oscilloscope RIGOL DS1202CA (USA) and light detectors with resolution better than 5-ns - R-108 (BG).

At the left side of Fig.1 are shown the typical marked spot by Q-switched pulse (Fig.1a) and the graphs, obtained by 3D (Fig.1b) and 2D (Fig.1c, across the spot diameter of ~ 0.7 cm) computer treatment of its whitening. The Q-pulse duration is ~ 1 μs and the pulse energy is 0.88 J on the 1X type of paper. For comparison, in the same picture at the right side are shown - the spot, made by the free lasing laser light (Fig.1d) and the 3D (Fig.1e) and 2D (Fig.1f) computer treatment of the white spot. The free laser pulse duration is ~ 300 μs, pulse energy ~ 1.17 J and spot diameter is ~ 0.7 cm. The computer curves are normalized to their maximal values.

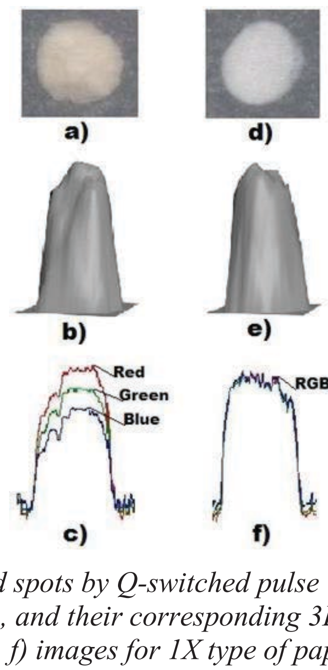

Fig.1. *Marked spots by Q-switched pulse (a) and free lasing (d), and their corresponding 3D (b, c) and 2D (e, f) images for 1X type of paper.*

The general difference between the Q-switched and free lasing spots, as it can be seen also in Fig.1, is that the Q-spots are colored in red. This leads to different colors presentation of the 2D image of the spot – red, green and blue curves. This is quite different from the 2D image of the spot for the free lasing, where the three colors practically coincide completely. We attribute this difference with formation of products of burning and/ or photochemical reaction at the black layer due to the high power of the illuminating light in the Q-pulses. The nature of the coloring needs future chemical investigation. Thus, the first step of the investigation is to see: i) at which degree the registration (near constant R, see below) is correct when we use for beam chosen color and ii) which color corresponds better with the real energy density distribution in the spot. The curves of the three colors that describe the 2D description of the graph are shown in the figure with notation – Red, Green, Blue and their composition as RGB.

We accept, as approach to computer treatment of the spot, the methodology argumented, developed and experimentally tested in details in Ref. [3] (our previous work for the free lasing case). Thus, following the discussion of this work, for criterion of correctness for the obtained energy density distribution $W_E\,(x, y)$ J/cm^2 in the spots, we will use the ratio $R = E/\,V$ of the pulse energy E and the calculated volume V under the computer obtained envelop graph $W_H\,(x, y) = W_E\,(x, y)/\,K_1$ of the whitening. The constant value of $K_1 = R = E/\,V$ can serve as a criterion for correctness of energy density distribution, obtained by the experimental measurement of E and computer treatment - the arbitrary graphs of whitened and computed volumes under the 3D graphs.

Following the formulated above problems, we treated series of stamps with spots on the described blacked tracing papers, illuminated by variety of Q-switched pulses (Nd:YAG, 1.06 μm). The passive Q-switched operation of the laser was with controlled variable energy output between 0.1 J and 1.5 J and pulse length of ~ 1 μs. For the spots with diameter of 0.7 cm, the energy (and the power) density vary respectively between ~ 0.5 J/cm^2 (0.5 MW/cm^2) and 3 J/cm^2 (3 MW/cm^2).

Preliminary question is the dependence of the pulse energy (and power) density and especially limits of notable marking and saturation. We found that for the three investigated type of papers - 1X, 2X, 3X the noted limits are relatively close to each other - minimum energy density for reliable registration was ~ 0.5 J/cm^2 (power density ~ 0.5 MW/cm^2) and the saturation was observed for ~ 3 J/cm^2 (~ 3 MW/cm^2).

As example of the realized investigations, a collection of Q-switched laser light spots marked with different pulse energies on the paper 1X, noted as Q1, Q2, Q3, Q4 and their computer treatment are given in Fig.2. For comparison are given also the two spots F1 and F2 of free lasing pulses.

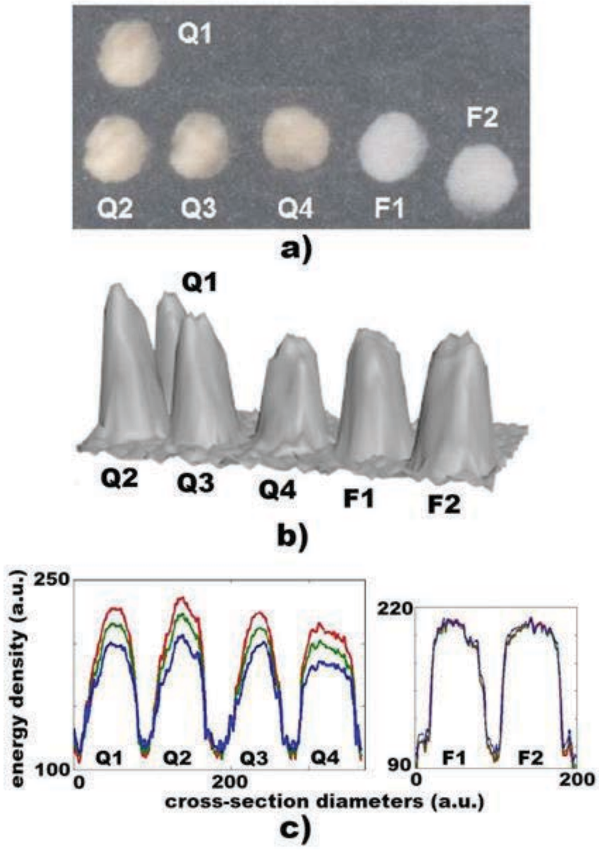

Fig.2. *Marked spots by Q-switched pulses Q1 - Q4 and free lasing light formed spots F1, F2 on 1X type of paper (a); their 3D (b) and 2D (c) graphics.*

The correctness of TeSPeRT applications for the free lasing case is shown in Ref. [3]. Thus, we treat here the Q-switched pulse spots. The pulse length is ~ 1 μs and the pulse energies are given in Table 1. In the same table, the calculated volumes under the 3D graphs and the ratio R_i for the RGB registration are also given. With RGB are noted the averaged curves, giving the average value for each point from the sum of the corresponding points for the three curves. The computer program automatically gives the averaged volume of the volumes for the three colors scanning. We have also study separately the 3D images for each color and the results are shown in the Table 2 and Table 3.

Processing of each paper type will be detailing described on the example of 1X, for which the best results are obtained. After computer treatment of the four (Q1 – Q4) spots shown in Fig.2 and with measured light energy that forms each of them, we obtained the average value $R_{av}=(\sum V_i/E_i)/N=\sum R_i/N$, where sum is for i = 1 - 4,

V_i and E_i are the volume and the energy of the spots numbered as ***i*** and $N = 4$; $R_{av} = 1.29$. We defined the deviation (or error) ΔR_i for each spot as $\Delta R_i = R_i - R_{av}$ and the relative average deviation for the considered group spots of 1X sheet was $\Delta R_{av} \approx 0.12 = 12$ %.

Table 1 and Table 2 are illustrations of the analisys - measured energies and calculated characteristics of the computer treatment for the averaged three colors (RGB) and separately – for each color – red, green, blue. The sheet is 1X, which gives the best results.

In the same manner, we have treated the noted other cases. The results are given in Table 3 - comparison of the results of treatment for the two types blacked tracing paper - 2X and 3X.

Table 1. *Characteristics for 1X type of paper – energy and results for averaged three colors (RGB)*

№	E, [J]	V(RGB), [a.u]	R_i, [a.u.]	R_{av}, [a.u.]	$\lvert\Delta R\rvert$, [a.u.]	ΔR_{av}, [a.u.]	ΔR_{av}/R_{av}, %
Q1	0,95	1,09	1,14	1,29	0,14	0,12	9
Q2	0,82	1,21	1,48		0,19		
Q3	0,76	1,01	1,32		0,04		
Q4	0,88	1,06	1,20		0,08		

Table 2.a. *Characteristics for 1X type of paper – volume and R_i for R, G, B colors*

№	V(Red), [a.u.]	R_i, [a.u.]	V(Green), [a.u.]	R_i, [a.u.]	V(Blue), [a.u.]	R_i, [a.u.]
Q1	1,19	1,24	1,06	1,19	0,93	0,98
Q2	1,34	1,63	1,19	1,45	1,02	1,25
Q3	1,01	1,44	0,99	1,30	0,87	1,15
Q4	1,17	1,33	1,03	1,17	0,9	1,02

Table 2.b. *Characteristics for 1X type of paper - R_{av}, ΔR_{av}, $\Delta R_{av}/R_{av}$ for R, G, B colors*

Color	R_{av}, [a.u.]	ΔR_{av}, [a.u.]	$\Delta R_{av}/R_{av}$, %
Red	1,41	0,13	8,8
Green	1,26	0,12	9,1
Blue	1,26	0,10	8,8

Table 3. *Characteristics for 2X and 3X type of paper*

Sheet	R_{av}, [a.u.]	ΔR_{av}, [a.u.]	$\Delta R_{av}/R_{av}$, %
2X (RGB)	1,54	0,17	11,4
2X (Red)	1,68	0,19	11,2
2X (Green)	1,51	0,17	11,3
2X (Blue)	1,36	0,17	12,2
3X (RGB)	1,79	0,44	24,8
3X (Red)	1,89	0,45	23,8
3X (Green)	1,77	0,44	25
3X (Blue)	1,55	0,4	25,6

3. Discussion.

The syntheses of the typical most important results of the investigation are summarized in the examples in Table 1, Table 2 and Table 3. Following the results, we can conclude that the application of the technique developed gives acceptable accuracy of the beam profile registration. For the defined parameters of the Q-switched illuminating laser, described in the work, as most suitable blacked paper can be considered the 1X paper type. The average error for this case is ~ 12 %, which is acceptable information for the desired energy density distribution. Interesting fact is that the treatment taking the three colors gives not very different results - less than 1 %.

4. Conclusion.

In the work we present results of developed by us simple, cheap and accessible technique (TeSPeRT) for Q-switched laser beam profile study. We have shown this study using appropriate, well defined and reproducible as a production sensible materials – xerox blacked tracing papers for laser spot registration in combination with suitable computer treatment. This technique can be successfully employed as beam-profile registration method with well acceptable accuracy. We present the conditions (our experiments), when the developed technique shows such applicability. Note that, such technique represents some general essential advantages in comparison with electronic based beam-profile treatment techniques: the registration is not affected by electromagnetic noise and has spectral insensitivity in very large range (from UV to IR).

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REFERENCES

1. Ifflander, R. (2001). *Solid-State Lasers for Materials Processing*. Springer-Verlag Berlin. Heidelberg, New York, series in Optical Sciences. ISSN0342-4111, ISBN 3-540-66980-9 (2001).
2. Carlos B. Roundy, Spiricon, Inc., http://aries.ucsd.edu/LMI/TUTORIALS/profile-tutorial.pdf, Beam Profile Measurements and the literature therein.
3. V.P. Kazakov, M.A. Deneva, M.N. Nenchev, N.Y. Kaymakanova. Xerox treated tracing paper as suitable and accessible material for development of new laser beam–profiler technique. Journal of the Chemical Institutes of

the Bulgarian Academy of Sciences and of the Union of Chemists in Bulgaria 2016 Volume 48 / Special issue G, pp 85-90.;

M. Deneva, M. Nenchev, V. Kazakov, N. Kaymakanova. Development of the thermo-sensitive paper application as method for laser beam spot study. Journal of the Technical University – Sofia, Plovdiv branch, Bulgaria "Fundamental Sciences and Applications", Volume 22, 2016, pp 92-95.

4. P. Uzunova, S. Rabadgiiska, M. Deneva, M. Nenchev et al**.** Proc. SPIE, Vol.8770-54, (2013). Study the penetration of IR laser radiation in human teeth: determination of the absorbed and scattered parts.
5. Deneva M., Nenchev M., Wintner E., Topcu S. (2015). Coaxial-geometry tunable dual-wavelength flashlamp-pumped Nd:YAG laser. *Opt. Quant. Electronics*, DOI 10.1007/s11082-015-0205-5 online publ.

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THE OBSERVATION OF ATMOSPHERIC ELECTRICITY AND LIGHTNING EFFECTS

METIN SALTIK

Abstract: *In this study, using high-precision JFET sensor, the impact of lightning and electrical changes in the atmosphere have been observed. Observations made 24 hours, electrical changes in the atmosphere was recorded. As a result of the observations, in the case of the rise and fall of the sun was observed to vary the electrical load in the atmosphere. On the other hand, is the electrical changes in the atmosphere has been observed that the maximum level of the lightning event. This study also showed that the most important changes are lightning current parameters of atmospheric electricity. Another feature of this study also, taking advantage of the electrical changes in the atmosphere before the earthquake, is to predict earthquakes.*

Keywords: *Atmospheric electricity, lightning, JFET, earthquakes, global atmospheric electricity.*

1.Introduction

The Earth's atmosphere is continually electrified. Our understanding of the global atmospheric electrical circuit has improved since its discovery in the early twentieth century, although this area of geophysics still provides both theoretical and experimental scientific challenges. The variability of the electric field and current density measured at the surface is attributed to meteorological sources, both global and local in origin. By investigating the variability in electrical parameters under different atmospheric conditions, these global and local sources can be separated. As a consequence, information on global thunderstorm and shower cloud activity can be retrieved, which is of direct relevance to research on global climate change.

Thunderstorms, earthquake fault and shower clouds cause separation of electric charge between the ground and ionosphere, an electrically conductive layer about 60 km above the surface. This charge separation causes the ionosphere to have a potential (U_1) of approximately +300Kv with respect to the surface. Ionization from cosmic rays and terrestrial sources produce cluster ions which make the atmosphere weakly electrically conductive. These ions flow vertically because of the vertical potential difference, causing the air-Earth conduction current density, J_c, of order $10^{-12}Am^{-2}$.The total electrical resistance for a unit area of the atmospheric column from the surface to the ionosphere is called the columnar resistance, R_c. The ionosphere-Earth potential difference (U_1), columnar resistance and conduction current area related by Ohms law,

$$U_1=j_c.R_c$$

The physical units of R_C are Ohm.meter^2(or more commonly Pico.Ohm.meter^2 due to the inherently large values).This is because R_C is the integral of resistivity .U_1represents the electric potential of a layer at a height above the surface (the zero potential reference) so the units are in volts(usually quoted in KV).

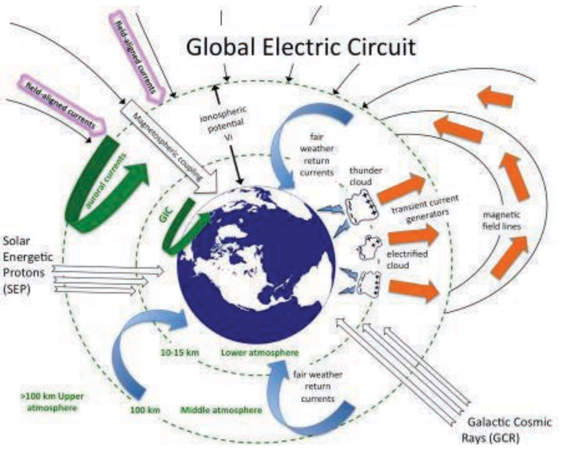

Fig. 1. *Basic components of global atmospheric circuit*

By convention, the electric field (E) is referred to as the potential gradient, defined as the negative of electric field: potential gradient given by

$$F=-E$$

At the surface, the PG arises because of J_C flowing through the electrically conductive air. It is therefore J_C that is the parameter that permits the effect of the global circuit to be measured at the surface, either directly through measurement of J_c itself, or by PG. However, PG is also a function of the local air conductivity (ɗ$_T$). Away from sources of charge separation, the air conductivity (ɗ$_T$),potential gradient (F) and conduction current density are related by Ohm's Law:

$$F=J_C/ ɗ_T$$

The atmosphere is positively charged with respect to the ground during fair weather and fraction to the fault system. This produces a downward pointing (negative) electric field (E) so PG is positive for fair weather conditions. In the fair –weather part of the circuit, small ions dominate the charge transport since that have a large electrical mobility. Therefore an increase in small ion concentration will increase the air conductivity by providing more charge carriers. Aerosol in the atmosphere removes small ions by attachment. An increase in aerosol number concentration therefore reduces the ion number concentration and decreases the air conductivity. A change in aerosol number concentration subsequently modifies the total columnar resistance (R_c) between the ionosphere and the surface, and therefore J_c directly through and consequently has an indirect effect on PG through .

Of the quantities which can be measured at the surface, the air-Earth conduction current density (J_C) presents one of the most fundamental parameters of the global circuit (Chalmers, 1967).   It is therefore of great importance in this study, with its continuo us measurement being one of the aims of this thesis. The conduction current density is one of several components contributing to the total current density, J_S received by a horizontal conducting electrode at the earth's surface, electrically isolated from the ground. J_S comprises contributions from turbulence J_T, conduction J_C, displacement J_D and precipitation J_p,

$$J_S=J_C+J_D+J_T+J_P$$

2. Experimental study

In this study, the electrical changes the electrical charge in the atmosphere with a sensitive FET sensor've recorded._When the records, especially at sundown and sunrise varies the electric field in the atmosphere. This result is evidence that a significant change in the sun's atmosphere electric field._Change features is the sunrise and sunset.

Another important influence,Lightning effect. Lightning effect, other solar influence is dominant or effective. Lightning events, they make a greater impact on global atmospheric cycle. Effects of lightning currents are changes from cloud to cloud. The other effect is from cloud to cloud and the ground. Until the changes in atmospheric electrical activity,_24 hours is seen in the records.

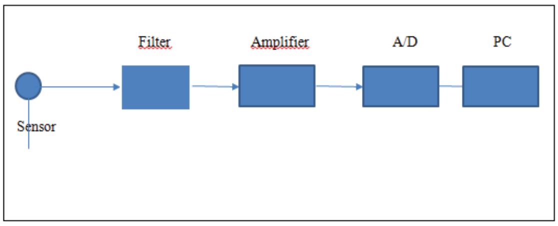

Fig. 2. Block diagram of the measurement system used in the experiment.

3. Results and Discussion

This study is provided below the records obtained. Recordings were obtained on uninterrupted for 24 hours. Register in accordance with the impact of the effects created by the sun seems to be more dominant lightning.

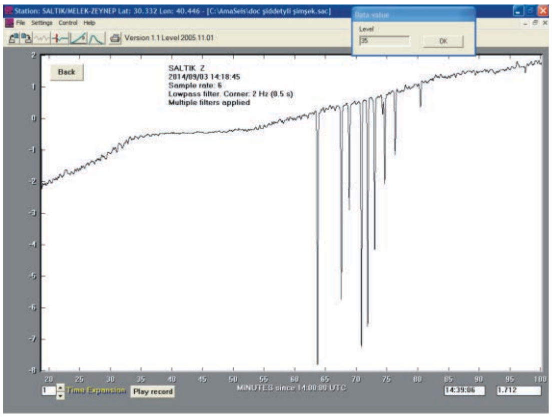

Fig. 3. Changes in the electric field (Heavy rain and lightning two-hour recording)

Changing the direction of flow will change the direction of the electric field change. Here it is seen that the lightning is cloud-to-cloud from the ground or floor.

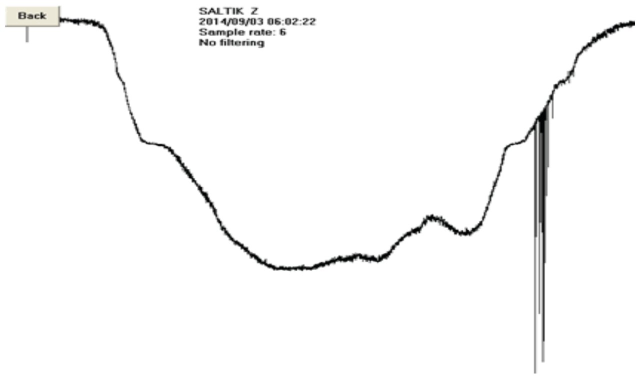

Fig. 4. 24-hour electric field change.(A 10-minute lightning transitions can clearly be seen.)

4. Conclusion

From this experimental study,very significant results were obtained. In this study, it was concluded that the power structure of the atmosphere has been observed many alternate. Results obtained from the experimental study can be expressed as follows.

1. Global atmospheric, other electrically varies from seasonal variations.
2. In electrical changes, the effect of the sun is changing the ion density.
3. Lightning currents cause the biggest change in the atmosphere.
4. Lightning strokes, gives rise to the formation of ions in the atmosphere greatly.
5. Lightning currents, thus affecting a large proportion of the global atmospheric cycle is changing the electrical parameters of the atmosphere.
6. After the lightning impact, depending on the severity of impact parameters, which come to its normal state after a certain time.

References

1._Doctoral studies, Metin SALTIK
2. electrical-engineering-portal 2014
3.Mike Bertone,protect electrical equipment from solar flare,2014
4.V.Gopalakrishnan,S.D.Pawar,P.Murugavel,Kirankumar P.Jhare,Agust 2011
5.Agro meteorology Group-1997
6.Svensmark and Friis-Christensen,1997
7.By Donald E.olson,The evidence for Auroral Effect on Atmospheric Electricity
8.Nehar.1967 and Indian Institude of Tropical Meteorology
9.Bolestad and Nashewski; Pearson Publishing

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SECTION 3 • СЕКЦИЯ 3

INFORMATICS AND COMPUTER SYSTEMS AND TECHNOLOGIES

ИНФОРМАТИКА И КОМПЮТЪРНИ СИСТЕМИ И ТЕХНОЛОГИИ

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RSA ENCRYPTION USING MORE THAN TWO PRIME NUMBERS

TARIK YERLİKAYA, EMRECAN ADLI

Abstract: *Fast and easy usable internet services are one of the gaining of 21.th Century. Online shopping, online messaging even online bank services are most popular ones. Also new attacking techniques have been evolved. To prevent attack to similar services, we have to strengthen our encryption systems. One of them is RSA Algorithm. In this paper we try to increase complexity RSA Algorithm to make it more secure.*

Key words: *RSA, Encryption, Decryption*

1. Introduction

With the developments in technology, computers and the Internet have become an important part of our lives, which also has increased the number of operations carried out on the Internet. Therefore, it is important to provide security for users to help them with their commercial, official or private transactions.

Cryptology and authentication is very important for providing security. There are two ways of cryptography, which are symmetrical and asymmetrical. Asymmetrical encrypting is based on prime numbers. Very large or very long numbers are needed to be used as "keys" in cryptographic applications

The most used communication systems are the public ones. In the public communication systems there is a risk of reading, recording or changing of the messages by the unauthorized people.[6]

If we want to secure a message, we must make it unreadable or inexplicable. Only receiver must understand what the message is. So before sending the message to the receiver, it must be encrypted. To understand the message by receiver it must be decrypted [1]. A lot of algorithms exist to provide this process. One of them is RSA Algorithm. RSA crypto system, also using for generating digital signatures.[7]

RSA Algorithm developed by Ron Rivest, Adi Shamir and Leonard Adleman in 1978. The algorithm uses two prime numbers to generate encryption/decryption key [2]. To increase security, numbers must be selected very high [3],[4].

In this paper tried to use more than two prime numbers instead of two to calculate key generation [5].

1.1. Base of RSA Encryption

The RSA algorithm was publicly described in 1978 by Ron Rivest, Adi Shamir, and Leonard Adleman at MIT; the letters RSA are the initials of their surnames, listed in the same order as on the paper.

The RSA algorithm involves three steps: key generation, encryption and decryption. Big prime numbers are selected in the key generation step. Then encryption and decryption rules are provided using generated key. In the encryption step the unencrypted message powered by *e* and mod *n* is calculated, it gives encrypted message ($c = m^e \mod n$). In the decryption step the encrypted message powered by *d* and mod *n* is calculated, it gives the main message($m = c^d \mod n$).

- M is the message
- C is the encrypted message.
- K is the key.
- ek is the encryption rule and dk is the decryption rule which provide k Є K rule.
- ek : P → C is an encryption function and dk : C → P is a decryption function.

1.2. Existing RSA Algorithm

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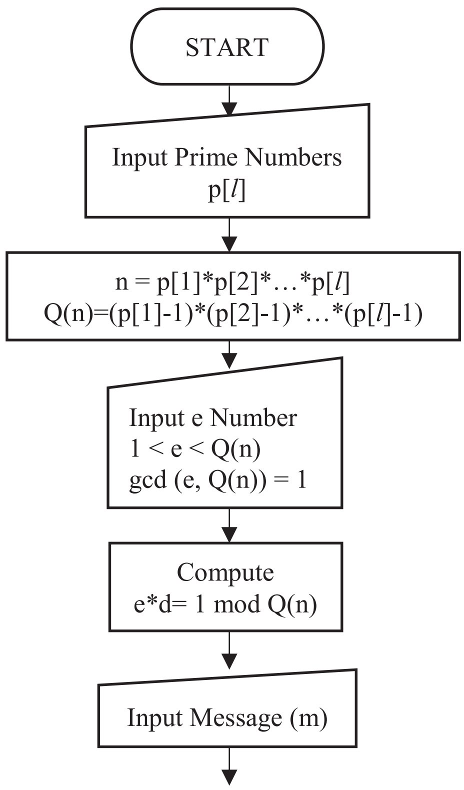
- Key generation : Select two different primes, p and q
- Calculate n = p * q
- Calculate Q(n) = (p – 1)*(q – 1)
- Select an integer e which provides 1 < q < Q(n) ; gcd(e, Q(n)) = 1
- Calculate private key d = e-1 (mod Q(n)), then public key is { e , n } and private key is { d , n }
- Encryption $c = m^e \bmod n$
- Decryption $m = c^d \bmod n$

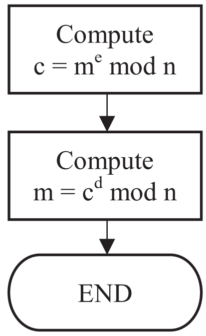
The gcd(e , Q(n)) = 1 function is Euclidean Algorithm. Used for *e* and *Q(n)* coprime.

1.3. Designed RSA Algorithm

- Key generation : Insert different prime numbers in array p[*l*]
- Calculate n = p[1] * p[2] * … p[*l*]
- Calculate Q(n) = (p[1] – 1)*(p[2] – 1)*…(p[*l*] – 1)
- Select an integer e which provides 1 < e < Q(n) ; gcd(e, Q(n)) = 1
- Calculate private key d = e-1 (mod Q(n)), then public key is { e , n } and private key is { d , n }
- Encryption $c = m^e \bmod n$
- Decryption $m = c^d \bmod n$

1.4. Flow Chart





1.5. Example

- p[1] = 11, p[2] = 7, p[3] = 5, p[4] = 3
- n = 11 * 7 * 5 * 3 = 1155
- Q(n) = 10 * 6 * 4 * 2 = 480
- e = 419 , 1 < e < 480 ; gcd(e , Q(n)) = 1
- d = 419-1 (mod 480) = 299 than
- Public Key = { 419 , 1155 }
- Private Key = { 299 , 1155 }
- Normal message is m = 12
- $c = 12^{419} \bmod 1155 = 738$ (c is encrypted message)
- Decrypted message is
- $m = 738^{299} \bmod 1155 = 12$ (m is decrypted message which is normal message)

1.6. Application Program

Proposed algorithm is written as a c# application. Results can easily verified by the application. Prime numbers can be added as requested. Then the numbers can processed. *n* and *Q(n)* values are displayed. After that, *e* value must be selected to process private and public keys. Then message can be encrypted.

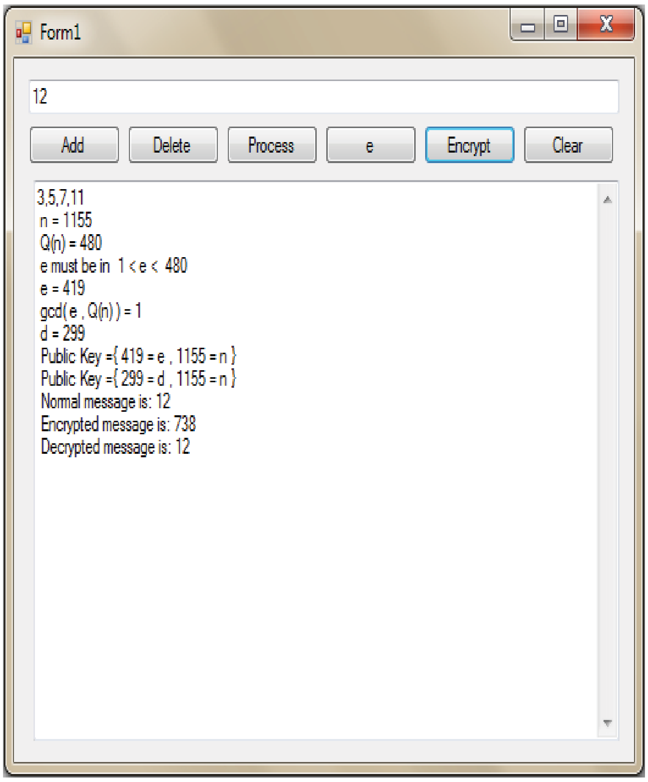


Fig. 1. *Example 1.5 in program*

2. Conclusion

Using more than two prime numbers increase *n* value which can increase algorithm complexity and security. Especially if small prime numbers must be used, it gives *n* and *Q(n)* value that is higher than existing RSA algorithm. Also designed RSA algorithm can easily implement in existing RSA algorithm because they share same formulas. However, all those big prime numbers must be considered to cause more process time and memory space requirements.

REFERENCES

1. D. R. Stinson, Cryptography, Theory and Practice, 3rd Ed., CRC Press, Boca Raton,FL (2002).
2. R. Rivest, A. Shamir and L. Adleman, A Method for Obtaining Digital Signatures and Public-Key Cryptosystems, Communications of ACM, 21(2), 120-126 (1978).
3. B. P. U. Ivy, P. Mandiwa and M. Kumar, A Modified RSA Cryptosystem Based on 'n' Prime Numbers, Int. J. Engg. Comput. Sci., 1(2), 62-66 (2012).
4. S. Pund and C. Desai, Implementation of RSA Algorithm using Mersenne Prime, Int. J. Networking & Parallel Computing, 1(2), 33-41 (2013).
5. Ch. J. L. Padmaja, V. S. Bhagavan and B. Srinivas, RSA Encryption Using Three Mersenne Primes 14(4), 2273-2278, (2016)
6. YERLİKAYA, T., GENÇOĞLU, H., EMİR, M. K., ÇANKAYA, M., & BULUŞ, E. RSA ŞİFRELEME ALGORİTMASI VE ARİTMETİK MODÜL UYGULAMASI.
7. Yerlikaya, T., Buluş, E., & Buluş, N. (2006). ASİMETRİK ŞİFRELEME ALGORİTMALARINDA ANAHTAR DEĞİŞİM SİSTEMLERİ.

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PASSWORD CRACKING ATTACKS

ŞENOL ŞEN, TARIK YERLIKAYA, TRAKYA UNIVERSITY

Abstract: *Today, password cracking attacks are one of the most dangerous attacks. We use passwords to login information systems like our computers, social accounts, etc. Password is the biggest and mostly only barrier between a hacker and an information system. The only thing that can be the weakest link in the security chain of information security is weak passwords. The reason for this is the human factor. To create passwords with the names of our hobbies or beloved ones that everyone knows are main mistakes which people usually make. Even the most secured institutions can be exposed to these kind of attacks because they are too lazy or they ignore. From the expert user, using the most powerful security tools, to the end user connecting via home computer to internet, the first thing to be learned is how to create secure and robust passwords. A password cracking example has been given in this study, by explaining how password attacks are carry out and the popular main tools used in these attacks. Also things to create a strong password has been explained at the last part of our study.*

Key words: *password cracking, password attack*

1. Introduction

Close your eyes and think. After a nice day, you came home and it's time to sleep. You slept by leaving all the doors and windows of your house open. You may have survived that day without coming to somebody's attention, but what about other day? Will you be able to get the same chance the next day? Stepping into the world of informatics in an environment where security is not provided is similar to leaving your door and windows open with the thought of "I hope someone will not notice" your house.

Your password is the first obstacle between the attacker and your information system. The first attack type that attackers will attempt before attacking a system is password cracking attacks. If we see the password as the key of the house door here and it's under the door mat, there is no need to strive to open the door. Because the key is in the place we guess, that is under the door mat. Weak and predictable passwords are like keys under the door mat as in our example. These can be found and break within the seconds in today's technological possibilities. To protect against these attacks, we must create strong passwords and securely store our passwords.

2. Password

Passwords are used in many fields for identity and authorization checking. The only element in information security that may be the weakest link in the security chain is weak passwords and codes. Passwords are usually encrypted and stored as hash rather than as plain text. When a hash is generated, the text in variable length is converted to fixed length, and when this convertion is in process, unique texts consisting of mixed numbers and digits are produced due to the utilization of a one way mathematical function. For example, the user information stored in the database or the user information stored in the operating systems are not stored directly in plain text. Considering the possibility that someone can read the information, it is kept in a hashed form, ie a kind of encrypted form. Keeping information in this way makes things more difficult for attackers, because the hashes have a one-way mathematical connection with the original text. It is often a difficult task to convert a text that is reached to its Hash into its original form.

Since Hashes are one-way mathematical functions, the task to find the original text is to do a trial from a list of words. It is to try until right hash matching is ensured by comparison via the conversion of the text into hash. So if the password is in our word list, the password can be found at the end of this trial. Otherwise, it will not be found[1].

Also, while a hash is being created, a small change in the text changes the entire structure of the Hash. For example, if we encode the "trakya" text with md5 algorithm, we get 2c8135467f5423f06d297d4d276456f3 hash. We get

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the hash of d9052fa7adb01862abd6d81be4e66ce7 by enlarging the letter T and using the md5 hash of "Trakya" again. It is obvious that there is no connection between the two hashes when they are compared. Therefore, it is not possible to understand that hash is close to being solved. We can group the methods that are used to capture the password into 4 main headings[2].

2.1. Active Online Attacks
2.2. Passive Online Attacks
2.3. Offline Attacks
2.4. Non Technical Attacks

2.1. Active Online Attacks

Brute-force and dictionary attacks are listed in this kind of attack. Brute-force attack is a simple but effective method. It is based on the testing of all possibilities. Optionally, all possible combinations of letters, numbers, special symbols that may exist in the specified length are tried. Weak and predictable passwords can be broken easily through brute - force. The important thing here is the time. 100% success can be achieved within sufficient time.

In the case of the dictionary attack, the combinations that are tried are a predetermined list. This is the main difference with brute force. More targeted, customized dictionaries are needed to be prepared. In addition, different combinations can be tried with numbers and special characters instead of the letters in the password.

Brute force can be largely avooided through policies that detect and block false password attempts.

2.2. Passive Online Attacks

This attack happens in 2 ways: Man-in-the-middle and sniffing. In the case of the man-in-the-middle kind of attack, environment and the traffic on the targeted computers are tapped and the password is tried to be obtained. In this type of attack sniffing tools may be used as well.

On the other hand, sniffing attacks are effective when being connected on the same network and in the case of using a networking tool such as a hub in the system. Because the hub sends a package to all ports, by this means, all devices on the network can see the package sent. If such tools as switches, bridges, etc., are used, since these tools only filter in a way to be sent to the destination port, sniffing will not be effective in this environment. The tools used for such attacks are: Cain & Abel (Windows), ettercap, hash, Dsniff, SSLStrip.

2.3. Offline Attacks

In this type of attack attempts, attackers try to gain access to the spots where usernames and passwords are stored on the system. User names and passwords may be kept as text or as encrypted and hashed. While the redirecting is made, the summary value of the password is taken and compared with the summary of the password, entered by the user, previously saved on the system. Accordingly, the user is authorized. There are methods such as MD5, SHA, NTLM for summary processing[2].

In this type of attack, three different methods can be mentioned as brute-force, dictionary and rainbow tables.
Rainbow Table: Because many system passwords are stored in hash form, even if this data is reached, data must be detected by matching. One way to do this is to find through comparison by converting the words into hash with a wordlist in hand. Also, another way is to use the rainbow table, which has hash in it for each word and has tables ready for direct comparison.

2.4. Non Technical Attacks

We can group the attacks in this title as social engineering and forecasting. Social engineering is to obtain information from victims or make them to do the desired processes by using influence and persuasion methods. It is basically a type of assault that is carried out with the use of trust, fear and compassion which are readily available in human nature. Generally being considered as the weakest link of the security chain, human factor is one of the biggest threats despite network filtering devices, antivirus softwares and all the security methods.
On the other hand, the estimation method is a method of finding the password by prediction by means of the usage of the information (name, surname, telephone number, supported team, etc).

3. Tools that can be used during an attack

Ophcrack: A free application that works with rainbow table logic. Windows password can be used to break hash.

Cain Abel: One of the most popular password cracking tools developed for Windows. It can crack many hash such as NTLM, NTLMv2, MD5, wireless, Oracle, MySQL, SQL Server, SHA1, SHA2, Cisco, VoIP.

Brutus: Supports many authentication methods only developed for Windows such as HTTP, POP3, FTP, SMB, TELNET, IMAP, NNTP.

John The Ripper: A popular password cracking tool developed with C language.

Cupp: A powerful tool for creating original wordlists. It tries to make more relevant words by asking questions about the target user.

Cewl: Wordlist creation tool. It aims to increase the relevancy of the words by examining the web page provided.

Crunch: A very successful software used to create wordlist in order to use brute force attacks.

Hydra: Working with dictionary logic, a password-cracking tool that can execute remote attack for more than 50 protocols. It is not only limited to the forms in the web services but it can also attack many services such as MAP, SMB, HTTP, VNC, MS-SQL, MySQL, SMTP and SSH. It can be run through the Linux terminal as well as in the user interface.

Medusa: A fast password cracking tool that can execute parallel scan and is very easy to syntax. It provides an opportunity to test services such as HTTP, HTTP Form, IMAP, MS-SQL, MySQL, NCP, Oracle, POP3, AFP, CVS.

It is important that the words in the wordlist used for the attack contain the language, the level of relevancy and the most used passwords. We are more likely to guess the passwords that someone you know will use. Most people choose either the most common insecure passwords to remember easily, or create a password with the information like animal name, birth date and phone number. Therefore, it is more logical to create a wordlist in accordance with the individiual. Thus, the tool named Cupp which asks questions about the person and Cewl which creates words by examining the web sites can be used[1].

4. Brute force attack on SSH service

The most important step to take before attack is to collect information about the system, system administrator, or system users to be attacked. If we want to break a user's password, we need to get information about that user and write it into the dictionary list, which we will use on the attack. In addition to user information, we also need to create a file of possible password information. Crunch is one of the most useful tools we can use when creating password files. This tool allows us to create various combinations of the characters given to it[3].

The sample password file we have created for our example is shown in "Fig. 1".

In our example, we only need to enter the password list because we know the name of the user in our target to Hydra. Therefore, we enter the name of that user and the IP of the computer that is running ssh service with -l instead of -L. We run the Hydra tool with these parameters and find the root password of the SSH service as 1qaz2wsx, as shown in "Fig. 2".

With the Hydra tool, brute force attacks against many systems (http, ssh, ftp, telnet, pop3, smtp etc.) can be done[4].

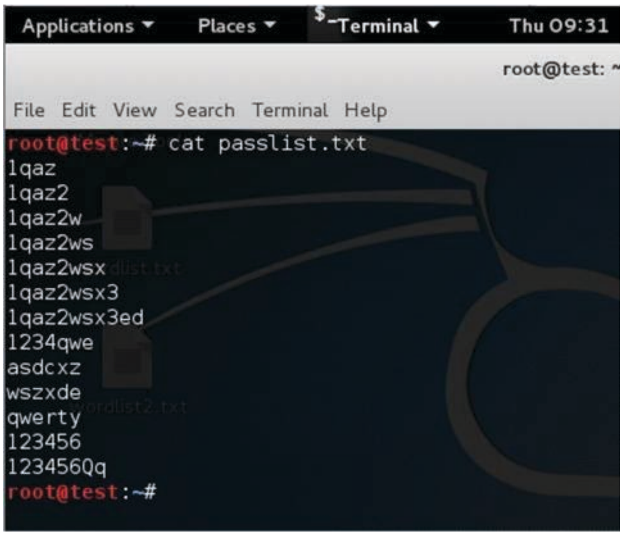

Fig. 1. *The contents of the created passlist.txt file*

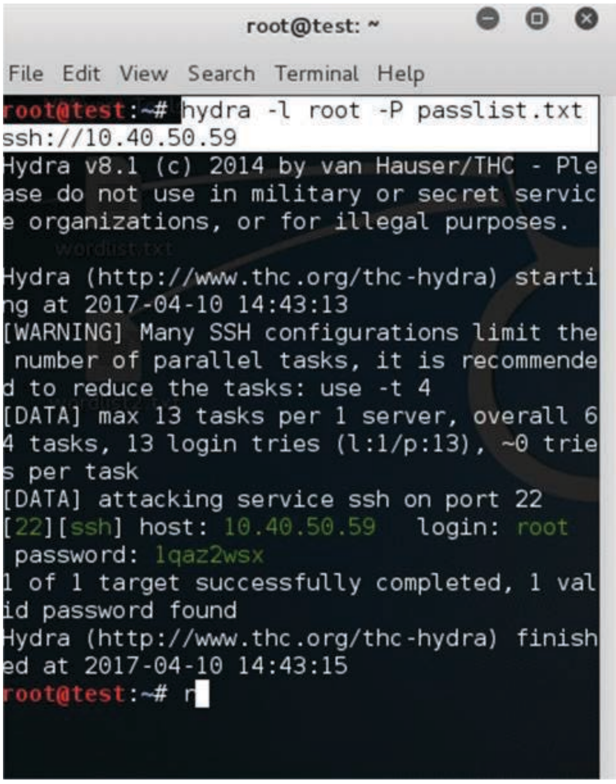

Fig. 2. *Example of attack against SSH service with Hydra*

5. Powerful Password Creation

Strong passwords consist of random characters and strings. The two most important rules for creating a strong password are the length and complexity of the passwords. An ideal password is long and contains letters, punctuation marks, symbols and numbers at the same time[5]. The most important points to note about creating a secure password are:

1. It must be longer than eight characters. Short passwords are easier to resolve than long passwords.
2. It must consist of letters, numbers and symbols. Consecutive or repeating combinations (such as "12345678," "222222," "abcdefg") or letters that stand side by side on the keyboard should not be used. There should not be any known words that use numbers instead of letters. (Such as "M1cr0 $ 0ft" or "P @ ssw0rd"). Unfortunately, hackers know these tricks too.
3. It must be easy for you to remember, but hard to guess for others.
4. Your sign-in name should not be your spouse's name or your birthday.
5. There should not be words from any languages which exist in any dictionary. Hackers use sophisticated tools that can quickly guess passwords using words in various dictionaries and also their reverse spellings.
6. It must be easy to remember. There should be no random combinations of letters, numbers and symbols that must be taken note down, misspelled or should be found and use by others.
7. Under any circumstances, you should not share your password with anyone else. You may be meticulous, but the person who knows your password may not be careful and may leave you in a difficult situation. If we have to share, as a method changing the password would be a solution.
8. Update your password on a regular basis. This method is a bit differs from the structure of the encrypted account, especially if the account contains your critical information this method must be used. For example, most banks, various communications companies apply this for their users and send new passwords to their users.
9. Do not use your passwords on computers you do not know. One of the most common methods used by identity thieves is to install spywares such as a keylogger on target computers and access the information of persons who use the computer.
10. Never send your password by email to any address. Some malicious people may look like Internet sites and could ask for your password, never send your password in this way[5].

6. Conclusion

Today, passwords are the only form provided for the security of websites and computer systems. It has become one of the easiest ways for hackers to get access to our computer or network.

Along with social networks, password security has increased extremely in line. As we write our own information about ourselves, passwords present great importance with the increase of these environments. Of course, password security does not go beyond just creating your password difficult. Protection and keeping safe are also important. You should never save your password on your or another computer and also phones and tablets.

Protecting the critical information in computer systems by recollective, repeatable and simple passwords, is increasing the risk of system breakage. When it is thought the next generation computers will control by voice commands, open and close with visual commands, it's certain that stronger passwords will be needed to store high importance information. It is a fact that there will be systems which will support all of these and biometric-based passwords and these passwords can be obtained by using features such as fingerprints, iris or face in the near future[6].

REFERENCES

1. Turkoglu, C., *Password cracking*, http://blog.btrisk.com
2. Onal, H., Akbas, E., *Password cracking attacks in penetration tests,* https://www.slideshare.net/ bgasecurity/.
3. Altuntas, A. (2016). *Kali Linux*, 275-289, Kodlab, İstanbul.
4. Hydra, https://www.thc.org/thc-hydra/.
5. Dogu, K., *Keep your password strong,* http://www.bilgiguvenligi.gov.tr.
6. Canbek G., Sagiroglu Ş.(2006), *Information and Computer Security Spyware and safeguarding methods,*82-83, Grafiker Ltd.Sti., Ankara.

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IMAGE PROCESSING ON ANDROID DEVICES WITH OPENCV

CEM TASKIN, ALTUG YIGIT, DENIZ TASKIN, AYSE CELIK TASKIN

Abstract: *Nowadays, computer vision is a popular approach in computer science. Many applications running on personal computers use computer vision libraries in order to have object detection capability for many years. Today mobile devices have powerful hardware like quad core cpus, high density cameras and high speed internet connection. With the hardware achievements in mobile devices, programmers developed mobile versions of computer vision libraries. In this paper, we are testing an Android application using computer vision library for distinguishing colors. This sample application works on real time camera and distinguish a color from others in the scene that was selected by user.*

Key words: *image processing, mobile device, android, color, filtering, opencv*

1. Introduction

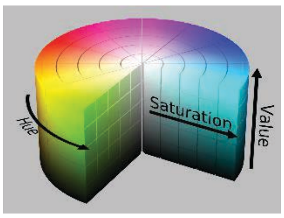
Object detection is one of the most challenging problems in computer vision. It is difficult to detect due to the significant amount of variation between images belonging to the same object category. Other factors, such as changes in viewpoint and scale, illumination, partial occlusions and multiple instances further complicate the problem of object detection. Most state-of-the-art approaches to object detection rely on intensity-based features that ignore color information in the image. Color has been shown to yield excellent results in combination with shape features for image classification. [1]

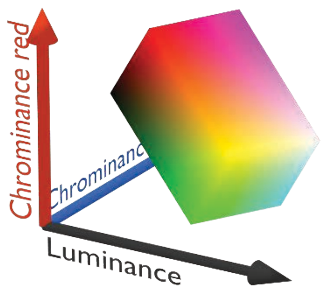
Usually computer vision libraries use captured images as input. But in real time applications, the input is always a collection of continuous frames (pictures). It is a main problem processing these frames in short times. And also it is very important to give the result of process as soon as possible. Computer vision techniques like 3D segmentation and modelling is not suitable for real time processing. In this study, color filtering method is used for distinguishing colors and tested on an Android mobile device.

2. Color Filtering

In color filtering method, determining the correct threshold value is the most important fact on accuracy. In order to get consistent results, appropriate color space must be selected before processing images.

Restricting the color information merely to RGB components is a simple abstraction that dismisses the information available within the color object. A color is fully defined by its complete wavelength response, whereas the RGB color space represents only three wavelengths. The perceived color also depends on the illumination condition, viewing angle, and sensor type. As a consequence, efficient color image processing requires an adequate color representation. Different color spaces can be used to represent various color components, with different degrees of interdependency among them. Of the four classic color spaces, the hue/saturation/value (HSV), YCbCr , L*a*b*, and RGB shown as Figure 1. [6]





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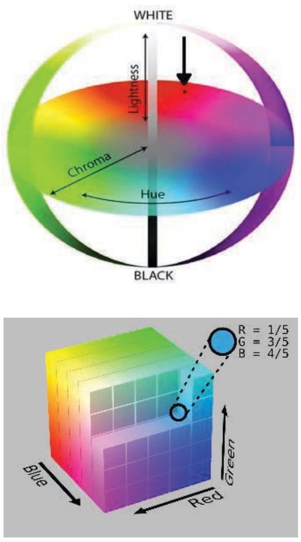


Fig. 1. *HSV, YCbCr , L*a*b*, and RGB Color Space*

The HSV (Hue-Saturation-Value) theory is the most common representation of points in an RGB (Red-Green-Blue) color technical model. Computer graphics pioneers developed the HSV model in the 1970s for computer graphics applications (A. R. Smith in 1978, also in the same issue, A. Joblove and H. Greenberg). A HSV theory is used today in color pickers, in image editing software, and less commonly in image analysis and computer vision. [7] The HSV color space is more related to human color perception. [8]

HSV color space separating luminance component with chrominance component. The luminance component lies in V (intensity value) and the chrominance component lies in H (Hue) and S (Saturation). In HSV model, Hue defines the kind of color like red, yellow, green, blue, or the combination between those colors. Hue value is between 0-360. Saturation gives a measure of the degree by which a pure color is diluted by white light, and value show the intensity of light-dark color.[9]

Color is a strong tool for image segmentation. Color-based segmentation is better than edge-based and luminance histogramming techniques because color is computational inexpensive, and it can give more information than a luminance-only image or an edge-segmented image which need more computational resources, so they make real time application systems hard to realize.[5]

3. OpenCV and Android

OpenCV (Open Source Computer Vision) is a library of programming functions mainly aimed at real-time computer vision. Originally developed by Intel's research center in Nizhny Novgorod (Russia), it was later supported by Willow Garage and is now maintained by Itseez. The library is cross-platform and free for use under the open-source BSD license. The image processing algorithms are implemented using OpenCV. OpenCV was designed for high computational efficiency with a strong focus on real time applications. OpenCV was written with optimized C. [3,4] OpenCV library is a common library used in image processing applications.

Table 1. *Worldwide Smartphone Sales by Operating System*

Worldwide Smartphone Sales to End Users by Operating System in 4Q15 (Thousands of Units)

Operating System	4Q15 Units	4Q15 Market Share (%)	4Q14 Units	4Q14 Market Share (%)
Android	325,394.4	80.7	279,057.5	76.0
iOS	71,525.9	17.7	74,831.7	20.4
Windows	4,395.0	1.1	10,424.5	2.8
Blackberry	906.9	0.2	1,733.9	0.5
Others	887.3	0.2	1,286.9	0.4
Total	**403,109.4**	**100.0**	**367,334.4**	**100.0**

Source: Gartner (February 2016)

It is possible to use this library on Android Studio by adding OpenCV Android Software. Development Kit (SDK). This SDK can be downloaded from the http://opencv.org/downloads.html.

As seen on Table 1, Android OS is the common operating system used by mobile devices. Android as a development platform use the Java Standard Edition with additional Android classes. Applications are developed in the Java language using Android Software Development Kit (SDK). For a low level interaction with hardware, a modified Linux kernel is used [2].

4. OpenCV on Andoroid OS

In our study, we are testing an Android application using OpenCV for real time color based image segmentation. The flowchart of the application is shown on Figure 2. OpenCV's onCameraFrame method captures frames in RGBA color space. These frames are converted into 8-bit 4-channel pixel matrix. After that step, RGBA to HSV conversion are applied.

5. Application Flow Chart

In the RGBA color space R (Red), G (Green), B (Blue), A (alpha) channels are available. For each channel, color values are stored in 8 bits and has a range between 0 and 255. Alpha channel is ignored on conversion from RGBA to HSV. In the first step of converting we divide each color value with 255 and we obtain a conversion value between 0 and 1.

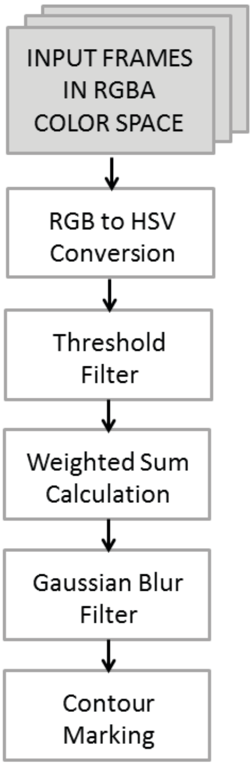


Fig. 2. *Flow Chart of Our Application*

In the next step, we are using following formulas to calculate HSV values [11].

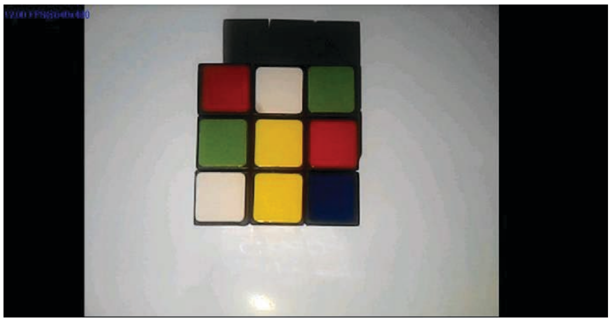
$$V \leftarrow max(R, G, B)$$

$$S \leftarrow \begin{Bmatrix} V - \dfrac{\min(R,G,B)}{V} & If\ V \neq 0 \\ 0 & otherwise \end{Bmatrix}$$

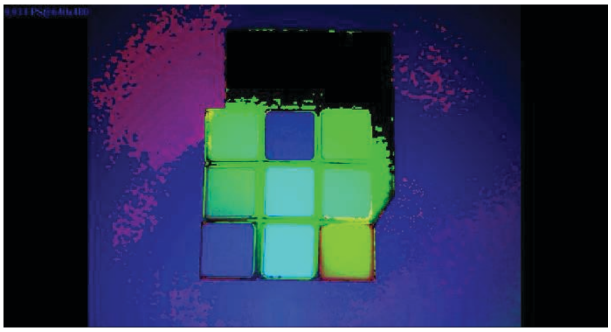
(1)

$$H \leftarrow \begin{Bmatrix} \dfrac{60(G-B)}{V-\min(RGB)} & If\ V = R \\ 120 + \dfrac{60(B-R)}{V-\min(RGB)} & If\ V = G \\ 240 + \dfrac{60(R-G)}{V-\min(RGB)} & If\ V = B \end{Bmatrix}$$

This conversion can be performed in OpenCV with function cvtColor. In Figure 3 a conversion from RGB to HSV is shown



Original image



Converted Image

Fig. 3. *RGB to HSV Conversion*

5.1. Threshold

After RGB to HSV conversion, we select a color for filtering. In our test, we select Red color. Before the threshold filtering, two color range values are selected (The low and high color tone). For threshold filter we use OpenCV's inRange function. The formula used by this function is shown in Formula 2.

$$Output \leftarrow \begin{Bmatrix} 1 & If\ Input \in Range \\ 0 & If\ Input \notin Range \end{Bmatrix} \tag{2}$$

In Figure 4, the output of this function applied to sample image is shown.

Fig. 4. *Output After Threshold Filter*

5.2. Weighted Sum of Two Arrays

In order to increase performance of color filtering, weighted sum of two threshold output matrix is calculated. In this calculation operation, two matrix has equal weight (50% and 50%). We use Formula 3 for this operation. In OpenCV, for calculating the weighted sum of two threshold output matrix,addWeighted function is used.

(3)

$$dst(I) = saturate(src1(I) * alpha + src2(I) * beta + gamma)$$

Parameters:

src1 – first input array.
alpha – weight of the first array elements
src2 – second input array
beta – weight of the second array elements
dst – output array
gamma – scalar added to each sum.[11]

5.3. Gaussian Blur

We use Gaussian Blur to reduce noise of the weighted sum value obtained. When the Gaussian blur applied, pixel values apart from the others become closer. We use Formula 4 for this filter. In OpenCV, for applying Gaussian Blur filter GaussianBlur function is used.

(4)

$$G_0(x, y) = Ae^{\frac{-(x-\mu_x)^2}{2\sigma_x^2} + \frac{-(y-\mu_y)^2}{2\sigma_y^2}}$$

In Figure 5, the output of Gaussian Blur filter applied to sample image is shown.

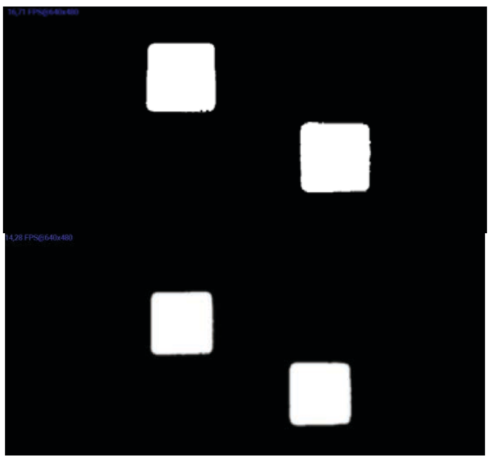


Fig. 5. *Output After Gaussian Blur Filter*

5.4. Contour Marking

After applying Gaussian Blur filter we obtain a smooth image. In this output image, we find the positions of white pixels and the relationship of each other.

Contours can be explained simply as a curve joining all the continuous points (along the boundary), having same color or intensity. The contours are a useful tool for shape analysis and object detection and recognition. In OpenCV that can be applied by calling the findContours function. This function has three arguments. First one is source image. The second is contour retrieval mode. Third parameter is contour approximation method. And it outputs the contours and hierarchy. [13] Contour retrieval mode selected for this Android application is CV RETR TREE. In this mode all of the contours output vector are obtained with hierarchical relationships. [12] The approximation method selected for this Android application is CV CHAIN APPROX SIMPLE.

By using CV CHAIN APPROX approximation method all redundant points are removed and that saves memory which is very important for mobile devices.

After this step, the pixel locations of the rectangle are obtained. In OpenCV rectangle function is used for drawing a rectangle. In Figure 6, the result of color filtering is shown. In our test, the application follows the color and draws contours in real time video.

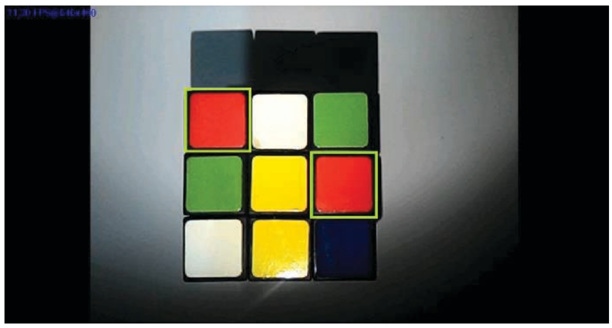
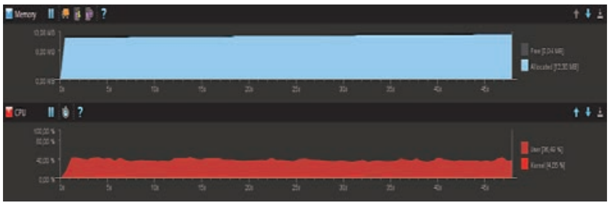


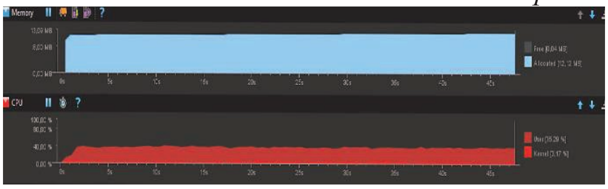
Fig. 6. *Result Of Color Filtering*

6. Performance Testing

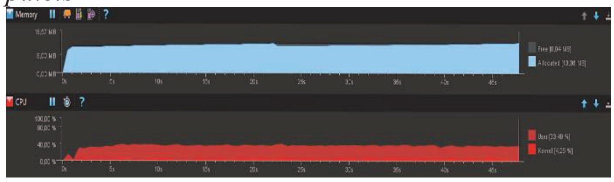
Application performance was tested with an Intel® Atom™ Z2560 1.6 GHz CPU equipped mobile device on Android Studio. The results of CPU usage, Memory usage and FPS(Frame Per Second) are shown in Figure 7.



Threshold Filter performance
FPS value is between 17.50-21.0 at 640x480 pixels



Gaussian Blur filter performance
FPS value is between 15 and 17.50 at 640x480 pixels



Contour Marking
FPS value is between 9.0 and 16.50 at 640x480 pixels

Fig. 7. *Test Results*

7. Conclusion

As a result of our mobile application tests, we can say that mobile devices has capable of color filtering in real time. Our future work is to test real time object detection methods that use deep learning techniques.

REFERENCES

1. Fahad Shahbaz Khan, Rao Muhammad Anwer, Joost van de Weijer, Andrew D. Bagdanov, Maria Vanrell, Antonio M. Lopez. Color attributes for object detection. In CVPR, 2012.
2. Damir Demirovi´c, Amira Šerifovi´c-Trbali´c, Naser Prljaˇca, Philippe C. Cattin. Evaluation of image processing algorithms on ARM powered mobile devices. MIPRO, 2014.
3. https://en.wikipedia.org/wiki/OpenCV#cite_note-2
4. Deepthi.R.S, S.Sankaraiah. Implementation of mobile platform using qt and open cv for image processing applications. IEEE Conference, 2011.
5. Houssem Lahiani, Mohamed Elleuch, Monji Kherallah. Real time hand gesture recognition system for android devices. ISDA, 2015.
6. Hossein Nejati, Victor Pomponiu,Thanh-Toan Do, Yiren Zhou,Sahar Iravani, and Ngai-Man Cheung. Smartphone and mobile image processing for assisted living. IEEE Signal Processing Magazine, 2016.
7. Ján Haluska, On fields inspired with the polar HSV -- RGB theory of colour. In arXiv, 2015.
8. Alberto Albiol, Luis Torres, Edward J. Delp. Optimum color spaces for skin detection. IEEE Image Processing Conference, 2001.
9. Priyanto Hidayatullah, Miftahuddin Zuhdi. Color-texture based object tracking using HSV color space and local binary pattern. In International Journal on Electrical Engineering and Informatics, 2015.
10. http://docs.opencv.org/2.4/modules/imgproc/doc/miscellaneous_transformations.html
11. http://docs.opencv.org/2.4/modules/core/doc/operations_on_arrays.html
12. http://docs.opencv.org/2.4/modules/imgproc/doc/structural_analysis_and_shape_descriptors.html
13. http://docs.opencv.org/trunk/d4/d73/tutorial_py_contours_begin.html

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COMMON ATTACKS TYPES AND PENETRATION TESTING ON WI-FI NETWORKS

OĞUZ KIRAT, TARIK YERLİKAYA

Abstract: *Wi-Fi is widely used wireless technology but not secure if it is not configured properly. This paper discusses Wi-Fi networks' weaknesses and possible attack vectors. Penetration testing methods and tools to measure security of certain wireless networks are also discussed.*

Key words: *Wi-Fi, wireless, networks, penetration testing, network security*

1. Introduction

Wi-Fi (Wireless Fidelity) or 802.11 was firstly introduced back in 1997 [1] as a low cost, user-friendly and simple wireless local area network solution. It is widely used as a network solution in universities, businesses and homes. Many devices are Wi-Fi enabled including mobile phones, tablets, computers and IoT devices. Though, Wi-Fi is not always secure, if not configured properly. We will discuss common attack vectors in this paper.

2. Network monitoring, sniffing and package capturing

Sniffing is a technique to capture network packets and analyze network traffic. Many wireless networks are open to network sniffing vulnerabilities, including Wi-Fi because packages are transferred over-the-air.

To "sniff" a Wi-Fi network there is no need to join it, that makes sniffing attacks hard to detect. If the attacker has a supported Wi-Fi hardware that supports "monitor mode" he/she can capture network packages.

Sniffing tools are widely available: On the Microsoft® Windows® operating system WinPcap, and on the Linux® distribution airodump-ng and available for package capturing.

In MacOS™ operating system, wireless network sniffer tool for network diagnostic is included.

Some networks on hotels and schools provide no encryption and uses HTTP based user authentication. Wireless networks that are not secured exposes all the traffic passing on the network to everyone sniffing the network and should be considered non-secure.

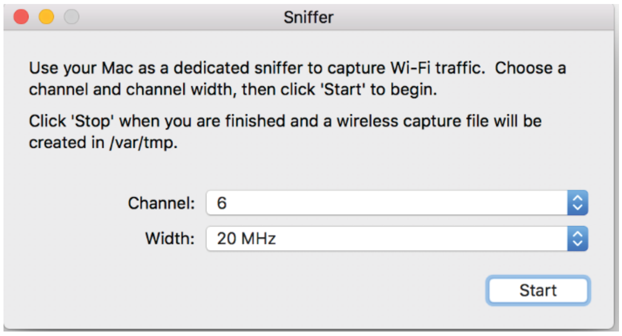

Fig. 1. MacOS™ Sniffer Tool

3. Package analysis on non-secured or decrypted Wi-Fi networks

Wireless network traffic can easily be inspected on non-secured Wi-Fi networks. If users connected networks uses insecure network protocols (such as HTTP, FTP, Telnet) it can be monitored using tools and changed.

Wireshark is popular tool and available on major operating systems to inspect network packets.

All the HTTP traffic (including passwords) can be monitored using Wireshark if traffic is not encrypted.

4. MAC address spoofing and ARP table attacks

The Address Resolution Protocol (ARP) is a telecommunication protocol used for resolution of Internet layer addresses into link layer addresses, a

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critical function in computer networks. ARP was defined by RFC 826 in 1982 [2]

ARP is used to link local IP addresses to physical addresses (MAC address). airodump-ng tool can be used to discover MAC addresses of access points and clients connected them. MAC spoofing methods can be used to trick MAC based limitations on the network and combined with ARP spoofing can be used for man in the middle and DDOS attacks. [3]

It is also demonstrated that MAC spoofing can be used to connect to most insecure Wi-Fi networks even if they use time and MAC based restrictions. [4]

5. Session Hijacking

Session hijacking attacks can compromise user accounts on Wi-Fi connections. Combined with package sniffing attackers can hijack, for example HTTP cookies, to steal account information.

One of the popular proof-of-concept tools about session hijacking is Firesheep which is an extension for Mozilla® Firefox® web browser. It is designed to steal session cookies of popular social-network sites [5] (which were not using HTTPS protocol back in the days)

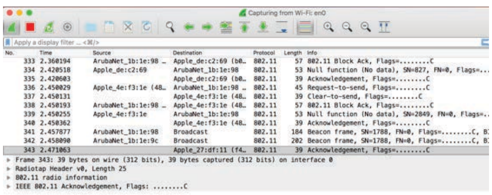

Fig. 2. *Wireshark can be used to view HTTP session on the network.*

6. Man In The Middle Attacks

If attacker can capture network packages and decrypt them, he/she can secretly capture and relay the wireless communication between the access point and clients.

Attackers can force clients to reconnect to capture handshakes and use ARP poisoning methods to act as a wireless access point. aireplay and d-sploit are tools designed for man in the middle attacks and packet injection.

7. Denial of Service Attacks

The purpose of the Denial of Service Attacks (DOS) is slowing down or stopping a running system.

There are various DOS attack types on the WiFi networks such as TCP/SYN floods, TCP Replay, Land Attack and teardrop.

8. Password Cracking

8.1. WEP Password Cracking

WEP's main goal was to provide data privacy by encapsulating data frames. [6]

WEP uses 24 to 48 bit key (Initialization Vectors) and CRC32 as the control algorithm. WEP is considered insecure and can be cracked if enough IVs captured.

aircrack-ng is tool developed to crack WEP based passwords in minutes.

8.2. WPA/WPA2 Password Cracking

The weakest point of WPA/WPA2 is using the same pre-shared keys for all users. Which means it is still to open brute-force attacks of network sniffers.

WPA2 brings Enterprise mode which can strengthen security.

8.3. WPS Based Methods

There possibility of attacking WPS registrar PINs.

Reawer is one of the proof-of-concept tools that can crack plain text WPA/WPA2 passwords in 4-10 hours.

9. Conclusion

Though Wi-Fi is widely used technology, there are many vulnerabilities and attack vectors available to abuse connections.

Advanced firewall and authentication servers are required with strong encryption methods (such as WPA2 Enterprise) required.

REFERENCES

1. IEEE standard for information technology-telecommunications and information exchange between systems-local and metropolitan area networks-specific requirements-part 11: Wireless LAN medium access control (MAC) and physical layer (PHY) specifications. IEEE Std 802 11-1997. 1997:i-445.
2. David C. Plummer (November 1982). "RFC 826, An Ethernet Address Resolution Protocol

-- or -- Converting Network Protocol Addresses to 48.bit Ethernet Address for Transmission on Ethernet Hardware". Internet Engineering Task Force, Network Working Group.[Online] Available: https://tools.ietf.org/html/rfc826

3. Ramachandran, Vivek & Nandi, Sukumar (2005). "Detecting ARP Spoofing: An Active Technique". In Jajodia, Suchil & Mazumdar, Chandan. *Information systems security: first international conference, ICISS 2005, Kolkata, India, December 19-21, 2005 : proceedings*. Birkhauser. p. 239. ISBN 978-3-540-30706-8.
4. McDonald, Kyle, Free Wifi, [Online] Available: https://github.com/kylemcdonald/FreeWifi
5. Firesheep, A Firefox extension that demonstrates HTTP session hijacking attacks.[Online] Available: https://github.com/codebutler/firesheep
6. Wang Shunman, Tao Ran, Wang Yue, Zhang Ji. WLAN and it's security problems. Parallel and Distributed Computing, Applications and Technologies, 2003 PDCAT'2003 Proceedings of the Fourth International Conference on. 2003:241-244.

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ALTERA AND XILINX TOOLS IN EDUCATION

ATANAS KOSTADINOV

Abstract: *In this paper, Altera and Xilinx tools used in Technical University - Sofia, Plovdiv branch are presented. Initially, Altera (now the Intel Programmable Solutions Group) tools are applied in Reconfigurable Logic and VLSI (Very-large-scale integration) design courses. Recently, it has been received donation from Xilinx university program (XUP) in the form of FPGA (Field-programmable gate array) design kits and Vivado Design Suite: System Edition. Now tools from both reconfigurable logic market leaders are used as themes in bachelor's and master's degree syllabuses.*

Key words: *Altera and Xilinx tools, Xilinx university program, Vivado Design Suite: System Edition, Nexys4 DDR*

1. Introduction

The reconfigurable integrated circuits especially CPLD (Complex programmable logic device) and FPGA (Field-programmable gate array) are used in higher education very often [1, 2, 3, 4, 5, 7, 8, 9, 10, 11] in different courses. The subjects can vary from Digital logic design [1, 2, 10, 11], Embedded Systems design [7, 8, 9] to Reconfigurable Logic and VLSI (Very-large-scale integration) design [4, 5]. In the lectures are presented some basic issues regarding reconfigurable integrated circuits, their internal organization and the way of their reconfiguring. In laboratory exercises are used CPLD and mainly FPGA boards and students implement some digital and microprocessor circuits. This practically oriented higher education helps students to make required steps from using fixed logic to applying reconfigurable one and corresponding hardware description languages as Verilog and VHDL (Very high speed integrated circuits description language).

Technical University - Sofia, Plovdiv branch has about fifteen years tradition of using contemporary reconfigurable integrated circuits in the educational process [2, 3, 4, 5]. During these years some improvements have been done in course syllabuses as well as in software and hardware tools. The last change was received donation from the Xilinx University Program (XUP) [12] in the form of five FPGA design kits of type Nexys4 DDR and twenty licenses for Vivado Design Suite: System Edition. Together with previously used Altera tools now design software and FPGA boards from both major reconfigurable logic suppliers are used in bachelor's and master's degree syllabuses. In the next sections are presented some details about reconfigurable integrated circuits and tools used from the beginning up to now.

2. Altera (now the Intel Programmable Solutions Group) tools

Initially, the current lecturer of Reconfigurable Logic and VLSI design courses has graduated from ALaRI (Advanced learning and research institute) [13] in Lugano, Switzerland. During education process, there were two subjects related to reconfigurable integrated circuits produced by Altera and VHDL. After finishing master degree course and returning to Bulgaria, I have been involved in teaching of similar material to students from Technical University - Sofia, Plovdiv branch. Together with it, the education in reconfigurable circuits has been started in the former John Atanasoff Technical College. In order to get licensed version of the design software and to obtain boards for laboratory exercises, it has been applied for a donation through Altera University Program [14].

2.1. First CPLD board

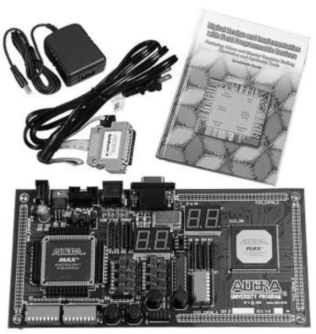

Fig. 1. UP2 board

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The application was successful. The first donation from Altera Corporation has been in form of licensed software (Quartus II and ModelSim) and one CPLD board (UP2). The received UP2 (University Program 2) is presented in Fig. 1.

It has been realized a license server in 2202 computer hall and the students have been used the licensed versions of Quartus II and ModelSim design software. The obtained single UP2 board was a good starting point in the lab equipment process. It has been used as a demonstration of loading a simple design into one of two CPLDs located on the board. UP2 connection to personal computer (PC) was parallel interface using printer port (LPT - Line print terminal 1) of the PC. The length of this cable was not enough UP2 to be put on the laboratory desk. It has been decided to be found another way in order to be increased the number of the FPGA boards that are needed for the laboratory exercises.

2.2. Support from the University

With the financial support of the Technical University - Sofia have been obtained two Cyclone II FPGA starter development boards. One of them is presented in Fig. 2.

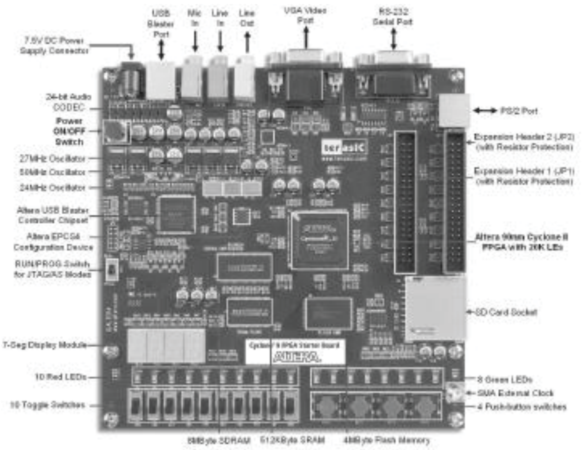

Fig. 2. Cyclone II FPGA starter development board

These boards are used in the laboratory exercises of the courses connected to the reconfigurable integrated circuits.

2.3. Donation from the firm partner

With help of the firm partner (ASIC Depot) of Computer Systems and Technologies Department has been added additionally two Cyclone II FPGA starter development boards. In this way the number of existing FPGA boards are very close to the sufficient amount required for the laboratory exercises.

Unfortunately, we had no laboratory equipment and design software by another major FPGA producer - Xilinx. We have decided to apply for Xilinx University Program [12]. The results of this application was again successful. Details about new donation are presented on the next lines.

3. Xilinx tools

We have applied for the five FPGA boards of type Nexys4 DDR. The application was again successful, as it mentioned before, and we have obtained these boards. The view of one of them is presented in Fig. 3.

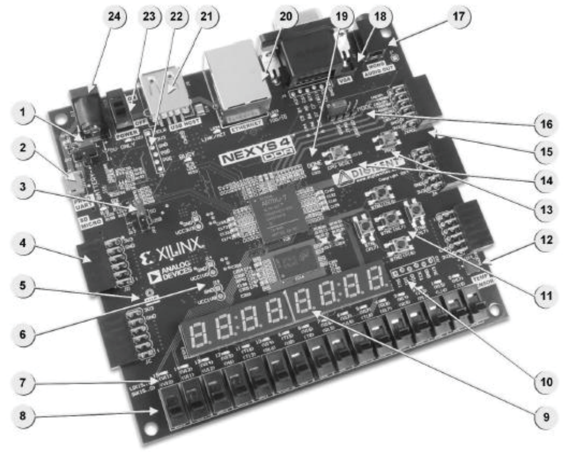

Fig. 3. Nexys4 DDR board

Additionally, we have received twenty licenses for the Vivado Design Suite: System Edition. Now we have FPGA boards and corresponding design software from both global players of reconfigurable integrated circuit market. These tools we use in the educational process in Technical University, Plovdiv branch as well in the research activities, too.

4. Altera and Xilinx tools used in the teaching and research activities

4.1. Educational process using both tools

At the beginning, we have started using Altera (now the Intel Programmable Solutions Group) tools. The corresponding syllabuses were presented in the paper [5]. As example, in the lectures are introduced IPs (Intellectual Properties) modules. In the Fig. 4 is presented a block diagram of the PLL (Phase - locked loop) circuit. Then corresponding IP module called ALTPLL Megafunction is presented [15].

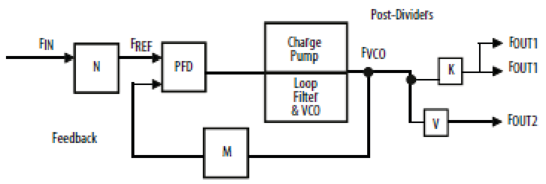

Fig. 4. PLL block diagram

At the end of Reconfigurable logic course a small design task is given to the students. They have to describe in VHDL a simple test system. This system uses a 4-bit binary counter and a LFSR (Linear feedback shift register) in order to be generated input stimuli to device under test. One solution of this task is presented in Fig. 5 [5].

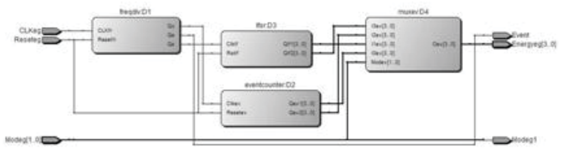

Fig. 5. Synthesized test circuit

Now, in the lectures' material an information about Nexys4 DDR and Vivado Design Suite: System Edition has been added. In the Fig. 6 an electronic circuit of Nexys4 DDR basic I/O (connected Input / Output devices) is presented.

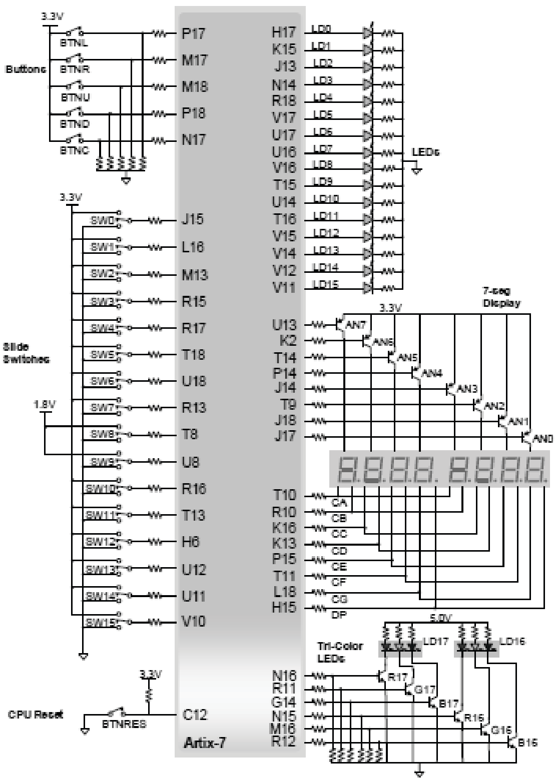

Fig. 6. Nexys4 DDR basic I/O electronic circuit

In the Fig. 7 a screenshot of a simple VHDL design (multiplexer) realized using Vivado Design Suite: System Edition is presented . This a part of the lectures in Reconfigurable Logic and VLSI (Very-large-scale integration) design courses.

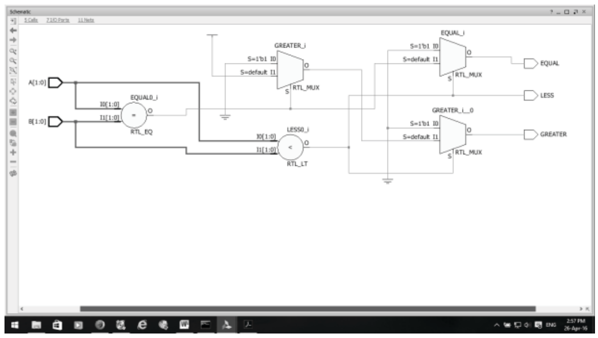

Fig. 7. Vivado Design Suite: System Edition project

4.2. Research achievements using both tools

It has been published many research papers in which FPGA boards and tools (mainly from Altera Corporation) have been used [2, 3, 4, 5]. Some research results have been included in the book section [6].

As example, a predicate logic processor (PLP) has been designed and tested during ERCIM (European research consortium for informatics and mathematics) postdoctoral fellowship in NTNU (Norwegian University for Science and Technology) under guidance of Prof. DSc. Guennadi Kouzaev.

A simplified block diagram of the PLP is presented in Fig. 8.

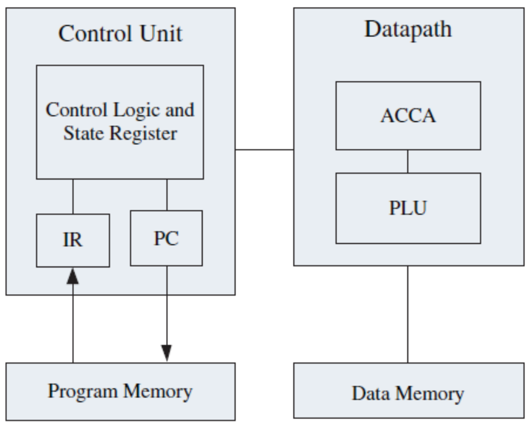

Fig. 8. PLP block diagram

Additionally, a patent application has been done [16]. Now, in the future research activities will be added some results using Nexys4 DDR FPGA board and Vivado Design Suite: System Edition. We have already started with a bachelor thesis connected to design of a master device controlling I2C (Inter-Integrated Circuit) bus. After successful defense and with an additional work, the material is able to be presented on a scientific conference.

5. Conclusion

In the paper, the organization of the educational process and research activities connected to the reconfigurable integrated circuits have been presented.

It has been given information regarding using tools from both major suppliers of CPLDs and FPGAs.

It has been mentioned that the XUP donation is already used in the teaching activities. The current lecturer plans that this donation will be used also in the future research activities.

6. Acknowledgements

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I would like to thanks to Prof. DSc. Guennadi Kouzaev for his excellent supervisory role.

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REFERENCES

1. Kiray, V. and Jambulov, A. (2009). FPGA based digital electronics education and a simulator core design for a/d communication. *Academic Journals*, vol. 4, no. 11, pp. 1292 - 1301.
2. Kostadinov, A. (2009). Using of a hardware description language in the digital design subject. *Journal of the Technical University – Sofia, Plovdiv branch "Fundamental Sciences and Applications"*, vol. 14, no. 1, pp. 421-426.
3. Kostadinov, A. (2009). Using of embedded logic analyzer in laboratory exercises of testing and diagnostics subject. *Journal of the Technical University – Sofia, Plovdiv branch, "Fundamental Sciences and Applications"*, vol. 14, no 1, pp. 427-432.
4. Kostadinov, A. (2009). Using HDL translators in VLSI design laboratory exercises. *Annual Journal of Electronics*, vol. 3, no. 2, pp. 56-59.
5. Kostadinov, A. (2013). Field-Programmable-Logic device education, *Annual Journal of Electronics*, vol. 7, pp. 46-49.
6. Kouzaev, G. (written together with Kostadinov A.). (2013) *Lecture notes in electrical engineering 169, Applications of advanced electromagnetic, Components and systems, Predicate logic, gates and processor for topologically modulated signals (TMS)*, pp. 451 – 460, Springer, Germany.
7. Kumar, A., Fernando, S. and Panicker, R. (2013). Project-Based Learning in Embedded Systems Education Using an FPGA Platform. *IEEE Transaction on Education,* vol. 56, no. 4, pp. 407 - 415.
8. Mahmoodi, H. at al. (2012). Hands-on Teaching of Embedded Systems Design Using FPGA-Based tPad Development Kit. Interdisciplinary Engineering Design Education Conference, Santa Clara, USA, pp. 1 - 6.
9. Nakano, K. and Ito, Y. (2008). Processor, Assembler, and Compiler Design Education Using an FPGA. 14th IEEE International Conference on Parallel and Distributed Systems, Melbourne, Victoria, Australia, pp. 723 - 728.
10. Petrescu, I., Păvăloiu, I. and Drăgoi, G. (2014). Digital Logic Introduction Using FPGAs. The 6th International Conference Edu World, Pitesti , Romania, pp. 1507 - 1513.
11. Zeyad, A., Sulaiman, N. and Hamidon M. (2009). FPGA-based Implementation of Digital Logic Design using Altera DE2 Board. *International Journal of Computer Science and Network Security,* vol. 9, no. 8, pp. 186 - 194.
12. https://www.xilinx.com/support/university.html
13. http://www.alari.ch/
14. https://www.altera.com/support/training/university/overview.html
15. https://www.altera.com/en_US/pdfs/literature/ug/ug_altpll.pdf
16. https://www.ipo.gov.uk/p-ipsum/Case/PublicationNumber/GB2508162

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IMPLEMENTATION OF SOFTWARE ARCHITECTURE FOR COMPLEX ANALYSIS OF SOLAR CORONA IMAGES

DIMITAR GARNEVSKI

Abstract: *A study of the processes in the nearest star - the Sun is important because of its influence on space weather and life of the planet as a whole. As in any scientific fields research in the solar corona require specialized software for processing the received data. This publication will investigate aspects of the architecture and the way of implementation of software for processing and analyzing images of the solar corona and in particular data retrieval for CME (Coronal Mass Ejection).*

Key words: *image processing, filters, parallel computing, solar corona, OpenCL, file formats, meta-data*

1. Introduction

In process of analysis of Solar corona and especially research of events and processes in magnetic field scientists uses special software which meets their requirements. Common tasks can be divided in few groups like initial discover of the event (CME - Coronal Mass Ejection), estimation of parameters of the event, additional classification of the CME, tracing of changes in the CME in time. Software must also present information to the scientists in proper format for additional processing.

2. Requirements

We can be define following requirements which must be fulfilled by the implemented software

- defining model of processed data (solar corona images and meta-data)
- defining states of images quality estimation algorithms
- implementation of adaptive model of input images pre-processing depending on images parameters
- implementation of pre-processing of the images like noise filtering etc.
- implementation of common processing algorithms stages
- visualization of the result and output data formats

3. Stages of image processing

Relying on initial requirements we can define following stages of solar corona image processing in developed software. The diagram at Fig.2 presents different stages of processing of image and flow of data between steps.

3.1. Pre-Processing

One of the additional steps which can be implemented and can improve results of image processing is quality estimation of input images and their initial pre-processing. Although currently significant amount of solar corona images which captured from Earth surface (capturing Solar corona with coronagraph with CCD or CMOS technology camera) has parameters which in significant amount cases meet requirements of used algorithms for image analysis and processing. When we use images received from cosmic probes cannot always guarantee good quality of input images. If we leave aside the parameters such as number of bits per pixel and levels of compression of images, most modern tools are able to provide color or black and white images with dimensions at least 1024 x 1024 pixels, it provides a starting point for further processing.

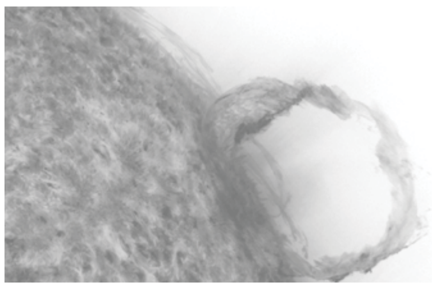

Fig. 1. *Prominence sample image*

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Initial image quality estimation include estimation of noise level and level of shining from camera lenses. Noise level estimation is performed with stochastic approach.

Undesirable shining at the edges of the image can be removed by estimation of these pixel values and following normalization against average values available in entire image.

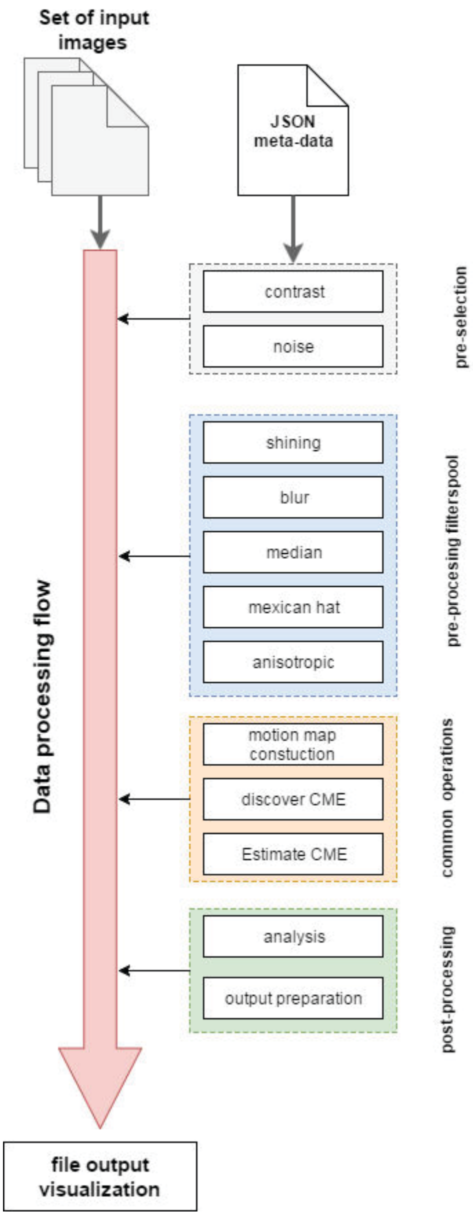

Fig. 2. Data processing flow

Noise removing is performed via filtering input images with one or combination of multiple filters like Mexican hat, median, anisotropic filter, etc. Common task of this operation is removing of pixel values which are out-of desired range without damaging structure of captured objects (lines, edges). In this situation anisotropic filtering has some benefits against other filters like blur because anisotropic filtering blurs image without damaging edges between objects in image [1][2][6][8].

3.2. Meta-data

For the purposes of the processing and in particular tracking changes over time are necessary metadata to images (date and time of capture, necessary adjustments, etc.). The date and time can both be obtained from the file or from meta-data (in cases when the data file does not correspond to actual shooting time). In implemented application when as input the data files FITS time are obtained from the file. In cases when using JPEG and processed series of images to store metadata using text file containing JSON (JavaScript Object Notation) with the necessary meta-data (in the basic version it is a list of files for processing and shooting time).

Format used contains data preprocessing:

- image contrast requirements - min and max values
- noise level
- possibility for preprocessing: pre-filter: shining removing, blur, median, Mexican hat, anisotropic (2 types with parameters)
- motion map stage
- output dir
- output file format

Fragment of a JSON file metadata is presented below:


```
{
  "inputDir": "C\\TestFilesInput",
  "inputFiles": [
    {
      "file": "test1.jpg",
      "timestamp": "2017-02-02 20:23:25",
      "preprocess": "true"
    },
    {
      "file": "test2.jpg",
      "timestamp": "2017-02-02 21:24:25",
      "preprocess": "true"
    }
  ],
  "preProcess": [
    {
      "filter": "glow",
      "mask": 3
    },
    {
      "filter": "median",
      "mask": 3
    },
    {
      "filter": "mexican",
      "mask": 3
    }
  ],
```

```
"process": [
  {
    "step": "motionmap"
  },
  {
    "step": "discover"
  },
  {
    "step": "cme_params"
  }
],
"postProcess": [
  {
    "step": "image",
    "format": "jpg"
  },
  {
    "step": "video",
    "format": "avi"
  },
  {
    "step": "cme_params",
    "format": "csv"
  }
],
"outputDir": "C\\TestFilesOutput"
}
```


Fig. 3. *JSON file with metadata*

3.3. Image analysis

Image processing core of the application include algorithms like generation of motion map, discovering of prominence at the boundary of occulting disk, estimation of prominence parameters like height, direction and their evaluation in time and estimation of connection between changes in Sun brightness and probability for solar prominence.

Generation of motion map is performed via algorithm described in [3][4][5]. In application is used its OpenCL implementation with platform independent optimizations.

Once built the map with the movement of the particles may be estimated height of the prominence and its direction.

Discovery the borders of occulting disk (artificial moon). In assessing the images and special about calculating the data for the height of the protuberance having matching the size of the solar disk image and the actual size of the Sun. In this case the work is performed with parts of images that include approximately 1/2 to 2/3 of the entire solar disk.

In this case, be carried out two operations, alignment of the images with respect to each other and detecting the boundary of the artificial moon. Artificial moon itself is depicted as a dark area defining the border is done by detecting the two endpoints that are located in border areas of the image and the central point, which is positioned between them.

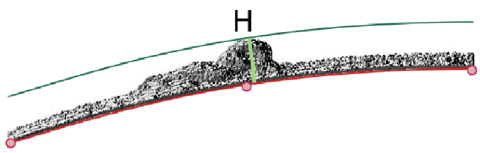

Fig. 4. *Generated motion map with prominence height estimation markers*

With these data points are build arc that defines the boundary of occulting disk and allows to calculate the correlation in size.

Estimation of connections between changes in Sun brightness and solar prominence is performed via processing of number of images in selected interval and discovering prominence in this interval.

For the implementation of the software used language C++, OpenCL environment for parallel processing, OpenCV library for image processing and number of additional libraries for FITS and JSON processing. For the implementation of key filtering functionality used OpenCL so calculations can be performed on CPU and GPGPU. Using of OpenCL provides needed flexibility in selection of different computational platforms. Also each filter can be defined as one separate kernel function in OpenCL which provides standardized approach in filter execution and opportunity for filter replacement.

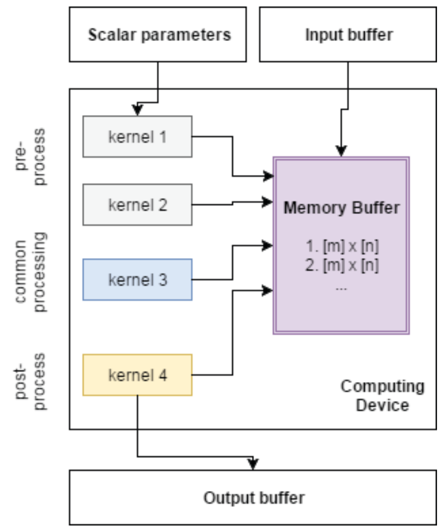

Fig. 5. *Kernel processing model*

Additionally be can perform changes in filter algorithm (kernel function implemented in OpenCL language) during development process without performing changes in entire application and we don't recompile it.

3.4. Post-processing

Post-processing of results include generation of out data in human readable format or format which can be used in another application. Developed application creates output in common images formats like JPEG or FITS (Flexible Image Transport System) [9] and also generates video based on frame sequences. For numerical data we use CSV (Comma-Separated Values) [11] format which is human readable and can be imported in most of data processing software like Microsoft Excel, it's open-source alternatives or other applications. Basic example of generated CSV is shown at image.

Table 1. *Sample CSV data format generated by the application*

1	2017-02-02 20:23:25	2017-02-02 21:24:25	128	46720
2	2017-02-02 20:24:25	2017-02-02 21:27:25	134	48910

CSV data format generated by the application is shown in Table 1. Individual columns are separated by the comma or tab-space depending on preferences. Shown in Table 1 file contains information amount measured high of discovered coronal mass ejection (CME). First column represents sequence number, 2nd and 3rd start and end time of measured interval (filled against input meta-data or timestamp of the input images), 4rt columns represent height of the CME in pixels and the last columns shows height in km, which was calculated depending of scale factor (filled in meta-data) and image resolution.

3.5. Result visualization

As we mentioned in 3.4 application generates images depending on desired result. So they can be viewed by external image viewers. Soft has embedded viewer which uses OpenCV [7] image processing library for additional image processing before visualization. This type of additional processing includes conversion between color spaces, basic filtering or adding of geometrical objects (lines, arc, markers, etc.) to the image.

For in example image at the Fig.4 are visible object (arcs and markers) which has been added with usage of OpenCV image processing library.

Generation of video files (.avi format) is also performed via OpenCV library.

4. Conclustions

Adaptation of the application to work with web-based storage systems and organization of images. This will include implementation of API which can be used by external systems.

Implementation of additional pre-processing and common filtering algorithms.

Integration of distributed computations like MPI (Message Passing Interface)

REFERENCES

1. Al Bovik. (2004). *Handbook of image and video processing*, Academic Press. Canada.
2. Rafael C. Gonzalez Richard E. Woods (2002) *Digital Image Processing*, 2nd Edition, Prentice Hall
3. Petya Pavlova, Elena Duncheva, Kostadinka Koleva (2010). Method for tracking and mapping a motion based on images of the solar corona. *Proceedings of the VII Bulgarian-Serbian Astronomical Conference (VII BSAC)*, Chepelare, Bulgaria.
4. Petya Pavlova, Kristina Staneva (2005). Dependence of the Colour in Computer Models on the Colour-reproducing Signals Discretization. *E+E*.
5. Petya Pavlova, Dimitar Garnevski, Kostadinka Koleva (2016). Optimization of a motion tracking and mapping method based on images of the solar corona. *Bulgarian Astronomical Journal, Volume 24*
6. S. G. Hoggar, *Mathematics of digital images. Creation, Compression, Restoration, Recognition*, Cambridge
7. http://opencv.org/, OpenCV (Open Computer Vision) Reference
8. Frery A. C, Perciano T. (2013*). Introduction to Image Processing Using R*, Chapter 2, Springer
9. https://fits.gsfc.nasa.gov/, The FITS Support Office, NASA/GSFC
10. http://www.json.org/, ECMA-404 The JSON Data Interchange Standard.
11. https://tools.ietf.org/html/rfc4180, Common Format and MIME Type for Comma-Separated Values (CSV) Files
12. Markus J. Aschwanden, A Code for Automated Tracing of Coronal Loops Approaching Visual Perception, *Springer Science+Business Media B.V. 2010*

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ADVANCED ALGORITHM FOR CANNY EDGE DETECTION GRADIENT MAGNITUDE COMPUTATION TO BE IMPLEMENTED ON FPGA

DIMITRE KROMICHEV

Abstract: *The paper presents a Pythagorean theorem computing algorithm aimed at simultaneously satisfying both the requirement for mathematical exactness and the demand for maximum speed of gradient magnitude computations in the FPGA orientated Canny edge detection realization. Proposed are several criteria to be satisfied for a computational algorithm to be labelled as advanced. The focus is on advantageously utilizing the FPGA integer arithmetic capabilities for providing a hundred per cent accuracy of square root calculations at optimal speed.*

Key words: *Canny edge detection, gradient magnitude, FPGA, accuracy, speed, algorithm, square root, interval*

1. Introduction

Canny edge detection is a low level digital image processing technology. It was intended to be used in software. Field Programmable Gate Array (FPGA), as a representative of the widely applicable programmable logic, has been increasing its market share over the last two decades. The two capital requirements for FPGA-based hardware implementation of Canny edge detection are accuracy and speed, the former being a function of the mathematical exactness of computational algorithms within each of the modules framed by the maximun utilization of FPGA capabilities. Speed depends upon several factors, among them of tremendous importance being the algorithms calculations are realized through. FPGA functionalities and characteristics should be taken into account by the computational algorithms in terms of utilizing those favourable to fast executions whereas avoiding operations and methods serving as bottlenecks. Speed is worthy of being set as an accomplishable goal only on the peremptory platform defined as total accuracy of calculations and veracity of detected contours. Thus, in FPGA-based Canny every single algorithm requires a multifaceted approach targeting the results' being reliable as well as feasible.

The implementation of Pythagoras aimed at computing the gradient magnitude in the FPGA orientated Canny which is described in the literature [7][8][9][10] relies on the approximation

$$|G_M| = |G_X| + |G_Y| \qquad (1)$$

where Gx and Gy are the x- and y-gradients. Although fast, this technique is very inaccurate. So far, in the literature there has been no algorithm addressing both the requirement for mathematical exactness and the demand for speed.

The objective of this paper is to present an advanced gradient magnitude algorithm aimed at speeding up the FPGA-based Canny on the basis of providing a hundred per cent mathematical accuracy of results. The task is to describe in detail the sequence of steps, to thoroughly analyze the computational reliabilty, to expose the characteristics, and to point out the applicability of the proposed algorithm. taking into account the FPGA functionalities. Essential criteria to be satisfied for an algorithm to be labelled as advanced are set forth. The targeted hardware is Altera FPGAs. Relevant to the analyses and conclusions arrived at in this paper are only gray-scale images.

2. Criteria for advanced algorithm

Canny edge detection includes these consecutive modules: Gaussian smoothing, computing the orthogonal gradients, computing

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gradient magnitude and direction, non-maximum suppression, hysteresis thresholding. Labelling an algorithm should reflect its essential computational characteristics, and rely upon definite criteria, the latter in the FPGA-based Canny being as follows.

1) Satisfying the peremptory demand for a hundred per cent mathematical accuracy of results. This is the solid guarantee for veracity and reliability of detected contours. In this respect, gradient magnitde is of tremendous importance for the overall plausibility of Canny computations in terms of procuring the values to be compared in the non-maximum suppression module, thus directly and immediately impacting one of the few most significant and applicabale qualities of contour – its precise localization.

2) Serving as a tangible tool for optimally enhancing the speed parameter of Canny computations on FPGA. This criterion has a quantitatvely measured characteristic presented by the smallest possible amount of clock cycles requred for executing the surveyed algorithm. Two particular aspects are to be taken into account here. Speed is a function of the appropriate and expedient organization of calculations in the algorithm being analyzed. On the other hand, fast and computationally sofisticated as it can seem, any algorithm should comply with the integer arithmetic peculiarities and benefit from the advantageous functionalities of the FPGA hardware implementation. Thus, the more mathematically complicated the algorithm (such as Pythagoras), the heavier the speed dependence on the programmable logic's computation accelerating capabilities.

3) Boosting the efficiency of pipelining, the latter being indispensable to the FPGA–based Canny edge detection implementation focused on speed. This criterion proves to be of particular importance in case of algorithms being executed in parallel within the main flow of computations on FPGA, gradient magnitude and gradient direction algorithms being indispensable here. Taking into account that calculating the local maximum requires a square neighbourhood of pixels, the calculated gradient magnitude values have to be ready for use at a rate that allows for a comparison of the central pixel with the adjacent pixels along the axis of gradient direction without any delays.

4) Minimizing the impact of input data width. Confining the input data to 8 bits is of significant importance in the Canny modules as a tool for diminishing delays. On Altera FPGAs, the fastest integer arithmetic execution in terms of clock cycles is guaranteed for 8-bit values [1][2][3][4][5]. In respect to this criterion, an advanced algorithm should optimally commence computations with integer arithmetic which takes exactly one clock cycle to execute, whatever the width of input values. Fulfillment of that requirement is well manifested for the Pythagoras, the FPGA implementation of the algorithm peremptorily starting with multiplication.

3. The proposed algorithm

Mathematically, gradient magnitude G_M is computed using

$$G_M = \sqrt{G_x^2 + G_y^2} \quad , \qquad (2)$$

where

Gx and Gy are the x- and y-gradients.

Altera provides a specialized integer square root function – ALTSQRT [5]. Although the 8-bit gray scale image values are definitely advantageous to the speed parameter, the maximum clock rate the function can be executed at [5] is not campatible with the accomplishment of the speed optimization goal – calculating the correct result requires nine clock cycles. Thus, an optimized approach is needed.

3.1. Input data

Gx and Gy are computed in the Canny orthogonal gradients module by employing two approaches:

1) Exact mathematics. The equations used to accurately calculate the x gradient and the y gradient are:

$$G_x = \frac{(N_3 + 2N_4 + N_5) - (N_1 + 2N_8 + N_7)}{4} \qquad (3)$$

$$G_y = \frac{(N_7 + 2N_6 + N_5) - (N_1 + 2N_2 + N_3)}{4} \quad , \qquad (4)$$

where

N1..N8 are the neighboring pixels in a 3x3 neighborhood.

The values calculated here are within the intetval [-255,255].

2) Approximation.

$$Gx = [(N_3 + 2N_4 + N_5) - (N_1 + 2N_8 + N_7)] \qquad (5)$$

$$Gy = [(N_7 + 2N_6 + N_5) - (N_1 + 2N_2 + N_3)] \quad , (6)$$

where

N1..N8 are the neighboring pixels in a 3x3 neighborhood.

With division by the power of 2 being dropped out, the values calculated here are within the intetval [-1020,1020]. Consequently, proper scaling is required for all the results to fit within the maximum gray scale image pixel range.

3. 2. Advanced gradient magnitude computation

On FPGA, computing Pythagoras starts with multiplying $|G_X|$ by $|G_X|$, and $|G_Y|$ by $|G_Y|$. The largesr positive pixel value being 255, the results of both multiplications are within the interval [0, 65025].

In the next step, the multiplication results are added, and consequently the numbers to be square rooted are within [0, 130050].

Thus, all the possible values at the input of the square root function are 130051, And all the possible values at its output are 2^8, taking into account that only numbers in the interval [0, 255] are relevant for pixels in the gray scale matrix. Consequently, the exact mathematical results of the square root function can be determined by 256 closed intervals, each of them representing a single integer from the interval [0,255]. These intervals contain all the 130051 values calculated by adding the squared gradients.

Defining the smallest and the largest in each interval is based on the fact that the difference between squares of two consecutive integers is equal to the smaller integer multiplied by 2, and then 1 is added to the result. Thus, the smallest of all the consecutive values contained in an interval is determined through:

1) squaring the gray scale image pixel value represented by this particular interval;

2) the gray scale image pixel value represented by this particular interval is decremented, and the result is subtracted from the result computed in 1) .

The largest of all the consecutive values contained in an interval is determined through:

1) squaring the gray scale image pixel value represented by this particular interval;

2) the gray scale image pixel value represented by this particular interval is subtracted from the result computed in 1) . The only exception is the value in the interval representing 255 – here the largest possible number is 130050.

The comparisons of all values for computing the gradient magnitude are executed simultaneously on FPGA, utilizing one of the most significant capabilities of hardware implementation – parallel computations. Thus the proposed algorithm satisfies the criteria for being labelled as advanced. It guarantees a hundred per cent mathematical accuracy of gradient magnitude computation. It also utilizes the fastest integer arithmetic on Altera FPGAs. The presented algorithm is not susceptible to any input data width driven delays. Being that fast, it is capable of increasing the efficiency of pipelining in the FPGA-based Canny.

4. Conclusions

The paper focuses on presenting and analyzing a new gradient magnitude algorithm addressing the goal of speed enhanced and mathematically exact Canny edge detection computations intended to be implememted on FPGA. Essential criteria to be satisfied for an algorithm to be labelled as advanced are defined. A thorough description of the algorithm's peculiarities is set forth. The algorithm is scrutinized in terms of its applicability, computational reliability and speed characteristics. The technological capabilities of efficiently avoiding speed eroding computational approaches and satisfying the peremptory demand for mathematical accuracy and plausibility of results pinpoints the feasibility of the proposed algorithm as a tangible tool for enhancing Canny's performance on FPGA.

REFERENCES

1. Altera Corporation. Cyclone IV Device Handbook. 2014, Volume 1
2. Altera Corporation. Cyclone V Device Handbook. 2014, Volume 1
3. Altera Corporation. Stratix III Device Handbook. 2014, Volume 1
4. Altera Corporation. Stratix IV Device Handbook. 2014, Volume 1
5. Altera Corporation. Integer Arithmetic IP Cores User Guide, 2014
1. Altera Corporation. Cyclone II Device Handbook, Volume 1, 2014
7. Chandrashekar N.S., K. R. Nataraj. Design and Implementation of a Modified Canny Edge Detector based on FPGA, *International Journal of Advanced Electrical and Electronics Engineering*, (IJAEEE). 2013, Vol.2, (1), pp. 17-21
8. Chandrashekar N.S., K. R. Nataraj. NMS and Thresholding Architecture used for FPGA based Canny Edge Detector for Area Optimization, *Proceeding of International*

Conference on Control, Communication and Power Engineering. 2013, pp. 80-84

9. Divya. D., P. S.. Sushma. FPGA Implementation of a Distributed Canny Edge Detector, *International Journal of Advanced Computational Engineering and Networking.* 2013, Vol. 1, (5), pp. 46-51
10. Shamlee V., Jeyamani.. A Split Canny Edge Detection: Algorithm and its FPGA Implementation. *International Journal of Science and Research* (IJSR). 2014, Vol. 3, pp. 1198 -1205

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APPROXIMATION IN THE FPGA BASED CANNY EDGE DETECTION COMPUTATIONS

DIMITRE KROMICHEV

Abstract: *The paper deals with the technology of approximation and its impact on the computational results in the FPGA based Canny edge detection modules. Presented are four general types of approximation and their essential functions and characteristics are exposed. The impact of approximation on the mathematical exactness of calculations in the Canny algorithm is scrutinized with respect to the peculiarities of hardware implementation and the targeted veracity of the mapped contours. Analyzed is the relevance of approximation in terms of speed vs. accuracy.*

Key words: *Canny, FPGA, approximation, type, algorithm, accuracy, speed*

1. Introduction

For decades now, Canny edge detection has gained a well deserved reputation of being an efficient and reliable low level digital image processing technology. Inasmuch as this precise yet complicated operator is orientated towards being used in software, its hardware implementation on the Field Programmable Gate Array (FPGA) is particularly difficult and requires that the computations be executed by strictly taking into account the capabilities and functionalities of that widely used representative of programmable logic. The goal to enhance performance while sparing the area of FPGA generaly involves certain precision decreasing approaches in the realization of the basic computational algorithms Canny relies upon. Thus, addressing the quality and plausibility of detected edges, the technique of purposely replacing exact mathematical values with numbers that are close demands an in depth analysis. In the FPGA based Canny, approximation has several aspects of utilization, each of them impacting the calculations in its own way and worthy of being duly assessed.

Described in the literature are different uses of approximation related to Canny edge detection on FPGA. In [10], the approximation is focused on computing the gradient magnitude in terms of replacing the square root function with the sum of positive values of x- and y-gradients, and is aimed at enhancing the speed performance. In [8], split Canny uses approximation gradient magnitude and direction computations for the purpose of increasing pipelining efficiency. In [6][3][9], distributed Canny attemps to spare the on-chip memory at the expense of approximation orientated calculations and maintaining constant throughput through performing the computations at block level. In [5], area optimized Canny is mainly focued on a new architecture of the non-maximum suppression and approximation framed hysteresis thresholding modules. In modified Canny [4] [7], the image is partitioned into q sub-images and each sub-image is further divided into p m×m blocks. Approximation is applied to gradient magnitude and direction module, as well as the calculation of high and low thresholds.

The objective of the paper is to thoroughly analyze the approximation patterns employed in the FPGA based Canny calculations. The task is to scrutinize the computational results which are close but do not coincide with the exact numbers obtained through using the standard mathematics in terms of: types, distribution by Canny's modules, attitude towards speed optimization, effect on the utilized FPGA area, influence on the precision of detected contours, impact on speed and accuracy relation with respect to FPGA's advanced capabilities. It is the Altera FPGAs that are referred to throughout this study. Relevant to the conducted analyses and conclusions arrived at are only gray scale images.

2. Types of approximation

Canny edge detection includes five modules: Gaussian smoothing, computing the orthogonal gradients, computing gradient magnitude and direction, non-maximum suppression, hysteresis

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thresholding. With respect to its utilization and effect on the calculations in FPGA orientated realization of Canny, approximation is to be presented within four types.

2.1. Mandatory approximation

It is imposed by the requirements of the discrete domain in digital image processing. In that respect, actually two out of the five computational modules in the Canny algorithm are entirely based on approximation.

Any weighted average filter employed in the Gaussian smoothing module is a discrete approximation of the 2-dimensional function

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} , \quad (1)$$

where

G is the Gaussian mask weight with coordinates x and y,

σ is the standard deviation of Gaussian distribution; it determines the filter's size,

$\frac{1}{2\pi\sigma^2}$ is normalization constant.

On FPGA, the filter performs a ZxZ neighborhood operation (Z is an odd number and Z ≥ 3)

$$v(m,n) = \frac{1}{s} \sum_{k=-w}^{w} \sum_{l=-w}^{w} g(k,l) u(m+k, n+l) \quad (2)$$

where

u(m,n) is the input image,

v(m,n) is the filtered image,

$w = \frac{z-1}{2}$, w = {1,2,..},

g(k,l) is the Gaussian filter ,

s is the sum of all coefficients in the mask; the coefficients are integers based on the binominal series.

The Sobel approach for computing the orthogonal gradients is actually the result of a two stage approximation:

1) the central difference approximation

$$\Delta f(x) = [\, f(x+1) - f(x-1)\,] * 0.5 \quad (3)$$

to the derivative of a continuous function

$$f' = \frac{df}{dx} = \lim_{\Delta x \to 0} \frac{f(x) - f(x - \Delta x)}{\Delta x} \quad (4)$$

for $\Delta x = 1$ as the smallest possible value of Δx in the discrete domain of digital image pixels;

2) approximation to (3) for the purpose of defining two 1-D masks: -1 0 1 and -2 0 2. They are the platform of the two 2-D filters employed in the calculation of the vertical and horizontal gradients (Fig. 1.)

-1	0	1
-2	0	2
-1	0	1

Gx

-1	-2	-1
0	0	0
1	2	1

Gy

Fig. 1. Sobel filters for *x* and *y*

2. 2. Targeted approximation

Precise and reliable, Canny is computationally complicated, extensively demanding in terms of hardware implementation, and relatively slow algorithm. Thus, approximation is deliberately employed to address different aspects of performance being optimized.

2.2.1. Speed enhancing approximation

Accomplishing the goal of a fast FPGA based Canny is favoured by a set of approaches related to approximation.

1) Reducing and exploiting only the fastest integer arithmetic needed to fulfil a particular computational task. With respect to both the highest frequency and clock cycles taken for execution, the most speed advanced on FPGA are multiplication, addition and subtraction [1] [2]. In terms of speed, division is definitely a weak point. Using a divider by employing the Altera LPM_DIVIDE function [2] will immensely erode the speed parameter of Canny's algorithm execution. Consequently, the conventional integer division is typically omitted. Thus, in computing the orthogonal gradients the normalization division is dropped out, the gradient magnitude calculation is modified to rely on a single addition, and the gradient direction value is the result of utilizing only the signs of the vertical and horizontal gradients.

2) Avoiding those Altera LPM functions [1] [2] which, despite being handy, take more than two clock cycles to output a correct result and lead to speed eroding delays. The focus here is on omitting the square root function for the gradient magnitude and the division in the gradient direction computations.

3) Keeping the sequential logic input data width optimally within 8 bits for executing the FPGA integer arithmetic at the highest frequencies [1] [2]. The impacted values are those of the vertical and horizontal gradients which need to be confined to the interval [-255, 255].
4) Replacing a slow computational procedure with values determined in advance. To this point, fixed values for the high and low thresholds tend to be used instead of assessing the entire image statistics in the non-maximum suppression module.

2.2.2. FPGA hardware sparing approximation

Typically, the less the utilized FPGA area, the more efficient the Canny implementation. This aspect of approximation in the FPGA based Canny, despite sometimes being colateral and far from particularly intended, is important in two ways. It is an implicit indicator of the efficiency of a computational mechanism, thus presenting tangible measurement for the practical applicability of any technique or algorithm aimed at optimizing the organization of Canny calculations to be implemented on FPGA. The hardware sparing approximation can also serve as guidelines for assessing the extent a proposed computational approach is functionally advanced.

This approximation type is present mainly in the calculations of the gradient magnitude and direction wherein, instead of the very expensive hardware realization of exact mathematical algorithms, the results are achieved through relying on addition and comparison. It is also appropriate for sparing the limited in quantity on-chip memory in terms of using predefined low and high threshold values to avoid computations involving the entire image statistics after executing the non-maximum suppression.

2.3. Complete approximation

This approximation type is focused on replacing a whole computational algorithm and its territory is the gradient magnitude and direction module. Mathematically, gradient magnitude G_M is calculated using

$$G_M = \sqrt{G_x^2 + G_y^2} \tag{5}$$

where

Gx and Gy are the x- and y-gradients.

In the FPGA based Canny, Pythagoras is generally replaced with

$$|G_M| = |G_X| + |G_Y| \,. \tag{6}$$

The accurate calculation of gradient direction G_D is

$$G_D = \tan^{-1}\left(\frac{G_y}{G_x}\right) \tag{7}$$

where

Gx and Gy are the x- and y-gradients; $G_y \in [-255{,}255]$; $G_x \in [-255{,}255]$.

Calculating the gradient direction by applying expression (7) has the following inauspicious aspects:
1) The FPGA implementation is computationally expensive, and therefore leads to substantial delays.
2) The divisor G_X can be equal to 0. In that case calculating the gradient direction is practically irrelevant, and, consequently, additional computational conditions should be introduced to ensure the correctness of results.

For hardware implementation, (7) is typically replaced with the sign relations of the gradients.

$$\begin{aligned} &Gy > 0 \;\;\&\;\; Gx > 0 \\ &Gy < 0 \;\;\&\;\; Gx < 0 \\ &Gy > 0 \;\;\&\;\; Gx < 0 \\ &Gy < 0 \;\;\&\;\; Gx > 0 \;. \end{aligned} \tag{8}$$

2. 4. Partial approximation

This approximation type deals with a limited portion of the algorithm's computations and has its indispensible application in the calculations for determining the angular values 0, 45, 90, 135 which define the four axes of gradient direction. Two values are utilized to optimally approximate the two angles of crucial importance to the mathematical accuracy of gradient direction calculation.

Taking into account that four intervals are needed to contain all results of computing the Gy and Gx ratio, two referece points are employed. One of them should represent an angle of 22.5°, and the other - 67.5°. In the integer domain of FPGA based Canny, the most appropriate approximation to angle 22.5° is the fraction

$$\frac{2}{5} \quad \left(\tan^{-1}\left(\frac{2}{5}\right) = 21.8014094°\right) \tag{9}$$

and to angle 67.5° - the fraction

$$\frac{5}{2} \quad \left(\tan^{-1}\left(\frac{5}{2}\right) = 68.1985905°\right). \tag{10}$$

3. Assessment of approximation

3.1. Approximation in terms of impact on computational results

Inasmuch as the weighted average filter approximation has steadily defined its presence in the Gaussian smoothing, the appropriate selection of the fiter's size is of significant importance as a tool to compensate for the omission of not to be underestimated subtleties imposed by the discrete domain of digital image processing. Thus, taking into account the numerical characteristics of the bell shaped curve, the most suitable variants prove to be sizes 5x5 and 7x7. With respect to the fact that the larger the size the worse the localization, and taking into account the amount of computations required for the hardware implementation, the optimal option is filter of size 5x5.

As gradient filters, the two Sobel matrices have positive and negative coefficients. If in a 3x3 neighborhood C(x,y) is the central pixel, and the numbers of neighboring pixels are as shown (Fig. 2.) ,

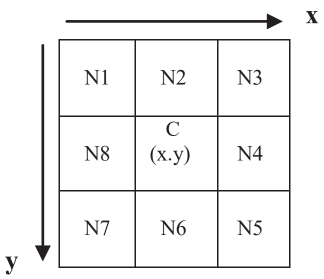

Fig. 2. 3x3 neighborhood pixels

the exact equations to calculate the x gradient and the y gradient for C(x,y) are:

$$G_{\dot{x}} = \frac{(N_3 + 2N_4 + N_5) - (N_1 + 2N_8 + N_7)}{4} \quad (11)$$

$$G_y = \frac{(N_7 + 2N_6 + N_5) - (N_1 + 2N_2 + N_3)}{4} \quad . \quad (12)$$

On FPGA, the approximation in computing the orthogonal gradients practically reduces the necessary integer arithmetic to addition and subtraction with division by the power of 2 being dropped out:

$$Gx = [(N_3 + 2N_4 + N_5) - (N_1 + 2N_8 + N_7)] \quad (13)$$

$$Gy = [(N_7 + 2N_6 + N_5) - (N_1 + 2N_2 + N_3)] \quad . \quad (14)$$

This approach presents two flaws. On the one hand, omitting division leads to lack of additional averaging, thus impeding a certain extra noise suppression to be applied to the image. On the other hand, taking into account that computing the gradient magnitude refers to the Pythagorean theorem, and magnitude values larger than 255 are irrelevant to the calculations of local maxima in the next Canny module, all the results equal or exceeding 2^8 are scaled down to the appropriate 255. Consequently, the division's being omitted requires that all the results larger than 255 should be cut down to fit the maximum value of a gray scale image pixel, and this entails serious disproportionality among this module's output results.

The gradient magnitude and direction module is of capital importance for the quality of detected contours. In computing the gradient magnitude, replacing (5) with (6) leads to calculated numbers which differ from the exact mathematical results in the range of 0.2-30 per cent. In terms of quantity, this lack of precision is irregularly distributed across the calculated gradient magnitudes, and any computational mechanism aimed at offsetting the inaccuracy is practically irrelevant. The largest differences are calculated for pixel values that are among the most frequently to be met in a gray scale image. In view of the fact that it is the gradient magnitude results that are compared in the non-maximum suppression module to perform edge thinning, the overall effect is poor localization and lack of plausibility, thus resulting in detected contour's getting unreliable for production line applications wherein taking correct measurements is of crucial importance. Depending only on (8) to compute gradient direction instead of (7) halves down the accuracy by reducing the required intervals from 8 to 4. The consequence is decreased correctness in the results of the algorithm involved in determining the local maxima, with eroded precision and gaps in the mapped contours.

The values calculated for the gradient magnitude and direction are straightforwardly used in the non-maximum suppression module. Utilizing (13), (14), and (6) can result in computing values exceeding 2^8 As long as only comparison of values limited of up to 255 is relevanly employed, keeping within 8 bits has no alternative.

Convenient as it is, utilizing two static values instead of a costly algorithm employing the entire image statistics to compute the high and low thresholds results in both omitting real edges and defining noise as contours, the latter being capable of considerably compromising the output of Canny in terms of veracity, particularly with respect to uses orientated towards machine-to-machine interface.

Inasmuch as every pixel in the processed image is surrounded by 8 other pixels, the approximation in (9) and (10) is actually characterized by accuracy that is enough to provide computational results commensurable to those achieved through utilizing the conventional mathematical expression in (7).

3.2. Approximation in terms of speed vs. accuracy

Overtly or in the background, the analysis of approximation and its impact on the FPGA based Canny calculations eventually comes down to the speed vs. accuracy model. In this respect, there are two important facts.

Computationally expensive and slow as Canny is, addressing the accomplishment of speed optimization goal should peremptorily focus the proposed approaches on the framework of detected contours' being optimally plausible. Achieving reliability of the edge detected image especially for more demanding production line applications is feasible on the basis of using mathematically accurate algorithms to realize the calculations in the Canny modules. This being taken into account, approximation is a tangible technique as long as it does not violate the pattern of exactness and veracity at each successive stage in the flow of computations. Approximation for speed enhancement purposes which functions as a hurdle to the accuracy of results is unacceptable.

Even though being hard to implement on FPGA, Canny can afford avoiding approximation that compromises accuracy through utilizing the programmable logic's typical characteristic - executing computations in parallel. Whatever the complexity of an algorithm in a Canny's module, the simultaneity of calculations is quite an efficient tool to accelerate calculations without having to rely on accuracy decresing approximation. The additional requirement to be satisfied here is for the parallel computations to utilize the fastest integer arithmetic on FPGA.

4. Conclusions

Presented in this paper are four general types of approximation used in the FPGA based Canny edge detection computations: mandatory, targeted, complete, and partial. Mandatory approximation is imposed by the requirements of the discrete domain in digital image processing. In that respect, Gaussian smoothing and orthogonal gradients are entirely based on approximation. Accomplishing the goal of a fast FPGA based Canny is favoured by a set of approaches related to approximation. Complete approximation is focused on replacing a whole computational algorithm and its territory is the gradient magnitude and direction module. Partial approximation deals with a limited portion of the algorithm's computations and has its indispensible application in the calculations for determining the gradient direction. Two values are utilized to optimally approximate the two angles of crucial importance to the mathematical accuracy of gradient direction Each approximation type is analyzed and assessed in terms of: Canny's module it is used in, characteristics, expediency, departure from the mathematical exactness of results, impact on the reliability of calculations, relevance to the quality of detected contours. The attitude of approximation towards speed and accuracy relation with respect to FPGA's advanced functionalities is scrutinized.

REFERENCES

1. Altera Corporation. Cyclone II Device Handbook, Volume 1, 2014
2. Altera Corporation. Integer Arithmetic IP Cores User Guide, 2014
3. Aravindh G., C. S. Manikandababu, Algorithm and Implementation of Distributed Canny Edge Detector on FPGA, *ARPN Journal of Engineering and Applied Sciences,* Vol. 10 (7), 2015, pp. 3208-3216
4. Chandrashekar N .S. and Nataraj K. R., Design And Implementation of a Modified Canny Edge Detector based on FPGA, *International Journal of Advanced Electrical and Electronics Engineering, (IJAEEE),* Vol.2, (1), pp. 17-21
5. Chandrashekar N.S. and Nataraj K.R., NMS and Thresholding Architecture used for FPGA based Canny Edge Detector for Area Optimization, *Proceeding of International Conference on Control, Communication and Power Engineering,* 2013, pp. 80-84
6. Divya. D. and Sushma P. S., FPGA Implementation of a Distributed Canny Edge Detector, *International Journal of Advanced Computational Engineering and Networking,* Vol. 1, (5), 2013, pp. 46-51
7. Ramgundewar, Pallavi, S. P. Hingway, K. Mankar. Design of Modified Canny Edge Detector based on FPGA for Portable Device, *Journal of The International Association of Advanced Technology and*

Science. Vol. 16 (2), 2015, pp. 210-214

8. Shamlee V. and Jeyamani, A Split Canny Edge Detection: Algorithm and its FPGA Implementation, *International Journal of Science and Research (IJSR),* Vol. 3 (12), 2015, pp. 1198-1205
9. Veeranagoudapatil, Chitra Prabhu. Distributed Canny Edge Detector: Algorithm & FPGA Implementation, *Internationa Journal for Research in Applied Science & Engineering Technology* (IJRASET), Vol. 3 (5), 2015, pp. 586-588
10. Xianghua Hou, Honghai Liu, Welding Image Edge Detection and Identification Research Based on Canny Operator, *International Conference on Computer Science and Service System,* 10-13 Aug. 2012, pp. 602-610

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INTRUSION DETECTION AND PREVENTING SYSTEM

KOLYO RAYCHINOV, HRISTO VALCHANOV

Abstract: *The attacks against computer and network security are a real threat in the modern Internet world. Detection of attacks is a process of monitoring of computer systems or networks and analyzing them for signs of possible events that are violations or threats. Developing of intrusion detecting and preventing systems (IDPS) requires the availability of resources that are needed to be integrated within the protected network infrastructure. This paper presents the architecture and functionality of IDPS, which offers affordable, flexible and efficient solution for building such as systems in different fields.*

Key words: *Network Attacks, Intrusion Detecting and Preventing System, Raspberry Pi*

1. Introduction

Besides the advantages offered by the Internet technologies, they hide many risks that professionals in the IT field have to deal. Cybercrime is a growing criminal activity, and the convenience of fast connections to multiple resources connected to Internet makes hackers to invent increasingly clever and high-tech ways to exploit vulnerabilities in the systems. The attacks are a real threat for the information, which is a valuable resource in today's world, both for individuals and for businesses. The corporate sector often falls under similar attacks because of financial reasons - companies own resources and information that can be stolen or to speculate with them. For this reason the companies pay special attention on used hardware and software - they are usually of significantly higher class and price compared to widely used ones. There is need for effective, smart and cheap solutions for threat recognition and preventing.

This paper presents the basic architecture and functionality of intrusion detection and preventing system, which offers simple, flexible and efficient solution for building similar systems in different fields.

2. Attacks detection and prevention

Detection of attacks is the process of monitoring of events in computer systems or networks and analyzing them for signs of possible violations or threats of computer security policies [1]. The events may be due to many reasons such as malware (spyware and worms) which acquire unauthorized access to the system through the Internet, or intrusion by unauthorized people who are using incorrect privileges.

The system for detecting attacks (Intrusion Detection System - IDS) is software that automates the process of detecting the attacks. The system to prevent attacks (Intrusion Prevention System - IPS) is software that has all the capabilities of IDS and can take to deter possible incidents. IDS and IPS technologies offer many similar features and administrators can usually exclude options for the prevention of IPS products, forcing them to function as IDS. Today in cyber security is widely used the term “Intrusion Detection and Prevention Systems” (IDPS), which combines two technologies [2].

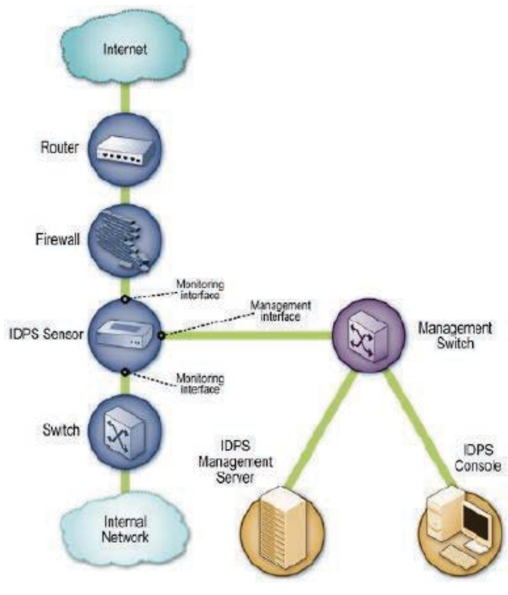

Fig. 1. *IPDS infrastructure*

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The implementation of IDPS requires certain resources that need to be integrated within the protected network infrastructure (Figure 1). Typical components are as follows:

- Sensor or agent. They monitor and analyze activity. The term "sensor" is typical for the IDPS who monitor networks and the term "agent" - for those tracking only one device.
- Management Server. It is a device that receives information from sensors or agents and manages them.
- Database server. It is a repository of information regarding the events detected by sensors, agents and management servers.
- Console. This is a program that provides an interface for access to IDPS of users and administrators.

The building of such infrastructure requires substantial costs, both from financial and organizational point of view. A number of manufacturers offer complete solutions on the market, including special devices and software that are however acceptable only for large companies.

The IPDS technology uses several basic methods for detection of attacks. Anomaly based detection is the process of comparing definitions of what activity is considered normal for watched events and then to recognize large deviations. Such a system has profiles that represent the normal behavior of elements such as users, devices, network connections or applications. The profiles have been developed by monitoring the characteristics of a typical activity for a given period of time. A major problem in the generation of profiles is that it can be quite difficult in some cases to be made precise, because of complexity of the computer activity.

Detection based on state of the protocols is the process of comparing the pre-set common definitions of normal actions for each protocol's state with observed events to identify deviations. Unlike anomalies based detection that uses network or host-based profiles, this analysis relies on universal profiles developed by manufacturers that describe how each protocol should or should not be used. The main disadvantage of this type of analysis is that they require a great intensity of resources, because of the complexity and the additional load during the simultaneous tracking of multiple sessions.

A more efficient method is the detection based on the signature. This is the process of comparing the signature and the observed events to be identified a possible attack. This approach is very effective for detection of known attacks. In terms of implementation and use of resources, this is the simplest method because there is only a comparing the current element of activity as a package or a log entry with a list of signatures using strings compare operations.

3. Architecture of the system

The architecture of the presented system is modular (Figure 2). It comprises a multiple modules, each having a specific functionality. This allows easy modification of system functionality in future extensions.

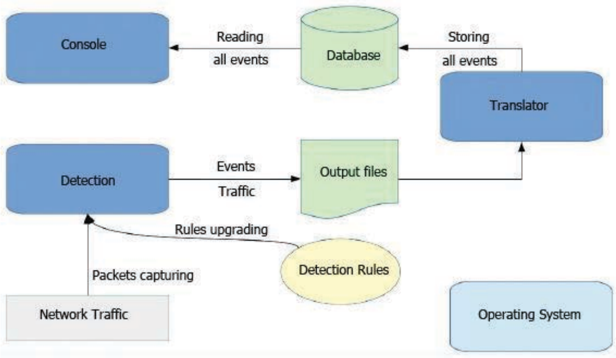

Fig. 2. *Architecture of IPDS*

The system consists of the following components:

- Operating System under which runs the software implementation.
- Software performing detection of attacks.
- Events translator.
- Console for showing the results of the analysis of the network traffic.

The main idea of the developed system is its easy integration into any network infrastructure. For this purpose is proposed a simple and efficient solution using a single board computer Raspberry Pi [3]. A characteristic feature of this system is its integrity - the concentration of all software components on the powerful hardware, at the same time with small size and low cost of ownership.

There are possible alternative configurations of the presented architecture. One configuration is a simplified version of that where IDPS records the output messages directly in the database, skipping the binary file and the translator. In this case the performance of the software is low, as it concentrates more functionality. In another architecture a file for direct analysis at a later stage is generated (for example, *csv* or *tcpdump*) and completely are absent translator, database and front-end interface. The proposed system takes account of the convenience and functionality it provides the graphical console for the analysis of the detected threats. Thus, it is realized an architecture with high efficiency.

As an operating system is used Debian Linux based system - Raspbian [4] which is one of the officially supported according to the Raspberry Pi Foundation and provides opportunities to meet the requirements of current implementation.

Under the operating system is running another important component for the IDPS – the software for control of the traffic that passes through the device. For fulfilling this role is used Snort, which is a fundamental component in the network IPDS [5]. In this implementation the IDPS interacts with network traffic through a transparent bridge through which the traffic passes.

For greater efficiency of Snort, the data from the system are generated in binary file in *unified2* format. This file is processed by translator - it parses recorded events and particular traffic and redirects them to a database. The used translator is Barnayrd2, running parallel with Snort and redirecting new events from the binary file to the database in real time [6]. As a database management system is used MySQL [7].

Key for each signature-based IDPS are lists of rules according which the events are defined as having possible degree of threat or not. These signatures are stored by Snort in several types of local files. Because of the dynamics of the security systems, the information about each newly discovered vulnerability or malicious code must reach the protected systems as soon as possible. To satisfy this requirement, in the system is implemented a tool which automates the process. The company, which develops Snort, supports a repository with signatures for detection of attacks. The updates are performed by the tool PulledPork, which connects to the central repository, downloads the new rules and applies them in IDPS [8].

4. Experimental study and results

Testing of the presented system is done in a real network infrastructure (Figure 3).

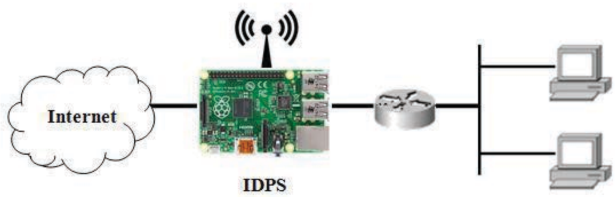

Fig. 3. *Integration of IPDS into a network*

An important issue is the management of the system. In order to avoid physical accessibility to Razpbery Pi (keyboard or console terminal) there is applied a solution by adding third WiFi network interface. The standard model of Raspberry Pi rev.2 has only one Ethernet interface, but for the realization of the system is required at least two (in the best case and three network communication interfaces). For this purpose, additional external USB modules are added - an USB-to-Ethernet adapter, an Ethernet card and a single USB dongle for wireless WiFi connection. Thus achieves the intended functionality via two interfaces through which to pass network traffic checked for problems and an interface to access the system for its management. Both the Ethernet interfaces have no IP addresses and are connected as a bridge running on the link layer of the OSI model, which is transparent to the upper layers.

The network system for detecting attacks is situated in a part of the network that carries traffic between internal and external to the organization networks. The Snort sensor must be behind the devices communicating through encrypted connection (VPN routers), so watched traffic is not encrypted. At the same time, it must be located behind a firewall that prevents any attempts to attack. Thus, in a security breach, the system will detect the incidence and will notify by messages the responsible personnel.

There are simulated Denial of Service (DoS) attacks. Large amount of requests (hundreds of thousands) from spoofed sources are generated for the shortest period of time. This results in flooding of network. The attack is implemented by sending only SYN packets, as the attack is directed to the router in the network.

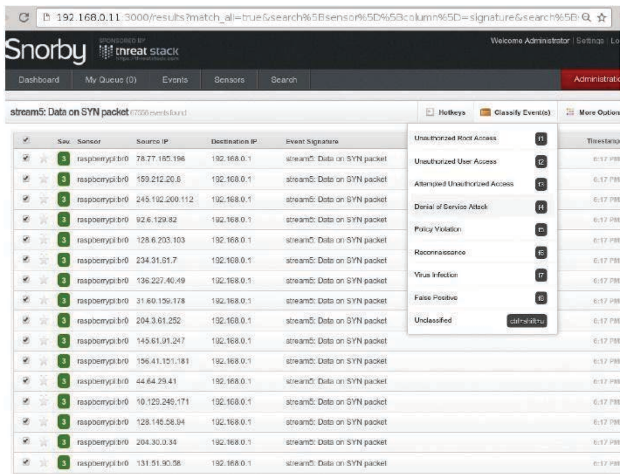

Fig. 4. *Events classification*

Over 65,000 messages (Figure 4) for unusual behavior in the network are generated. Its number continues to grow because the translator continues to read from the binary file and fill the database with new messages, although the simulated attack is over. The reason for detected by the system anomaly are data in SYN packets, intercepted by Stream preprocessor of Snort.

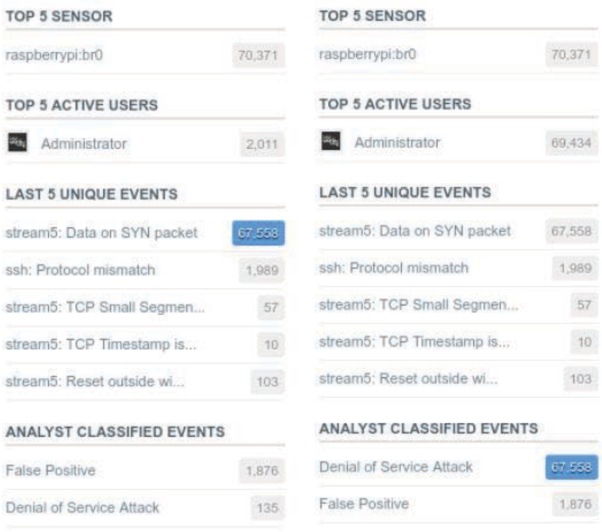

Fig. 5. *Events before and after classification*

After the detection of the events it is necessary to classify them. In this case, they are defined as DoS attack due to the amount of requests from multiple addresses without completed TCP dialogue. This classification is done through the management console - Snorby and is illustrated on Figure 5. After the process of mass classification of new events they are marked as a DoS attack.

5. Conclusions

The computer security will continue to be a serious problem in the coming years. However, with tools such as systems for attacks detection, countering threats would be an achievable goal. In this aspect, network security products developed for small organizations have great potential value.

This paper presents the architecture and basic functionality of an affordable, portable and easy to use system for detection and prevention of network attacks. The system is based on open source code, allowing tremendous flexibility in need of modifications and further developments.

The proposed IPDS is designed to be integrated easily into any existing network infrastructures. These can be both small business networks and organizations, as well as large corporate networks. The compactness of the system allows its use in different segments of the network, without the need for a physical change of its topology. This is especially effective for networks where is very important their operations to be uninterruptable, such as bank branches, hospitals, etc. The combination of cheap hardware and open source software is a possibility for widespread use of the system.

The goal of future work is the development of architecture by using multiple Raspberry Pi sensors distributed in various key network nodes to redirect the output data to a centralized database, thereby optimizing use of the IPDS system.

REFERENCES

1. Sanders C., Smith J. (2014). *Applied Network Security Monitoring: Collection, Detection, and Analysis*, Syngress.
2. Richard B. (2013). *The Practice of Network Security Monitoring: Understanding Incident Detection and Response*. No Starch Press.
3. RaspberryPi Project. http://www.raspberrypi.org.
4. Raspbian OS. http://www.raspbian.org.
5. Snort. http://www.snort.org.
6. Barnyard2. http://www.github.com/firnsy/barnyard2
7. MYSQL. http://www.mysql.org.
8. PulledPork. http://www.github.com/shirkdog/pulledpork/.

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SIMULATION FRAMEWORK FOR REALIZATION OF PRIORITY-BASED LTE SCHEDULER

VENETA ALEKSIEVA, AYDAN HAKA

Abstract: *The LTE Technology provides simultaneously voice, data and video with different priority on networks. LTE applies the QoS bearers technique that provides high performance in packet delivery based on prioritization of the traffic. In this paper is proposed a simulation framework for LTE technology, which realized a priority based algorithm for LTE Scheduler, which reorders packets, based on classification mechanism.*

Key words: *LTE, Scheduler, prioritization, QoS*

1. Introduction

In the middle of 2016 the European Commission in [1] presents coordinated designation and authorization of the 700 MHz band for wireless broadband by 2020 and coordinated designation of the sub-700 MHz band for flexible use which safeguards the provision of audiovisual media services to mass audience, as well as investments into more efficient technologies, which are needed in order to vacate the current use of the 700 MHz band by digital terrestrial television. The prognosis of these estimates require the search of optimal 4G solutions in terms of QoS offered by telecom providers. According to published from Ericsson paper [2], suggests that by 2020 it is expected a growth of LTE subscriptions up to 3.7 billion. In February 2015 Cisco System published, in turn, prognosis for the period 2014-2019 [3], where the Global mobile data traffic will grow three times faster than global fixed IP traffic from 2014 to 2019. The Mobile data traffic will grow 10-fold from 2014 to 2019, a compound annual growth rate of 57%, and it will reach an annual run rate of 291.8 Exabytes by 2019, up from 30.3 Exabytes in 2014.

Requirements of IMT-Advanced [4] are 1 Gbit/s speeds for fixed and 100 Mbit/s for mobile users. Up to 2016 under these requirements, providers of 4G services choose between two advanced wireless technologies - LTE [5] or WiMAX [6], but since 2016 widely used 4G technology is LTE and many vendors implement only this technology in their end devices.

Solutions are needed to improve QoS in terms of delays in larger loads and any packet loss. For communications to be successful, it is also essential to focus on network traffic prioritizes for different types of communication streams.

2. Priority in LTE networks

After the first implementations of LTE the focus in the allocation of resources is shifting towards to the profit maximization and user satisfaction [7]. Even with the developing of LTE technology the QoS for uplink is discussed by many authors [8,9,10,11,12].

In 3GPP, the QoS Class Indicator (QCI) consist of basic classes, which are defined as "default", "expedited forwarding", and "assured forwarding". It means: expedited forwarding is used for "strict" priority (video and voice), and "assured forwarding" is used for business differentiation (e.g., weighted-fair priority).

In LTE network QoS is between end-user devices and Packet Data Network (PDN) Gateway applying the "bearers". "Bearers" is a set of network configurations to provide a special handling of traffic to its set prioritization. Their hierarchy is presented in Table 1. Default bearer is established when the user equipment (UE) connects to the LTE network, while Dedicated bearer is established whenever must be set QoS for a specific traffic type (service) as VoIP, video and etc.

GBR (Guaranteed Bit Rate) provides guaranteed bandwidth and monitors two parameters in directions uplink and downlink:

- GBR- minimum GBR for EPS (Evolved Packet switched System) bearer,
- MBR- maximum GBR for EPS bearer,

Non-GBR bearer does not provide guaranteed bandwidth and also monitors two parameters in directions uplink and downlink: A-

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AMBR-general maximum speed permitted for the entire non-GBR throughput for specific APN (Access Point Name) and UE -AMBR- overall maximum speed permitted for the entire non-GBR throughput for all of APN particularly UE.

Table 1. *LTE QoS*

Dedicated Bearer		Default Bearer
Non-GBR	GBR	Non GBR
QCI 5-9 APN-AMBR UE-AMBR TFT ARP L-EBI	QCI 1-4 GBR MBR TFT ARP L-EBI	QCI 5-9 APN-AMBR UE-AMBR APN IP Address ARP

In LTE networks for differentiation of QoS same as in WiMAX are applicable classes which here are called QoS Class of Identifier (QCI). They define the basic characteristics of the IP packet level, as presented in Table 2.

Table 2. *QCI classes in LTE*

QCI	Bearer Type	Priority	Delay of the Packet	Packets Loss	Example of Traffic Type
1	GBR	2	100ms	10^{-2}	VoIP
2		4	150ms	10^{-3}	Video call
3		3	50ms	10^{-3}	Real time games
4		5	300ms	10^{-6}	Video stream
5	Non-GBR	1	100ms	10^{-6}	IMS Signaling
6, 8, 9		6, 8, 9	300ms	10^{-6}	TCP based services – chat, ftp...
7		7	100ms	10^{-3}	Voice, video, interactive games

Then in the base station (eNodeB) is applied a preemption algorithm, which allows high priority requesting bearers to displace low priority connected bearers in order to reduce the cell load. This algorithm coupled with a priority-based admission control can achieve low dropping and blocking probabilities.

3. Proposed algorithm for prioritization of UEs in the LTE

The aim of the proposed algorithm is to achieve keeping the network throughput as high as possible at a small price of only a bit more handovers. The functions for management of QoS in access networks are responsible for the efficient allocation of resources in a wireless interface. They are generally defined as the control algorithms of radio resources and incorporate power management, control of the transfer connection, access control , load control and the management packet , but directly related to QoS level cell are the last three. They are used to ensure a maximum throughput for individual services.

LTE uses multiple access technology (OFDMA), where the total bandwidth is divided into Resource Blocks (RBs) in the frequency domain. The Data is transmitted in the Transport Blocks (TB) in one transmission time interval (TTI) for 1ms. Each RB consists from 12 subcarriers (each of them is 15kHz). The frame is 10ms and divides into 10 equal subframes. Each subframe contains 2 slots*0.5ms. Each RB is related to one slot in time. One TB is related to 1 subframe and it is the minimum unit to schedule. The serve rule is to find first space that can fit the TB. If there are not enough RBs in the current TTI, the scheduler tries to find resources in the next TTI. This strategy minimizes the response latency, which is the best practice for delay sensitive traffic.

But in 1 Timeslot number of RB depends from frequency. It is presented in the Table 3.

Table 3. *Number of RB in LTE*

frequency	RBs for users traffic	RB for overhead
25MHz	4 RB	2 RB
2. 5MHz	10 RB	2 RB
5MHz	23 RB	2 RB
10 MHz	48 RB	2 RB
15MHz	73 RB	2 RB
20 MHz	98 RB	2 RB

But this procedure is not applicable for beacon transmissions (it is sent among devices each 100ms), because of emergency information it conveys, therefore the reserved resource blocks exist to accommodate the temporary overload.

The present paper offers an algorithm for UEs service in the distribution of resources in the uplink of LTE network as composed of two modules - by a control mechanism for admission (admission control) and Scheduler.

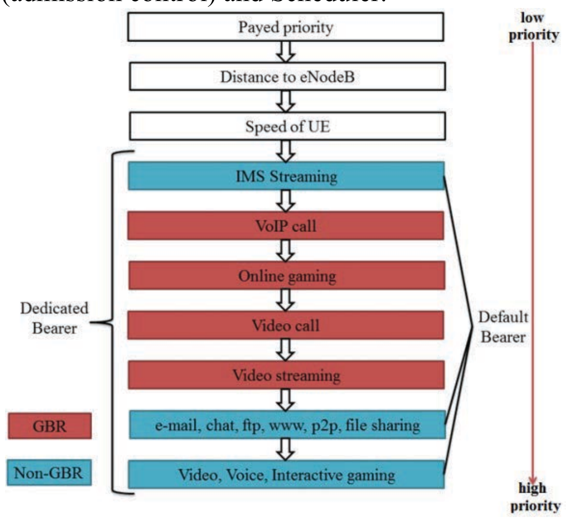

Fig. 1. *Traffic Prioritization in the Scheduler*

According to the network load, the admission control for the reception of orders manages the number of UEs, which can enter into the Scheduler, in order to avoid overloading the system with too many UEs.

The Scheduler allocates RBs among UEs according to UEs needs. Resource allocation in the Scheduler is based on the priority, which is presented on the Figure 1.

4. Simulation Framework of LTE Scheduler

In this approach a simulation environment was established for implementation and exploration of the proposed algorithm. Used software tool is Visual Basic 2010. The architecture of the simulator is presented on the Figure 2.

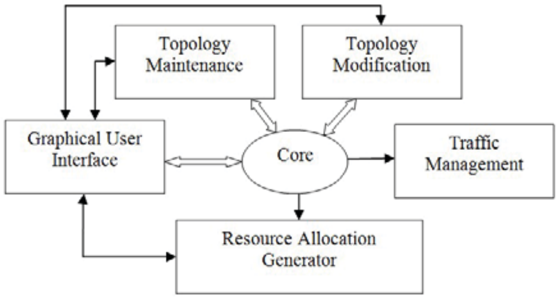

Fig. 2. *The LTE simulator's architecture*

The modules "Topology Maintenance" and "Topology Modification" are realized with classes "Form1" and "Form2". The classes contain methods for adding parameters of eNodeB and related UEs. A database for storing data from individual experiments for each eNodeB and its connected UEs is created. The tables from database with parameters for coordinator and related devices are presented on the Figure 3.

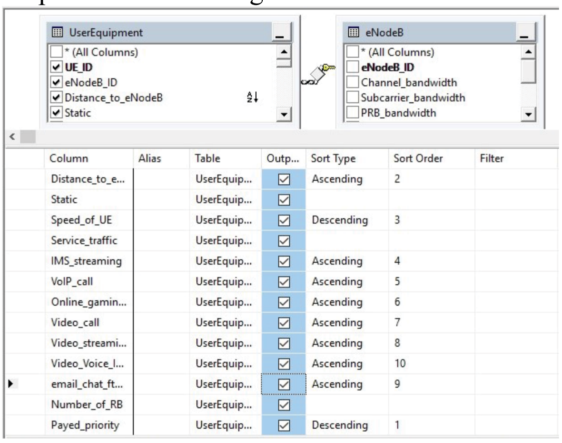

Fig. 3. *Database of LTE Prioritization in the eNodeB*

The module "Traffic Management" is realized with class "Form3". It loads data into the 'UserEquipment' table and visualizes the chart of the timing diagram.

The module "resource Allocation Generator", based on class "eNodeBdata", realizes the proposed algorithm for priority. The class contains methods for sorting UEs, adding it's data in array and arranging them.

Thus, the input of data for each device starts from initial parameters for the eNodeB. This is represented in the example of Figure 4. Another eNodeB (the next in the order) receives serial number. After that the user must type the number of UEs that will participate in the network of this base station, according to the limits imposed by the standard. The choice of bandwidth sets limits in the cell radius of the eNodeB and the transmission speed (bandwidth).

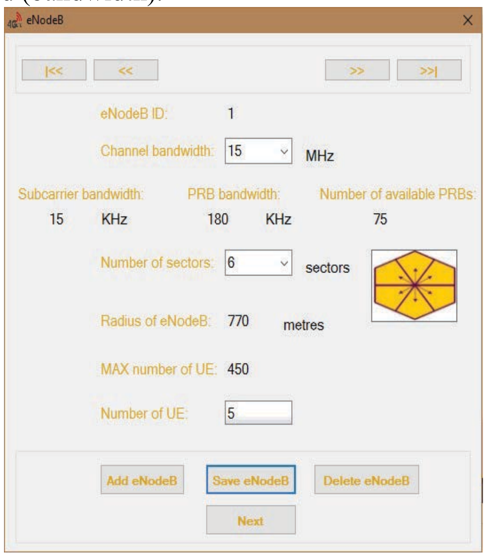

Fig. 4. *Input form of the parameters of eNodeB*

The tabular presentation of base stations and the information for UE (Figure 5) is suitable for displaying of multi aspected information that can be edited (Figure 6).

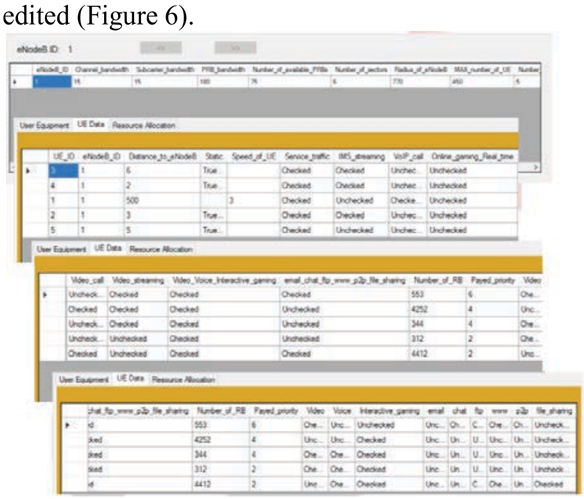

Fig. 5. *Database with information of eNodeB and related UEs*

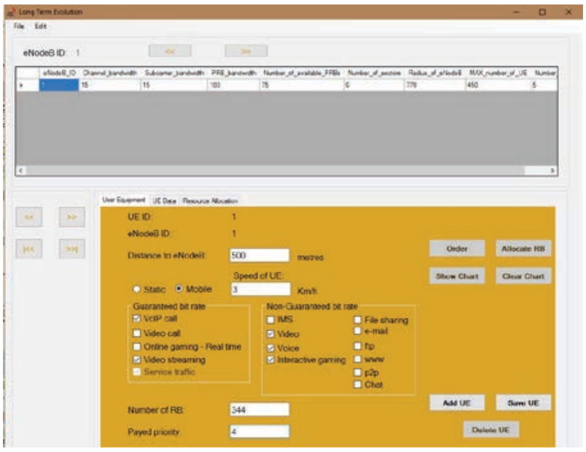

Fig. 6. Data of UE, connected to the eNodeB

One example of resource allocation and transmission matrix is presented on figure 7.

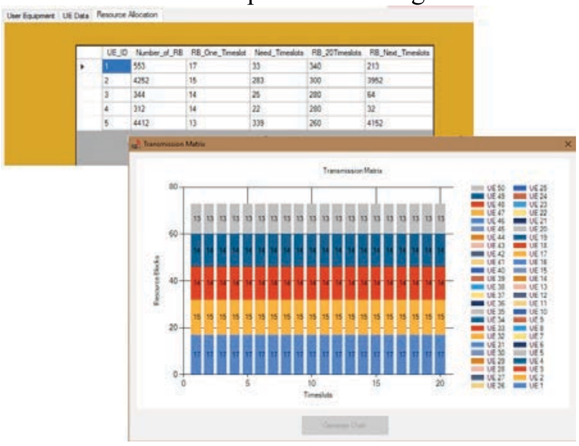

Fig. 7. Resource Allocation and Transmission Matrix

5. Experimental Results

The data from different experiments are send in .xls format to the next estimation.

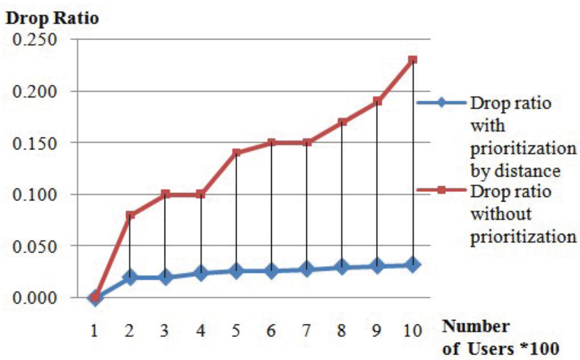

Fig. 8. Drop Ratio

On Figure 8 is presented the Drop ratio. It is possible to compare the number of drops when it is applied the prioritization, based on distance between the user and Base station and drops without prioritization. When the number of users grows up, the numbers of rejected beacons grow up too. This is the reason to increase the drop ratio when the number of the users is increased. The observed parameters degradation when connecting more users is related to the priority implemented scheduler, in which case the less priority queues may not be served in the case of network overload or congestion.

In assessing the performance of proposed algorithm of LTE Scheduler it also is assumed that UEs are evenly distributed within the range of the cell according to Section 7.1.6.1 of [13]. Each UE sends a signal periodically to know the channel condition of the UE for each TTI period of 1ms.

Figure 9 shows the dependence of the average time to establish a connection from UE to the eNodeB at different average intensity of applications when under area of the eNodeB are 100 UEs. An increase of the time for establishing a connection from the UE to eNodeB when the intensity of the requests is increased, as for the first 10% of the increase is from 10ms to 17ms, then the increase is significantly smoother and it amended in the range of 18ms to 23ms.

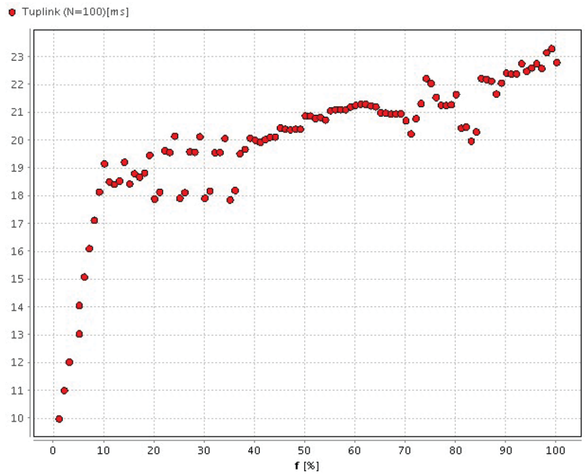

Fig. 9. Average time for connection establishment with 100 UEs

The results give reason to conclude that the presented algorithm for admission control in the Scheduler for LTE network can be applied successfully in the number of UEs under 100, because regardless of the intensity of the requests of the active UEs the average connection time is under 25ms-time, fully satisfying the requirements of [13].

In the Figure 10 it presents the dependence of the average time to establish a connection from the UE to eNodeB depending on the number of the UE, which are within the scope of the eNodeB for three different values of intensity of applications - 10%, 50% and 100%.

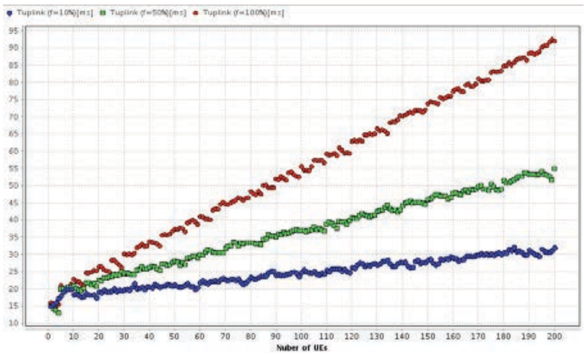

Fig. 10. *Average time for connection establishment with requests intensity of 10%, 50% and 100%*

It is easy to see a trend of increase in the time for establishing connection with an increase in the number of UE within the eNodeB, such as at a higher intensity time is significantly larger. If number of UEs is 200 and 100% intensity is reached 92ms, while number of UEs is 200 and 10% intensity the average time is 3 times less - 32 ms.

6. Conclusion

In this paper is proposed a simulation framework for LTE technology, which realized an efficient method for QoS for LTE service classes. In this framework is realized an algorithm for Scheduler to prioritize users in order to fit the bandwidth requirements, which are satisfying the application needs, based on the number of users and the prioritization of users. Simulation's results show that the proposed mechanism improves QoS, but the observed parameters degrade when the use of more subscribers is related to the priority implemented Scheduler, in which less priority queues may not be served in the case of network overload or congestion. There are presented drop ratio with prioritization and without prioritization. It was always assured a minimum transmission for all the service classes, although with different performances due to prioritization.

REFERENCES

1. EC (2016). Use of the 470-790 MHz frequency band in the Union, http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1454410061980&uri=COM%3A2016%3A43%3AFIN, June 2016.
2. P. Cerwall and others (2015). Ericsson Mobility Report-On the Pulse of the Networked Society, http://www.ericsson.com/res/docs/2015/ericsson-mobility-report-june-2015.pdf, June 2015.
3. Cisco System (2016). VNI Mobile Forecast Highlights 2016-2021, http://www.cisco.com/c/dam/assets/sol/sp/vni/forecast_highlights_mobile/index.html#~Region, February 2015.
4. (2008). Document IMT-ADV/1-E, Background on IMT-Advanced, ITU Radiocommunication Study Groups, ps. 3, 7 March 2008.
5. (2014). LTE: capacity and cell-edge performance improvements, February 2014, http://www.3gpp.org/.
6. Ramadas K., R. Jain, (2008). WiMAX System Evaluation Methodology v2.1, WiMAX Forum, July 2008.
7. Abu-Ali N., Abd-Elhamid M. Taha, Mohamed Salah, and Hossam Hassanein (2014). Uplink Scheduling in LTE and LTE-Advanced: Tutorial, Survey and Evaluation Framework, IEEE Communications Surveys & Tutorials, vol. 16, Issue:3, pp. 1239-1265, Aug. 2014.
8. Al-Rawi M., R. Jantti, J. Torsner, and M. Sagfors (2008). On the Performance of Heuristic Opportunistic Scheduling in the Uplink of 3G LTE Net- works, in Personal, Indoor and Mobile Radio Communications, 2008. PIMRC 2008. IEEE 19th International Symposium, pp. 1 –6, 15-18 2008.
9. Calabrese F., C. Rosa, M. Anas, P. Michaelsen, K. Pedersen, and P. Mogensen (2008). Adaptive Transmission Bandwidth Based Packet Scheduling for LTE Uplink, in Vehicular Technology Conference, 2008. VTC 2008- Fall. IEEE 68th, pp. 1 –5, 21-24 2008.
10. Calabrese F., C. Rosa, K. Pedersen, and P. Mogensen (2010). Performance of Proportional Fair Frequency and Time Domain Scheduling in LTE Uplink, pp. 271 –275, May. 2009.
11. Liu F., X. She, L. Chen, and H. Otsuka (2010). Improved Recursive Maximum Expansion Scheduling Algorithms for Uplink Single Carrier FDMA System, pp. 1 –5, may. 2010.
12. Ruiz de Temino L., G. Berardinelli, S. Frattasi, and P. Mogensen (2008). Channel-Aware Scheduling Algorithms for SC-FDMA in LTE Uplink, in Personal, Indoor and Mobile Radio Communications, PIMRC 2008. IEEE 19th International Symposium, pp. 1–6, 15-18 2008.
13. 3GPP (2015). 3GPP, Tech. Specif. Group Radio Access Network; Physical layer procedures, 3GPP TS36.213, ver.12.4, 2015.

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АВТОДИАГНОСТИКА ПОСРЕДСТВОМ ДЕЛФИ DS150E

ИБРЯМ АХМЕДОВ, ЕБРУ АДЕМ, НИКОЛИНКА ЯНКОВА

Резюме: *Delphi DS150E е софтуер, предназначен за лесно диагностициране на моторни превозни средства. Той улеснява многократно работата на човека предназначен обучен да работи с този софтуер . Целта на софтуера е да открива грешки съответно и причината за тази грешка , чрез този софтуерен инструмент откриването на електрически повреди се намалява многократно. Посредством софтуерния инструмент можем да постигнем желания положителен резултат за отрицателно време също така без това устройство с просто око не може да се рискува при поправка на автомобилна електроника.*

Ключови думи: *автомобилна диагностика, интерфейс за превозни средства*

DIAGNOSTICS USING DELPHI DS150E

IBRYAM AHMEDOV, EBRU ADEM, NIKOLINKA YANKOVA

Abstract: *Delphi DS150E – software designed to easily diagnose vehicles. It makes it much easier for people who are trained to work with this software. The aim of this software is to detect errors and the reasons for those errors respectively. With this software tool finding electrical failures is much easier. Through this software tool we can achieve the desired positive results in no time. Also, without this device we can't risk to make repairs of car electronics with a naked eye.*

Key words: *On-board diagnostics, Vehicle Communication Interface*

1. Увод

DS150E е най-новия модел диагностичен интерфейс от продуктовата гама на Delphi. Общият му вид е показан на Фиг 1.

Фиг. 1. *Делфи DS150E*

Инструментът използва оригиналните данни от производителите на превозни средства. Това е необходимо условие, за да бъде в състояние да предложи качество и функционалност.

За да направи работата по-лесна, инструментът съдържа редица функции, за да помогне на потребителя да направи правилните решения. Базата данни често се актуализира с оригиналните данни от производителите на превозни средства. Софтуера е 100% преведен на БЪЛГАРСКИ език в софтуера за леките коли и около 40% при тежкотоварните.

Устройството има функцията Flight Recorder, за запис на „живи данни“ по време на движение, чрез microSD карта памет. Като допълнение е монтиран светодиод на OBD конектора, за по-лесно намиране на OBD буксата. Поддържани интерфейси от устройството за диагностика са USB и като допълнителна възможност – Bluetooth.

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2. Особености на устройството за диагностика:

• **Конектор с LED** – за да намерите конектора за диагностика на автомобила с лекота, дори ако той е разположен в тъмно и недостъпно място

• **Проверка на напрежението** – когато DS150 е свързан към превозното средство, уредът ще провери напрежението на автомобила и автоматично се настройва към нивото на напрежение на превозното средство от 12 или 24 волта. Ако напрежението стане твърде високо или твърде ниско, DS150 ще ви предупреди със звук, светлина и чрез иконата на батерията в нашия диагностичен софтуер.

• **Номер на шасито VIN** – софтуерът за коли поддържа функция, която ви позволява да прочете номера на шасито от превозното средство, което бихте искали да се диагностицира. Това гарантира, че правилният модел и година е избран автоматично.

• **ISS – Intelligent System Scan** – сканира всички системи в автомобила и показва кодовете за грешки, които се съхраняват във всяка система. Това спестява време и можете да получите бърз преглед на актуалното състояние на цялото превозно средство.

• **ISI** – интелигентна система за идентификация - (ISI) идентифицира и избира автоматично вида на контролера на превозното средство. Това гарантира, че диагностичната сесия се извършва правилно с точните параметри.

• **Функция ДОКЛАД** – с помощта на тази функция, вие ще бъдете в състояние да видите адаптациите и корекциите, които са възможни за конкретен автомобил, без да се налага да сте в близост до превозното средство . Заедно с помощните текстове като ръководство, можете да планирате и да бъде ефективни в работата си дори и при сложни ситуации.

• **OBD функции** – Диагностичният софтуер DS150 е проектиран с технология, която му позволява да комуникира с всички видове протоколи. За лекотоварни и тежкотоварни средства, които не използват стандартния 16-пинов конектор, са предназначени други видове конектори като например : конектор за BMW кръгъл 20 пинов, конектор за Mercedes-benz кръгъл 38 пинов, конектор за Opel кръгъл 10 пинов, и др.

• **Други функции на продукта са:**

- връща базовите настройки на автомобила
- нулиране на сервизни интервали
- чете текущите кодове на грешки
- изтрива текущите кодове на грешки
- тестване на изпълнителните механизми
- адаптация на отделни параметри и изтриване на адаптационните стойности
- показва каталожния идентификационен номер, записан от производителя на тестваното ECU, версията на записаната в него програма, кодировката, датата, на която е програмиран и други.

3. Диагностика на дебитомер (MAF)

3.1. Какво е дебитомер.

Дебитомерът (MAF) е отговорен за преносът на данни които казват на ECU-то какво количество въздух постъпва. Това е относително прост процес. Основната част в този сензор е горещия елемент. Когато колата се движи и въздух минава през сензора, той има охлаждащ ефект върху него. ECU-то компенсира това охлаждане като изпраща точна информация за горещия елемент и това променя температурата. Това повишение в текущите данни се отчита от ECU-то и се конвертира в колко въздух е преминал през сензора (и от там постъпил в двигателя).

3.2. Причини поради което сензорът не отчита правилни параметри.

Елемента на дебитомера (MAF) може да се зацапа с прах и масло (от нередовна смяна на въздушния филтър или от маслените пари от отдушника на картерните газове). За съжаление тези малки проблеми могат да доведат до повреда в дебитомера (MAF), също проблем може да създаде и масивното преминаване на вода през него. Тези фактори играят ролята на изолатор или охлаждащ ефект. При Bosch дебитомерите (MAF), тези причини могат да доведат до прегряване и последствие да бъде физически деформиран елемента в сензора. Това ще доведе до некоректни данни които се изпращат до управляващия блок (ECU). В следствие на това се намалява горивото за да се предотврати черния пушек поради намаления обем въздух.

повреден. Сменете го.

<u>3.3 Почистване на дебитомер</u>

Почистването на дебитомер е важно поради факта замърсяване на сензора следователно което води до грешни отчитания на данни.Вади се дебитомера инсталиран на входящата връзка към смукателните колектори .

Изважда се връзката куплонга и след това с специален спрей предназначен за измиване на дебитомер като например този:

Измива се сензора и се оставя да изсъхне. Тази манипoлация се препоръчва да се извърши на изключена клема на батерия (акумулатора).

4. Принцип на работа на MAF – Mass air flow sensor (дебитомер)

Дебитомер е сензор, който преобразува количеството въздух постъпващо в двигателя в напрежение подавано към ECU на двигателя (или ЕБУ – електронен блок за управление).

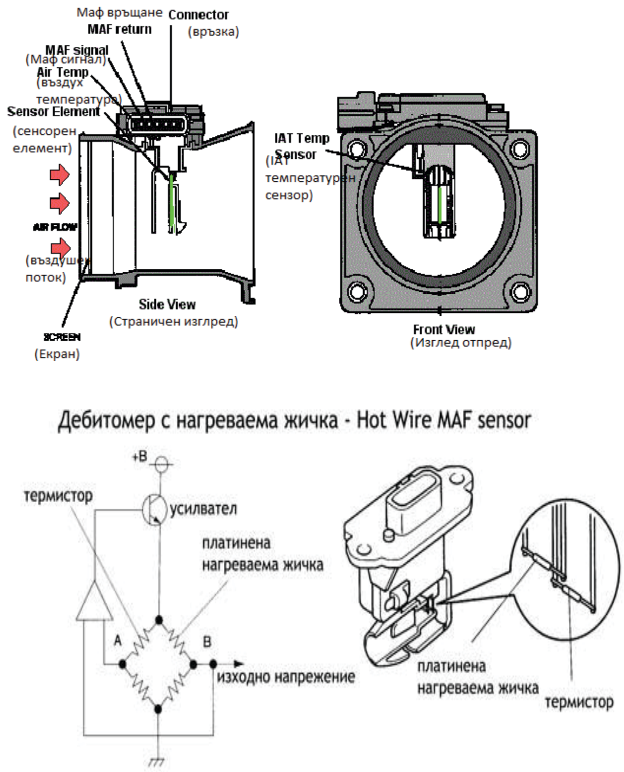
Към ECU на двигателя трябва да постъпва информация за количеството входящ въздух в двигателя, за да може да се изчисли натоварването на двигателя (engine load). Това е важно, за да се определи колко гориво да се впръска, кога да се подаде искра за запалване (за бензинов двигател) и дори кога да превключи трансимията ако е автоматична. Дебитомера обикновено се намира между въздушния филтър и тялото на дросела.

Съществуват различни видове дебитомери – механични и електронни. Пример за механичен такъв е VAF или vane air flow meter – по-стар модел дебитомер, като типа му може да бъде определен по формата му. При него измервателна плоскост се отмества пропорционално на обема въздух постъпващ в двигателя. Демпферна камера намалява рязкото придвижване на измервателната плочка.

5. Дебитомер – тип MAF с нагреваема жичка

Основните компоненти на този тип дебитомер са термистор, платинена нагреваема жичка и контролна електрическа верига, показани на Фиг. 2.

Термистора измерва температурата на входящият въздух. Нагреваемата жичка е с константна температура поддържана от ЕБУ, с помощта на сигнала от термистора. Повишаване на потока входящ въздух, причинява понижение на температурата на нагреваемата жичка и блока за управление на двигателя компенсира това незабавно, чрез подаване на по-голям ток през жичката. Контролна електрическа верига същевременно отчита подаваният ток и пропорционално го преобразува в напрежение. Така ЕБУ на двигателя, разполага с максимално прецизна и мигновено опресняваща се информация за количеството постъпващ в двигателя въздух.



Фиг. 2. *Mass air flow sensor (дебитомер)*

Този тип дебитомер има и вграден датчик за температурата на постъпващият в двигателя въздух или IAT – intake air temperature. Той подава информация към ЕБУ на двигателя и така допълнително спомага за поддържането на коректното отношение гориво/въздух.

Възможни причини и решения на проблема са:

1. Винаги използвайте високо качествени хартиени филтри. Това ще държи прахта далеч от дебитомера (и далеч от вашият двигател). Когато монтирате филтърът убедете се, че е хубаво легнал в кутията си.
2. Проверявайте често въздушният филтър и почиствайте кутията му.
3. Ако сензора не е прекалено замърсен или повреден, понякога може да бъде почистен (понякога дава добри резултати). Може да бъде почистен с контактен спрей, но не докосвайте горещата част с нищо (пръст, парцал и т.н.). Оставете го напълно да изсъхне преди обратно да го монтирате.
4. Буксата също може да се замърси или да не е добре вкарана. Това може да доведе до

некоректни стойности. Почистете я с контактен спрей, това може да нормализира нещата.

6. Измерване на живи данни на изряден дебитомер (MAF)

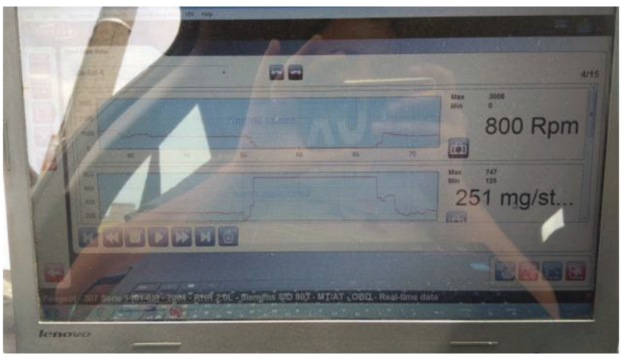
Delphi DS150E позволява следенето на „живи“ данни в реално време, както са показани по-долу. При невъзможност за излизане на трасе с компютър, производителите на устройството са дали възможност то самостоятелно да записва върху SD карта памет.

Величина на измерваната единица количество въздух на софтуера DELPHI DS150E е : ***mg/stroke .***

Измереното количество въздух 294mg/stroke искано при 2112 оборота, съответно, по този начин ЕКУ-то изисква **294 mg/stroke** въздух Фиг. 3.

Фиг. 3. *Измерване на количеството въздух*

Работа на празен ход 800 оборота в минута съответното желано (поискано) количество въздух 251 mg/stroke дадено на Фиг. 4.



Фиг. 4. *Измерено количество на празен ход (работа на място)*

7. Заключение:

Полезността на софтуера е особено голяма в използването му при всички съвременни леки и товарни автомобили. Проследяването на текущите параметри и сравняването им с желателните много бързо ориентира авторемонтните работници къде по цялата съвкупност от механизми и електроника да търси проблема.

Откритите кодове на грешки, записани в контролен блок от превозното средство, могат да посочат единицата, която е дала отказ.

Не на последно място е цената на диагностичния интерфейс, която е достъпна за малките и средни автосервизи.

ЛИТЕРАТУРА

1. User Guide for DS150E.
2. http://europe.delphi-dso.com/
3. http://www.obd-codes.com/trouble_codes/

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BENCHMARKING HASH FUNCTIONS

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Abstract: *This paper presents the most effective use cases of hash functions. The purpose of the developed practical tests is evaluating hash functions by speed and security. They show how the different cryptographic algorithms, application level hashing, database layer hashing and even disk encryption can impact both the overall performance of a system and are crucial for the security of the data implied in it. The results of this experimental research are presented in this paper.*

Key words: *hash functions, cryptographic algorithms, security, performance, encryption*

1. Introduction

Hash functions are any functions that can be used to map data of various size to data of fixed size. The value returned by a hash function is called a digest, hash value or just hash and are commonly represented as a hexadecimal number. [1]

There is a special class of cryptographic hash functions that can map data with arbitrary size to a fixed bit string. This class is characterized by the one-way mathematical design used in the generation of digests and can also be referred as a digital fingerprint of the input data. Said in others words, every input should have an associated unique digest output without a chance of finding duplicates. [2]

Hash functions are used a lot in computer science and have many information-security applications, such as:

- Identifying duplicated files or substrings;
- Detection of accidental data corruption;
- Providing forms of authentication;
- Secure storage of sensitive data;
- Fingerprinting of data;
- Digital signatures;
- Caching identifiers.

Nowadays every modern programming language, database script language, software framework or plugin library has a set of cryptographic functions that comes preinstalled with it. Also, every hash function can have a different kind of complexity, amount of required resources, security level, performance grade and realization for the its algorithm.

The most frequently used functions in software development currently are: [1] [3]

- MD5 – not suitable for securing data [4], but usable for caching, verify data integrity, etc.
- SHA-1 – not suitable for protecting data [5], but usable for detection of corruption, identifying duplicates, etc.
- SHA-2 – a set of six hash functions that are cryptographically secure and can be used for all purposes. Every one of them has a different output size and level of security. They produce 224, 256, 384 or 512 bit hash values. Those algorithms are SHA-224, SHA-256, SHA-384, SHA-512, SHA-512/224, SHA-512/256. The last two are rarely used.

The main purpose of this article is testing the performance of different algorithms when used in various ways. This way we can define the correct use cases for each algorithm and find its best use. The main tests are focuses on the hashing of 100000 strings in three lengths:

- Password type size – 20 symbols;
- Identifier type size – 50 symbols;
- Comment type – 100 symbols.

The hashing is tested both from an application point with PHP web pages and from database level point with MySQL stored procedures. For both PHP and MySQL, we used the internal realizations for the algorithms MD5, SHA-1, SHA-244, SHA-256, SHA-384 and SHA-512, being the mostly used hash functions. We have performed two tests for each layer:

- Read and hash the values;
- Read, hash and update the values.

Besides that, this paper also includes an overview of the time that would be needed when combining both application and database hashing

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for higher security, other problems that may change the software climate and how can using disk encryption effect the performance and resources of the software system, while boosting protection.

All the practical tests in this article have arisen from the need of implementing both the protection of sensitive data, passwords verification and generating caching identifiers for an improved second version of a private online website.

2. Testing environment specification

For the results to be adequate we have chosen to run the test on a virtual machine, created with Oracle VM VirtualBox version 5.1.14, that has a typical web development stack installed on it. The specification of the allocated resources for the virtual machine and the software on it are shown on Table 1.

Table 1. *Virtual machine specification*

	Detail
CPU	Intel i7-6700HQ, 2 cores, 2.59GHz
RAM	DDR4, 2048 MB, 2.40 MHz
GPU	Intel HD Graphics 530, 32 MB, 2.40 MHz
HDD	20GB, 7200 RPM, 32 MB cache
OS	Ubuntu Server 16.04.2 LTS, Kernel 4.4.0
LAMP	Apache 2.4, PHP 7.0.15, MySQL 5.7.17

The virtual machine has installed all available updates, kernel drivers and virtualization needed packages. All settings for the LAMP stack (Linux Apache MySQL PHP) are by default, with the exception of boosting the values for maximum memory usage by both PHP and MySQL to allow the allocation of all available random-access memory (RAM).

The tests times for PHP are just for the section of the program that does iteration, hashing and updating of values. The time needed for generating 100000 strings with the various length is explicitly excluded.

The MySQL database has three tables having per 100000 strings, for each of the three length types tested. The time for generating digests and running the select or update statements is only taken under consideration.

Each single experiment is executed 10 times and the average time of those runs is taken as final. All the results will be in seconds with 6-digit precision after the decimal point.

3. Application vs. Database level hashing

Most of the developers are feed up with the dilemma where to put the encryption logic and how much will it cost the system. The two daily operations that every kind of cryptography logic needs to imply are read-hash-use and read-hash-update. The next two sections show how PHP and MySQL handle those two with different string lengths.

3.1. Read and hash experiment

This experiment will test the situations when you need to get some string data and hash it so that you can do some sort of verification, comparison or uniquely map the data. For PHP, we used an array with the strings to iterate and hash them. While for MySQL, a table with the data in it, so that we could do a select statement with an alias that calls the current hash function and returns the result for all rows.

3.1.1. Password length results

For the password type size of 20 symbols experiment, the results for application and database hashing times are shown on Table 2.

Table 2. *20 symbols hashing results*

	PHP	MySQL
MD5	0.026375	0.050560
SHA-1	0.033895	0.058299
SHA-224	0.059067	0.078799
SHA-256	0.059711	0.081613
SHA-384	0.072731	0.096270
SHA-512	0.075571	0.113985

As we can see from the results, the application level hashing is faster than the database one. The MD5 and SHA-1 can be easily used for generation of identifiers from PHP, but not for passwords. The SHA-2 algorithms performance is pretty close on both sides, so you can easily use it for protecting data and moving some of the pressure away from the application code to the database.

Because this test is overviewing sensitive data hashing, stick with the SHA-2 algorithms for better security.

3.1.2. Identifier length results

When using hashing for caching purposes, you would probably need an identifier for data of size about 50 symbols. The performance of all the chosen hashing algorithms can be seen on Table 3.

Table 3. *50 symbols hashing results*

	PHP	MySQL
MD5	0.026706	0.049312
SHA-1	0.034188	0.055153
SHA-224	0.059884	0.082104
SHA-256	0.060874	0.094240
SHA-384	0.072884	0.107898
SHA-512	0.076474	0.122992

The final results show that it is better to use application layer hashing when using multiple time generation of identifiers and that the MD5 and SHA-1 are the fastest to compute. However, if you are using it for one-time generation for some third party in memory table or MySQL memory table, it probably will not slow the software system much.

This type of strings is probably used for caching or mapping and this means security is only needed for the cached data, but not for the identifier. This means you can use SHA-1 for balancing performance with ease.

3.1.3. Comment length results

Sometimes the developer needs to hash longer data, for example finding duplicate comments that can be about 100 long and above. This is why we will use string length of 100 symbols for this experiment. The performance of the hash functions for this experiment is shown on Table 4.

Table 4. *100 symbols hashing results*

	PHP	MySQL
MD5	0.037308	0.063266
SHA-1	0.048937	0.075928
SHA-224	0.094610	0.128636
SHA-256	0.100509	0.130748
SHA-384	0.072727	0.105875
SHA-512	0.076085	0.106118

The length of input data seems to be affecting every algorithm in a way. The first thing that can be notice is that SHA-224 and SHA-256 computation time is slower that the more secure algorithms SHA-384 and SHA-512. The second thing is that you can use SHA-512 hashing from the database side and be as fast as using SHA-256 from the application layer.

Comments sometimes may be sensitive information and you should be careful what you are comparing, use SHA-2 algorithms. You can drop some of the computation pressure by using SHA-512 from the database side or stick to the faster SHA-512 from application level.

3.2. Read, hash and update experiment

The second test will apply to the scenarios where you are obliged to save the computed hashes. It is way normal of saying that the application side results will be faster here. This is only because resaving data for use there will happen in the random-access memory which is faster than any available storage drives today, but is only temporary media. We will talk about combining application and database hashing for more security later in this paper. The point of this test is mostly for identifying the generation times differences on each side.

For PHP, we used an array of arrays to contain both the input data and the computed hash in the same subarray. As for MySQL, we used a table with the data in it and added a second column for the computed digests. This way we could easily do an update statement that reads the first column, computes the hash of each value and saves it to the second column.

It should also be noted that when using hash functions with longer digest output size, you should prepare for bigger storage sizes.

3.2.1. Password length results

For the password type size of 20 symbols experiment, the final results are shown on Table 5.

Table 5. *20 symbols hashing results*

	PHP	MySQL
MD5	0.028027	0.317091
SHA-1	0.035334	0.363700
SHA-224	0.057294	0.398448
SHA-256	0.061983	0.441395
SHA-384	0.075343	0.450580
SHA-512	0.079736	0.592357

Since MD5 and SHA-1 algorithms are security broken, it is recommended to use the SHA-2 ones. As we can see from the test, the stronger the algorithm, the more computation time is needed.

Having in mind that passwords are always sensitive data, you would probably want to use application data encryption to reduce the time of insert or update in SQL. Still, adding a second layer of encryption from the database side will boost security a lot, but will cost you only a bit of performance.

3.2.2. Identifier length results

When needing to map unique data and save it somewhere for further use, you would need an identifier generation operation. For this test, the needed data to map should be at least 50 symbols. The computation and save time can be seen on Table 6.

Table 6. *50 symbols hashing results*

	PHP	MySQL
MD5	0.028937	0.343682
SHA-1	0.034090	0.375937
SHA-224	0.061613	0.374757
SHA-256	0.063669	0.381966
SHA-384	0.075568	0.434025
SHA-512	0.078516	0.459434

For this data length, using a stronger algorithm needs more time. When generating identifiers, you can easily choose MD5 or SHA1.

If you do want to use another algorithm, have in mind that you would need more space for the output digests. You would probably need to map the data once and only add some new records over time, but you should definitely use the application side computing to save time. Security is not a factor for the identifier, only for the underlining data that it maps to.

3.2.3. Comment length results

When needing to map comments or having their hash for faster comparison, the developer needs to compute digests for longer strings. We will use a 100 symbols length for this experiment. The computation results are shown on Table 7.

Table 7. *100 symbols hashing results*

	PHP	MySQL
MD5	0.038966	0.332903
SHA-1	0.050947	0.359913
SHA-224	0.102294	0.381809
SHA-256	0.104354	0.401970
SHA-384	0.075037	0.424538
SHA-512	0.078616	0.488914

The results show that SHA-384 and SHA-512 behave better with bigger strings on the application side, even faster than SHA-224. The database level hashing time seems to be affected only by the complexity of the current algorithm.

If you will be using the hashing for comparison only, it is not a problem using even MD-5 or SHA-1. In any other situation stick to SHA-2. Because comments can be edited often, the smartest thing is avoiding database computations.

3.3. Disk Encryption aftermath

We cannot skip that having a full software disk encryption is a big factor in securing your data. So we did a research on the performance of disk encryption and retested the above results on a fully encrypted virtual machine, equivalent to the machine we tested before on.

The interesting thing that we found out from both theory and practice is that it will not affect computation time in any way. This is because modern processors have a special set of instructions called AES-NI [6] that allows encryption of up to 1 Gbit of data per second fully transparently.

The process of encrypting and decrypting is directly in the random-access memory and this creates the so called transparent encryptions effect, only because of the high speed of RAM. When you need to write something on your disk device, the central processor will first encrypt it and after that send it to the storage device. [7]

If you are a professional, using this kind of encryptions can only boost your security status and it will not affect your performance in any fatal way. The only risk is that when rebooting you need to input your encryption password to boot into the operating system and it would be fatal if you have lost it or forgot it somehow. If you get any resource shortage, switch to partition encryption instead.

In any way, using disk encryption will protect your data, but can also be a double-edged sword. Use it with caution and do not try to optimize things before they need to.

4. Coping with the combined approach and real world problems

When dealing with sensitive and top secret data in the real world some other needs, specifications and problems may occur. Even when money and people power are practically unlimited, you can get bad results if you do not give professionals the time needed to get rid of all your problems at once.

The next sections show the most frequent situations and the extra needs that may occur.

4.1. Combined approach

In a software system that deals with private and security information, an extra need for multilayer security may apply. In this case, combining hashing from both application and database levels is a good choice.

When faced with this challenge, it is better to lay the complex encryption algorithm in application level and just send it to the database for a one-time hashing before saving. As said before, while both sides do calculations in the random-access memory, the database side will need more time because it saves data on a disk for further use.

An overview of a real world situation would be where PHP generates a digest, sends it to the database for MySQL to generate a hash value of it and saves the final hash to disk. Using the data from the experiments and calculating an average of the time needed for application generations, database computations and saving the values to storage, the final results per algorithm can be seen on Figure 1.

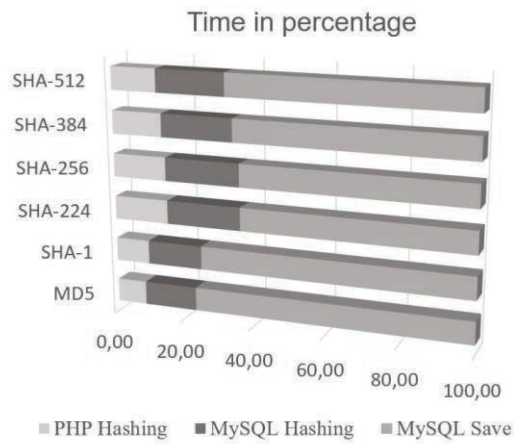

Fig. 1. *Combined approach times*

It is easy то conclude that the heaviest part of this approach is the process of saving data into the database. Application and database hashing are not the slowest operations. Having the results for each algorithm, we can easily calculate in percentage the average time taken from the three subprocesses. The result is shown on Figure 2.

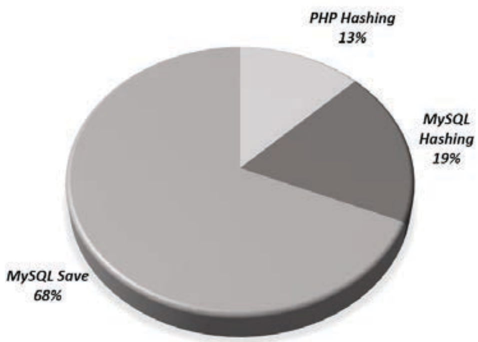

Fig. 2. *Average time for each part of the combined approach work*

When using both side calculations, we can conclude that the two most important parts of any kind of combined solution are:

- Choosing a number of secure algorithms that are proven to be effective and distributing them as needed. This is done in order to have a real point of using multilayer encryption;
- Profiling your application before and after realization, just to see if your software is dealing with more pressure on application or database level and double check final results before you shipping it.

Be cautious when having a security paranoia, because if things are not done right, this may damage your overall software performance. Finding equilibrium is the price for success.

4.2. Real world complications

Sometimes reality surprises us and changes our needs in an unpredicted way. That said: “If you believe everything you read, better not read.” - Japanese Proverb.

For an example, let say we have a fast application that needs 3 seconds for application computations and 1 second for database querying. You decide to add four time hashing in the application level and one-time digest generation at the database layer.

Your expectations should be that the whole software will load for maximum of 5 seconds. You profile it and it turns out to loads for 7 seconds. But how can this be possible? This is only because you have not taken these several factors:

- Network time – when the connection between the application and the database is over a network or a socket, you may get some extra delay for networking.
- Domain Name System resolution time – this is one of the most underestimated threats. After you ship your application online, some of your clients may notice a bigger delay than others. This may be because of the amount of request you do involving DNS queries.
- Database driver – have in mind that your database driver may behave differently on bigger amounts of data or because of your local network quality;
- Virtualization – although it can give you network isolation and less physical devices in your server room, sometimes the virtualization drivers cause extra slowness and may behave irradically. Placing software on top software may only slow your machine, but placing hardware on top of hardware is the real deal;
- Slow hardware – your oldest enemy. This may break your clients experience and security. Do not save money for hardware or system administrators and you will have less problems.

The above and other unknown problems may cause your system to get more than two time slower than you have expected.

Main point is, before you do anything, test your code in a real world situation and try to simulate the worst case scenarios before shipping it to the real world. Keep the balance between security and performance or you will slowly start losing your clients.

4.3. Professional data protection side notes

When taking care of sensitive data, sometimes just hashing your passwords may not be enough. When your information is strictly confidential, just combine compression, multilayer hashing, symmetrical encryption, secure connections, network isolation, firewalls, password policies and double side application validations. [1]

Do not assume that you are safe. Include thread assessment and insert security measures in every single part of your development cycle. Starting from the design phase, all the way to release and maintenance. This is the professional way of creating secure applications and not just adding security features on top of by design vulnerable software. [3]

We are not going to drill more into this topic, because the point of this paper is focused on hash functions.

5. Best hashing use case scenarios

Based on the results of this paper, we can say there are three main uses for hash function and the best ways of choosing algorithms for each one are summarized in the next sections.

5.1. Generating identifiers

Every developer comes to the need of mapping data and computing unique identifiers to associate the data with. Using MD5 or SHA-1 seems to be the smartest choice only because they the fastest and do not have a great chance of duplicated digests results. Of course using either SHA-224 or SHA-256 would not hurt your performance much.

5.2. Data verification

For verifying strings or easily comparing them, using any of the tested algorithms will do the trick for small amounts of data and be fast enough. However, we would suggest SHA-256, because it is currently used for professional application and digital signatures. When dealing with longer data, switch to SHA-384 instead.

5.3. Securing data

When using hash functions for protecting sensitive data, it is recommended to use only the SHA-2 algorithms. Choosing between SHA-224, SHA-256, SHA-384 or SHA-512 are the best choices for secure storage and data transfers. Of course in a real software system you would probably want more than one type of cryptographic algorithm involved.

6. Conclusion

This paper has tested the performance of all the most used and standardized hash algorithms from both application and database realization sides. It maps the best uses of each algorithm and shows the consequences a developer may be faced with by using them.

The most interesting results from the experiments are:

- Application layer hashing is faster that database, but are pretty close;
- SHA-384 and SHA-512 seem to deal faster with longer input data than others;
- Disk encryption does not affect your application speed, but requires more computation power;
- Using just hashing may not be enough for the security of your data.

REFERENCES

1. Katz, J., and Lindell, Y. (2007). *Introduction to Modern Cryptography: Principles and Protocols*. ISBN: 9781584885511.
2. Menezes, A., P. van Oorschot, and Vanstone, S. (1996) *Handbook of Applied Cryptography*. ISBN: 9781439821916.
3. Howard, M., and LeBlanc, D. (2004) *Writing Secure Code: Practical Strategies and Proven Techniques for Building Secure Applications in a Networked World.* ISBN: 9780735617223
4. Wang, X., and Yu, H. (2005) How to Break MD5 and Other Hash Functions. *Advances in Cryptology – EUROCRYPT 2005*. ISBN: 9783540259107
5. Wang, X., Yin, Y.L, and Yu, H. (2005) Finding Collisions in the Full SHA-1. *Advances in Cryptology – EUROCRYPT 2005*. ISBN: 9783540259107
6. http://www.intel.com/content/dam/doc/white-paper/enterprise-security-aes-ni-white-paper.pdf
7. https://wiki.archlinux.org/index.php/disk_encryption

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CLUSTERING TECHNIQUES FOR ANALYSIS OF LARGE DATASETS

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Abstract: *Constant advance in science and technology makes collection of data and storage much easier and very inexpensive than before. This led to the information of enormous datasets in science, government and industry, which should be processed or sorted to get useful information. The goal of this survey is to provide a comprehensive review of different techniques in data mining and how they can deal with large data sets.*

Keywords: *traditional clustering techniques, data stream clustering, incremental clustering*

1. Introduction

Constant advance in science and technology makes collection of data and storage much easier and very inexpensive than ever before. This led to the information of enormous datasets in science, government and industry, which should be processed and/or sorted to get useful information.

For example, if we consider the results generated by a search engine for a particular query, user has to sift through the long lists and find the desired solution. But this job can be very difficult for the user if there are millions of web pages displayed as solutions for a given query. Thus clustering techniques can be very useful in grouping the closely related solutions of a given query and displaying the results in the form of clusters so that the unrelated documents can be avoided even without taking a glimpse at them.

The main idea behind clustering any set of data is to find inherent structure in the data, and interpret this structure as a set of groups, where the data objects within each cluster should show very high degree of similarity known as intra-cluster similarity, while the similarity between different clusters should be reduced. There exist several clustering algorithms which can be used for large datasets. They can be separated in three different groups: partition methods, hierarchical and density based clustering algorithms. They can be called traditional clustering algorithms.

The main problems associated with the traditional clustering algorithms are handling multidimensionality and scalability with rapid growth in size of data. The increase in size of data increases the computational complexities which have a devastating effect on the runtime and memory requirements for large applications. There exist two approaches which deal with these issues: data stream clustering and incremental clustering.

Data stream clustering has recently attracted attention for emerging applications that involve large amounts of streaming data. Data stream model has some constraints. Data from the streams cannot be stored due to the large volume, therefore only summaries should be processed and stored. The speed of arrival is fast thus each item has to be processed in real time or only once. Data from past might become irrelevant and can even affect negatively the current summaries.

Incremental clustering, sometimes called data stream clustering, is a clustering problem, where the data to be clustered arrive continuously. In data stream clustering, the data is expected to be finite, but for the incremental clustering we have to expect the data stream to be infinite. Therefore, incremental clustering supposes two approaches online and offline clustering of streaming data.

In this work, first we present all the major traditional clustering techniques in brief and then we discuss how they can deal with a large data sets. Then we analyze how the data stream and incremental techniques can deal with issues from traditional techniques and large data sets.

2. Traditional techniques for clustering

Clustering can be done in many different ways. There exists different kind of clustering techniques deal with data sets. Some take input parameters from the user like number of clusters to be formed etc., but some decide on the type and amount of data given. Clustering algorithms can be classified in five distinct types: partitioning,

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hierarchical, model-based, density based methods and grid-based methods. In this section we have described partitioning, hierarchical and density based methods and how they can deal with large data sets.

2.1. Partitioning clustering

Let a database containing n data objects is given, then a partitioning method constructs *k* clusters of the data where $k <= n$ and *k* is the input parameter provided by the user. That is, it classifies the data into *k* groups (clusters) which should satisfy the following conditions: (1) each group must contain at least one data object and (2) each data object should belong to only one group. The most well-known and commonly used partitioning methods are k-means proposed by Mac Queen [1] and k-medoids proposed by Kaufman and Rousseeuw [2].

2.1.1. The k-means method

The k-means algorithm takes input k from the user and partitions n data objects into k clusters so that the resulting intra-cluster similarity is very high and inter-cluster similarity is very low. The cluster similarity is calculated based on the mean value of the objects in the cluster. First, it randomly picks k data objects as the mean or centroid points. For each of the remaining objects, an object assigned to the centroid to which it is most similar based on distance between the object and the cluster. This process iterates till good clusters are formed. Typically, squared root function is used for this which can be defined as

$$\boldsymbol{E} = \sum_{i=1}^{k} \sum_{x \in C_i} |\boldsymbol{x} - \boldsymbol{m}_i|^2 , \qquad (1)$$

where x is the point in space representing the given object, and m_i is the mean of cluster C_i. This function tries to make the clusters as separate as possible.

The method is relatively scalable and efficient in handling large data sets because the computational complexity of the method is O(nkt), where n is the total number of iterations, k is the number of clusters and t is the number of iterations. Normally $k<<n$ and $t<<n$ so, the method often ends up at local optimum. However, this method has some drawbacks: 1) it can be applied only when mean of a cluster is defined, but when data with categorical attributes is involved it cannot be the case; 2) the user should specify the number of clusters k in advance and 3) it is sensible to noise and outlier data points.

2.1.2. The k-medoids method

K-medoids algorithm was developed to overcome the drawbacks of k-means which is very sensitive to outliers. For example, an object with some extremely large value may substantially distort the distribution of data by k-means method. Therefore, instead of taking the mean value of objects in a cluster as a reference point, an object that is most centrally located in the cluster can be taken as a representative object, called as medoid. Thus the partitioning method can be performed by minimizing the sum of dissimilarities between each object and with its corresponding reference point.

The algorithm creates *k* partitions for *n* given objects. Initially k-medoids are selected which are located more centrally in each cluster. Then the algorithm repeatedly tries to make a better choice of medoids by analyzing all the possible pairs of objects.

The k-medoids method is more robust than k-means because it is less influenced by outliers or other extreme values than mean. But its processing is very costly than k-means method and it also has the drawback of user providing the input parameter k.

The main advantage of k-means and k-medoids is that their complexity is linear. Therefore, their execution time is proportional to the number n of data objects, so that they can be used with large volumes of data. The second advantage is that it is possible to detect outliers, which appear in the form of singleton clusters. There is also a third advantage. Unlike hierarchical methods, in which the clusters are not altered once they have been constructed, the reassignment algorithms constantly improve the quality of the clusters, which can thus reach a high level when the form of the data is suitable.

The first disadvantage is that the final partition depends greatly on the more or less arbitrary initial choice of the centers c_i. Consequently, we do not have a global optimum, but simply the best possible partition based on the starting partition. The second drawback of partitioning methods is that the number of clusters, *k*, is fixed in these methods, and it is not less than k unless certain clusters are empty. If this number does not correspond to the actual configuration of the cloud of data objects, the quality of the clustering may be adversely affected. The third drawback of these methods is that they are only good at detecting spherical forms. Even convex forms such as ellipses cannot be detected well if they are not sufficiently separated.

2.2. Hierarchical clustering algorithms

Hierarchical clustering, also known as connectivity based clustering, is based on the core idea of objects being more related to nearby objects that to objects farther away. These algorithms connect “objects” to form “clusters” based on their distance. A cluster can be described largely by the maximum distance needed to connect parts of the cluster. Strategies for hierarchical clustering generally fall into two types:

- **Agglomerative clustering** is a "**bottom-up**" approach: each observation starts in its own cluster, and pairs of clusters are merged as one moves up the hierarchy.
- **Divisible clustering** is a "**top-down**" approach: all observations start in one cluster, and splits are performed recursively as one moves down the hierarchy.

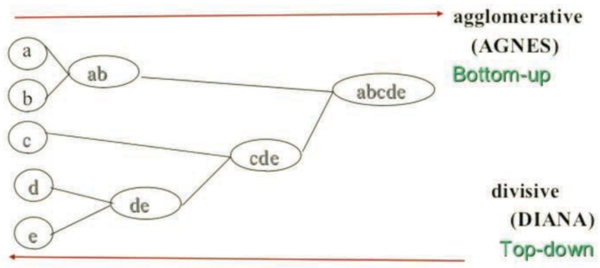

Fig. 1. *Examples of agglomerative "Bottom-up" and divisive "Top-down" clustering*

In general, the merges and splits are determined in a greedy manner. The results of hierarchical clustering are usually presented in a dendrogram. The complexity of agglomerative clustering is $O(n^2\log(n))$ [3], which makes them too slow for large data sets. Divisible clustering with an exhaustive search is $O(2^n)$, which is even worse. However, for some special cases, optimal efficient agglomerative methods (of complexity $O(n^2)$) are known: SLINK [4] for single-linkage and CLINK [5] for complete-linkage clustering.

The agglomerative clustering does not suffer from the two major drawbacks of the moving centers method, namely its dependence on the choice of initial centers and the fixed number of clusters chosen in advance. The second advantage is that it can detect clusters of different shapes, according to the distance chosen. The best possible distance can be chosen according to previous knowledge of the shape of the clusters to be detected, but the choice is mainly made by carrying out a number of trials and observing the results. It is possible to use a given distance because the resulting clusters are more easily described or because the number of clusters appears more natural with respect to the graphic indicators. The third advantage is that it enables us to cluster data elements, variables or centers of clusters obtained by using a moving centers algorithm.

The main disadvantage is its algorithmic complexity, which is non-linear: in order to move from $k + 1$ clusters to k clusters, we must calculate $(k + 1)k/2$ distances and combine the two closest clusters. If n is the number of data objects (elements) to be clustered, the complexity of the basic algorithm is of the order of n^3, and it will soon exceed the capacity of even a powerful computer. The difference from the moving centers method is that we are comparing individuals with each other instead of comparing them with the centers of the clusters only. The situation can be improved to a certain extent by the nearest-neighbor algorithm, which reduces a complexity of n^3 to n^2, by a judicious combination of more than two observations on each iteration. It can be used with the Ward, average linkage, single linkage and complete linkage methods. A second drawback is that, at each step, the partitioning criterion is not global, but depends on the clusters obtained so far: two individuals placed in different clusters will no longer be compared. In other words, this type of clustering into n clusters in not necessarily the best possible outcome, but only the best of those obtained by combining the clusters of a clustering procedure into $n + 1$ clusters. Thus some natural clusters may be hidden by an earlier branching.

2.3. Density based clustering algorithms

Density-based clustering [7] methods are based on a local cluster criterion. Clusters are assumed as regions in the data space in which the objects are dense and the clusters are separated by regions of low object density. These regions have an arbitrary shape and the data points inside a cluster may be arbitrarily distributed.

The most popular [8] density based clustering method is DBSCAN [9]. In contrast to many newer methods, it features a well-defined cluster model called "density-reachability". Similar to linkage based clustering, it is based on connecting points within certain distance thresholds. However, it only connects points that satisfy a density criterion, in the original variant defined as a minimum number of other objects within this radius. A cluster consists of all density-connected objects (which can form a cluster of an arbitrary shape, in contrast to many other methods) plus all objects that are within these objects' range. Another interesting property of

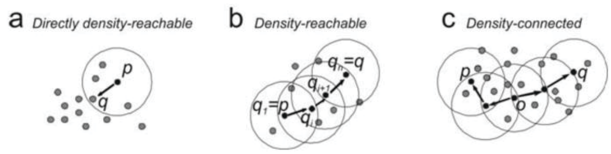

Fig. *2. Examples of (a) directly density-reachable, (b) density-reachable, (c) density-connected in density-based clustering.*

DBSCAN is that its complexity is fairly low – it requires a linear number of range queries on database

– and that it will discover essentially the same results in each run, therefore there is no need to run it multiple times. OPTICS [10] is a generalization of DBSCAN that removes the need to choose an appropriate value for the range parameter ε, and produces a hierarchical result related to that of linkage clustering. DeLi-Clu, [11] Density-Link-Clustering combines ideas from single-linkage clustering and OPTICS, eliminating the ε parameter entirely and offering performance improvements over OPTICS by using an R-tree index.

The key drawback of DBSCAN and OPTICS is that they expect some kind of density drop to detect cluster borders. Moreover, they cannot detect intrinsic cluster structures which are prevalent in the majority of real life data. A variation of DBSCAN, EnDBSCAN, [12] efficiently detects such kinds of structures. On data sets with, for examples, overlapping Gaussian distributions – a common use case in artificial data – the cluster borders produced by these algorithms will often look arbitrary, because the cluster density decreases continuously. On a data set consisting of mixtures of Gaussians, these algorithms are nearly always outperformed by methods such as EM clustering that are able to precisely model this kind of data.

3. Data Stream and Incremental clustering algorithms

Traditional clustering techniques are not suitable for large data sets. Many applications have massive amount of data which increases every day. This causes limitation in data storage capacity and processing time. In this section, we have described two techniques data stream and incremental clustering which can be used to deal with a big amount of data.

3.1. Data stream clustering

Data stream clustering algorithms have been developed as an adaption of traditional clustering algorithms to fit the streaming model and comply to its constraints. The data stream problem has been researched in recent years because of the large number of relevant applications [13, 14, 15, 16, 17]. Furthermore, data stream clustering has recently attracted attention for emerging applications that involve large amounts of streaming data. In the literature, one of the first results for data streaming appeared in 1980 [18] but the model was formalized in 1998 [19].

A formal definition for data stream S is that of a sequence of arriving data objects x_1, x_2, …, x_n, rendering $S = \{x_i\}$, where $i = 1, 2, \ldots, m$ and $m \to \infty$. Each data object is an m-dimensional attribute vector $x_i = [\mathbf{x}_\mathbf{i}^\mathbf{j}]$ where $j = 1, 2, \ldots, n$, belonging to an attribute space that can be continuous, categorical, or mixed.

The main disadvantage of data streaming algorithms is to fit a large data into main memory. It is not possible for the algorithm to "remember" too much of the data scanned in the past. This scarcity of space necessitates the design of a novel kind of algorithm that stores only summary of past data, leaving enough memory for the processing of future data [16, 17]. Researchers in [31] are developed a clustering method which is called CluStream. In the literature, CluStream is defined as algorithm which summarizes streams into micro-clusters to deal with memory limitations. The CluStream model has a wide functionality in characterizing data stream clusters over different time horizons in an evolving environment. They use a pyramidal time window assures that the essential statistics of evolving data streams can be captured without sacrificing the underlying space and time efficiency of the stream clustering process. [31] As advantages, CluStream is very flexible for real time transactions and pyramidal time window guarantees efficient time and space.

Another approach for these constraints have a direct impact in memory usage and data "age" relevance. Some techniques have been developed to deal with these problems such as sliding window combined with low memory functions. Sliding window is a technique where a window of size W keeps the last W items that arrived and run a desired algorithm on these items. The summary is then kept and the items are then discarded. In this way an up to data statistics is always computed. These statistics are usually kept by updating the model; in case of classification is could be the decision tree and in clustering could be the final clustering centroids.

Advantage of data stream algorithms instead of k-partitioning clustering methods is that we do not need to process the data multiple times to receive final clustering decision. Different techniques were created to deal with evolving data such as one pass processing and summarization. In literature, researches in [16] give a constant-factor approximation algorithms for the k-means problem in the data stream model of computation in a single pass.

As a conclusion of this section, clustering data streams is gaining a lot of importance and a lot of research is done on improving these algorithms to apply them on real time applications.

3.2. Incremental clustering

Incremental clustering is based on the assumption that it is possible to consider instances one at a time and assign them to existing clusters. Here, a new instance is assigned to a cluster without significantly affecting the existing clusters. Only the cluster representations are stored in the main memory to alleviate the space limitations.

One of the most famous example is the COWEB[20]. It keeps a classification tree as its hierarchical clustering model. Then the algorithms place new points in a top-down fashion using a category utility function.

Another incremental hierarchical clustering algorithm that works in a bottom-up fashion is described in [21].

SLINK [22] is the most time-wise effective implementation of single linkage hierarchical clustering. It works incrementally, building several linear indexes.

BIRCH [23] also uses a hierarchical clustering, but the hierarchy is built on so called clustering features. A clustering feature statistically summarizes the underlying data.

DBSCAN [24] searches for its nearest neighbors when placing a new point. If there are sufficiently enough points under a minimal distance of the new point, such point is then added into the respective cluster of the nearest nodes. A generalization of DBSCAN called OPTICS [25] work with a varying density of clusters.

CURE [26] uses yet another approach to clustering. It lies between BIRCH and SLINK, as it uses hierarchical clustering, but instead of representing the cluster with once center as BIRCH, or considering all points as SLINK, it chooses only several representatives of the cluster that are then moved closed to the center.

Algorithms such as DBSCAN, OPTICS and DENCLUE, STING, CLIQUE, Wave-Cluster and OPTIGRID do not optimize the k-means objective. An overview article of incremental data stream algorithms [27, 28, 29].

Order-independences is an important property of clustering algorithms. An algorithm is order-independent if it which the data is presented, otherwise, it is order-dependent. Most of the incremental algorithms presented above are order-dependent.

The major advantage for incremental algorithm is that, it can operate without having to revisit old data it is more applicable to situations with very large data sets that cannot fit in memory, and streaming data sets which are being produced for long periods of time. Additionally, these algorithms are better suited to data whose characteristics might be evolving over time.

One of the first incremental clustering algorithms was the leader algorithm describes by Hartigan [30]. This algorithm attempts to partition a set of data samples into a number of disjoint clusters. The desired number of clusters is not specified but a distance metric and maximum threshold must be defined.

The algorithm gets its name from the fact that cluster coordinates are set equal to the input used to create the cluster. This input is known as the leader. Once, the cluster is established new members can be assigned to it, but its coordinates are never adjusted from those of the leader. The decision to assign an input to an existing cluster instead of creating a new cluster is made based on distance. If the current input's distance is within a threshold from an existing cluster then it is assigned to that cluster, otherwise a new cluster is created. It should be noted that the algorithm assigns inputs to the first cluster that satisfies the threshold requirement rather than searching for the closest cluster.

The leader algorithm requires only one pass through the sample data so it has speed advantage over non-incremental techniques. A second advantage is that it does not require prior knowledge of the number of expected clusters. A drawback, however, is that the clustering is highly dependent on the other of the input samples. This dependence exists because samples are assigned to the first cluster that meets the threshold requirement rather than finding the nearest cluster.

It exists many different incremental clustering algorithms. Each of them attempts to improve clustering accuracy by adjusting the algorithm to the specific characteristics of the desired application. Though the overall flow of most incremental clustering algorithms is similar, they differ in their initialization of their conditions for creation of deletion of clusters.

4. Conclusion

This paper has presented a short review in most of all clustering techniques which can be deal with large data sets which requires a large memory, arrive continuously, and might change over time. The tradional clustering methods do not scale very large data sets since they either need several passes over the data or they create data structures that do not scale lineraly with the number of objects. Incremental and data stream clustering methods are gaining a lot of research which is done on improving these algorithms to apply them on real time applications.

In the future work, we are planning to research in this area, to seek new clustering algorithms which can deal with a large amount of data.

REFERENCES

1. MacQueen, J. B. (1967). Some Methods for classification and Analysis of Multivariate Observations. *Proceedings of 5th Berkeley*

Symposium on Mathematical Statistics and Probability. volume (1), 281–297.

2. Kaufman, L., and Roussew, P. J. (1990). Finding Groups in Data - An Introduction to Cluster Analysis. A Wiley-Science Publication.
3. Rokach, L., and Maimon, O. (2005). Clustering methods. *Data mining and knowledge discovery handbook*, 321-352, Springer US.
4. Sibson R. (1973). SLINK: an optimally efficient algorithm for the single-link cluster method. *The Computer Journal. British Computer Society*. 16 (1), 30–34.
5. Defays D. (1977). An efficient algorithm for a complete-link method. *The Computer Journal. British Computer Society.* 20 (4), 364–366.
6. Steinbach, M., Karypis, G., and Kumar, V. (2000). A comparison of document clustering techniques, 525-526. In KDD workshop.
7. Kriegel, H., Kröger, P, Sander, J. and Zimek, A. (2011). Density-based Clustering. *WIREs Data Mining and Knowledge Discovery.* 1 (3), 231–240.
8. Microsoft academic search: most cited data mining articles: DBSCAN is on rank 24.
9. Ester, M., Kriegel, H., Sander, J., and Xu, X. (1996). A density-based algorithm for discovering clusters in large spatial databases with noise, 226-231.
10. Ankerst, M., Breunig, M.M., Kriegel and H., Sander, J. (1999). OPTICS: Ordering Points To Identify the Clustering Structure, 49-60.
11. Achtert, E., Böhm, C., and Kröger, P. (2006). DeLi-Clu: Boosting Robustness, Completeness, Usability, and Efficiency of Hierarchical Clustering by a Closest Pair Ranking, 119-128.
12. Roy, S. and Bhattacharyya, D. K. (2005). An Approach to find Embedded Clusters Using Density Based Techniques. *Springer Verlag.* volume (3816), 523–535.
13. Aggarwal, C. C. (2003) A Framework for Diagnosing Changes in Evolving Data Streams. ACM SIGMOD Conference.
14. Babcock, B. and Other, (2002). Models and Issues in Data Stream Systems, ACM PODS Conference.
15. Domingos, P. and Hulten, G. (2000). Mining High-Speed Data Streams. ACM SIGKDD Conference.
16. Guha, S., Mishra, N., Motwani, R., O'Callaghan L. (2000). Clustering Data Streams. IEEE FOGS Conference.
17. O'Callaghan, L. and Other, (2002). Streaming-Data Algorithms for High-Quality Clustering. ICDE Conference.
18. Munro, J., and Paterson, M. (1980). Selection and Sorting with Limited Storage. *Theoretical Computer Science*, 315-323.
19. Henzinger, M., Raghvan, P., and Rajagopalan, S. (1998). Computing on Data Streams. *Digital Equipment Corporation*.
20. Douglas H Fisher. (1987). Knowledge acquisition via incremental conceptual clustering. *Machine learning*, 139-172.
21. Dwi H Widyantoro, Thomas R Ioerger, and John Yen. (2002). An incremental approach to building a cluster hierarchy. *In Data Mining ICDM.*, 705–708.
22. Robin Sibson. (1973). Slink: an optimally efficient algorithm for the single-link cluster method. *The Computer Journal*, 30–34.
23. Tian Zhang, Raghu Ramakrishnan, and Miron Livny. (1996). Birch: an efficient data clustering method for very large databases. *In ACM SIGMOD Record*, volume 25, 103–114.
24. Martin Ester, Kriegel Hans-Peter, J¨org Sander, and Xiaowei Xu. (1996). A density-based algorithm for discovering clusters in large spatial databases with noise. In KDD, volume 96, 226–231.
25. Mihael Ankerst, Markus M Breunig, Hans-Peter Kriegel, and J¨org Sander. (1999). Optics: Ordering points to identify the clustering structure. *In ACM SIGMOD Record*, volume 28, 49–60.
26. Sudipto Guha, Rajeev Rastogi, and Kyuseok Shim. (1998). Cure: An efficient clustering algorithm for large databases. *SIGMOD Rec.*, volume, 27(2), 73–84.
27. Mohamed Medhat Gaber, Arkady Zaslavsky, and Shonali Krishnaswamy. (2005). Mining data streams: A review. *SIGMOD Rec.*, volume 34(2), 18–26.
28. Sudipto Guha, Nina Mishra, Rajeev Motwani, and Liadan O'Callaghan. (2000). Clustering data streams. *In Foundations of computer science*, 359–366.
29. Moses Charikar, Chandra Chekuri, Tom´as Feder, and Rajeev Motwani. (1997). Incremental clustering and dynamic information retrieval. ACM symposium on Theory of computing, 626–635.
30. Hartigan J. A. (1975) Clustering Algorithms. New York: John Wiley and Sons.
31. Aggarwal C. and Other, (2003). A framework for Clustering Evolving Data Streams. Proceedings of the 29th VLDB Conference.

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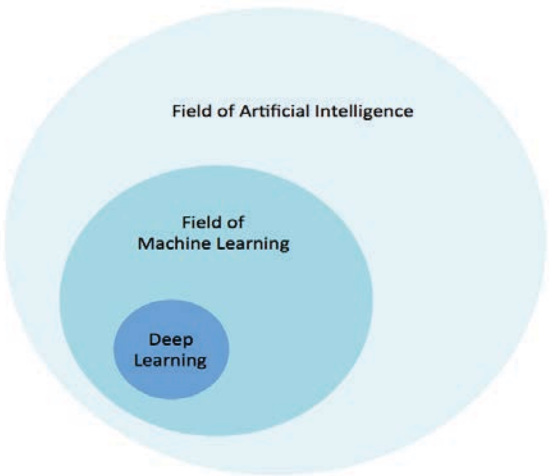
ALGORITHMS IN DEEP LEARNING

T. HRISTEVA, M.MARINOVA

Abstract: *Deep Learning is a software tool for learning in neural networks that utilizes multiple layers of abstraction. Today it has impact on many research areas. There are two broad types of machine learning – supervised learning and unsupervised learning. The supervised learning uses labeled datasets to produce the desired results. The supervised learning is useful for the classification and the regression. In the unsupervised learning the main purpose is to find out hidden models of data. The unsupervised learning is used for clustering and associative tasks.*

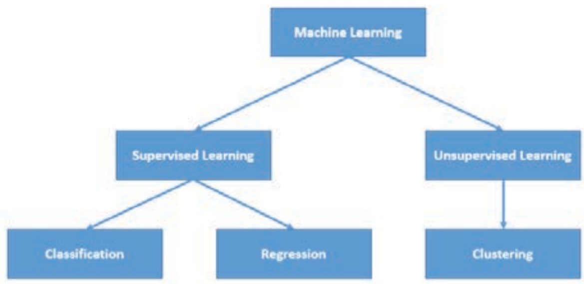
Key words: *deep learning, algorithm, neural network*

INTRODUCTION



Credit: http://blog.algorithmia.com

Deep learning is impacting everything from healthcare to transportation to manufacturing, and more. Companies are turning to deep learning to solve hard problems, like speech recognition, object recognition, and machine translation. It might seem like this technology is still years away, but we are beginning to see its commercial use. Such is the case with self-driving cars. Companies like Google, Tesla, and Uber are already testing autonomous cars on the streets.



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Supervised Learning

In supervised learning we have input variables (x) and an output variable (Y) and you use an algorithm to learn the mapping function from the input to the output(Y = f(X))

The goal is to approximate the mapping function so well that when you have new input data (x) that you can predict the output variables (Y) for that data.

It is called supervised learning because the process of an algorithm learning from the training dataset can be thought of as a teacher supervising the learning process. We know the correct answers, the algorithm iteratively makes predictions on the training data and is corrected by the teacher. Learning stops when the algorithm achieves an acceptable level of performance. Supervised learning problems can be further grouped into

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regression and classification problems. Classification: A classification problem is when the output variable is a category, such as “red” or “blue” or “animal” and “human”

Regression: A regression problem is when the output variable is a real value, such as “dollars” or “weight”. Some common types of problems built on top of classification and regression include recommendation and time series prediction respectively.

A popular example of supervised machine learning algorithms is support vector machines for classification problems

Unsupervised Machine Learning

Unsupervised learning is where you only have input data (X) and no corresponding output variables.The goal for unsupervised learning is to model the underlying structure or distribution in the data in order to learn more about the data. These are called unsupervised learning because unlike supervised learning above there is no correct answers and there is no teacher. Algorithms are left to their own devises to discover and present the interesting structure in the data.

Unsupervised learning problems can be further grouped into clustering and association problems.

Clustering: A clustering problem is where you want to discover the inherent groupings in the data, such as grouping customers by purchasing behavior.

Association: An association rule learning problem is where you want to discover rules that describe large portions of your data, such as people that buy X also tend to buy Y.

An examples of unsupervised learning algorithms are: k-means for clustering problems.

MOST IMPORTANT ALGORITHMS

Supervised Learning

Decision Trees

A decision tree is a decision support tool that uses a tree-like graph or model of decisions and their possible consequences, including chance-event outcomes, resource costs, and utility.A decision tree is the minimum number of yes/no questions that one has to ask, to assess the probability of making a correct decision, most of the time. As a method, it allows you to approach the problem in a structured and systematic way to arrive at a logical conclusion.

Decision trees have many advantages.They are simple to understand and interpret. People are able to understand decision tree models after a brief explanation, allow the addition of new possible scenarios easily.Help determine worst, best and expected values for different scenarios, can be combined with other decision techniques.As a disadvantages can be given that the calculations can get very complex if many values are uncertain or if many outcomes are linked.

Logistic Regression

Logistic regression is a powerful statistical way of modeling a binomial outcome with one or more explanatory variables. It measures the relationship between the categorical dependent variable and one or more independent variables by estimating probabilities using a logistic function, which is the cumulative logistic distribution.

Regressions can be used in applications such as:

- Credit Scoring
- Measuring the success rates of marketing campaigns
- Predicting the revenues of a certain product

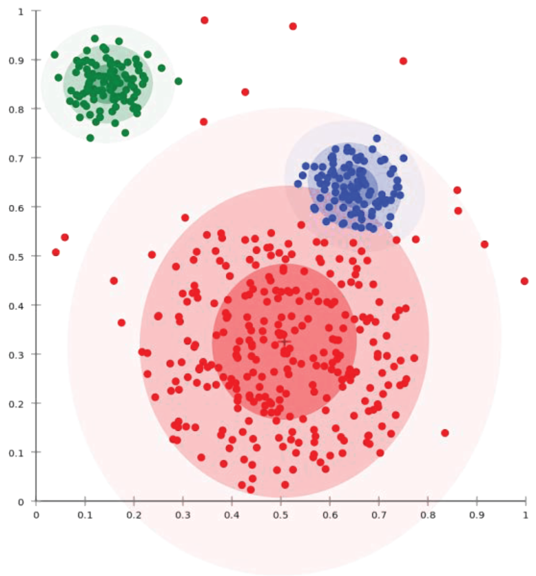
Support Vector Machines

SVM is binary classification algorithm. Given a set of points of 2 types in N dimensional place, SVM generates a (N—1) dimensional hyperlane to separate those points into 2 groups. Say you have some points of 2 types in a paper which are linearly separable. SVM will find a straight line which separates those points into 2 types and situated as far as possible from all those points.

In terms of scale, some of the biggest problems that have been solved using SVMs (with suitably modified implementations) are display advertising, human splice site recognition, image-based gender detection, large-scale image classification, etc.

Unsupervised Learning

Clustering Algorithms



Credits: http://www.machinelearningtutorial.net/

Clustering is the task of grouping data objects in such a way that objects in the same group (cluster) are more similar to each other than to the object in other groups.

Every clustering algorithm is different, and here are a couple of them:

- **Centroid-based algorithms**

In centroid-based clustering, clusters are represented by a central vector, which may not necessarily be a member of the data set. When the number of clusters is fixed to k, k-means clustering gives a formal definition as an optimization problem: find the {\displaystyle k} k cluster centers and assign the objects to the nearest cluster center, such that the squared distances from the cluster are minimized.

- **Connectivity-based algorithms**

Connectivity based clustering, also known as hierarchical clustering, is based on the core idea of objects being more related to nearby objects than to objects farther away. These algorithms connect "objects" to form "clusters" based on their distance. A cluster can be described largely by the maximum distance needed to connect parts of the cluster.

- **Density-based algorithms**

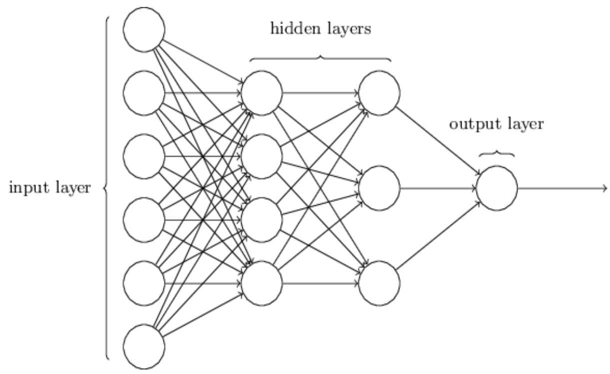
In density-based clustering, clusters are defined as areas of higher density than the remainder of the data set. Objects in these sparse areas - that are required to separate clusters - are usually considered to be noise and border points. The most popular density based clustering method is DBSCAN. In contrast to many newer methods, it features a well-defined cluster model called "density-reachability". Similar to linkage based clustering, it is based on connecting points within certain distance thresholds.

- **Neural networks.**

Neural networks are inspired by the structure of the cerebral cortex. At the basic level is the perceptron, the mathematical representation of a biological neuron. Like in the cerebral cortex, there can be several layers of interconnected perceptrons. The first layer is the input layer. Each node in this layer takes an input, and then passes its output as the input to each node in the next layer. There are generally no connections between nodes in the same layer and the last layer produces the outputs.

The middle part is called the hidden layer. These neurons have no connection to the outside (e.g. input or output) and are only activated by nodes in the previous layer.

Neural networks have the ability to derive meaning from complicated or imprecise data and can be used to extract patterns and detect trends that are too complex to be noticed by other computer techniques. A trained neural network can be thought of as an "expert" in the category of information it has been given to analyse.



Credit: Michael A. Nielsen, "Neural Networks and Deep Learning"

Deep learning can be described as the technique for learning in neural networks that utilizes multiple layers of abstraction to solve pattern recognition problems.It is a specific approach used for building and training neural networks, which are considered highly promising decision-making nodes. An algorithm is considered to be deep if the input data is passed through a series of nonlinearities or nonlinear transformations before it becomes output. In contrast, most modern machine learning algorithms are considered "shallow" because the input can only go only a few levels of subroutine calling.

Deep learning removes the manual identification of features in data and, instead, relies on whatever training process it has in order to discover the useful patterns in the input examples. This makes training the neural network easier and faster, and it can yield a better result that advances the field of artificial intelligence.

CONCLUSION

The digital era has brought un important amount of data in all forms and from every region of the world. This data, known simply as Big Data, is gotten from sources like social media, internet search engines, e-commerce platforms, online cinemas, etc. This enormous amount of data is readily accessible and can be shared through fintech applications like cloud computing. However, the data, which normally is unstructured, is so vast that it could take decades for humans to comprehend it and extract relevant information. Companies realize the incredible potential that this information has and are increasingly adapting to systems for automated support. This is where deep learning fits perfectly.In contrast to more conventional machine learning and feature engineering algorithms, deep learning has an advantage of potentially providing a solution to address the data analysis and learning problems found in massive volumes of input data. More specifically, it aids in automatically extracting complex data representations from large volumes of unsupervised data. This makes it a valuable tool for Big Data Analytics, which involves data analysis from very large collections of raw data.

BIBLIOGRAPHY

1. https://www.udacity.com/course/machine-learning--ud262
2. http://machinelearningmastery.com/supervised-and-unsupervised-machine-learning-algorithms/
3. http://blog.algorithmia.com/introduction-to-deep-learning-2016/
4. http://www.kdnuggets.com/2016/08/10-algorithms-machine-learning-engineers.html
5. http://www.iro.umontreal.ca/~pift6266/H10/notes/mlp.html
6. http://neuralnetworksanddeeplearning.com
7. http://deeplearning.net
8. Ian Goodfellow, Yoshua Bengio, Aaron Courville-Deep Learning,MIT Press
9. Deep Learning Tutorial,LISA lab, University of Montreal
10. Deng,Dong Yu, Deep Learning: Methods and Applications

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БЕЙСОВ МОДЕЛ ЗА ПРЕДВИЖДАНЕ НА ИЗХОДА ОТ ФУТБОЛНИ МАЧОВЕ

ЙОРДАН КЪРПАРОВ, ДИЛЯНА БУДАКОВА, ЛЮДМИЛ ДАКОВСКИ

Резюме: *В този доклад се разглежда Бейсова мрежа за предсказване на резултатите от футболни мачове. От направените експерименти се вижда, че с помощта на предложения модел се постигат прогнози с повече от 50% точност. Програмната система е реализирана в средата на Visual Studio.NET и с помощта на езикът за програмиране C#, а базата данни е реализирана с помощта на MS SQL.*

Ключови думи: *Бейсови мрежи, футбол, причинно-следствени връзки директен ацикличен граф.*

A BAYESIAN NETWORK MODEL FOR FOOTBALL GAMES OUTCOMES PREDICTION

JORDAN KYRPAROV, DILYANA BUDAKOVA, LYUDMIL DAKOVSKI

Abstract: *The present paper describes a Bayesian network model for prediction of football games outcomes. It can be seen from the experiments made, that predictions with more than 50 % accuracy are achieved using the proposed model. The programming system is realized in Visual Studio.NET environment and the programming language C#. The database is realized via MS SQL.*

Key words: *Bayesian networks, football games, causal connections, directed acyclic graphs*

1. Увод

В тази статия се изследва Бейсов модел за предсказване на изхода от футболни мачове. Използвана е база данни със статистики и наблюдения за мачовете от Висшата лига и испанската ЛаЛига за сезони 2009-2010, 2010-2011, 2011-2012, 2012-2013, 2013-2014, 2014-2015, 2015-2016 [4]. В съществуващите вероятностни модели за предсказване на изхода от футболни срещи се вземат предвид постиженията на всички играчи, психическото им състояние, средната възраст на играчите, кои са пострадалите играчи, резултатите от последните пет игри на разглежданите отбори [1,2]. Изследва се влиянието на временната спортна форма на отборите върху текущото им представяне като се вземат резултатите от последните 5-6 мача. Въвежда се рейтинг на отборите според тази тяхна моментна спортна форма. Доказва се силната корелация между математическото очакване за броя на головете, които отборът се очаква да реализира и средния брой успешни голове реализирани от отбора в миналото, броя допуснати голове от противниковия отбор, предимството на домакинството. Изчисляват се вероятностите двата отбора да реализират по 0, 1, 2 или повече голове и се построява разпределението на Поасон. Изчисляват се коефициентите за победа, загуба или равен мач [3]. В [5,6] се доразвива методът [2] като се вземат предвид повече данни и се изследват изчислените коефициенти и техните отклонения. Някои от характеристиките на вече проведените футболни срещи, които се използват в предложения вероятностен модел са: брой отбелязани голове, резултатите на срещите, имена на отборите, брой отправени точни удари към вратата на противника, текущо класиране на отборите. За да се верифицира, работата на реализирания Бейсов модел се

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сравнява с работата на модел базиран на напълно случаен принцип. За програмната реализация е използвана средата Visual Studio .NET Framwork, езикът C#, Windows Form Application и е разработена релационна SQL Data Base (фиг.3).

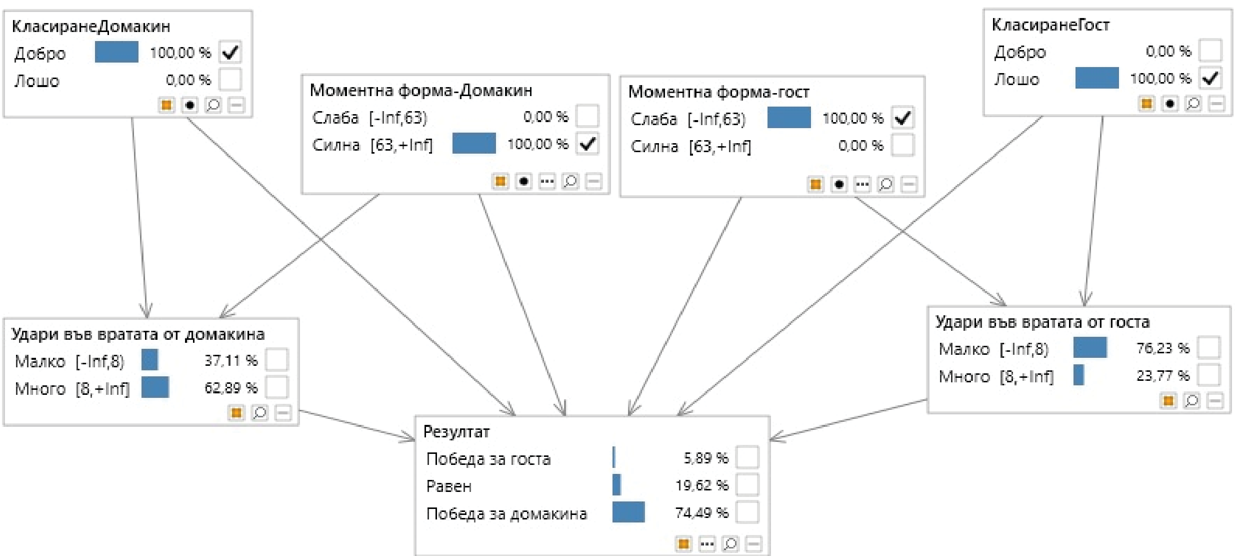
Фиг. 1. *Данни със статистики и наблюдения за мачовете от Висшата лига и испанската ЛаЛига за сезони 2009-2010, 2010-2011, 2011-2012, 2012-2013, 2013-2014, 2014-2015, 2015-2016 [4].*

2. Бейсов модел за предвиждане на изхода от футболни мачове

Бейсовите мрежи [9] са метод за извод, който ползва вероятности. Известни имена които също се използват в зависимост от статуса на мрежата са Belief networks, Knowledge maps, Probabilistic causal networks, и т.н. Този метод за извод е изключително популярен в общността на учените в областта на AI probability and uncertainty community. Бейсовите мрежи намират приложение за решаване на проблеми в медицинската диагностика, разбирането на естествен език, компютърното зрение, търсенето на евристики. В един Бейсов модел възлите показват състоянието на разглеждания проблем, а стрелките се разглеждат като причинно-следствени връзки и не са абсолютни. Моделът се използва за предсказване какво ще се случи или за да се намерят причините, които са довели до наблюдаван ефект.

Възлите в предложеният тук модел са (фиг.2): 1. Спортна форма на отбора домакин, определена на базата на последните 6 мача и наблюденията колко гола е реализирал и колко гола е допуснал неговият бъдещ противник в своята врата; 2. Спортна форма на отбора гост – определена по аналогичен начин; 3. Класиране на домакина за текущото първенство; 4. Класиране на госта за текущото първенство; 5. Брой точни удари във вратата отправени от единия отбор. 6. Аналогично - брой точни удари от във вратата отправени от противниковия отбор. 7. Вероятност за победа на домакина, вероятност за победа за госта и вероятност за равен резултат.

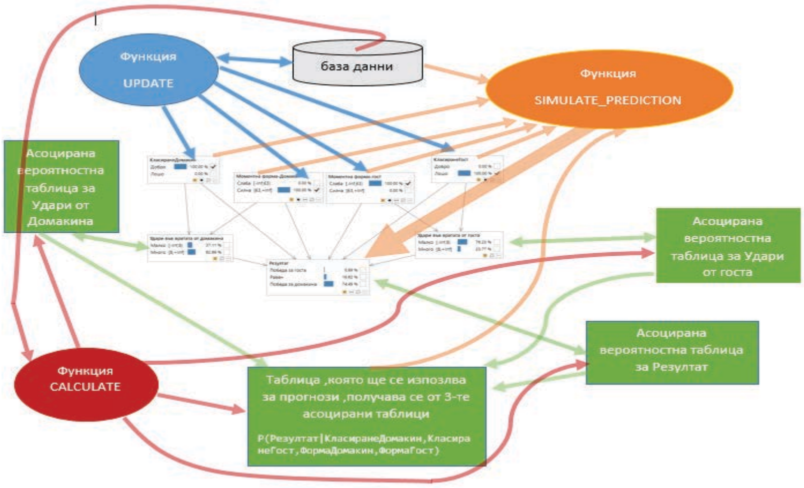
Причинно-следствените връзки в модела може да се разтълкуват по следния начин: Очаква се, че отборът, който е по-напред в класирането е в по-добра спортна форма и следователно ще отправи повече удари във вратата на противника. А колкото повече удари отправи към вратата на противника даден отбор, толкова по вероятно е той да реализира повече голове и толкова по вероятно е да спечели играта. Това, обаче не е сто процента сигурно, защото противниковият отбор може да е също в отлична спортна форма.



Фиг. 2. *Бейсов модел за предвиждане на изхода от футболни мачове.*

или просто да има повече късмет в даден мач, или защото футболът е силно конкурентен спорт, противниковият отбор може да се противопостави активно. Когато играят два отбора, може да се предположи, че отборът, който е по-добре класиран е по вероятно да спечели, но това също не е сигурно.

Предложеният модел може да се използва както за предсказване така и за намирането на причините, които са довели до очакваната победа, правилния залог или допуснатите грешки в предположенията на потребителите. Например (фиг. 2) какво ще се случи ако отборът домакин е в отлична спортна форма, класиран е на първо място, а противниковият отбор е по-назад в класирането и не е в толкова добра спортна форма.



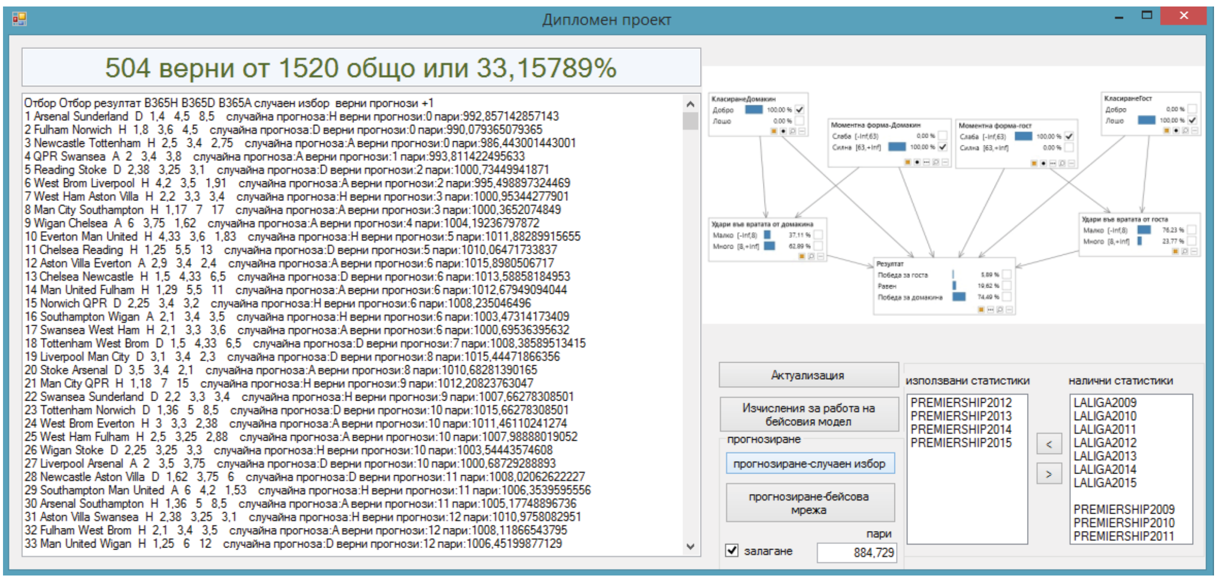
Фиг. 3. *Програмна реализация на Бейсов модел за предвиждане на изхода от футболни мачове.*

Очаква се, че в този случай отборът домакин ще отправи повече удари към вратата на противника и ще се увеличи вероятността за неговата победа.

Ако отборът гост е в отлична спортна форма, класиран е на първите места, а отборът домакин е по назад в класирането и не е в толкова добра спортна форма, то може да се очаква, че отборът гост ще има по голяма вероятност за победа. Ако даден отбор е победил в определена среща, то той вероятно се е намирал в добра спортна форма и е отправил много повече удари във вратата на противника.

3. Програмна реализация на Бейсовата мрежа и експериментални резултати

За реализацията на Бейсовия модел (фиг.3) е разработена функция Update, която обновява данните в таблиците на модела, изпълнява SQL заявките за да се определи информацията за прогнозирането; функция Calculate, която изчислява вероятностите за победа на даден отбор на базата на статистическите оценки от данните; функция Simulate_Prediction, която изчислява прогнозата според изчислените вероятностни стойности и проверява в каква степен прогнозата съответства на реалните постигнати резултати. За сравняване и оценяване на работата на степента на успешност на модела е реализирана функцията Simulate_Random, която изчислява прогнозата за резултатите от футболните срещи на случаен принцип. Направени са два експеримента, целта на които е да се сравнят прогнозите направени на базата на модела на реализираната Бейсова мрежа



Фиг. 4. *Бейсов модел за предвиждане на изхода от футболни мачове.*

и прогнозите направени чрез напълно случаен избор. Резултатите (фиг. 4) от многократното провеждане на експериментите показват следното: С помощта на предложения Бейсов модел се постигат 50% точни прогнози; С помощта на случайния избор се постигат максимум 33% точни прогнози. Изводът е, че предложеният модел значително подобрява вероятността да се направят точни прогнози. Ако се вземат предвид още повече факти за отборите, които се състезават този процент на точно направените прогнози ще се повиши.

4. Заключение

Предложен е Бейсов модел за предвиждане на изхода от футболни мачове. Използвани са статистически данни от мачовете от Висшата лига и испанската ЛаЛига за сезони 2009-2010, 2010-2011, 2011-2012, 2012-2013, 2013-2014, 2014-2015, 2015-2016.

За изчисляване на прогнозите Бейсовият модел взема предвид спортна форма на отбора домакин и на отбора гост; класирането на отбора домакин и отбора гост в текущо разглежданото първенство; брой точни удари отправени към вратата съответно на отбора гост и на отбора домакин. Изчислява се вероятността за победа на отбора гост, отбора домакин и вероятността за равен резултат. От направените експерименти може да се направи извода, че предложеният Бейсов модел увеличава вероятността да се направят точни прогнози в сравнение със случайно направените. Процентът на правилните прогнози направени с помощта на разгледания Бейсовия модел достига 50%, докато при случайно направените прогнози процентът на успешно залагане достига най-много до 33%. Моделът може да се подобри като се вземат предвид повече обстоятелства при прогнозирането. Моделът може да се използва от инвестиционни компании и за профилактика на зависимост от хазарта.

ЛИТЕРАТУРА

1. Owramipur F., Eskandarian P., and Mozneb F. S. (2013). Football Result Prediction with Bayesian Network in Spanish League-Barcelona Team, *International Journal of Computer Theory and Engineering*, 812-815, Vol. 5, No. 5. DOI: 10.7763/ IJCTE. 2013. V5. 802. http://www.ijcte.org/papers/802-N30016.pdf
2. MAHER M. J. (1982). Modelling association football scores, 109-118, *Statistica Neerlandica* 36 (1982), nr. 3., http://www.90minut.pl/misc/maher.pdf
3. Joe Buchdahl, (2003) Fixed Odds Sports Betting: The Essential Guide, High Stakes Ltd., 2003. http://www.football-data.co.uk/ratings.pdf
4. Футболни прогнози (2016) http://www.football-data.co.uk/
5. Langseth H., (2013). "Beating the bookie A look at statistical models for prediction of football matches", Norwegian University of Science and Technology SCAI 2013, http://www.idi.ntnu.no/~helgel/slides/Langseth.pdf
6. Mirza J., Fejes N., Sumpter D., (2016). "Statistical Football Modeling A Study of Football Betting and Implementation of Statistical Algorithms in Premier League", Project in Computational Science: Report, *UPPSALA University 2016*. http://www.it.uu.se/edu/course/homepage/projektTDB/ht15/project16/Project16_Report.pdf
7. http://www.smartodds.co.uk/About/Overview, Statistical research and sports modelling services.
8. https://bg.wikipedia.org/wiki/Хазартна_зависимост
9. Charniak E.(1991), Bayesian Networks without tears, AI MAGAZINE, 0738-4602/91/$4.00 ©1991 AAAI, http://www.cs.ubc.ca/~murphyk/Bayes/Charniak_91.pdf

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DEVELOPMENT OF CLOUD COMPUTING BASED SCADA IN ELECTRICAL POWER SYSTEMS

DIMITAR GROZEV, GRISHA SPASOV, NIKOLAY KAKANAKOV, GALIDIYA PETROVA

Abstract: *The report presents the development of an experimental platform for the implementation of Cloud Computing in SCADA systems for power systems. The general idea of the experimental platform is to realize the basic modules of SCADA systems for measuring electrical power on cloud platforms. The logical network structure of the SCADA Management Center is presented. Virtualization of the different types of servers in the Control Center is considered together with the physical network solution for the implementation of the cloud platform.*

Key words: *Cloud computing, SCADA, Power systems, Cross vC NSX, SRM*

1. Basics

An electric power system typically involves generation, transmission, transformation, distribution, consumption, and dispatching processes. Electric power is generated and consumed simultaneously and is not available for mass storage or transportation. Thus, as the key to the electric power system, monitoring and dispatching guarantee the reliability and security of electric power generation, transmission, distribution, and consumption, and play a key role in providing high quality and economic electric power. An electric power dispatching and monitoring system is often called a supervisory control and data acquisition (SCADA) system, energy management system (EMS), or distribution management system (DMS) globally. In this article, we call it the electric power SCADA system. In the early stage, the electric power SCADA system mainly used multi computer architecture, consisting of single server and two server cluster systems. Currently, the system uses computer systems with a distributed open architecture [1].

The electric power SCADA system provides SCADA, automatic generation control (AGC), automatic voltage control (AVC), EMS, DMS, dispatcher training system (DTS), geographic information system (GIS), and other useful functions. The software application system is constructed and developed by using the standard CIM model, and software architecture has evolved from the Client/Server architecture to the current Browser/Server architecture. The new generation Smart Grid [2] dispatching and control system uses multi-core computer cluster technology to improve system reliability and processing capacity, and uses a service oriented architecture (SOA) to enhance system interoperability and achieve horizontal integration and vertical interconnection of power grid dispatching services. Hardware infrastructure of these application systems involves high performance servers, complex high speed computer networks, high performance and highly reliable data storage systems, and workstations. The SCADA software is developed based on the platform which consists of Windows, UNIX, and Linux operating systems, and is based on relational databases.

The whole system is connected through computer networks for data exchange and sharing, and application programs share information through an enterprise service bus (ESB). With the development of the traditional IT application systems, IT-based applications have been expanding deeply to another industry field, and encountered various problems and bottlenecks. The same is true for the electric power SCADA system, which is a professional IT application system. The future electric power dispatching center should have high computing capacity, and powerful information acquisition, integration, and analysis functions especially with the advancement of Smart Grid applications.

Existing centralized computing platforms of electric power systems can hardly meet the above requirements, which have become one of the major bottlenecks in the Smart Grid. Some of the major disadvantages of these platforms are as follows [3]:

- Low basic resource utilization and poor scalability. A large amount of basic

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computing resources to meet the demands in peak hours are idle during off peak hours. To ensure reliability, lots of resources are redundant, and cannot be fully utilized. Contradictions are growing between energy demands and conservation policies. Due to the upgrade of business, the existing IT infrastructure cannot be reused. Currently, analysis and computing in the electric power system rely on the centralized computing platform in the dispatching center. Due to limited computing capacity, poor scalability, and high upgrade costs, large scale power systems suffer from insufficient data storage and analysis capabilities.

- Poor system interoperability leading to information islands. Parallel application systems have their own architectural features, and therefore resources cannot be exchanged or reused.

Increasing management costs and risks, and decreasing equipment utilization.

2. SCADA System Components

The main components of a traditional SCADA system applicable to power systems and the information connectivity between them are shown in Figure 1.

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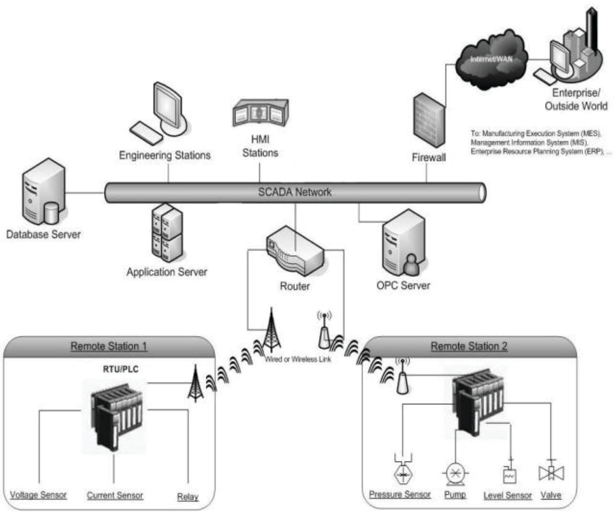

Fig. 1. *The traditional SCADA architecture.*

- RTU – remote terminal units are connected to sensors. They have telemetry hardware capable of sending digital data to the supervisory system, as well as receiving digital commands from the supervisory system.
- PLCs – programmable logic controllers are also connected to sensors. PLCs have more sophisticated embedded control capabilities than RTUs. PLCs do not have telemetry hardware, although this functionality is typically installed alongside them. PLCs are sometimes used in place of RTUs as field devices because they are more economical, versatile, flexible, and configurable
- Telemetry system is used to connect RTUs and PLCs to control center or data warehouse systems.
- A data acquisition server is a software service which uses industrial protocols to connect software services, via telemetry, with field devices such as RTUs and PLCs. It allows clients to access data from these field devices using standard protocols.
- HMI is the apparatus or device which presents processed data to a human operator, and through this, the human operator monitors and interacts with the process.6. A Historian is a software service which accumulates time-stamped data in a database which can be queried or used to populate graphic trends in the HMI. The historian is a client that requests data from a data acquisition server.
- A Historian is a software service which accumulates time-stamped data in a database which can be queried or used to populate graphic trends in the HMI. The historian is a client that requests data from a data acquisition server.
- A supervisory (computer) system, gathering (acquiring) data on the process and sending commands (control) to the SCADA system.
- Communication infrastructure.

In the implementation of modern SCADA systems the main accents are focused on the development of the communication infrastructure, on the other hand - on the development of the computer technologies and their integration in the sensor networks.

3. Cloud Computing Technologies For Electric Power Industry

Cloud computing can be used to solve various problems occurred during application deployment, use, and innovation process of the electric power SCADA system. Nowadays most of companies have their own cloud platform and virtual infrastructure, where they run business critical application and store data.

Private cloud advantages [4]:

- It is reliable and scalable. All resources are virtualized and in case of demand more storage or computing without downtime or impact can be added. With latest technology, virtual infrastructure can easily span across multiple data centers, without need to change/mapping IP addresses, FW rules, or deploy sophisticated clusters. Enhanced disaster recovery is supported.

- Fast provisioning. Using techniques like templates can deploy thousands of machines with few clicks.
- Automation. Pretty much everything can be automated using powercli, REST API, powernsx, ansible and more. Common user interface: decoupling the computation infrastructure and the input system, enables multiple user interfaces to exist side by side allowing user-centric customization.

Cost effective.

4. PRIVATE CLOUD INFRASTRUCTURE

For the purposes of proposed experimental study, we use two virtual environments. Primary site - private cloud infrastructure in Technical University of Sofia, branch Plovdiv and secondary site - private cloud infrastructure in Technical University of Sofia. Physical topology of two sites is similar. Difference is in used hardware. In Primary site, we use Enterprise class storage, switches (Ethernet and FC) and servers, while in secondary site we have micro computers Intel NUC and Synology storage.

Figure 2 (2a and 2b) shows secondary and primary site physical topology.

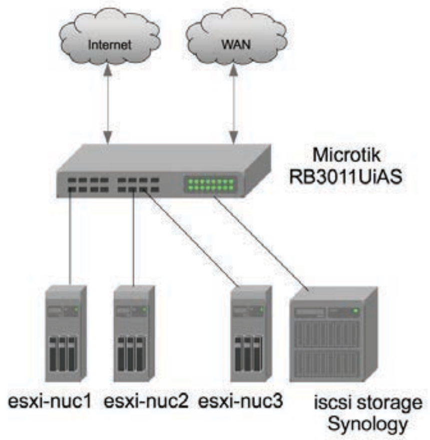

Fig. 2a. Secondary site cloud physical topology

Primary site private cloud in use is shared by the university departments and students. Everyone can request computing capacity and after an approval process one could receive VMs with requested parameters. Secondary site is dedicated only to SCADA system and it's used to cover HA requirements implementing disaster recovery site.

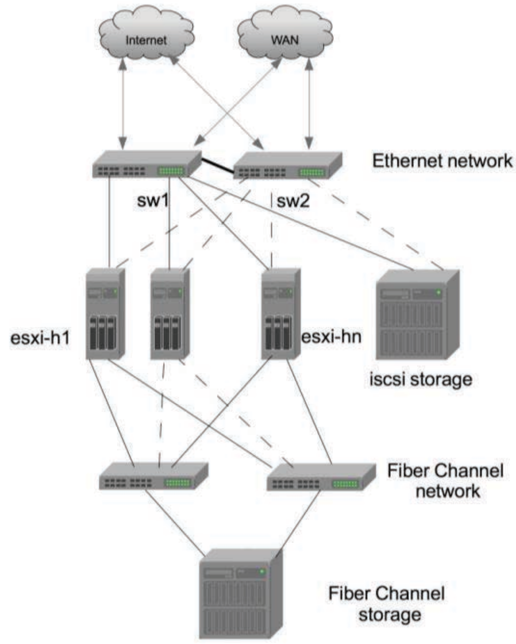

Fig. 2b. *Primary site cloud physical topology*

The following types of traffic are recognized:

Local in each site:

- Management – this include all traffic generated by virtual infrastructure: vMotion, iSCSI, NFS, fault tolerance, web-based graphical user interface, etc.
- VM traffic – this is traffic generated from all VMs connected to VLAN based port groups – various types, generated by different applications.
- VXLAN traffic – this include traffic generated from all VMs connected to logical switches - various types, generated by different applications.
- SCADA traffic – this include traffic generated from SCADA system servers

Between sites using WAN connectivity:

- Traffic generated by VMware Site Recovery Manager (SRM)
- VMs and SCADA traffic

Because of the importance and sensitivity of the SCADA traffic we implement partial application failover disaster recovery scenario using VMware site recovery manager (SRM) and Cross vCenter NSX deployment [5] [8]. All SCADA components are protected by SRM. Cross vCNSX technology solves issues like IP address mapping and FW policy. Universal Distributed FW allows deployment of security policy that span between primary and secondary site. Universal DLR along with universal distributed virtual switch span across sites too and allow same universal SCADA virtual switch on both locations. This way SCADA servers will keep their IP settings. (figure 3).

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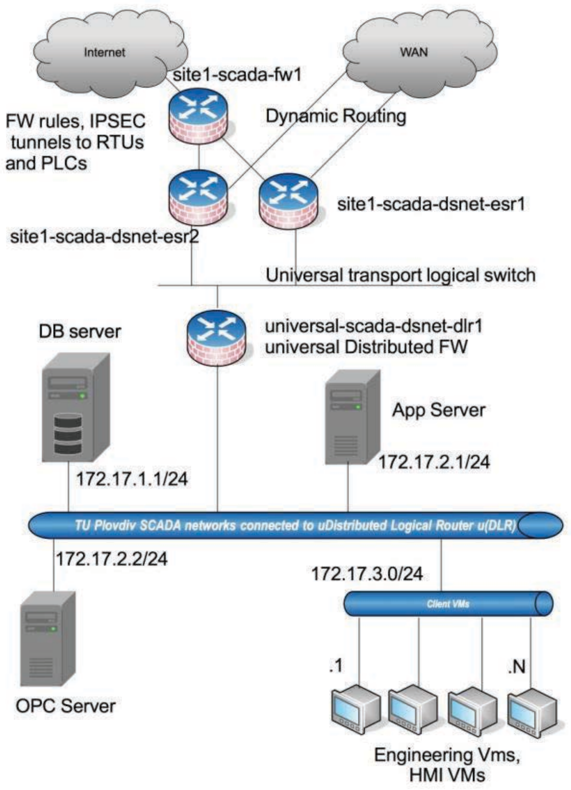

Fig. 3. *Private cloud network topology with universal objects: uDLR, uDVS*

WAN entry point of SCADA network aresite1-scada-dsnet-esr1 and esr2 - ECMP configured edges. They run dynamic routing protocol BGP and send updates for SCADA networks. Manipulate different BGP attributes in order to control SCADA networks entry point. Same pair of ECMP edges we have in both sites.Site1-scada-fw1 is NSX router connected to internet that has multiple features enabled: firewall, IPSec, SSL VPN support and load-balancing. It's an entry point for all internet accessible SCADA components like some RTUs and PLCs. To keep traffic private, we use IPSec and SSL tunnels. Through this secure channel data for controlled processes are collected. Universal-scada-dsnet-dlr1 is a universal distributed logical router (uDLR) [6][9] that optimize routing traffic between different SCADA components. Universal distributed FW [7][9] is used to control the communication.

5. References and citations

Number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [1]. Refer simply to the reference number, as in [2]. Do not use "Ref. [2]" or "reference [2]".

Use Harvard system to create the reference list: http://education.exeter.ac.uk/dll/studyskills/harvard_referencing.htm. For books and articles published in books use the referencing styles presented in [1] and [2] respectively. Papers and journal articles use referencing style as it is done for [3].

6. Conclusion

The paper presents an implementation of a cloud-based SCADA system for use in electrical power control systems. The private cloud infrastructure in use is based on VMware platform. Deploying SCADA in cloud infrastructure automatically inherits all cloud advantages:

1. Most of SCADA components are virtual machines: DB server, Application Server, OPC server, Engineering and HMI VMs. This means that we can easily create new ones, clone, backup, take snapshots, HW upgrade - change parameters like CPUs, RAM, HDD, software upgrades.
2. All SCADA components can be protected by technologies like HA and FT[7].
3. All communication nodes are virtual nodes and thus are also protected by HA - scada-dsnet-esr1 and scada-dsnet-dlr1.
4. VMware Site Recovery Manager and cross vC NSX technology is used to ensure SCADA service is available even if we have Data Center or site failure.

The presented test bed platform will allow various types of information flows and configurations to be investigated and analyzed and the best set-up for the production services to be selected. Based on the experiments with different configuration of network services in the cloud the traffic flows will be optimized for best performance in terms of delay and resource usage.

Glossary

vSphere - VMware vSphere is the brand name for VMware's suite of virtualization products.

ESXi/ESX – Elastic Sky X. An enterprise-class, type-1 hypervisor developed by VMware for deploying and serving virtual computers.

VXLAN (Virtual Extensible LAN) – A Virtual Network that emulates an Ethernet broadcast domain.

vMotion– VMware vSphere live migration allows you to move an entire running virtual machine from one physical server to another, without downtime.

NSX - VMware NSX is the network virtualization platform for the Software-Defined Data Center (SDDC).

DRS (Distributed Resource Scheduler) – technology for balancing the computing capacity by cluster to deliver optimized performance for hosts and virtual machines.

VDS – VMware vSphere Distributed Switch (VDS) provides a centralized interface from which you can configure, monitor and administer virtual machine access switching for the entire data center.

DLR – Distributed Logical Router. It separates Control and Data plane. Control plane is a VM, but data plane is part of hypervisor kernel.

ECMP – Equal Cost Multi Pathing. Routing data across multiple links with same metric.

7. Acknowledgments

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REFERENCES

[1] Arghira N., et al. Modern SCADA philosophy in power system operation – a survey, Scientific Bulletin, University POLITEHNICA Bucharest, Series C: Electrical Engineering, vol. 73, no. 2, pp. 153-166, 2011.

[2] Fang Xi, MisraSatyajayant, XueGuoliang, and Yang Dejun. Smart Grid – The New and Improved Power Grid: A Survey, IEEE Communications Surveys & Tutorials 2012, vol. 14, no. 4, pp. 944 – 980, 2012.

[3] Gang Tan, Li Zhao, Yaduan Wang, Jingwei Xu, and Honggang Liu. A Safety Design of Electric Cloud Computing Platform, In Proceedings of the Fourth International Conference on Computational and Information Sciences (ICCIS '12). IEEE Computer Society, Washington, DC, USA, pp. 868-871, 2012.

[4] Alamri A, Ansari WS, Hassan MM, Hossain MS, Alelaiwi A, Hossain MA. A survey on sensor-cloud: architecture, applications, and approaches, International Journal of Distributed Sensor Networks, Article ID 917923, Feb 2013.

[5] VMware NSX Technical Product Management Team. VMware® NSX for vSphere Network Virtualization Design Guide ver 3.0, Aug 21, 2014, online [04.02.2016]:

www.vmware.com/files/pdf/products/nsx/vmw-nsxnetwork-virtualization-design-guide.pdf

[6] B. Hedlund. Distributed virtual and physical routing in VMware NSX for vSphere, The Network Virtualization Blog, November 25, 2013. Online: [04.02.2016]:

https://blogs.vmware.com/networkvirtualization/2013/11/distribut ed-virtual-and-physical-routing-in-vmware-nsx-for-vsphere.html

[7] DebashisBasak, RohitToshniwal, Serge Maskalik, and AllwynSequeira.Virtualizing networking and security in the cloud. SIGOPS Oper. Syst. Rev. 44, 4 (December 2010), pp. 86-94, 2010.

[8] VMware NSBU team.Recovering NSX backed Data Ceneters utilizing SRM (Site Recovery Manager). Online [21.4.2016]:

https://blogs.vmware.com/networkvirtualization/2016/04/enhanced-disaster-recovery-with-nsx-and-srm.html#.WKWv6hD4Eg0

[9] VMware NSX for vSphere 6.2 Documentation Center, online [02.02.2017]:

https://pubs.vmware.com/NSX-62/index.jsp

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SECTION 4 • СЕКЦИЯ 4

MECHANICAL, TRANSPORT AND AVIATION ENGINEERING

МАШИНОСТРОИТЕЛНА ТЕХНИКА И ТЕХНОЛОГИИ; МАШИНОСТРОЕНЕ И УРЕДОСТРОЕНЕ; ТРАНСПОРТНА И АВИАЦИОННА ТЕХНИКА

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NUMERICAL ANALYSIS OF BI-METALLIC PARTS USING A FINITE ELEMENT SOFTWARE

CENK MISIRLI, ISIK CETINTAV, YILMAZ CAN, CEM MISIRLI

Abstract: *Numerical estimation of upsetting processes have very important role in manufacturing world. In this investigation, bimetallic cylindrical parts have an outside material and a different solid material inside has been upset in one operation and behavior of this component during the operation investigated. Two bimetallic component models were considered. Each model has a ring material as steel. Model 1 has a solid core material as brass and Model 2 has a solid core material as copper. Parts were upset to different heights by using parallel flat dies in press machine. Press load was recorded during the process. Loads and metal flows have been compared and shown reasonable results for two models. Different finite element software calculated and run very close results with th experiment.*

Key words: *bimetallic, upsetting, finite element*

In metal forming world, open die forging is the most important and fundamental technique. Over decades, about open die forging of single materials, such as steel, copper, aluminum, lots of works were studied both theoretically and experimentally. Vilotic et al.[1] have given particular attention to process of upsetting of cylindrical billets. K. Baskaran and R. Narayanasamy investigated study the bulging characteristics of preformed irregularly shaped aluminium billets (Elliptical billets) during cold upset forging using lubricanton both sides of elliptical billets of pure commercial aluminium under different stress state conditions namely uniaxial, plane and triaxial stress states [2]. S. Malayappan et al. studied experimentally the bulging effect of aluminium solid cylinders by introducing an extrusion die at one end [3]. Aksakal et al. investigated upsetting of polygonal samples by using dual stream functions theoretically and experimentally [4]. Thaheer and Narayanasamy[5] studied barrelling effect of truncated cone billets of various materials. Also Thaheer and Narayanasamy explained barrelling effect of truncated cone billets of various materials [6]. Chang and Bramley[7] investigate the determination of the heat transfer coeffcient at the workpiece-die interface for the forging process. Dyja et al. [8] worked theoretical and experimental analysis of rolling of bimetallic Cu-Al and Cu- Steel rods. Kocanda et al.[9] examined contact pressure distribution in upsetting of compound cylindrical and cubic metals. Senthilkumar and Narayanasamy[10] evaluates some of the cold-forging features of composite steel preforms of varying titanium carbide contents during cold upsetting under triaxial stress state conditions.

Nowadays, compared to single components, especially in marine industry, chemical industry and electrical equipment, bimetallic components are mostly preferred in industry due to their some better properties. For example, bimetallic parts especially provide corrosion resistance and better conductivity. Bimetallic components have an advantage due to each two materials consist of different chemical compositions. For example, impurities and different grain size in materials show different plastic deformation characteristics. But bimetallic components are not composite materials, because in composite materials reinforcing elements spread uniformly in matrix materials.

In recent years, plastic forming of bimetallic parts have studied by a lot of researchers. Jingcai Wang et al.[11] investigated hot forging of multi-material cladded work pieces using upsetting tests, Yang et al. [12] studied by using upper bound method. Eivani and Tahiri [13] used equal channel angular extrusion process to produce bimetallic rods and compared to one produced by general extrusion process. Plancak et al. [14] studied experimental analysis of joining of two bimetallic axisymmetric components from various materials by upsetting bimetallic components in a closed die. Plancak et al. [15] examined the behaviour of bimetallic components which consist of an outer ring of mild

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steel C45 and inner core of softer C15 steel during the cold upsetting process. Plancak et al. [16] then extended to this research and compared all the experimental data to one obtained by using finite element method.

Fig.1. Plancak Bi-metallic Model [16]

In this work, the open die forging of bimetallic cylindrical components producing using different materials designed as two models was examined both experimentally and analytically. This process may provide many parameters for metal forming operations, such as formability and barreling. The aim of this study was to examine and compare the metal flow and load requirement for these two models when upsetting of bimetallic cylindrical components.

2. EXPERIMENTAL WORK

For the interaction between different metals, two bimetallic models have been considered for this work. Material combinations and properties of these models have shown in Table 1. Basic design of Model 1 and Model 2 are shown in Fig. 2.

Table 1. Combinations of Model 1 and Model 2

Model 1: Ring material AISI 1020 STEEL
Solid inner cylinder material BRASS

Pb(%)	Al(%)	Fe(%)	Ni(%)	Sn(%)	Zn(%)	Cu(%)
1,6-2,5	0,05	0,3	0,3	0,3	Rest	57-59

Model 2: Ring material AISI 1020 STEEL
Solid inner cylinder material COPPER

O(%)	Cu(%)
0,04	99,9

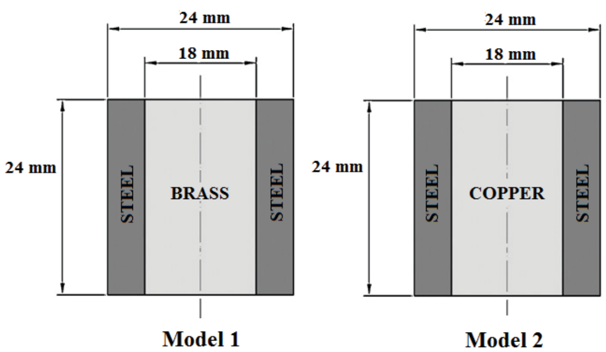


Fig.2. Design of Bimetallic Models

After prepared all the metals in lathe machine with appropriate dimensions, inner solid cylinder was pressed by low pressure into outer ring material in order to produce these bimetallic components. Produced bimetallic components are shown in Fig. 3.

Fig. 4 shows the 150 tons' hydraulic press that the experiments were carried out. It has a constant speed of 5 mm/s. The hydraulic press was equipped with a pressure current transducer in order to measure and record the experimental load. The pressure or load value was read by an I/O card of the personal computer during the experiment.

This value was converted into a resistance value, then this resistance value, consequently the pressure value was provided as an input value to the software.

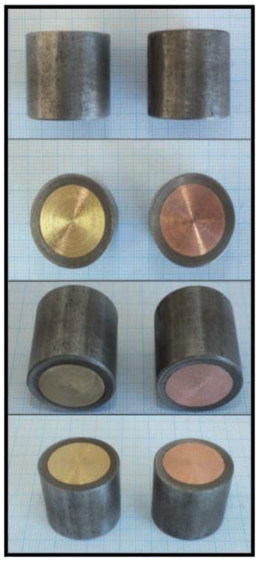


Fig.3. Produced Bimetallic Components

There were no special lubricants used but specimens and flat dies were sanded before the experiments. The fixation of components to hydraulic press is also shown in Fig. 4. Then bimetallic components were forged with reduction ratios %15, %30 and %40.

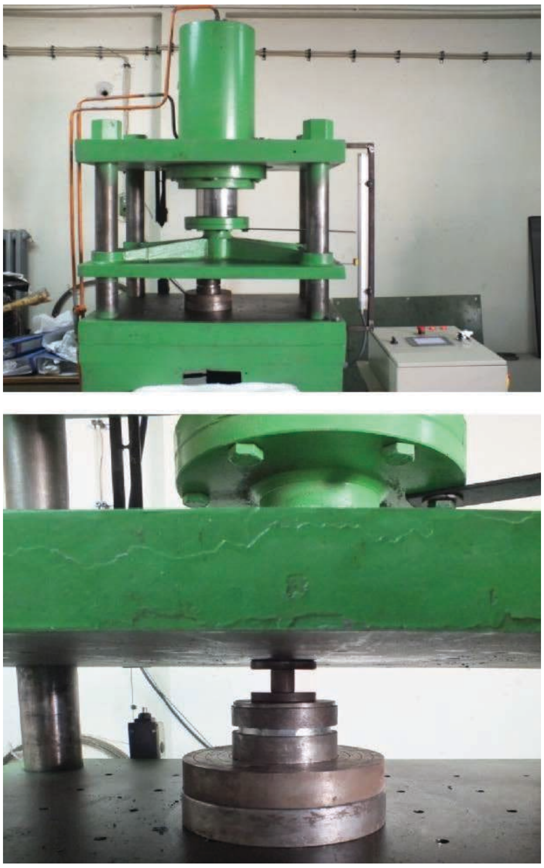


Fig.4. Hydraulic Press and fixation of parts

3. FE SIMULATION

In order to validate experimental work, a simulation model was designed using finite element softwares-DEFORM and ABAQUS. This gives more insight and helps to compare with experimental data of open die forging of bimetallic parts, also provides conducting further analyses about this work.

First, bimetallic parts were designed in Deform software as 2D model and due to the symmetry only one half of the parts were performed. All the metals properties were selected from Deform software library and they were assigned to the designed parts. For meshing, 8 node axisymmetric elements were used. For all the FE models, at the part-die interfaces a friction coefficient 0.1 is considered, but between the inner solid cylinder and the outer ring interface zero friction was assumed. Surface-to-surface contact was applied to all the friction locations. Fig.5 shows meshed component and interactions between all the contact surfaces.

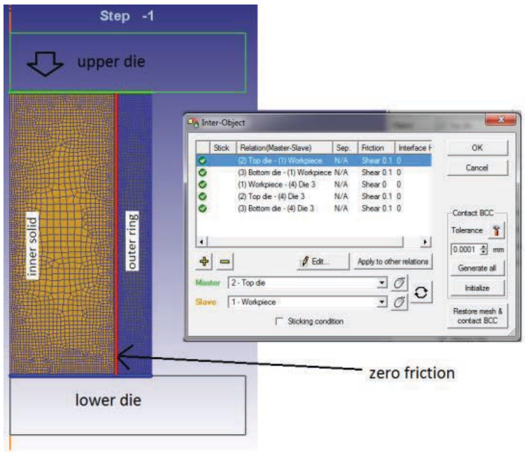


Fig.5. Meshed component and interactions

4. RESULT AND DISCUSSION

Open die forging of bimetallic cylindrical parts producing using different metals was studied experimentally and analytically for two different models. Three different metals have been used in order to produce bimetallic part models that have a ring and a solid cylinder. Model 1 has a ring material brass, and Model 2 has copper, each of these has steel solid cylinder. These parts were forged in an open die with reduction ratios %15, %30 and %40 experimentally and FE simulation model has run for the same conditions.

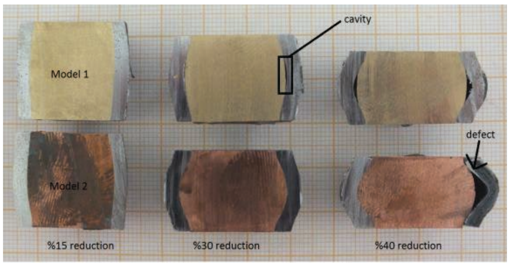
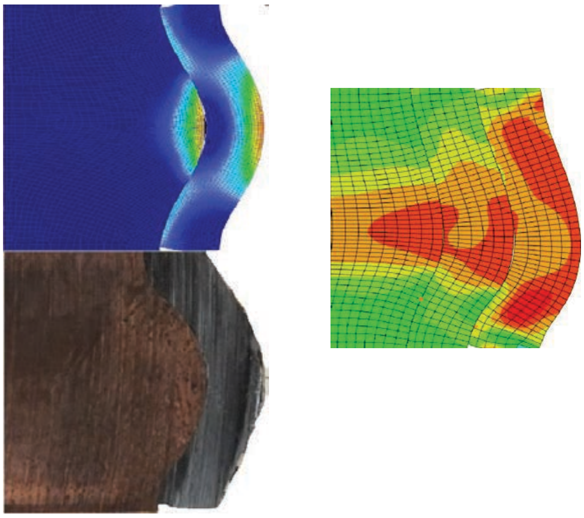
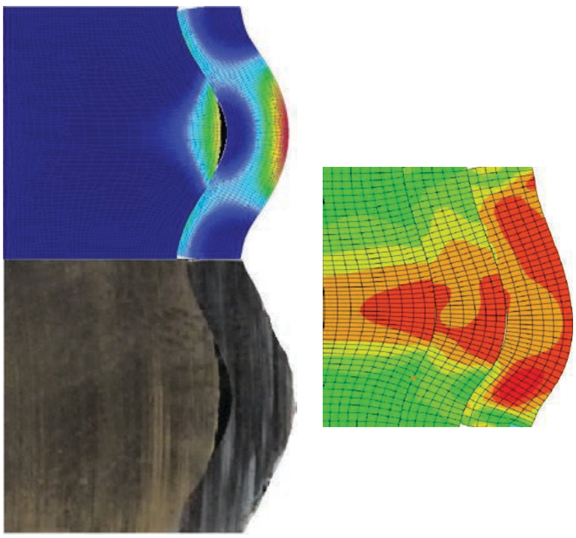


Fig.6. Meridional cut after %15, %30 and %40 reductions

After reduction, samples were cut and barrel profiles of the inner solid cylinder and outer ring were observed. Fig.6 and Fig. 7 shows that deformations and barreling of bimetallic parts after %15, %30 and %40 reductions. Clearly it is shown that Model 2 has much better material flow and zero cavity between the inner and outer interface. It is observed that the meridional cross section of inner cylinder material flows very fast and occurred a barrel profile is different from a normal barrel arc. Inner cylinder material barrel profile is not the same as outer ring material barrel profile. It can be also seen that in Model 1 there is no contact between inner and outer material and a cavity occurred in the inner meridian part of inner material. This cavity can be explained that inhomogeneous deformation occurs in the centerline and this cavity is attributed to a state of hydrostatic stress. At %40 reduction Model 2 has a defect on the right side. It is guessed that high speed of hydraulic press and the close flow curves of copper and steel may cause this fracture.



(a)



(b)

Fig.7. Comparison of FE simulation and experimental work after %40 reduction, (a) Model 1 (b) Model 2

Fig.7 shows that comparison of FE simulation and experimental work after %40 reduction. FE simulation has really similar agreement with the experimental results.

5. CONCLUSIONS

- Obtained experimental results showed that metal flow has inhomogeneity for these two models especially for solid cylinder materials. The shift of ring and solid cylinder materials also affects metal flow and load requirement.
- A defect occurred at %40 reduction of Model 2 as seen in Fig.6. It is considered that due to the high speed of hydraulic press this defect has taken place. In the future works about this topic experimental works will be carry on lower hydraulic press speed.
- As considered the load-stroke and load-reduction graphs, Model 2 or Steel-Copper bi-metallic sample needs lower load to produce or use. Also it can be seen that Model 2 has better material flow than Model 1. Copper and steel are more useful to produce bi-metallic materials.
- This work has shown that under certain conditions, in a range of tolerances, bimetallic cylindrical components may be forged while carrying on a good interface contact between the two components. This establishes the possibility of producing bi-metallic components via this process either as a finished component or, more likely, as a pre-forming operation prior to further processing.
- In future works, flow curves of single metals copper, brass and steel will be obtain and investigate how effect the flow curves to form of bi-metallic samples.
- In order to obtain further information for producing different bimetallic components for different materials, more FEM simulation and more experimental work are planning.

6. ACKNOWLEDGEMENT

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7. REFERENCES

[1] Vilotic, D.; Vujovic, V. & Plancak M. (1992). *Analysis of Upsetting of Cylinder by Conial Dies.* Journal for Technology of Plasticity. Vol., 17 (1-2), pp. 67-72

[2] K. Baskaran, R. Narayanasamy (2008). *Some aspects of barrelling in elliptical shaped billets of*

aluminium during cold upset forging with lubricant. Materials and Design 29, 638–661

[3] S. Malayappan, R. Narayanasamy, K. Kalidasamurugavel (2007). *A study on barrelling behaviour of aluminium billets during cold upsetting with an extrusion die constraint at one end.* Materials and Design 28, 954–961

[4] Aksakal, B.; Sezek, S. & Can Y. (2005). *Forging of Polygonal discs using the dual stream functions*. Materials & Design. Vol., 26, pp 643-654

[5] Thaheer, A. S. A. & Narayanasamy, R. (2007). *Barrelling in truncated lubricated zinc cone billets during cold upset forging*. Materials & Design. Vol., 28, pp. 434-440

[6] Thaheer, A. S. A. & Narayanasamy, R. (2007). *Barrelling in truncated lubricated zinc cone billets during cold upset forging*. Materials & Design. Vol., 28, pp. 434-440

[7] Zhang, H.G., Dean, T.A.,(1995). *Interaction of process and machine in multi-stage forging on a mechanical press.* Part B: Journal of Engineering Manufacture. Proc Instn Mech Engrs Vol 209, 19-32. [8] Dyja, H.; Mroz, s. & Milenin, A. (2004). *Theorical and experimental analysis of the rolling process of bimetallic rods Cu-steel and Cu-Al*. Journal of Materials Processing Technology. Vol. 153-154, pp. 100-107

[9] Kocanda, A.; Presz, W.; Adamczyk, G.; Czyzewski, P. & Mazurek, W. (1996). *Contact pressure disrtubition in upsetting of compound metals.* Journal of Materials Processing Technology. Vol., 60, pp. 343-348

[10] Senthilkumar, V., Narayanasamy, R., (2008). *Influence of titanium carbide particles addition on the forging behaviour of powder metallurgy composite steels.* Proc. IMechE Vol. 222 Part B: J. Engineering Manufacture, 1333-1345.

[11] Jingcai Wang, Laurent Langlois, Muhammad Rafiq, Régis Bigot, Hao Lu (2014). *Study of the hot forging of weld cladded work pieces using upsetting test.* Journal of Materials Processing Technology. 214, 365– 379

[12] Yang, D. Y.; Kim, Y. G. & Lee, C. M. (1991). *An upper-bound solution for axisymmetric extrusion of composite rods through curved*. International Journal of Machine Tools and Manufacture. Vol. 31, pp. 565-575

[13] Eivani, A. R. & Taheri, A. K. (2007). *A new method for producing bimetallic rods*. Materials Letters. Vol. 61, pp. 4110-4113

[14] Miroslav PLANČAK, Zlatan CAR, Dragiša VILOTIĆ, Dejan MOVRIN, Marko KRŠULJA (2011). *Upsetting of bimetallic components in a closed die*. Engineering Review Vol. 31, Issue 2, 105-109

[15] Miroslav PLANCAK, Igor KACMARCIK, Dragiša VILOTIC, Marko KRSULJA (2012). *Compression of bi-metallic components- analytical and experimental investigation*. International Journal of Engineering. 1584-2665

[16] K. Essa, I. Kacmarcik, P. Hartley, M. Plancak, D. Vilotic (2011). *Upsetting of bi-metallic ring billets*. Journal of Materials Processing Technology. 212 817– 824

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COMPUTER AIDED RESEARCH OF THE SHAFT OF A ROTOR CRUSHER OF AN ECCENTRIC TYPE

ZHIVKO ILIEV, GEORGI DINEV

Abstract: *The present article reviews the basic classification of a rotor crusher of an eccentric type as well as its usage in the field of mining industry. The analytical active forces of the eccentric shaft have been determined as well as the reactions in the bearing supports have been calculated. A 3D model of the crusher has been made as it has been used for the purpose of computer aided simulation research of one of the most stressed details, namely, the eccentric shaft. The obtained results have been analyzed as well as some recommendations have been given as they concern the possibilities for prolongation of the durability of the researched unit.*

Key words: ***mine transport,*** *rotor eccentric crusher, finite element method*

1. Basic classification

According to their pattern of action, the rotor crushers of eccentric origin are classified somewhere between the conic types and the jaw types of crushers. The process of grinding for this type of crushers is conducted by the use of two steep working chambers that shrink up and down as they are placed symmetrically in accordance with the vertical plane (fig 1). The vertical plane is the symmetrical plane of the machine itself. The operation of that type of a crusher is driven by an eccentric type of mechanism. There are four basic cinematic groups: grinding jaws, a rotor, an eccentric type of a shaft and a support protection system. Fig. 2 and fig.3 show cinematic sketches of an eccentric type of a rotor crusher along with a hydraulic type of a support protection system and an outlet that is hydraulically controlled.

The grinding chambers [1, 4, 16, 17] are placed between the curved operational surfaces (fig. 1) of the immobile jaws 1 and the cylindrical mobile rotor 3 that is mounted between them along with the shaft that is placed horizontally. Rotor 3 is located into the eccentric part of shaft 2 which is located in accordance with the basic pins. The shaft is fixed within the frame of the crusher in accordance with the pins. The crushing jaws 4 are located next to the both sides of the rotor as they are symmetrical to the basic pins of the eccentric shaft. They are mounted on the upper part as they hang fixed on axes 5 that are fixed within the frame of the crusher. Each jaw has hinged connection with the hydraulic cylinders 1 in its lower part as the jaws are fixed within the frame of the crusher by the use of special cylindrical pins.

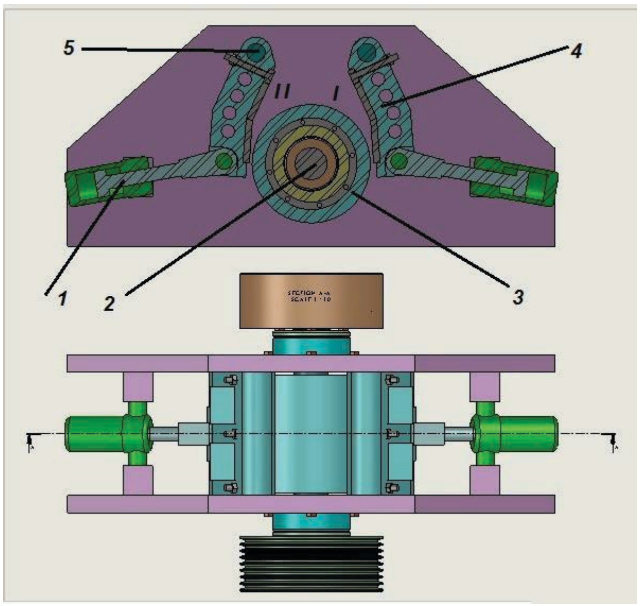

Fig.1 *Common look of a rotor crusher of an eccentric type*

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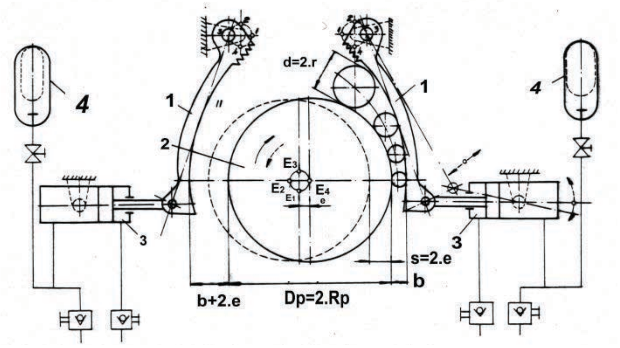

Fig. 2 *A cinematic sketch of a rotor crusher of an eccentric type and a hydraulically controlled outlet*

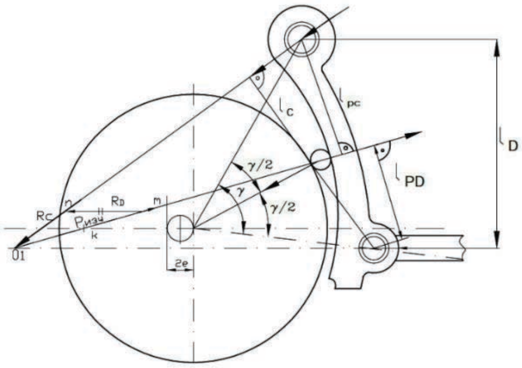

Fig. 3 *Forces of grinding of the rotor crusher of an eccentric type*

Figure 2 depicts a cinematic sketch of a rotor crusher of an eccentric type with hydraulic control of its outlet as it has the following composite details: 1 a grinding jaw, 2 mobile brake of a rotor, 3 hydro cylinders, 4 pneumatic-hydro accumulator.

Fig.3 illustrates a sketch of the forces of crushing of the crusher that shows $\theta = 10^0$ and $\gamma = 25^0$ – angles which combine forces Q and Pe along with axis OY. The forces of the belt gearing are depicted on Fig 4.

Force Q = 7452 N is the maximum force which is applied upon the shaft as a result of the forces of the belt gearing [3, 21].

2. Determination of the reactions in the bearing supports of the eccentric shaft.

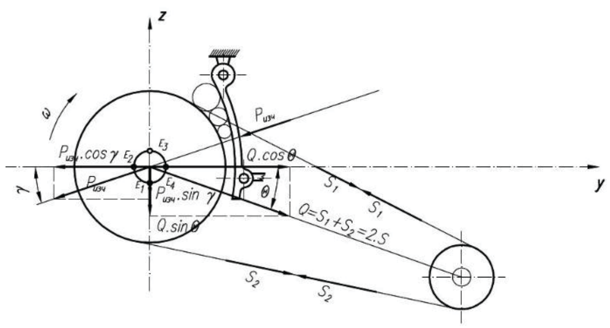

Fig. 4 *Forces within the belt gearing*

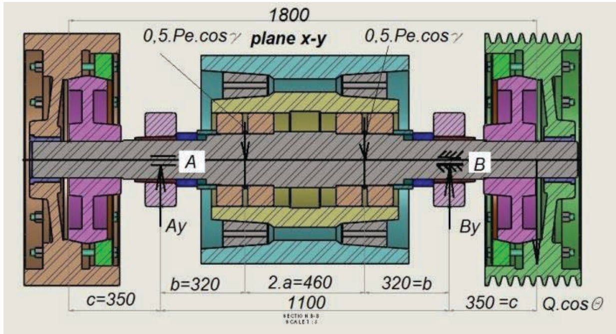

Fig. 5 *A sketch that is used for determination of the reactions of the bearing supports within the plane of X-Y*

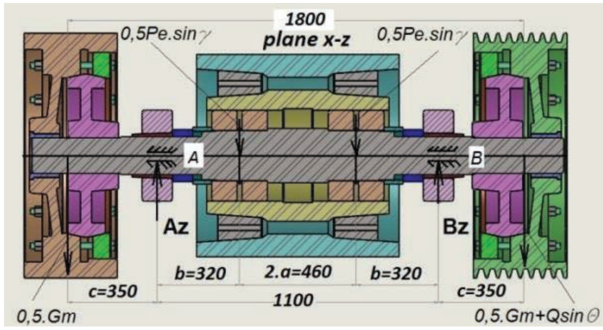

Fig. 6 *A sketch that is used for determination of the reactions in the bearing supports within the plane of X-Z*

The reactions Az and Bz within the bearing supports (Fig. 4) are to be defined by the moment equations:
Regarding plane ***X-Z*** *(Fig.6)* we have the following:

$$\sum M_B = 0; \qquad (1)$$

$$0{,}5.G_m(c + b + 2.a + b) - A_z(2.a + 2.b) +$$
$$+0{,}5.P_e.sin\gamma.(2a + b) + 0{,}5.P_e.sin.b -$$
$$-(0{,}5.G_m + Q.sin\theta).c = 0;$$
$$A_z = 53\,504, N$$

where ***2.a=460 mm; b=320mm; c=350mm*** is the geometrical size of the rotor head along with the shaft

$$\sum M_A = 0; \qquad (2)$$

$$0{,}5.G_m.c - 0{,}5.P_e.sin\gamma.b - 0{,}5.P_e.sin\gamma.$$
$$(2.a + b) + B_z.(2.a + 2.b) -$$
$$-(0{,}5.G_m + Q.sin\theta).(2.a + 2.b + c) = 0;$$
$$B_z = 55\,620, N$$

where $G_m = 6800N$ –is the weight of the flywheel [2,3]

$$P_e = \frac{1000.\eta_m.N_{eng}}{4.e.z} = 239\,062N; \qquad (3)$$

Force P_e is perpendicularly [2] applied according to the operational plane of the grinding jaw (Fig.3).

where $\eta_m = 0{,}85$ – a mechanical К.П.Д.;

- $N_{eng.} = 90 kW$ – power of the drive;
- e =10 mm – eccentricity of the shaft;
- z = 8 Hz –number of swaying movements of the shaft;

Regarding plane ***X-Y*** (Fig. 5) we have the following:

$$\sum M_A = 0; \qquad (4)$$

$$B_y.(2.a + 2.b) - 0{,}5.P_e.cos\gamma.b$$
$$-0{,}5.P_e cos\gamma(2a + b) + Q.cos\theta(2.a + 2.b + c) = 0$$
$$B_y = 206\,637, N$$

$$\sum M_B = 0; \qquad (5)$$

$$A_y.(2.a + 2.b) - 0{,}5.Pe.cos\gamma.(2.a + b) +$$
$$+0{,}5.P_e.cos\gamma.b + Qcos\theta.c = 0$$
$$A_y = 105\,997, N$$

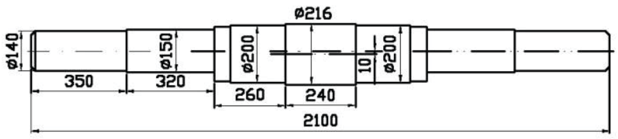

Fig.*7 A drawing of the eccentric shaft*

2.1. Methodology of researching

In order to increase the values of the exploitation indexes throughout the process of designing of the machine elements, one can use the capabilities of contemporary software products.

The first stage of execution of the research is creation of a 3D CAD model of the eccentric shaft of the rotor crusher *(fig. 7)*. The instance applies to a detail that is shown on *fig. 8*. which has been drawn by usage of Solid Works. Limitation with zero displacements has been imposed using the option of 'fixed' as it is required for the purpose of execution of the computer aided simulation. The consequent reactions within the bearing supports will affect the stress upon the shaft significantly. Concerning that fact, one has to assume the greater values, namely the results from plane X-Y, as they represent a more serious case of operation of the shaft.

A computer aided simulative and structural analysis has been conducted in order to determine size and distribution of the equivalent stresses.

The material that is assumed to be used for the explored detail is steel type S 235 J2G3 БДС EN 10025, as it sustains allowable stresses of approximately $[\sigma_{AL}] = 160 MPa$.

2.2. Results from the static analysis that was conducted.

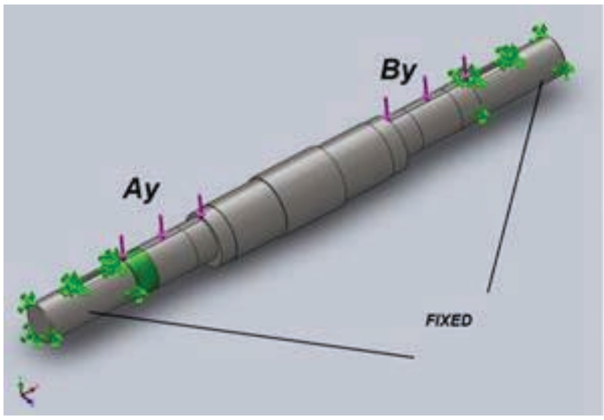

Fig.8 *Loading applied upon the eccentric shaft*

The capabilities for MKE investigation of the software product will be applied throughout the process of researching by simulation. These are as follows:

- Equivalent stress according to the Theory of von Mises [5, 6, 18, 19, 20];
- Reliability (Safety) coefficient according to the Theory of Mises-Henky

According to the Theory of von Mises-Henky, the limit of protraction is to be defined by the correspondence between the amount of equivalent stress according to von Mises σ_{VON} and the amount of allowable stress $[\sigma_{AL}]$ [7]

$$\sigma_{VON} \geq [\sigma_{AL}]$$

The stress types, according to von Mises, can be defined by the three main types of stress in correspondence with dependency [6, 11, 12, 13].

$$\sigma_{VON} = \sqrt{\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_1 - \sigma_3)^2}{2}} \qquad (6)$$

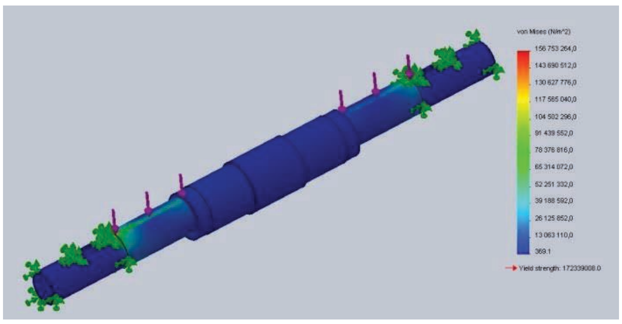

Fig. 9 *Distribution of the equivalent types of stress within the eccentric shaft*

3. Application of Expert system for design filet curve.

Production rules are a formalism used in design of program languages before it was used in psychological modeling [7] and in Expert systems [8],[9].

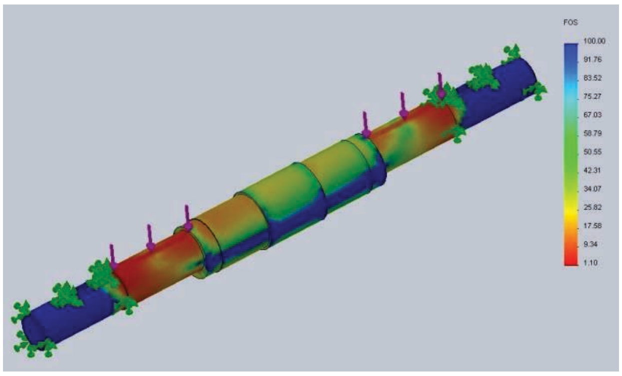

Fig. 10 *Distribution of the Factor of Reliability (Safety) within the eccentric shaft*

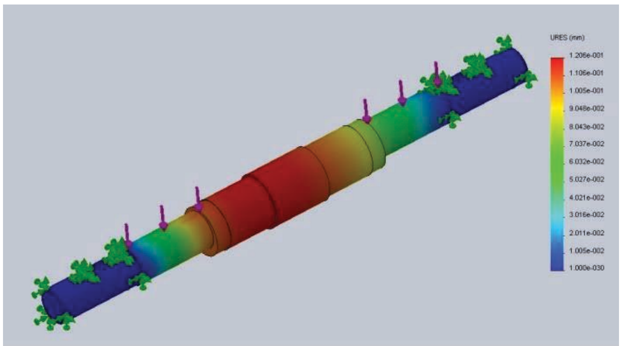

Fig. 11 *Distribution of the equivalent displacements within the eccentric shaft*

Some of most popular model from "production rules" include: Rules from kind "IF" and "THEN"; Different kinds of network; Logistic equations for coding of facts and principles"[10].

In the literature concerning expert systems sometime they are call rules from type "condition-action" or "situation-action". This is so because in general they are used to code empiric relations between models of data presented to the system and actions, which the system must execute as a consequence.

3.1. Solving of conflicts

The strategy for solving conflicts is of particularly importance for the work of production system and for this purpose must be chosen precisely. The mechanisms for conflicts solving varied but three of them are very popular and often are used in combination thus forming a global direction regime.

Unity. One rule cannot be used more than once for one and the same data.

Actuality. The elements in operational memory in OPS5 contain a field for time, thus it is known on the period of wich cycle they are added to operational memory.

***Specificity*.** The concrete elements, drawn from more specific rules, for example rules with greater number of condition, are more difficult to be satisfied and therefore are prefered before more general rules with smaller number of conditions.

3.2 Production Ruls

In the process of designing the shaft designer may use the production rules by carrying out simulation analysis by the finite element method searching the optimum value of the filet radius from the standpoint of stress concentration.

This is illustrated by the following algorithm:

If: 1. The radius of curve is 0,5 mm;
2. The stress $\sigma > 0{,}260E9$.MPa
Then: To change the radius of 1,5 mm.
If: The stress $\sigma > 0{,}200E9$.MPa
Then: To chose Steel grade 41Cr4
If: The stress < 0,200E9.MPa.
Then: The concentration of stress are lucky.

In next *Fig.12* are shown the results from investigation of shaft with Finite Element Methods-ANSYS by 3D geometrical model and determined theoretical distribution of stresses in character points and surfaces concentrators. The designer can to used *expert system* included some *algorithms*. For example let to illustrate choice of fillet curve of shaft.

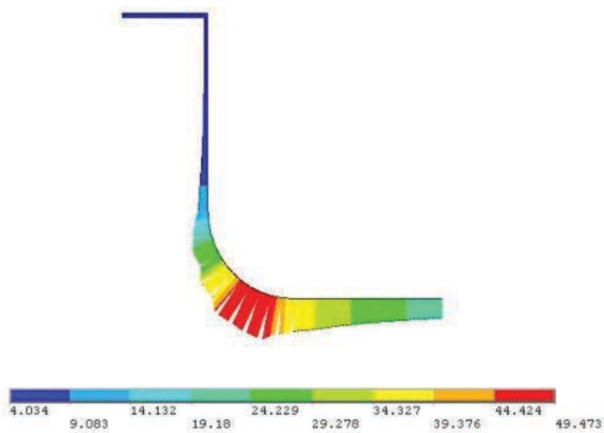

Fig. 12 *Distribution of stresses on fillet curve of shaft*

The results shown that maximum value for stresses are in left and right zone of fillet curve.

This value are from *49 MPa to 53 MPa.*in the both sides of shaft. The designer can to used the same algorithm.

4. Analysis of the obtained results and conclusions

Fig. 9 shows clearly that, according to Von Mises, the maximum amounts of stress within the shaft are of the value of *156,7 MPa.* All types of stress are concentrated within the bearing supports. In *Fig. 10*, it is evident that the minimum factor of reliability (Safety) *FOS = 1,1* is quite noticeable at the place of fixation. However, the maximum of equivalent displacements appears at the middle shoulder of the shaft (Fig. 11). This is due to the resilience of the detail. The maximum of displacements is of a value around 0, 12 mm. These results are normal and quite anticipated. It is possible that the factor of reliability (Safety) could be raised by constructive changes. An example of such changes is enlargement of the diameter of the vulnerable shoulders.

In the process of constructing machine parts using the capabilities of expert systems and the method of finite elements is improved the concentration of stress in their operation.

REFERENCES

1. Iliev Zh., Perenovski N. (2014) *"Opportunities for using the finite element method by computer research on rotary crusher of the eccentric type 800D x75"*, International multidisciplinary scientific symposium "Universitaria Simpro 2014", Petrosani, Romania..

2. Цанев Ц. (1973) *„Върху някои кинематични и конструктивни особености на роторна трошачка ексцентиков тип", сп.* Рудодобив, бр. 9, София.

3. Цветков Хр., Цанев Ц. (1976) „*Кинематика на роторна трошачка ексцентриков тип при задействане на предпазната й система."* Годишник на ВМГИ, София.

4. Dinev G, Zh. Iliev (2016) *"About computer design of machine and equipment the general machine building"*, International Journal "MACHINE, TECHNOLOGIES AND MATERIALS".

5. Lawrence, K.,(2005) *ANSYS Workbench Tutorial, SDC Publications*, Texas

6. Iliev Zh., (2016) " *Computer modal analysis of a eccentric shaft of a complex pendulum jaw crusher""5- National scientific and technical conference with international participation"*, "Technologies and Practices in Underground Mining and Mine Construction", Devin, Bulgaria.

7. Dinev G. *An approach for simulation design of mechanical assembled unit*, Journal Advanced Material Research , Vol. 463-464, Trans Tech Publication, Switzerland, (2012), pp.1085-1088.

8. Jackson P. *Introduction to expert systems. Allison Wasley Longman*, 1998.

9. Dinev G. *Expert systems used throughout the training of master engineering in the field of industrial engineering*, International virtual journal for science, technics and innovations for the industry, MTM, Year IX Issue 1/2015, ISSN 1313-0226, pp. 25-28.

10. Dinev G. *Course on principles of mechanical design.* In: AVANGARD PRIMA, 2011.

11. Iliev Zh., Dinev G.(2016) "*Improving the maintance of drive sheave of hanging ropeway",* International Conference on Engineering, Technologies and Systems, TECHSYS 2016, Technical University – Sofia, Plovdiv branch, Bulgaria.

12. Iliev Zh., Dinev G.(2015) *„About an education of engineering specialists for a computer design of the technical products in mining production",* Technologies and Systems, TECHSYS 2015, Technical University – Sofia, Plovdiv branch, Bulgaria.

13. Iliev Zh.,(2012) *"Opportunities for using finite element method by computer research of three roll directive devices of mine skip winding machines"* 12th INTERNATIONAL SCIENTIFIC CONFERENCE VSU'.

14. Iliev Zh.,(2012) "*Компютърно моделиране по метода на крайните елементи на двуролково направляващо устройство на подемни съдове за руднична клеткова уредба",* "Technologies and Practices in Underground Mining and Mine Construction", Devin, Bulgaria.

15. Iliev Zh., Perenovski N. (2016) *"Computer modeling and investigation of the operating parts of the screw conveyor by finite element method",* "Technologies and Practices in Underground Mining and Mine Construction", Devin, Bulgaria.

16. Iliev Zh., Bogdanov Iv.(2015)" *Analysis of the vibration state of the eccentric shaft with the bearings of a complex pendulum jaw crusher",* XVI Balkan mineral processing congress, Belgrad, Serbia.

17. Tsvetkov Kr., Iliev Zh., Perenovski N.,(2013)"*Power of electric motor and forces of breakage in jaw crushers with direct drive of the*

movable jaw.” International Scientifis Conference, UNITECH 2013, Gabrovo, Bulgaria.

18. Iliev Zh., Perenovski N. (2015) *“Computer simulation research of hydrostatic thrust bearings of cone crusher type "kubria" by finite element method”*, Scientific journal 'Mechanics Transport Communications': 3 / 2015.

19. Iliev Zh., Perenovski N. (2014) *“Using finite element method by design of impact crusher for average crushing”,* Scientific journal 'Mechanics Transport Communications': 3 / 2014 Faculty scientific conferences.

20. Radlov K., Iliev Zh. (2011) *“Opportunities for using finite element method by design of disk feeder for mining and building materials”,* International Scientific Conference, UNITECH 2011, Gabrovo, Bulgaria.

21. Цанев Ц. (1976), *“Изследване на функционалната връзка между основните технологични и технически параметри на роторна трошачка ексцентриков тип* “,Дисертация, ВМГИ-София,

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COMPARATIVE STUDY OF THE MECHANICAL PROPERTIES OF TI AND CR BASED HARD COATINGS DEPOSITED BY CLOSE FIELD UNBALANCED MAGNETRON SPUTTERING

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TETIANA CHOLAKOVA

Abstract: *Two quaternary hard coating structures Ti/TiN/TiCrAlN and Cr/CrN/CrTiAlN, were deposited on HSS substrates by close field unbalanced magnetron sputtering (CFUBMS). A comparative study of their mechanical characteristics, nanohardness, a coefficient of friction and adhesion was carried out. The effect of the nitrogen flow controlled by an Optical Emission Monochromator (OEM) on the adhesion and transition layers was investigated. Among both investigated structures, the Cr-based coating showed better mechanical properties pronounced by higher nanohardness of 27 GPa, a lower coefficient of friction of 0.089 and excellent adhesion up to 30N loading.*

Key words: *coatings, nanohardness, adhesion, CFUBMS*

1. Introduction

Chromium nitride (CrN) and titanium nitride (TiN) coatings have well established background in advance machining operations [1]. The subsequent ternary nitride coatings like TiAlN [2] and CrAlN [3] exhibit improved tribological, mechanical, thermal and oxidation properties compared to the binary nitride based coatings. Besides, CrTiN coatings show enhanced mechanical behaviour [4]. The development of TiAlCr alloys allowed applications at temperatures as high as 1000 ^{o}C [5]. The CrTiAlN coatings obtained by Close Field Unbalanced Magnetron Sputtering (CFUMS) exhibit a high hardness and strong adhesion between the coating and substrate [6]. Furthermore, this technology allows deposition of compositionally graded structures, which improves the tribological characteristics of the coatings [7]. In this study, Ti/TiN/TiCrAlN and Cr/CrN/CrTiAlN graded coatings deposited by CFUBMS were comparatively studied in respect to their mechanical properties, a nanohardness and adhesion.

2. Experimental

The quaternary coating structures, Ti/TiN/TiCrAlN and Cr/CrN/CrTiAlN, named Ti-based and Cr-based, respectively, were deposited on high speed steel (HSS) specimens by close field unbalanced magnetron sputtering in UDP 800-4 equipment (Teer Coatings, UK). Figure 1 presents a scheme of the CFUBMS vacuum chamber used for deposition of hard coatings. Two Al targets, one Cr and one Ti targets were used for the coatings deposition.

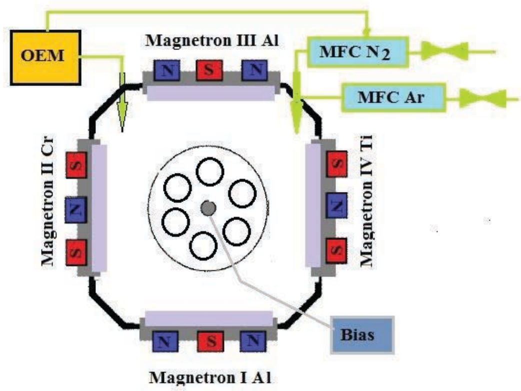

Fig. 1. *A vacuum chamber scheme of the UDP 800-4 equipment.*

Before the coating deposition the specimens were ultrasonically cleaned in an alkaline solution, rinsed in deionised water and dried at temperature of 130 °C. After that the substrates were loaded and the vacuum chamber was evacuated to $1.5x10^{-5}$ torr. The ion cleaning in an Ar plasma and at a bias voltage of − 500 V was performed for 30 min immediately before the coating deposition. To obtain better adhesion with the substrate an adhesion layer of Ti or Cr was

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deposited in an Ar plasma. After that a transition layer of TiN or CrN was grown by a gradiently increased N_2 flow. The internal stress between the transition layer and the active coating layer was reduced with deposition of a gradient TiCrAlN or CrTiAlN layer. In this step, both parameters, the target power and nitrogen flow were increased to values optimal for the active top layer of the coating. The active coating CrTiAlN and TiCrAlN layers were deposited at constant values of the regime parameters. The total thickness of the Ti-based coating is 2.0 μm, while of the Cr-based it is 2.2 μm. During deposition, the nitrogen flow was controlled by an OEM monochromator, which was tuned to the Ti peak at 501 nm or to the Cr peak at 421nm. The target's current was kept the same and the OEM set points were chosen to fix the same N_2 flow during the graded layer deposition. The sputtering process was adjusted by the power and was controlled by the current. It was found out that best mechanical parameter were achieved at a current of 5 A, 8 A and 3 A of the Cr, Ti and both Al targets, respectively. The currents of the different material targets differ due to the different sputtering material rates and their reaction activity to N_2 [8]. The argon (Ar) flow was controlled by a Mass Flow Controller (MFC) and was kept at 25 sccm during the whole process. The pulsed bias voltage was maintained at −70 V during deposition. The working preassure during the process was between $1.6x10^{-3}$ and $1.9x10^{-3}$ torr. The carousel was rotating with 5 rpm.

The mechanical parameters were determined with a Compact platform CPX- MHT/NHT – CSM Instruments, Anton Paar, Austria. The nanohardness was measured with a nanoindentation module. A microindentation module with a Rockwell indenter was used performing a scratch test in order to study the adhesion and to determine the coefficient of friction against the diamond indenter. The nanoindentation module has a diamond Berkovich indenter that allows indentation in the interval 0.01-500 mN. The equipment software automatically calculates the nanohardness and elastic module depending on the penetration depth. The Oliver and Pharr methodology is implemented for the calculations. An indentation with a load of 200 mN was made for characterization the complex nanohardness including the coating and substrate influence. Besides, a loading of 15 mN was performed to eliminate the substrate effect keeping the well-established 10% rule of penetration in the coating. The scratch module has a certified diamond spherical Rockwell indenter with a radius of 200 μm and cone angle of 120°. The equipment allows loading in the interval of 0.1-30 N. The precision of the measurement of the loading is 0.3 mN. The maximum loading depth is – 200 μm. The software allows display of the penetration depth, friction and load forces, acoustic emission and coefficient of friction. The scratch tests were made with a progressive load from 1 to 30 N and a length of 1 mm for each investigated sample. The scratch velocity was 0.5 N/min.

3. Mechanical properties

The load–displacement curves of the Ti-based coating at indentation loads of 15 mN and 200 mN are shown in Fig. 2.

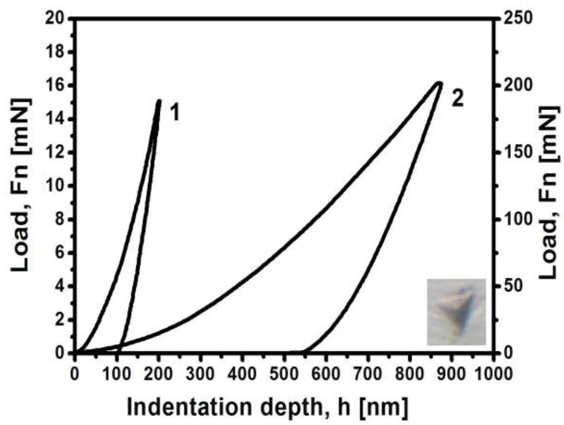

Fig. 2. Load-displacement curves of the Ti/TiN/TiCrAlN coating measured at: 1 - 15 mN, 2 - 200 mN.

The nanohardness H, elastic module E and maximum indentation depth h_{max} are summarized in Table 1. A highest nanohardness of 23 GPa was measured at h_{max}=202 nm, which value evidences that the influence of the substrate could be accepted negligible according to the 10 % rule. The corresponded module of elasticity was 271 GPa.

***Table 1.** Nanohardness and elastic module*

Fn [mN]	H [GPa]	E [GPa]	h_{max} [nm]
Ti/TiN/TiCrAlN			
15	23.3	271	202
200	16.5	292	875
Cr/CrN/CrTiAlN			
15	27	385	185
200	15.4	305	889

The are few published results about the nanohardness of the TiCrAlN coatings deposited with CFUBMS. A value of 32 GPa is reported for the same coating structure obtained by cathodic arc evaporation [9]. This technique allows achievement of high ionisation rates and deposition of dense coatings with an increased nanohardness, but in a combination with formation of macro particles.

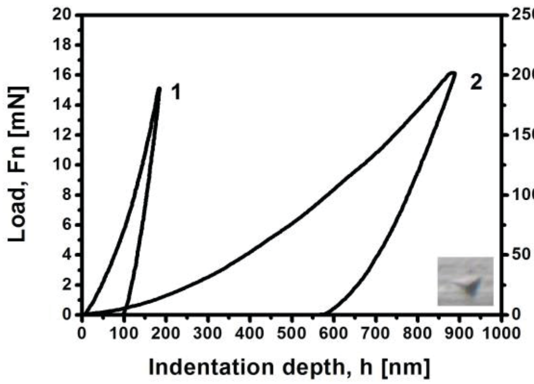

Fig. 3. Load-displacement curves of the Cr/CrN/CrTiAlN coating measured at: 1-15 mN, 2- 200 mN.

The results from measurements of the Cr-based structure are presented in Fig. 3 and Table 1. The inserted photo presents the residual indent on the coating surface after indentation with 200mN.

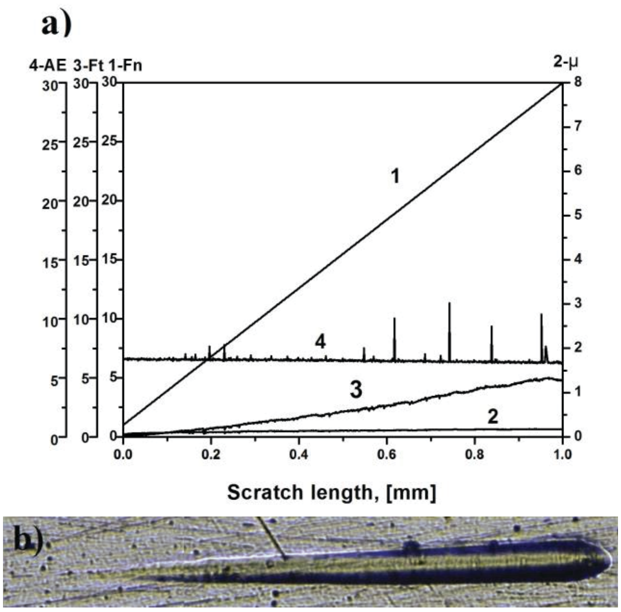

Fig. 4. *Scratch test results for the Ti/TiN/TiCrAlN coating:*
a)Graphic trends of the test process, 1-Load force, 2- Coefficient of friction, 3-Friction force, 4-Acustic emission;
b) A photo of the scratch test track;

For the Cr based coating, the measured nanohardness at the maximum indentation depth of 185 nm was 27 GPa and the elastic module was 385 GPa. The obtain result for the nanohardness is comparable with that reported in other publications for CFUBMS [10, 11] but still could be improved by an optimisation of the N_2 partial pressure [12].

The scratch test trends of the Ti based coating are presented in Fig. 4. Four signals are presented in the graph: the load force Fn increased from 1 to 30 N, coefficient of friction μ, friction force Ft and acoustic emission AE. As it is seen, there is a very good adhesion between the coating and the substrate. There is no delamination of the coating. The AE signal has several peaks, which correspond to rare small and short semi-circular and angular cracks, which are not considerable for the very good resistance of the coating during the scratch test. For the whole test loading up to 30N, coating chipping and spalling do not appear. The measured coefficient of friction at the end of the test was 0.167.

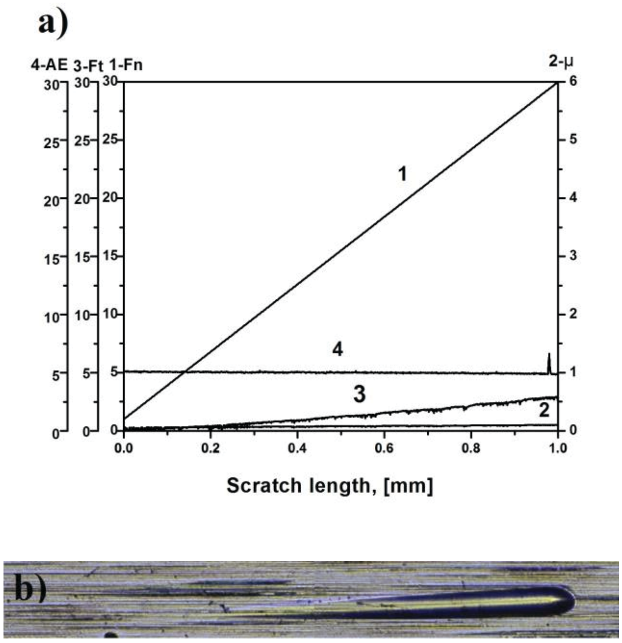

Fig. 5. *Scratch test results for the Cr/CrN/CrTiAlN coating:*
a) Graphic trends of the test process, 1-Load force, 2- Coefficient of friction, 3-Friction force, 4-Acustic emission;
b) A panoram photo of the scratch test track;

The scratch test results of the Cr/CrN/CrTiAlN coating are given in Fig. 5. This coating also have not delamination. The AE signal is clear and no cracks were found during the test. The only one pick at the end of AE signal could be attributed to the unloading process of the indetor or defect in the substrate and it is not corresponding to a crack in the scratch track. The resistance of the coating during the scratch was excellent, i.e. the adhesion is excellent. The coefficient of friction at the end was 0.089.

The deposition of Ti–based and Cr-based quaternary structure at the same technological conditions allows the comparative study of the mechanical behavior resulting from the interactions between the Ti and Cr layers and the HSS substrate, as well as from the influence of TiN/ TiCrAlN and CrN/CrTiAlN transition layers. The N_2 flows during the main coating layers deposition were 21.2 sccm and 21 sccm for Ti-based and Cr-based coating, respectively. Thus, it can be consider that these layers were deposited at the same nitrogen flow.

The dependence of the hardness and elastic modulus on the loading is presented in Fig. 6. The mechanical parameters were measured in two characteristic points 15 mN and 200 mN, corresponding to the depth penetration giving information about the coating hardness itself and the hardness influenced by the substrate. It is seen that no significant difference of the coating hardness were observed at 15 mN loading. It is expectable because there are no differences in the technological parameters at which these layers were deposited. With the increase the load the composite hardness decreases due to the increased influence of the substrate.

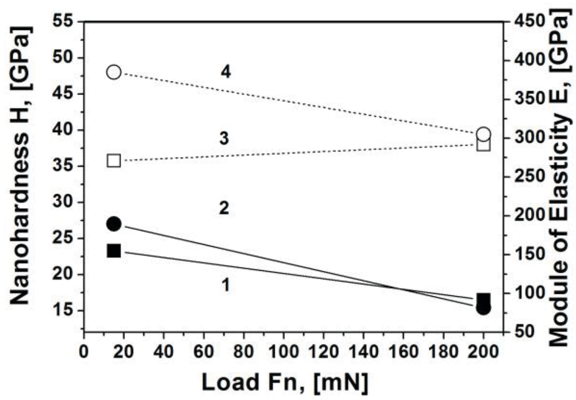

Fig. 6. *Dependence of the nanohardness and elastic modulus of the Ti- and Cr-based coatings:*
1- Nanohardness of Ti/TiN/TiCrAlN coating,
2- Nanohardness of Cr/CrN/CrTiAlN coating,
3- Module of elasticity of Ti/TiN/TiCrAlN coating,
4- Module of elasticity of Cr/CrN/CrTiAlN coating.

The scratch parameters for both coatings are presented in Table 2. It can be seen that the Cr-based coating has a better coefficient of friction and excellent resistance to the progressive load from 1 to 30 N, while the coefficient of friction is higher and the scratch resistance is very good with small non-essential cracks of the Ti-based coating. This difference in the scratch resistance is because of the better adhesion strength and coefficient of friction of the CrN layer than the TiN one. No delamination was observed in both scratch tracks, which implies the good adhesion to the substrates.

Table 2. *Comparison of the Scratch results*

Layer	**Coefficient of friction**	**Scratch resistance to progressive load**	**Adhesion**
TiCrAlN	0.167	Very good	yes
CrTiAlN	0.089	Excellent	yes

4. Conclusion

The investigated quaternary Ti- and Cr-based coatings consist of an adhesition, transition and main layers. The technological parameters during the main layer deposition were set the same for both coating structures.

The study of the mechanical properties of both structure types showed that the same deposition conditions affect the same coating hardness. However, the different composition of the adhesion and transition layers lead to different adhesion to the substrate.

Because of the better scratch properties of the Cr/CrN interlayers the Cr/CrN/CrTiAlN structure has lower friction coefficient of 0.089 and excellent scratch resistance to loads up to 30 N, which defines it as more suitable for industrial applications.

REFERENCES

1. Cakan, A., Ozkaner V. and Yildirim M. M. (2008). Quantifying Cutting and Wearing Behaviors of TiN- and CrN Coated AISI 1070 Steel. *Sensors*, volume(*8*), 6984-6998.
2. Chauhan, K. V. and Rawal, S. K. (2014). A review paper on tribological and mechanical properties of ternary nitride based coatings, *Procedia Technology*, volume (14), 430-437.
3. Chim Y.C., Ding X. Z., Zeng X. T. and Zhang S. (2009). Oxidation resistance of TiN, CrN, TiAlN and CrAlN coatings deposited by

lateral rotating cathode arc, *Thin Solid Films*, volume (517), 4845–4849.

4. Zhanga, G.A., Yana, P.X., Wangb P., Chenb, Y.M. and Zhang J.Y. (2007). The structure and tribological behaviors of CrN and Cr–Ti–N coatings. *Applied Surface Science*, volume (517), 7353–7359.
5. Lee, J.K., Oh, M.H. and Wee D.M. (2001). Long-term oxidation properties of Al–Ti–Cr two-phase alloys as coating materials for TiAl alloys. *Intermetallics*, volume (10), 347-352.
6. Bai L., Zhu X., Xiao J. and He J. (2007). Study on thermal stability of CrTiAlN coating for dry drilling. Surface & Coatings Technology, volume (201), 5257–5260.
7. Kabir, M.S., Munroe, P., Zhou, Z. and Xie Z.(2016), Structure and mechanical properties of graded Cr/CrN/CrTiN coatings synthesized by close field unbalanced magnetron sputtering, *Surface & Coatings Technology*, volume (309), 779-789.
8. Danek M., Fernandes F., Cavaleiro, A., Polcar T., (2017) Influence of Cr additions on the structure and oxidation resistance of multilayered TiAlCrN films, *Surface & Coatings Technology*, volume (313), 158-167.
9. Saleem H., (2014) Thermal stability of cubic and nanocrystalline arc evaporated TiCrAlN coatings, Master's Thesis, Department of Physics, Chemistry, and Biology, Linköpings universitet.
10. Wu W., (2010) Development and characterization of novel low-friction wear-resitant multilayer nanocomposite CrAlTiCN coatings. Ph.D. thesis, University of Birmingham, 2010.
11. Zhou Z., Tam P., Shum P., Li K., (2009) High temperature oxidation of CrTiAlN hard coatings prepared by unbalanced magnetron sputtering, *This Solid Films*, volume (517), 5243-5247.
12. Kim Y., Lee H., Kim S.and Han J., (2007) Microstructural and Mechanical Properties of CrTiAlN Nanocomposite Thin Films Synthesized by Closed Field Unbalanced Magnetron Sputtering, *Journal of the Korean Physical Society*, volume (51), 1183-1186.

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TOPOLOGICAL FEATURES OF PHOSPHATE TREATED SPECIMENS OF PRELIMINARY CERIUM OXIDE COATED AIRCRAFT ALLOY

STEPHAN KOZHUKHAROV, CHRISTIAN GIRGINOV

Abstract: *The highly doped constructive aluminum alloys are from crucial importance for the aircraft, automobile and marine transport. These alloys, however, are very susceptible to localized corrosion, due to occurrence of various intermetallic inclusions, which form galvanic elements with the basic Al matrix. That is the reason for the necessity for reliable corrosion protective systems development. In this sense, the present brief research represents the results of the finishing phosphate sealing of cerium oxide coated aircraft alloy.*

Key words: *aircraft alloy, anodizing, cerium oxide coating, phosphatation, SEM, EDX*

1. Introduction

Aluminum (Al) is a lightweight, relatively easily treatable metal that possesses an aptitude for passivation by formation of a natural oxide layer. Nevertheless, the pure Al is inapplicable in the industrial practice, since it does not present satisfying mechanical properties.

Recently, besides in the aircraft industry [1-3], the aluminum alloys have found continuously increasing applications for car body panels [4], and even in the modern shipbuilding [5, 6]. Besides, it is a common practice to apply multilayered coating systems for corrosion protection of metallic details, assemblies, and entire vehicle constrictions [7].

The remarkably heterogeneous chemical composition of these alloys causes galvanic coupling between the intermetallics and the basic Al-matrix, which gradually converts to localized corrosion phenomena, as is established by D. Balgude, A. Sabnis, [8].

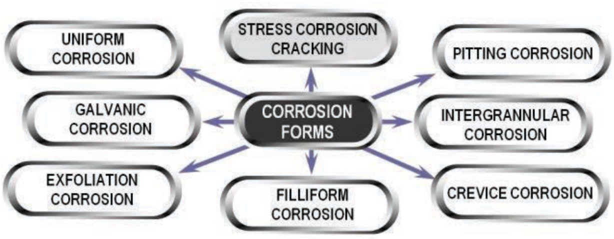

Fig. 1. *Schematic representation of (a) conventional chromate-based coating system, (b) newly developed sol–gel based films and (c) environmentally friendly chrome-free super primer technology [8]*

In addition, the nowadays environmental restrictions impose new challenges regarding the elaboration of environmentally benign efficient corrosion protective coatings **[9]**.

In this sense, the aim of the present research work is to determine the impact of the subsequent phosphating on cerium oxide coated anodized specimens of aircraft alloy.

2. Experimental

The experimental procedures were performed with nine square coupons with dimensions 30 x 30 mm (3 mm thick) A2024-T3 aircraft alloy. All samples underwent preliminary treatment for removal of the temporal corrosion protective films. It was performed by subsequent etching in 50 g dm^{-3} of NaOH solution at 60 °C and activation in diluted with water 1:1 v/v HNO_3 at room temperature. Both operations were done for 2 minutes each. The specimens were then cleaned with tap and distilled water after each treatment. The anodizing was performed in galvanostatic regime at 15mA cm^{-2} for 1 hour with intensive stirring in 15% H_2SO_4. The already anodized samples were subsequently dip coated in 150 ml of mixed cerium ions containing solution.

Following the main objective of the present research, the already anodized and coated samples were divided in two groups: (i) reference samples, without additional treatments and (ii) additionally phosphated samples;

The further phosphatation procedures were carried out as follows: immersion in 0.3 mol dm^{-3} $(NH_4)H_2PO_4$ for 12 minutes at 60 °C.

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In order to perform systematical investigations, all specimens were submitted to methodical research activities, which were divided into two groups:

Structural and topographical observations, including Scanning Electron Microscopy (SEM),

Compositional analysis, by Energy Dispersion X-ray (EDX) spectroscopy.

The investigations were performed by *TESCAN, SEM/FIB LYRA I XMU* working at 30 kV. The SEM observations were combined by elemental analysis, with energy dispersion spectroscopy (EDX), using Energy Dispersion Spectrometer Quantax 200 (*BRUEKER*).

3. Results and discussion

The low resolution SEM images in **Fig. 2** show comparable film surfaces, revealing lack of distinguishable impact of the subsequent phosphatation and thermal finishing on the film morphology.

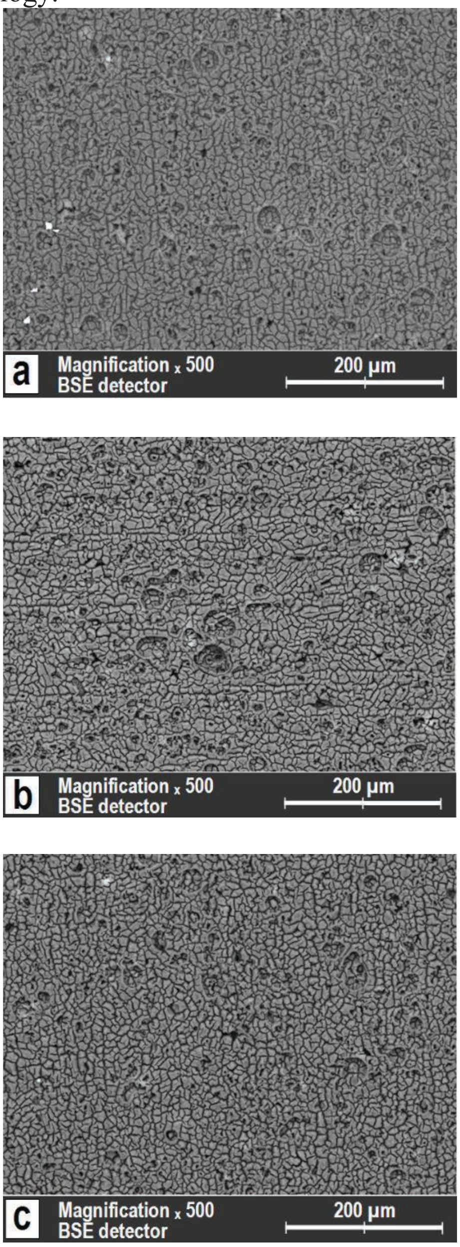
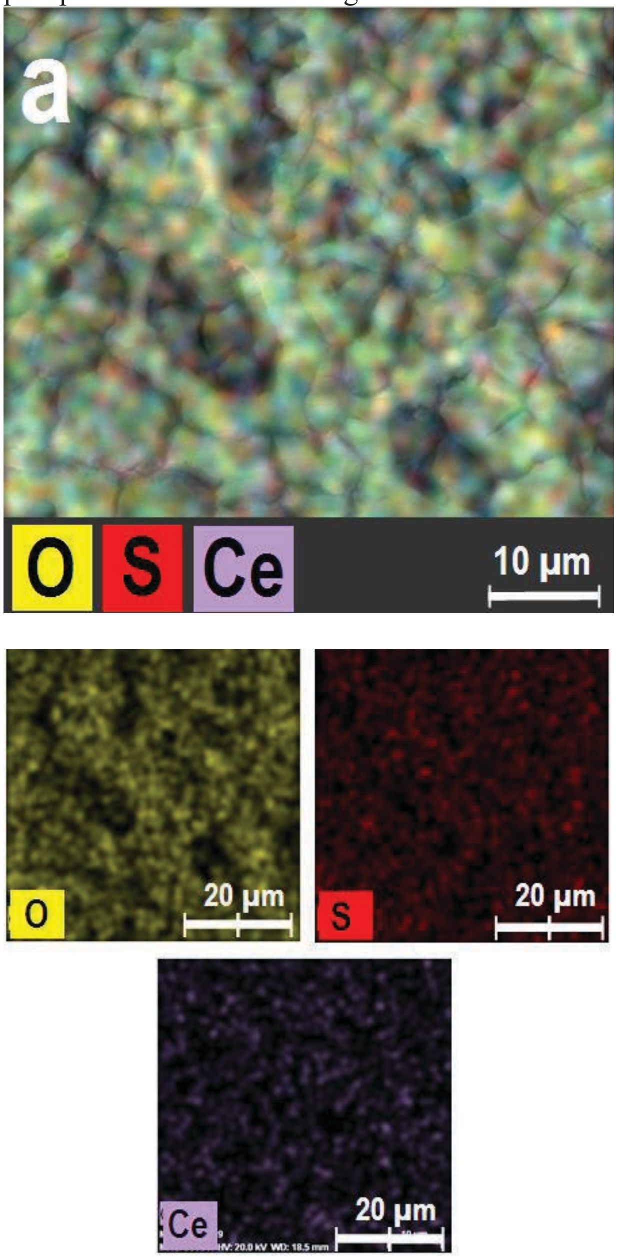


Fig. 2. *Low resolution topographical SEM images of the investigated samples (a) reference CeCC coating; (b) phosphated CeCC coating; (c) CeCC coating after phoisphatation and subsequent thermal treatment*

The films reveal identical morphology, being strongly cracked possessing a multitude of concavities. Nevertheless, the films maintain excellent coverage and uniformity. The film uniformity was confirmed by the element distribution, established by the EDX map analysis, shown in Fig. 3. The main film elements selected for observation were: oxygen from the anodization process, cerium from the subsequent cerating and phosphorus from the finishing treatments.



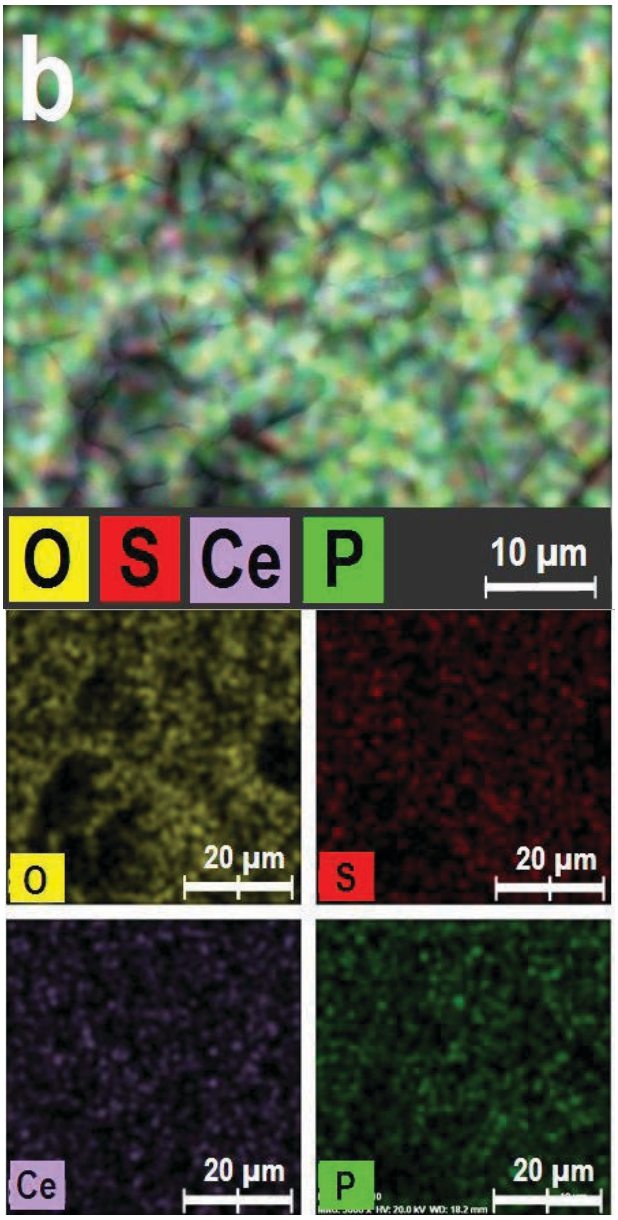


Fig. 3. *EDX map analyses of the element distribution of the investigated samples (a) reference CeCC coating and (b) phosphated CeCC coating*

4. Conclusions

The proposed approach in the present brief research of subsequent combination of anodizing, cerium oxide coating and finishing phosphating enables formation of uniform coating primers with remarkable coverage and equal coating ingredient's distribution of:

- Oxygen from the anodizing procedure
- Cerium from the subsequent cerium oxide coating
- Phosphorous from the finishing coating sealing

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LITERATURE

1. Wildey, J. F., Aging Aircraft, Materials Performance, 1990, 29, 80–85
2. Komorowski, J. P., et al., Quantification of Corrosion in Aircraft Structures with Double Pass Retroreflection, Canadian Aeronautics and Space Journal, 1996, 42, 76–82
3. Starke E. A., Jr., and J. T. Staley, Application of Modern Aluminum Alloys to Aircraft, Prog. Aerospace Sci., 1996, 32, 131-172
4. Davies G., Materials for Automobile Bodies, Linacre House, ed. (2003), ISBN 0 7506 5692 1, pp. 146 – 156.
5. Eyres D., "Ship construction", 6th ed. 2007, Linacre House, p. 50–52, ISBN 10:0- 75-068070-913.
6. "Aluminium in shipbuilding", access via: http://www.aluminiumleader.com/en/around/transport/ship 7.
7. G. Tsaneva, V. Kozhukharov, S. Kozhukharov, M. Ivanova, J. Gerwann, M. Schem, T. Schmidt, Functional nanocomposite coatings for corrosion protection of aluminum alloy and steel, J. Univ. Chem. Technol. Met. 43–42 (2008) 231–238.
8. D. Balgude, A. Sabnis, *Sol–gel derived hybrid coatings as an environment friendly surface treatment for corrosion protection of metals and their alloys*, J. Sol-Gel Sci. Technol. DOI 10.1007/s10971-012-2838-z
9. Kozhukharov, S. V. (2016) Deposition of Environmentally Compliant Cerium-Containing Coatings and Primers on Copper-Containing Aluminium Aircraft Alloys, PUBLISHED IN: Biobased and Environmental Benign Coatings (eds A. Tiwari, A. Galanis and M. D. Soucek), John Wiley & Sons, Inc., Hoboken, NJ, USA. doi: 10.1002/9781119185055.ch2

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SENSORS MASS INFLUENCE ON THE NATURAL FREQUENCY OF A CANTILEVER BEAM

SVETLIN STOYANOV

Abstract: *The influence of relation between the sensor mass and the beam mass to the natural frequencies of a cantilever beam is investigated theoretically. This influence is not simple, because it depends from the mode number, and a three dimensional plot is used to present the results.*

Key words: *natural frequency, cantilever beam, modal analysis, Fourier transform, Matlab.*

1. Introduction

Over recent decades, modal analysis has been widely used in aerospace, mechanical and civil engineering. One of its advanced applications is for damage detection in beams [1].

The **experimental modal analysis** makes use of input (excitation) and output (response) measurements to estimate modal parameters: natural frequencies, mode shapes, and damping ratios [2]. Usually, the input is applied through an impulse hammer.

The **operational modal analysis** carries out in operational environment. In this case, structures are exited naturally due to external dynamic forces or displacements. Therefore, the information about these input excitations is absent or incomplete [2, 3, 4].

The **theoretical modal analysis** tries to predict the values of the modal parameters by solving the eigenvalue problem of structures [3].

In [5], theoretical and experimental modal analysis of a cantilever beam is conducted and the results are compared. It is raised the problem about the influence of sensor mass on the beam natural frequencies. This justifies **the aim of this work** – to investigate theoretically the influence of relation between the sensor mass and the beam mass to the natural frequencies of a cantilever beam.

2. Theoretically obtaining of the natural frequencies

The frequency equation of a cantilever beam without a lumped mass added (i.e. without sensor mass accounting) is [6]

$$\cos(kL)\cosh(kL)+1=0, \qquad (1)$$

where L is the beam length. The values of k for which this equation is satisfied are his characteristic numbers. Each of the characteristic numbers corresponds to one natural frequency ω:

$$\omega_n=(kL)^2\sqrt{\frac{EI}{mL^4}}, \qquad (2)$$

where m is the mass of the one meter of the beam.

The acceleration sensor acts as lumped mass in the end of the cantilever beam. As a result of this, the cantilever beam is loaded with a constant force – the gravitational force of the sensor. Therefore, the differential equation of the forced vibration of the beam is used for the frequency equation derivation. The frequency of the distortion force is set to be zero and the frequency equation becomes [7, 5]:

$$\begin{vmatrix} A(kL)+kL\dfrac{m_1}{mL}(kL) & B(kL) \\ D(kL)+kL\dfrac{m_1}{mL}C(kL) & A(kL) \end{vmatrix}=0, \qquad (3)$$

where:

$$A(kL)=\frac{1}{2}(\cosh(kL)+\cos(kL)), \qquad (4)$$

$$B(kL)=\frac{1}{2}(\sinh(kL)+\sin(kL)), \qquad (5)$$

$$C(kL)=\frac{1}{2}(\cosh(kL)-\cos(kL)), \qquad (6)$$

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$$D(kL)=\frac{1}{2}(\sinh(kL)-\sin(kL)) \qquad (7)$$

are the Krilov's functions and m_1 is the mass of the sensor.

3. Experimental evidence of sensor mass influence

In [5], an experimental setup is created (fig. 1) and the acceleration of the free vibration of the end point of a cantilever beam is measured as a function of the time (fig. 2). From this time signal, the spectrograms are calculated using Fourier transform (fig. 3).

Fig. 1. *A photography of the experimental setup*

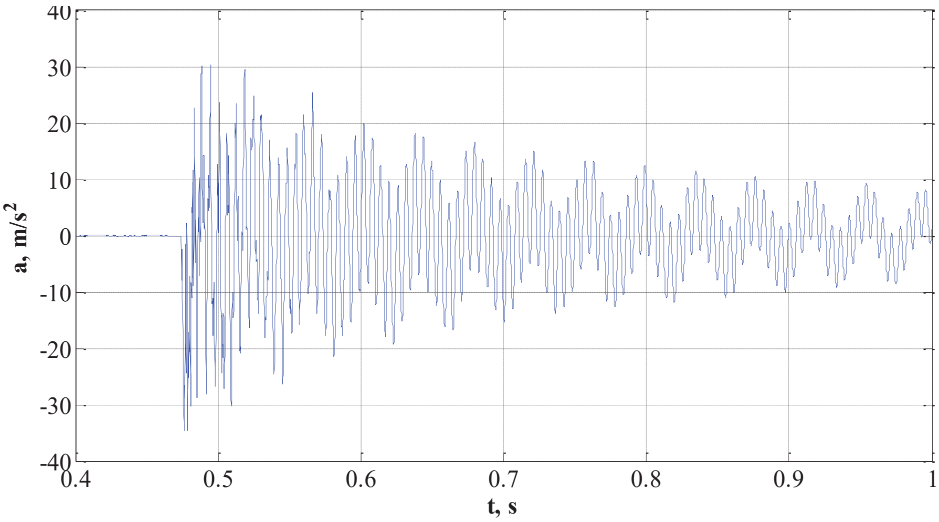

Fig. 2. *Time-diagram of the experimentally obtained acceleration of the end point of the beam*

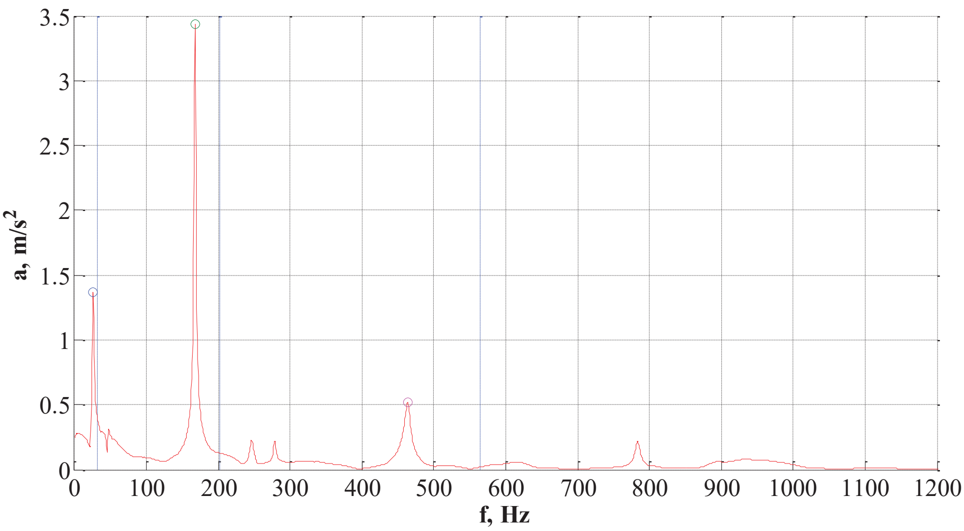

Fig. 3. *The experimentally obtained acceleration (red line) and the theoretically predicted natural frequencies without sensor mass accounting (blue marker lines)*

The peak points of the red line on Fig. 3 indicate the frequencies f_{exp} of the harmonics contained in the measured acceleration. These frequencies are shown in the first row of Table 1. The blue straight lines marks frequencies f_t, this is theoretically calculated without sensor mass accounting, according to Eq. 1 and Eq. 2. These frequencies are shown in the second row of Table 1. The third table row presents the relative difference.

Similarly, Fig. 4 and Table 2 show the corresponding frequencies for the case with sensor mass accounting, according to Eq. 3. One can observe significant better results in this case. This justifies the need for a detailed investigation.

***Table 1.** Numerical comparison of the case without sensor mass accounting*

f_{exp}, Hz	26.25	167.85	463.26
f_t	32.173	201.85	564.562
$(f_{exp}-f_t)/f_{exp}$, %	-22.6	-20.1	-21.9

***Table 2.** Numerical comparison of the case with sensor mass accounting*

F_{exp}, Hz	26.25	167.85	463.26
f_t	27.55	178.64	510.89
$(f_{exp}-f_t)/f_{exp}$, %	-5.0	-6.4	-10.3

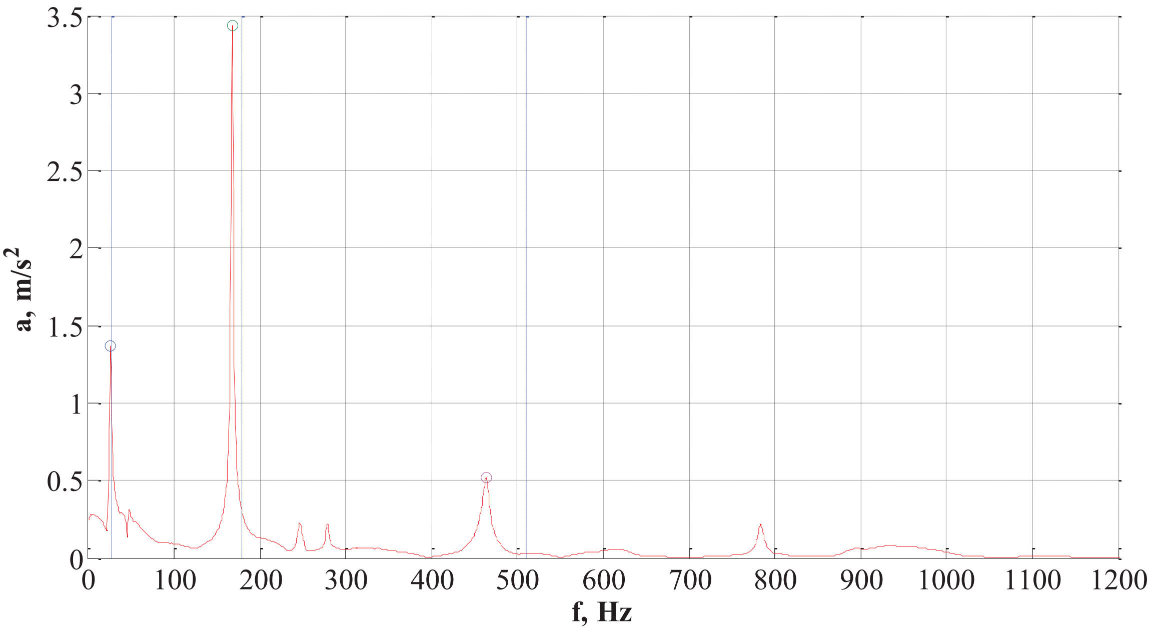

***Fig. 4.** The experimentally obtained acceleration (red line) and the theoretically predicted natural frequencies with sensor mass accounting (blue marker lines)*

4. An investigation of sensor mass influence

To evaluate the influence of sensor mass on natural frequencies, two quantities are defined as follows:

- mass relation factor

$$\delta = \frac{m_1}{m} \tag{8}$$

- frequency relation factor

$$\lambda = \frac{f_1}{f} \tag{9}$$

where f_1 is the natural frequency for the case of sensor mass accounting (according to Eq. 3) and f is the natural frequency for the case without sensor mass accounting (according to Eq. 1 and Eq. 2)

Fig. 5 presents the influence of the mass relation factor to the frequency relation factor for the first three natural frequencies. As can be seen from this figure, the influence is the greatest for the first mode (red line). For the second mode and for the third mode, when the mass relation factor is greater than about one, the relation is close to a straight line, i.e. the change of the frequency relation factor can be neglected.

Fig. 6 presents the influence of the mode shape number to the frequency relation factor for six values of the mass relation factor. One can observe that the influence grows with sensor mass increasing.

The relations from Fig. 5 and Fig. 6 are combined together in a three dimensional plot – Fig. 7.

5. Conclusion

An experimental evidence of significant sensor mass influence on the cantilever beam natural frequencies is presented. This justifies the necessary to investigate theoretically this influence. The investigation is done through the frequency equation describing the eigenvalue problem.

The frequency equation and the equation of the forced vibrations of the beam are solved numerically by the help of the software system Matlab. The results obtained are presented and discussed. The influence of the sensor mass is not simple, because it depends from the mode number, and a three dimensional plot is used to present the results. It was found that the influence is the greatest for the first mode. Furthermore, it is of interest to obtain theoretically and experimentally the natural frequencies of a truss structure.

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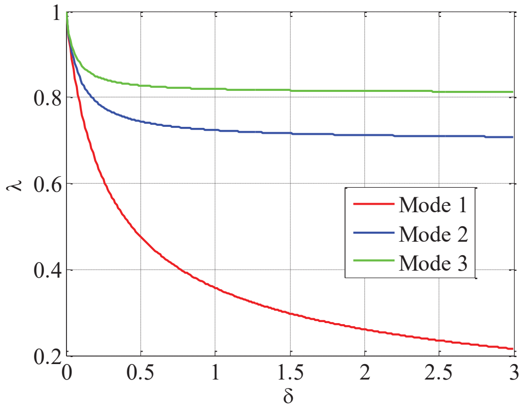

Fig. 5. *Dependences of the frequency relation factor on the mass relation factor*

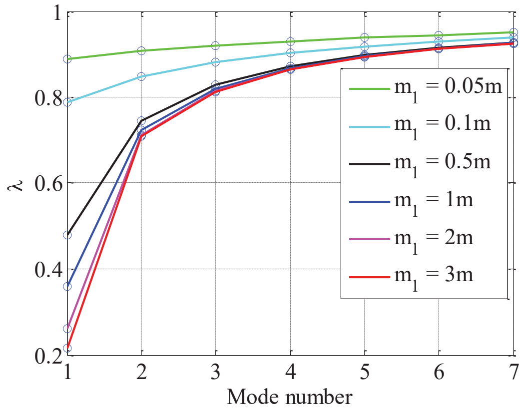

Fig. 6. *Dependences of the frequency relation factor on the mode number*

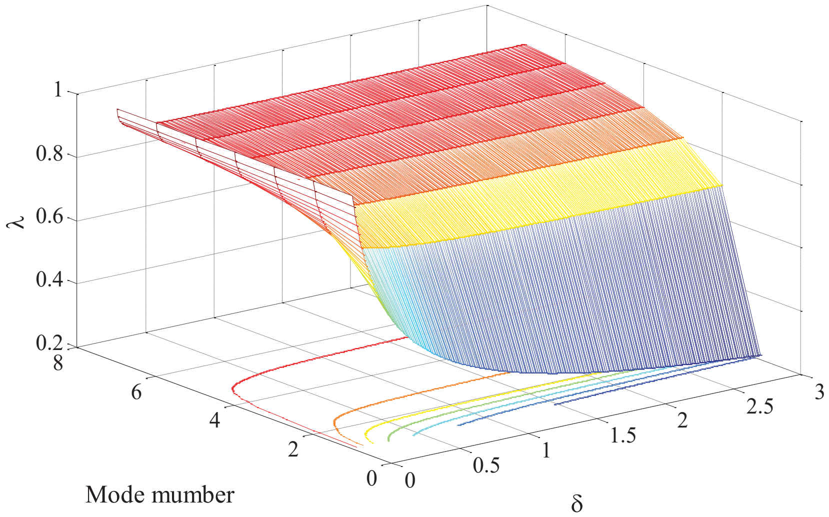

Fig. 7. *Three dimensional representation of the frequency relation factor dependence*

REFERENCES

1. Yang Z., Radzienski M. and Kudela P., Ostachowicz. (2017) 'Fourier spectral-based modal curvature analysis and its application to damage detection', *Mechanical Systems and Signal Processing*, vol. 84, pp. 763-781.
2. De Vivo A., Brutti C. and Leofanti J.L. (2013) 'Modal shape identification of large structure exposed to wind excitation by operational modal analysis technique', *Mechanical Systems and Signal Processing*, vol. 39, pp. 195–206.
3. Aenlle M.L. and Brincker R. (2013) 'Modal scaling in operational modal analysis using a finite element model', *International Journal of Mechanical Sciences*, v76, pp. 86-101.
4. Dziedziech K., Staszewski W.J. and Uhl T. (2015) 'Wavelet-based modal analysis for time-variant systems', *Mechanical Systems and Signal Processing*, vol. 50-51, pp. 323–337.
5. Stoyanov, S. (2016) 'Experimental setup for the determination of the natural frequencies of a cantilever beam', *Scientific proceedings of University of Ruse*, Ruse, ISSN 1311-3321. (In Bulgarian. In press.)
6. Zannon M. (2014) 'Free Vibration of Thin Film Cantilever Beam', *International Journal of Engineering and Technical Research (IJETR)*, vol. 2, pp. 304-314.
7. Repetto S. E., Roatta A. and Welti R.J. (2012) 'Forced vibrations of a cantilever beam', *European Journal of Physics,* vol. 33, pp. 1187-1195.

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THE APPLICATION OF THE MODAL ANALYSIS IN DETERMINING THE DYNAMIC MODULE OF ELASTICITY OF POLYMER-CONCRETE COMPOSITES

ILIA POPOV, SABI SABEV

***Abstract**: This article presents the quantitative values of the dynamic modulus of elasticity (Young's modulus) of gamma polymer-concrete composites. Experimental studies are based on the experimental modal analysis method. Using the similarity and comparison methods, the results of the experimental determination of the dynamic modulus of elasticity of samples of gray cast iron GF20 and C45 steel with the same dimensions as PC samples are presented.*

***Keywords**: Polymer-concrete Composites, Dynamic Modulus of Linear Deformations, Experimental Modal Analysis.*

1. Introduction

Knowing the material constants of structural engineering materials is a must when defining the strength deformation behaviour of the parts and structures produced by these materials.

In this aspect, the study and the determination of the quantitative values of the elastic characteristics (such as the modulus of the linear deformations E, the modulus of the angular deformations G, and the Poisson μ coefficient, which are in simple algebraic relations) of the gamma polymer-concrete composites is an up-to-date engineering task. These features, as well as the density of the material, are input data for any software product for static or dynamic engineering analysis (CAD, CAM CAE), which greatly assists in designing and enables reliable results to be obtained quickly.

The application of the polymer-concrete (PC) composites as an alternative non-metallic structural material for the production of bodies and body parts (B and BP) of the support system of the production equipment is an innovation activity which creates prerequisites for improving the technical and operational qualities of the manufactured machines such as:

- ✓ static stability;
- ✓ dynamic sustainability;
- ✓ thermal behaviour.

The article has an experimental-research character and its main objective is: Quantification of the dynamic elastic modulus E_d of gamma PC composites, created and realized in the testing and research laboratory of Metal cutting-machines at TU-Sofia, branch Plovdiv.

2. Theoretical prerequisites

Theoretically, natural beam frequencies with a rectangular cross section are determined by the dependence [2]:

$$\omega = \beta_n{}^2 \sqrt{\frac{E_d I}{\rho A}} = (\beta_n l)^2 \sqrt{\frac{E_d I}{\rho A l^4}} \qquad (1)$$

From equation (1) E_d is expressed and the following is obtained:

$$E_d = \frac{\omega^2 \rho\, b\, h\, l^4}{(\beta_n l)^4 I} \qquad (2)$$

Where

ω - is the frequency of vibration
b - beam thickness
h - height of the material
ρ - density of the material
n - density of the material
I - beam moment of inertia around y
$(\beta_n l)$ - depends on the boundary conditions of the beam.

$$(\beta_1 l = 4.730;\ \beta_2 l = 7.853;\ \beta_3 l = 10.996)$$

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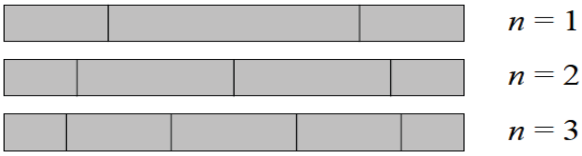

Fig. 1.1. *Forms for bending a rectangular beam with designated detail lines*

3. Methodology of the experiment

By impulse (shock) excitation of the system with a subsequent analysis of free damping oscillations. The impulse method is realized with an unattached exciter - an impact (power) hammer. Thus, the generated energy is distributed over a wide frequency spectrum and excites all the mods in the considered frequency range of the sample [4,5].

For the quantification of the dynamic elastic modulus, the following experimental approach was used: - A test piece of dimensions 30x30x350 of PC is suspended freely in strings, fig.1.2. At one end of the beam the impulse dynamic effect is applied and at the opposite side at the other end the repercussion is measured by the microphone.

The method is easy to implement, and only requires some basic components: a computer with a suitable sound card and a microphone.

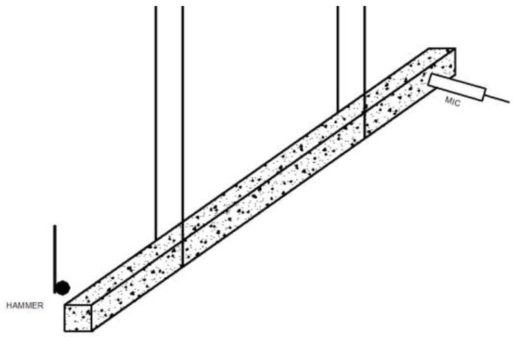

Fig. 1.2. *Transverse vibration study*

The assembly of measuring equipment includes:

- ✓ Microphone of the company "Audio Technica" - AT2031;
- ✓ Sound card M-Audio Audiophile 192
- ✓ Specialized software "Spectra PLUS".

Experimental results for the dynamic modulus of linear deformations E_d of PC samples are obtained by pulse excitation, Fig. 1.2 and processed with the specialized software "Spectra PLUS".

SpectraPLUS is a powerful 2-channel spectral analyser. Software interfaces provide real-time spectral analysis. Spectrum analyser is a tool used to convert a time domain signal (amplitude-time) into a frequency domain (amplitude-frequency). The Audio Spectrum Analyser, by definition, is limited in signal bandwidth processing. The limit of the analysed frequency is determined by the capabilities of the sound card used.

The software uses Fast Fourier Transform (FFT), which converts the signal from the time domain into the frequency domain.

Fig.1.3. *Test bench*

Table 1 *Experimental results*

Sample	f [Hz]	r [m^3]	ω[rad]	E_d [Pa]
1	953	2381	5985	3,61E+10
	2537,5		15936	3,37E+10
	4751		29836	3,07E+10
2	866	2339	5438	2,93E+10
	2311		14513	2,74E+10
	4294		26966	2,46E+10
3	977	2365	6136	3,77E+10
	2576		16177	3,44E+10
	4817		30251	3,13E+10
4	899	2355	5646	3,17E+10
	2385		14978	2,94E+10
	4456		27984	2,67E+10
5	815,6	2268	5122	2,52E+10
	2165		13596	2,33E+10
	4044		25396	2,12E+10
6	761,7	2181	4783	2,11E+10
	2027		12730	1,97E+10
	3792		23814	1,79E+10
7	767	2258	4817	2,22E+10
	2129		13370	2,25E+10
	3398		21339	1,49E+10
8	799	2216	5018	2,36E+10
	2137		13420	2,22E+10
	3958		24856	1,98E+10
9	839	2300	5269	2,70E+10
	2184		13716	2,41E+10
	4090		25685	2,20E+10
10	864	2348	5426	2,92E+10
	2319		14563	2,77E+10
	4344		27280	2,53E+10
11	815	2252	5118	2,49E+10
	2184		13716	2,36E+10
	4068		25547	2,13E+10
12	785	2280	4930	2,34E+10
	2114		13276	2,24E+10
	3980		24994	2,06E+10
13	858	2342	5388	2,88E+10
	2281		14325	2,67E+10
	4250		26690	2,42E+10
14	939	2387	5897	3,51E+10
	2504		15725	3,29E+10
	4688		29441	3,00E+10
15	788	2245	4949	2,33E+10
	2105		13219	2,18E+10
	3937		24724	1,99E+10
FG20	1001	7203	6286	1,20E+11
	2643		16598	1,10E+11
	4891		30715	9,84E+10
C 45	1262	7803	7925	2,07E+11
	3342		20988	1,91E+11
	6225		39093	1,73E+11

4. Experimental results

The obtained experimental results for the dynamic modules of the linear deformations E_d of the PC composites are presented in Table 1. In Figure 1.4 these are represented graphically.

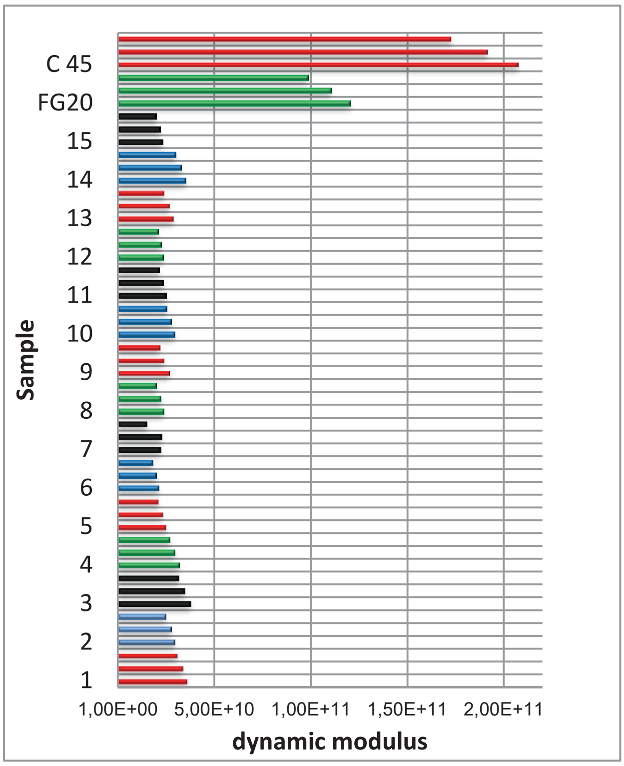

Fig.1.4.. *Experimental results for E_d*

We obtain the values, in which we are interested, of the sampling frequencies of the experimental PC composites from the auto-spectral characterization, fig.1.5 and 1.6.

Fig.1.5. *Autospectrum of sample 1*

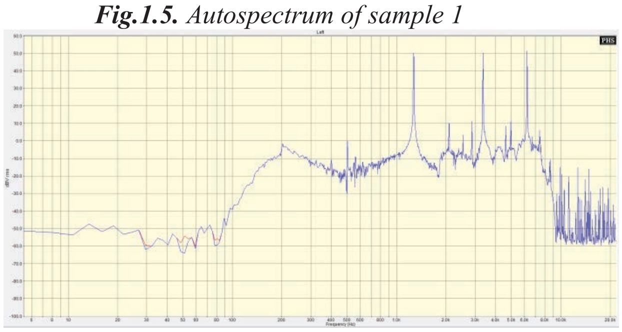

Fig.1.6. *Autospectrum of sample* C45

The theoretical verification of the first three forms (own frequencies) of the lateral oscillations of the 15 composites was performed using the dynamic simulation analysis module of SolidWorks 2014, fig.1.7. The results are shown in Table 2.

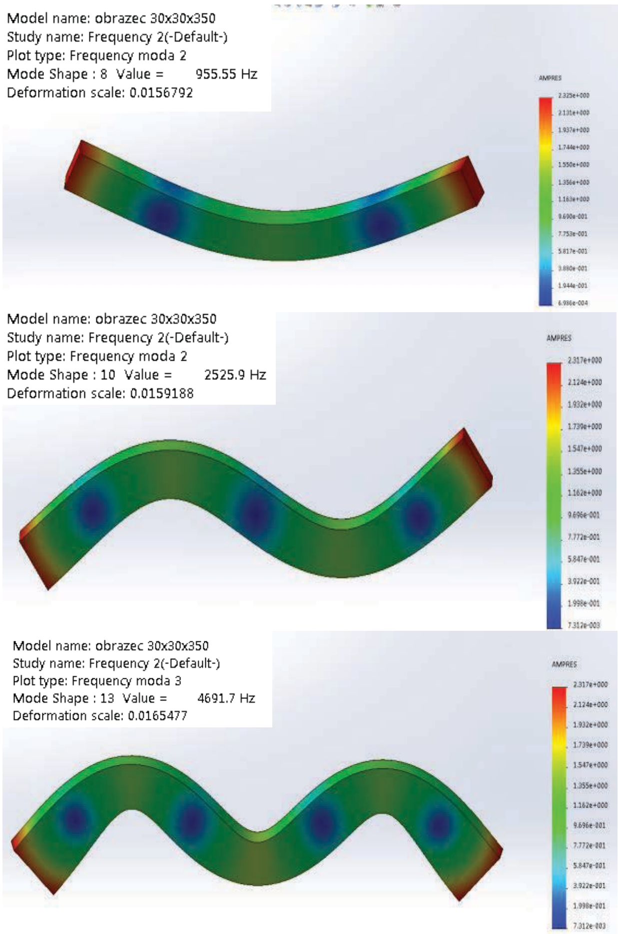

***Fig. 1.7** Graphics of the first three own forms of vibration for the transverse vibrations of sample 1.*

Table 2 *Modal frequencies*

Sample number	Measured values			Simulated values			Ratio to Percentage		
	f_{f1} [Hz]	f_{f2} [Hz]	f_{f3} [Hz]	f_{S1} [Hz]	f_{S2} [Hz]	f_{S3} [Hz]	f_{f1}/f_{S1} [%]	f_{f2}/f_{S2} [%]	f_{f3}/f_{S3} [%]
1	953	2538	4751	956	2526	4692	100%	100%	101%
2	977	2311	4294	868	2296	4268	113%	101%	101%
3	899	2576	4817	980	2591	4814	92%	99%	100%
4	870	2385	4456	900	2381	4428	97%	100%	101%
5	816	2165	4044	819	2166	4030	100%	100%	100%
6	762	2027	3792	764	2023	3766	100%	100%	101%
7	797	2129	3398	770	2039	3795	104%	104%	90%
8	799	2137	3958	801	2122	3946	100%	101%	100%
9	839	2184	4090	842	2227	4144	100%	98%	99%
10	864	2319	4344	866	2292	4265	100%	101%	102%
11	815	2184	4068	816	2159	4013	100%	101%	101%
12	785	2114	3980	786	2080	3869	100%	102%	103%
13	858	2281	4250	859	2275	4232	100%	100%	100%
14	939	2504	4688	938	2478	4600	100%	101%	102%
15	788	2105	3937	786	2081	3871	100%	101%	102%
FG20	1001	2643	4891	998	2636	4889	100%	100%	100%

5. Conclusion

The results of this work are limited to:

- Quantitative values for the dynamic elastic modulus of 15 different PC composites were obtained experimentally.
- By increasing the sequence of the sample's own resonance frequency, the module decreases.
- The method of experimental modal analysis is used with priority in the quantitative determination of the dynamic modulus of elasticity of the range of PC composites.
- The dynamic elasticity modulus of PC composites is determined on the basis of the dynamic response (response) of the free damping oscillations of the impulse excited dynamic system of the experimental samples.
- Opportunity to obtain reliable and realistic information about simulation shapes and own oscillation frequencies of each PC composites through SolidWork Simulation Module has been demonstrated.
- By a comparative analysis of the conducted tests and the results obtained for the elastic characteristics of the samples of gray cast iron BS20, the steel C45 and the PC composites it was found that the modulus of linear deformations is one level lower.

REFERENCES

1. S. Timoshenko, D. H. Young, and W. Weaver, Jr., Vibration Problems in Engineering (4th ed.), Wiley, New York, 1974.
2. Singiresu S. Rao, Mechanical Vibrations 5th Edition, University of Miam, 2011.
3. L. Klein, Transverse vibrations of non-uniform beams, Journal of Sound and Vibration,Vol. 37, 1974.
4. Ulbrich H. Vibration, Control of Nonlinear Mechanism and Structure. Technical University, Munich, 2005.
5. Попов Ил., „Изследване и оптимизиране на полимербетонни състави по отношение на демпферните им характеристики”, Докторска дисертация, (2013).

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ЧИСЛЕНО МОДЕЛИРАНЕ И ПАРАМЕТРИЧЕН АНАЛИЗ НА КАЛИБРОВЪЧНА ДВУСЛОЙНА РОЛКА

ИВО ДРАГАНОВ, ЮЛИЯН АНГЕЛОВ

Резюме: *Създаден е крайноелементен модел на калибровъчна двуслойна ролка от стенд за проверка на ходовата и свързаните с нея системи на автомобил. Чрез решаване на контактна задача е определено изменението на периферната повърхнина на ролката в зоната на контакта с автомобилната гума, като е отчетено нелинейното поведение на покриващия слой от ебонит. Извършен е параметричен анализ за влиянието на дебелините на ебонитовия и стоманения слой.*

Ключови думи: *калибровъчна двуслойна ролка, метод на крайните елементи*

NUMERICAL MODELING AND PARAMETRICAL ABALYSIS OF CALIBRATED DOUBLE LAYERED ROLL

IVO DRAGANOV, YULIAN ANGELOV

Abstract: *Finite element model of calibrated double layered roll for testing of automobile's transmission is created. The change of roll's external diameter in the tire's area is calculating using contact algorithm. The nonlinear behavior of covering ebonite layer is assumed. The parametrical analysis for influence of ebonite's and steel's thickness is made.*

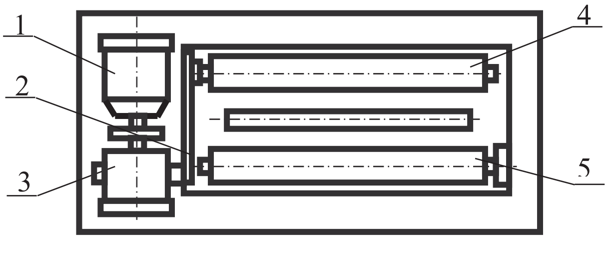
Key words: *calibrated double layered roll, finite element analysis*

1. Основни положения

Калибровъчните ролки намират редица приложения, като обект на изследване в настоящата работа е такава, използвана в стендове за изпитване на спирачна ефективност на автомобили [1], за проверка на таксиметрови апарати [2] и за други устройства, за които е необходимо да се отчитат оборотите на колелата на автомобила. Компановъчна схема на подобен стенд е дадена на Фиг. 1 [3], [4].

Двуслойните ролки се състоят от стоманена основа, даваща нужната коравина на конструкцията и вулканизиран ебонитов слой, чиято функция е да се намали преплъзването, между ролката и гумата на автомобила.

Калибровъчните ролки влизат в устройството на различните по вид стендове, като изчислителната им схема е греда на две упори с приложена сила в средата [4]. За да се отчете по-прецизно влиянието на геометрията и материалните характеристики на ебонитовия слой, върху напреженията и деформациите, е целесъобразно да се използва методът на крайните елементи (МКЕ) [5].



Фиг. 1. *Местоположение на ролката в стенд за проверка на таксиметрови апарати (1 – електродвигател; 2 – верижна предавка; 3 – редуктор; 4 – задвижваща ролка; 5 – калибрираща ролка)*

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Ебонитовият слой, с който е покрита стоманената основа, има нелинейни материални характеристики, описани от Давие [6].

Деформациите на покритието са най-големи в зоната на контакт между колелото на автомобила и ролката, което налага решаването на контактна задача [7].

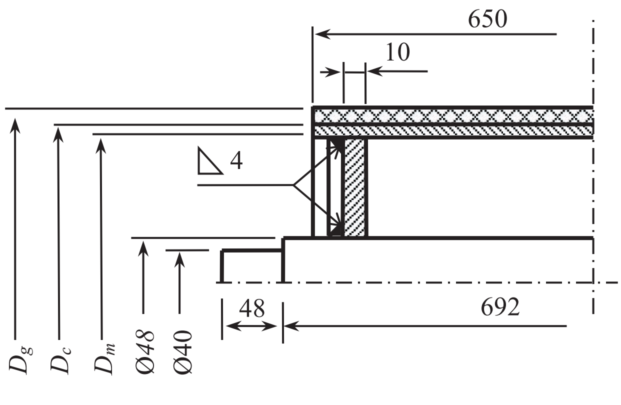
2. Крайноелементен модел на калибровъчната ролка

За изследване на напрегнатото и деформирано състояние на ролката е използвана програмна система Абакус (ABAQUS) [8].

2.1. Геометричен модел

Необходимостта от решаване на контактна задача налага построяването на геометричен модел на ролката и на част от гумата на автомобила.

Поради наличието на симетрия в надлъжно и напречно направление е разгледана една четвърт от ролката – Фиг. 2. Построяването на геометричния модел е извършено в средата на програмна система Абакус. Външният диаметър на ролката, диаметърът между ебонитовия и стоманения слой и вътрешният диаметър на стоманения слой приемат стойности, които могат да се видят на Фиг. 6. Останалите размери са избрани съобразно компановъчната схема и някои други съображения [10], [11], [12].



Фиг. 2. *Геометрия на ролката (D_g – външен диаметър на ролката, D_c – диаметър между ебонита и стоманата, D_m – вътрешен диаметър на ролката)*

Тъй като оебктът на изследване е ролката, геометричният модел на гумата е построен силно идеализирано, с цел да се минимизира изчилсителният обем на задачата. По съществените допускания са следните: прието е, че контактната повърхнина на гумата с ролката е равнина, не се отчитани наичието на грайфери по гумата, дебелината на гумата е значително по-голяма от съществуващите в практиката еднокамерни гуми. Прието е, че съществено влияние върху резултатите ще окаже ширината на гумата, като е прието тя да е 155 mm, с радиус на закръгление 20 mm. Поради симетрията се разглежда една четвърт от гумата.

2.2. Материални характеристики

Материалът, от който се изработват заварените детайли на ролката, е стомана S235 с якост σ_B = 360 MPa [9].

Прието е, че стоманената част на ролката и автомобилната гума ще действат само в границата на еластичност и връзката между напреженията и деформациите ще е линейна. В таблица 1 са дадени използваните материални характеристики.

Таблица 1. *Линейни материални характеристики*

Материал	Модул на Юнг, GPa	Коефициент на Поасон, [-]
Стомана	200	0,27
Гума	0,01	0,45

Ебонитът представлява материал с нелинейна връзка между напрежения и деформации и тъй като се очаква деформациите в него да окажат най-съществено влияние върху изследваните параметри, за него се решава физически нелинейна задача с материални характеристики дадени в таблица 2. Прието е, че коефициентът му на Поасон е 0,39.

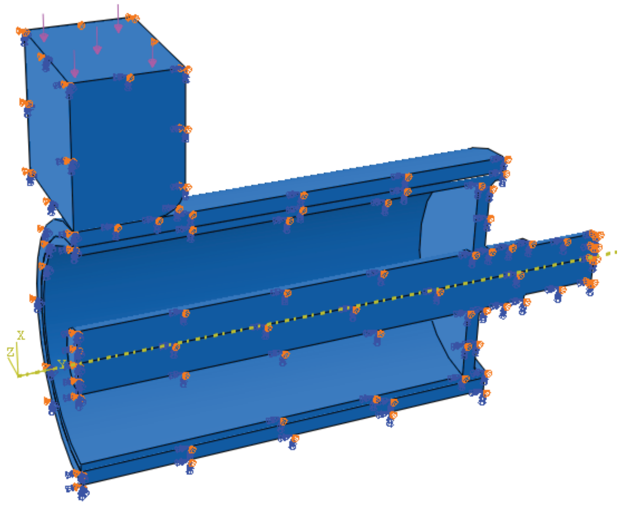
Таблица 2. *Материална нелинейност на ебонит*

Точка	Напрежение, MPa	Деформация, [-]
1	3	0
2	4	0,33
3	10	5

2.3. Гранични условия

Ролката е закрепена като са ограничени всички степени на свобода по челото на шийката на вала и са зададени равнините на симетрия – Фиг. 3. Гумата е закрепена като са ограничени степените на свобода в равнините на симетрия и степените на свобода в нормално напрвление за външната равнина на гумата.

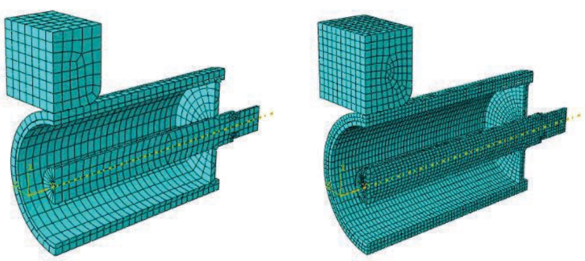
В гумата е зададен разпределен товар в напречно направление с интензитет 0,3871 MPa, еквивалентен на приетата съсредоточена сила с големина 3000 N – Фиг. 3, определена от максималната товароносимост на стенда.



Фиг. 3. *Гранични условия*

2.4. Дискретизация

Дискретизацията на ролката и гумата е извършена с хексаедърни крайни елементи с един междинен възел (C3D20R) – Фиг. 4 [8]. Направена е проверка за сходимостта на решенията като са сравнени резултатите за изменението на външния диаметър на ролката при две гъстоти на мрежата – 13996 и 83596 възела. Разликата в резултатите е под 2%.



Фиг. 4. *Дискретизация с 13996 (в ляво) и 83586 възела (в дясно)*

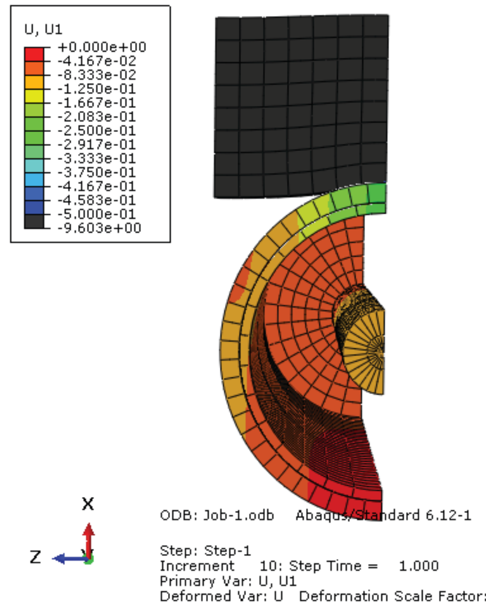
2.5. Контакт

Деформираното състояние на ролката е определено чрез решаване на контактна задача за взаимодействието между калибровъчната ролка и автомобилната гума, без да се отчита триенето.

За по-добра работа на изчислителния алгоритъм, е избрано гумата да се дискретизира с елементи по-големи, от тези на ролката [8].

2.6. Резултати

Отчетено е преместването в радиално направление на външните контури на средното и на още 6 сечения, отместени в осово направление през 10 mm - Фиг. 5.



Фиг. 5. *Премествания в радиално направление*

На база получените стойности за преместването е определен периметъра на контура - *P'*, за деформирантата ролка, по формулата:

$$P' = \sum_{i=1}^{n} u_{ri} \pi / n \,, \tag{1}$$

където u_r е преместването в радиално направление, а n е броя на точките в окръжно направление, за които е определено преместването.

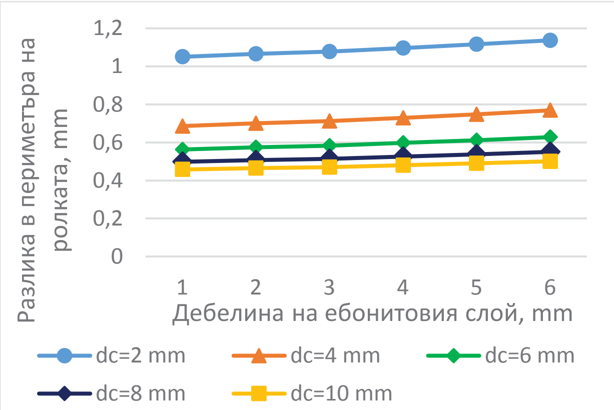
В таблица 3 са дадени измененията за отделните сечения при D_c = 171 mm и D_m = 159 mm, определени като разлика между началния периметър, който е P = 600,04 mm и периметъра на деформиранта ролка.

Таблица 3. *Промени на диаметрите на ролката при Dc = 171 mm и Dm = 159 mm*

Сечение	Средно	Отместено на 10 mm	Отместено на 30 mm	Отместено на 60 mm
Периметър (D_g), mm	599,46	599,46	599,46	599,47
Изменение, mm	0,58	0,58	0,58	0,57

3. Параметричен анализ

Създаденият крайноелементен модел е използван за изследване влиянието на дебелините на ебонитовия и стоманения слой, върху изменението на външния периметър на средното сечение на ролката. Резултатите от параметричния анализ са дадени на Фиг. 6.



Фиг. 6. *Параметричен анализ*

4. Анализ на резултатите и изводи

Извършената проверка за сходимост на резултатите от задачата за определяне на напрегнатото и деформирано състояние на калиброваща двуслойна ролка, показва удовлетворяваща, за практическите нужди, резултати.

Извършеният параметричен анализ показва, че изменението на периметъра на ролката е по-чувствително към дебелината на стоманения слой, отколкото към ебонитовия.

Получените резултати могат да се използват както за качествена оценка, така и непосредствено за избора на дебелина на ебонитовия слой в калибровъчна ролка за автомобилни стендове с различно предназначение.

В настоящата работа не е разгледано увличането, породено от триенето между автомобилната гума и ебонитовия слой.

5. Благодарности

Авторите на доклада изказват благодарност на Фонд „Научни изследвания“ за предоставените средства по договор № 2017-МТФ-02.

ЛИТЕРАТУРА

1. Министър на транспорта, информационните технологии и съобщенията. *Наредба № Н-32 от 16.12.2011 г. за периодичните прегледи за проверка на техническата изправност на пътните превозни средства*. София, 2011.
2. Министерство на транспорта. *Наредба № 34 от 06.12.1999 г. за таксиметров превоз на пътници*. София, 1999.
3. Trzeciak K. *Diagnostika samochodow osobowych*. WKL, Warszawa, 2005.
4. Сестримски, Д. *Диагностика на автомобила*. Техника, София, 1989.
5. Иванов, И. *Компютърно моделиране на непрекъснати среди*. Русенски университет, 2004.
6. Davies, B. *The Stress-Strain Relationship in Ebonite*. Transactions of the Institution of the Rubber Industry. Vol. 9 No. 2, pages 130-140, 1933.
7. Wriggers, P. *Computational Contact Mechanics*. Springer, 2006.
8. ABAQUS. *Analysis User's Manual*. ver. 6.12, Dassault Systemes Simulia Corp., Providence, RI, USA.
9. БДС EN 10025-2:2005. *Горещовалцувани продукти от конструкционни стомани.* Част 2: Технически условия на доставка за нелегирани конструкционни стомани.
10. Ангелов, Ю., И. Борисов. Моделиране изследване и оптимизация на ролков стенд за измерване на спирачна ефективност. Част I. Моделиране и изследване. Научни трудове на Русенски университет, том 52, серия 2, стр. 118-121, 2013.
11. Ангелов, Ю. Моделиране изследване и оптимизация на ролков стенд за измерване на спирачна ефективност. Част II. Параметрична оптимизация. Научни трудове на Русенски университет, том 52, серия 2, стр. 122-125 , 2013.
12. Драганов, И., Ю. Ангелов. Моделиране на ролката на стенд за измерване на спирачна ефективност по метода на крайните елементи. Научни трудове на Русенски университет, том 53, серия 4, стр. 183-187, 2014.

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ДИНАМИЧЕН СИНТЕЗ НА АГРЕГАТА НА ЕЛЕКТРОМЕХАНИЧНА ПРЕСА ЗА ПРОИЗВОДСТВО НА ПРОСЕЧЕНА МРЕЖА ПО ЗАДАДЕНА СТЕПЕН НА НЕРАВНОМЕРНОСТ

ЗДРАВКО ВИТЛАРОВ

***Резюме**: Извършен е динамичен синтез на агрегата на електромеханична преса за производство на просечена мрежа при зададена степен на неравномерност. Определени са параметрите на едномасовия динамичен модел на агрегата. Решено е диференциалното уравнение на движение и е определен необходимия маховик реализиран като втора ремъчна шайба.*

Ключови думи: *динамичен синтез, маховик*

DYNAMIC SYNTHESIS OF THE AGGREGATE OF ELECTROMECHANICAL PRESS FOR EXPANDED METAL AT A SET LEVEL OF INEQUALITY

ZDRAVKO VITLAROV

Abstract: *Dynamic synthesis is made of the aggregate of electromechanical press for expanded metal at a set level of inequality. Parameters of the mass dynamic model are determined of the aggregate. The differential equation of motion is solved and it was determined necessary flywheel realized like a second pulley.*

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Key words: *dynamic synthesis, flywheel*

1. Основни положения

Съществуват три режима на движение на машинните агрегати – пусков, стационарен и спирачен. За настоящата разработка интерес представлява стационарния режим на работа на електромеханичната преса. За оценка на отклонението на ъгловата скорост от средната такава е въведена безразмерната величина δ степен на неравномерност:

$$\delta = \frac{w_{max} - w_{min}}{w_{cp}} \qquad (1)$$

При работа на агрегата с постоянна ъглова скорост (δ = 0) в него възникват инерционни сили, които възбуждат трептения и създават динамични натоварвания на звената. Колебанията на ъгловата скорост $\Delta w = w(\varphi) - w_{cp}$ създават допълнителни инерционни сили, възбуждащи трептения и допълнителни динамични натоварвания.

От направения кинематичен синтез [1] на параметрите на механизмите от електромеханична преса (фиг.1) и последващия кинетостатичен анализ [2] даващ възможност да се направи и якостно оразмеряване елементите на пресата (звена и кинематични двоици) е установена необходимостта от извършването и на динамичен синтез за да се постигне зададената степен на неравномерност. Решението на тази задача, определя масовия инерционен момент на маховика, чрез поставянето на които се постига зададената степен на неравномерност.

2. Изложение

Към степента на неравномерност δ се предявяват изисквания, които се дефинират и от

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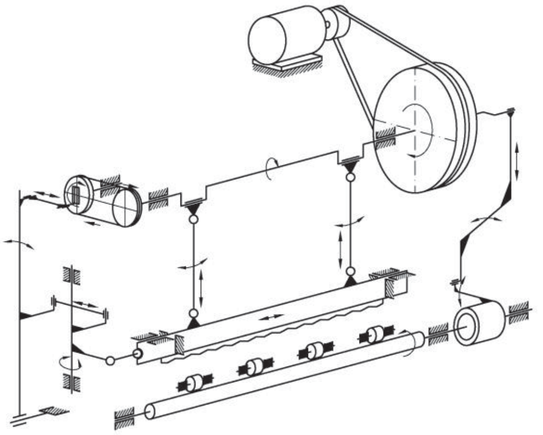
изискванията за нормална работа на машината. В литературата съществуват известни емпирични данни за допустимите степени на неравномерност (δ) – за металообработващи машини от 1/30 до 1/40.



фиг.1 Обща кинематична схема

Степента на неравномерност зависи от масовите и силовите параметри на агрегата. Тази зависимост може да се получи чрез интегриране на диференциалното уравнение за движение в границите, съответстващи на абсолютните екстремуми на скоростта. След известни преобразовани се получава:

$$\delta = \frac{\frac{2}{w_{cp}^2}\int_{\varphi_{min}}^{\varphi_{max}} M_r d\varphi - \Delta J(\varphi_{max}) - \Delta J(\varphi_{min})}{2J_0 + \Delta J(\varphi_{max}) + \Delta J(\varphi_{min})} \quad (2)$$

От получената зависимост (2) следва, че с увеличаване на постоянната част на масовия инерционен момент на агрегата степента на неравномерност се намалява. Освен това е видно, че най-лесно може да се влияе на δ чрез изменение на общия масов инерционен момент на агрегата J_0, който включва и масовия инерционен момент на маховика $J_0 = J_C + J_M$, където: J_C – масов инерционен момент на агрегата без маховик.

Задачата за синтез на машинния агрегат по зададена степен на неравномерност се свежда до определяне на необходимия масов инерционен момент на маховика. За целта се решава уравнение 2 относно J_0:

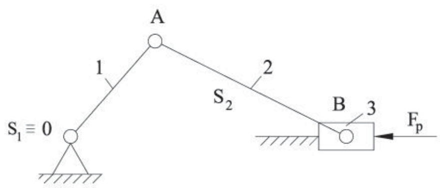
$$J_0 = \frac{1}{\delta w_{cp}^2}\int_{\varphi_{min}}^{\varphi_{max}} M_r d\varphi - \frac{1}{2\delta}\left[\Delta J(\varphi_{max})(1+\delta) - \Delta J(\varphi_{min})(1-\delta)\right] \quad (3)$$

За да се определи масовия инерционен момент на агрегата е необходимо да се извърши моделиране на механизмите на машината за производство на просечена мрежа. По принцип при кинематичния синтез [1] и кинетостатичния анализ [2] машината беше разделена условно на три механизма. За да се получи масовия инерционен момент на агрегата трябва да се добави и задвижването (двигател и ремъчна и верижна предавки). Ще приведем всички масови и силови параметри към главния вал на агрегата (фиг.1), където ще се разположи и маховика.

2.1.Механизъм за просичане (фиг.2)

Приведеният масов инерционен момент към началното звено 1 (главния вал на агрегата) се определя от:

$$J_{r1}^{(1)} = m_2\left(\frac{v_{S2}}{w_1}\right)^2 + m_3\left(\frac{v_B}{w_1}\right)^2 + J_{S1} + J_{S2}\left(\frac{w_2}{w_1}\right)^2, \quad (4)$$



Фиг.2 Кинематична схема на механизма за просичане

където:m_i – маса на i-то звено (i=2, 3);

J_{Si} – масов инерционен момент на i-то звено (i=1, 2);

w_i – ъглова скорост на i-то звено (i=1, 2);

v_{S2} – скорост на масовия център на звено 2;

v_B - скорост на т.B от звено 3.

а приведеният момент:

$$M_{r1}^{(1)} = -F_p . \frac{v_B}{w_1} \quad (5)$$

където: F_p- сила на просичане.

С оглед частично уравновесяване на механизма е необходимо масовият център S_1 на звено 1 да се доведе до неподвижната т.О.

2.2.Механизъм за структурно оформяне (фиг.3)

Приведеният масов инерционен момент към началното звено 1 се определя от:

$$J_{r1}^{(2)} = m_2\left(\frac{v_{S2}}{w_1}\right)^2 + m_4\left(\frac{v_{S4}}{w_1}\right)^2 + m_6\left(\frac{v_{S6}}{w_1}\right)^2 + m_7\left(\frac{v_H}{w_1}\right)^2 + J_{S1} + J_{S2}\left(\frac{w_2}{w_1}\right)^2 + J_{S3}\left(\frac{w_3}{w_1}\right)^2 + J_{S4}\left(\frac{w_4}{w_1}\right)^2 + J_{S5}\left(\frac{w_5}{w_1}\right)^2 + J_{S6}\left(\frac{w_6}{w_1}\right)^2, \quad (6)$$

където:m_i – маса на $i^{-то}$ звено (i=2, 4, 6, 7);

J_{Si} – масов инерционен момент на $i^{-то}$ звено (i=1, 2, 3, 4, 5, 6);

w_i – ъглова скорост на $i^{-то}$ звено (i=1, 2, 3, 4, 5, 6);

v_{S2} – скорост на масовия център на $i^{-то}$ звено (i=2, 4, 6);

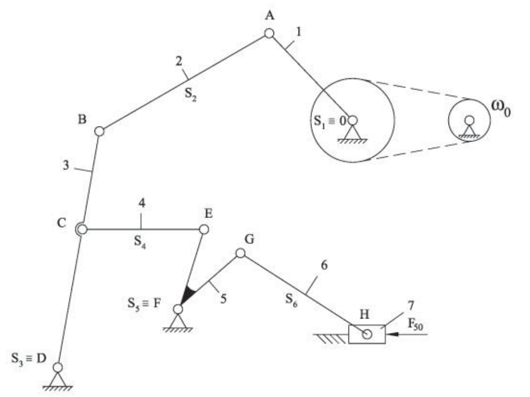
v_H - скорост на т.Н от звено 7.

а приведеният момент:

$$M_{r1}^{(2)} = -F_{so}.\frac{v_H}{w_1} \tag{7}$$

където: F_{so}- сила за структурно оформяне.

С оглед частично уравновесяване на механизма е необходимо масовите центри S_i (i=1,3, 5) на звена 1, 3 и 5 да се доведат до съответната неподвижна т.О, т.D и т.F.

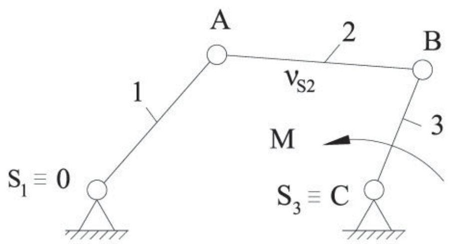


Фиг.3 Кинематична схема на механизма за просичане

2.3.Механизъм за подаване на ламарината (фиг.4)

Приведеният масов инерционен момент към началното звено 1 (главния вал на машината) се определя от:

$$J_{r1}^{(3)} = m_2\left(\frac{v_{S2}}{w_1}\right)^2 + J_{S1} + J_{S2}\left(\frac{w_2}{w_1}\right)^2 + J_{S3}\left(\frac{w_3}{w_1}\right)^2, \tag{8}$$



Фиг.4 Кинематична схема на механизма за подаване

където:m_2 – маса на звено 2;

J_{Si} – масов инерционен момент на $i^{-то}$ звено (i=1, 2, 3);

w_i – ъглова скорост на $i^{-то}$ звено (i=1, 2, 3);

v_{S2} – скорост на масовия център на звено 2;

а приведеният момент:

$$M_{r1}^{(3)} = \mathrm{M}_{pl}.\frac{w_3}{w_1} \tag{9}$$

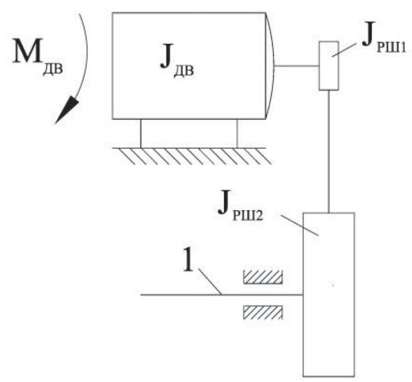
където: M_{pl} - необходим момент за подаване на ламарината в зоната на рязане.

С оглед частично уравновесяване на механизма е необходимо масовите центри S_i (i=1, 3) на звена 1 и 3 да се доведат до съответната неподвижна т.О и т.С.

2.4. Задвижване (Фиг.5)

Приведеният масов инерционен момент към началното звено 1 (главния вал на машината) се определя от:

$$J_{r1}^{(4)} = J_{дв}\left(\frac{w_{дв}}{w_1}\right)^2 + J_{рш1}\left(\frac{w_{дв}}{w_1}\right)^2 + J_{рш2}, \tag{10}$$



Фиг.5 Кинематична схема на задвижването

където:$J_{дв}$ – масов инерционен момент на ротора на ел.двигателя;

$J_{рш1}$ – масов инерционен момент на ремъчна шайба 1;

$J_{рш2}$ – масов инерционен момент на ремъчна шайба 2;

$w_{дв}$ – ъглова скорост на двигателя;

w_1 – ъглова скорост на главния вал на машината;

а приведеният момент:

$$M_{r1}^{(4)} = \mathrm{M}_{дв}.\frac{w_{дв}}{w_1} \tag{11}$$

където: $M_{дв}$ – въртящ момент на двигателя.

Ремъчна шайба 2 е необходимо да бъде конструирана така, че да представлява и маховик.

2.5.Параметри на модела за изследване и определяне на масовия инерционен момент на маховика.

Полученият едномасов динамичния модел ще има следните параметри:

-приведен масов инерционен моментна агрегата:

$$J_r = J_{r1}^{(1)} + J_{r1}^{(2)}.i_{vp}^2 + J_{r1}^{(3)} + J_{r1}^{(4)}\ , \qquad (12)$$

-приведен момент на агрегата:

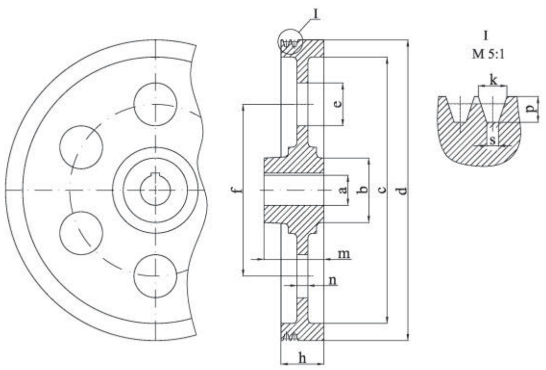
$$\mathrm{M}_r = \mathrm{M}_{r1}^{(1)} + \mathrm{M}_{r1}^{(2)}.i_{vp}^2 + \mathrm{M}_{r1}^{(3)} + \mathrm{M}_{r1}^{(4)}\ , \qquad (13)$$

където: i_{vp} – предавателно отношение на верижната предавка.

След извършване на голям обем от изчисления е определен маховик с J=……. и е разработен маховик оформен като втора ремъчна шайба (фиг.1).

2.6.Проектиране на маховика

Избираме принципна конструкция на маховика (фиг.6). Разделяме маховика на следните части: главина средна част и венец. Определяме инерционните моменти [4] спрямо оста на въртене за така определените отделни части.



Фиг.6 Принципна конструкция на маховика

-главина

$$J_z^{\text{гл.}} = \frac{\gamma}{g}.\frac{\pi.m}{2}.\left[\left(\frac{b}{2}\right)^4 - \left(\frac{a}{2}\right)^4\right] \qquad (14)$$

-средна част

$$J_z^{\text{ср.}} = \frac{\gamma}{g}.\frac{\pi.n}{2}.\left[\left(\frac{c}{2}\right)^4 - \left(\frac{b}{2}\right)^4\right] \qquad (15)$$

От средната част трябва да се извадят отворите, като за един отвор, спрямо оста на отвора:

$$J_{z'}^{\text{отв.1}} = \frac{\gamma}{g}.\frac{\pi.(0.5.e)n}{2} \qquad (16)$$

а спрямо оста на маховика използвайки теоремата на Щайнер:

$$J_z^{\text{отв.1}} = \frac{\gamma}{g}.\frac{\pi.(\frac{e}{2})^4 n}{2} + \frac{\gamma}{g}.\pi.\left(\frac{e}{2}\right)^2.n.\left(\frac{f}{2}\right)^2 \qquad (17)$$

-венец

От венеца трябва да се извадят каналите за ремъците:

$$J_z^{\text{вен.}} = \frac{\gamma}{g}.\frac{\pi.h}{2}.\left[\left(\frac{d}{2}\right)^4 - \left(\frac{c}{2}\right)^4\right] \qquad (18)$$

Окончателно за масовият инерционен момент на маховика се получава:

$$J_z^{\text{м}} = J_z^{\text{гл.}} + J_z^{\text{ср.}} - k.J_z^{\text{отв.1}} + J_z^{\text{вен.}} - z.J_z^{\text{р1}}$$

където:γ-специфично тегло (за чугун – 73600N/m^3);

g=9,81m/s^2;

k-брой отвори;

z-брой ремъчни канали.

3.Заключение.

На база на разработения динамичен модел на механизмите на електромеханична преса за производството на метална просечена мрежа е определен необходимия масов инерционен момент на маховик с оглед постигане на нужната степен на неравномерност.

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ЛИТЕРАТУРА

1. **Витларов З**., Методики за синтез на механизмите на електромеханична преса за производство на просечена мрежа, International Conference on Engineering, Technologies and Systems TECHSYS 2016, Technical University – Sofia, Plovdiv branch 26– 28 May 2016, Plovdiv, Bulgaria.
2. **Петришки Н., Витларов З.,** Кинетостатичен анализ на механизмите на електромеханична преса за производство на просечена мрежа, Mechanical Engineering & Science, сп.Механика на машините , кн.117, В., 2017.
3. **Минчев Н. и др.,** "Теория на механизмите и машините", „СОФТТРЕЙД", 2011.
4. **Кисьов И.,** Наръчник на инженера, част II, Механика, „Техника:, С., 1979.

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ЕДИН ПОДХОД ЗА ИЗБОР НА КРИТЕРИИ ЗА ОЦЕНЯВАНЕ НА СРЕДСТВА ЗА ЗАЩИТА НА ОБЕКТИ

НИКОЛАЙ ГЕОРГИЕВ, АЛЕКСАНДЪР КОЛАРОВ, ВЕНЦИСЛАВ ПЕХЛИВАНСКИ

Резюме: *Използването на разнообразни системи за защита прави актуален проблемът за избор на подходящи критерии за тяхното качество. В разработката се предлага подход за определянето им базиран на обобщени показатели за тяхното качество. Подходът е свързан с адаптиране на известни критерии за качество, отчитайки особеностите на системите за защита на обекти.*

Ключови думи: *критерии, качеството, система, защита*

AN APPROACH FOR SELECTION CRITERIA FOR EVALUATION OF REMEDIES OF PROJECTS

NIKOLAY GUEORGUIEV, ALEKSANDAR KOLAROV, VENCISLAV PEHIVANSKI

Abstract: *Using a variety of protection systems makes current problem of selecting appropriate criteria for their quality. The paper proposes an approach for their determination and based on generalizes indicators of their quality. The approach is related to the adjustment of certain quality criteria, taking into account the characteristics of the systems to protect objects.*

Key words: *criteria, quality, system, protection*

1. Въведение

Известно е, че основната част на стандартите от Системите за управление на качеството ISO 9000, които установяват принципи и основни понятия на управлението на качеството, се състои от пет международни стандарта (Фигура 1), които по същество са ръководство за разработка и внедряване на ефективна Система за управление на качеството [1,2]. Европейскиятстандарт EN ISO 9001:2015 е въведен в България като БДС EN ISO 9001:2015. В него е въведено изискването за идентифициране на рисковете и възможностите, които могат потенциално да повлияят на функционирането и ефективността на системите за управление на качеството, както и съответните „пропорционални" действия за справяне с тях. В съответствие с тези международнин стандарти, с публикациите на Американското общество за качеството и с много други организации[1,2,3], качеството се определя като съвкупност от свойства и характеристики на дадено изделие или действие, определящи способността му да задоволи определени потребности на потребителя при конкретно дефинирани условия. От това определение следва, че не всички свойства и характеристики на изделието или действието влизат в състава на тяхното качество, а само тези, които обуславят свойствата им да удовлетворяват определена потребност.

Използването на разнообразни системи за защита прави актуален проблемът за избор на подходящи критерии за тяхното качество както и подход за определянето им, базиран на обобщени показатели за тяхното качество.

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Фиг. 1 *Основни стандарти от Системата за управление на качеството*

2. Изложение

Показателят за качество е количествен израз на едно или на няколко свойства, а критериите за качеството са изисквания за това даден показател, или съвкупност от показатели да имат определени стойности. В зависимост от природата на свойствата, които количествено характеризират, критериите и показателите за качеството биват физични, химични, механични, и т.н., а в зависимост от техния характер - показатели за надеждност, за ергономичност, за функционалност и др. Освен това всички критерии и показатели за качество се разделят на единични, комплексни и интегрални[4,5].

Единичният показател за качество характеризира само едно от свойствата на продукта. Комплексният показател за качество характеризира определена съвкупност от свойства, влизащи в структурата на качеството. Той може да бъде групов и обобщаващ. Груповият показател за качество характеризира няколко прости свойства или сложно (комплексно) свойство. Обобщаващият показател за качество характеризира в количествено отношение цялата съвкупност от свойства, по които е прието да се оценява дадено изделие или действие. Най-често интегралният показател за качество отразява отношението между общия полезен ефект на дадено изделие или действие и сумата от разходите по неговото създаване и експлоатация или провеждане. Например интегрален показател за качеството на дадена система за защита може да бъде обемът на „защитаваната” зона с определена ефективност за определен период от време (напр. до излизането му от употреба), към разходите за създаването, поддържането, експлоатацията, ремонта и утилизацията на този модул.

Основната класификация на сложните системи, към които можем да отнесем и системите за защита на критичната инфраструктура, по отношение на целите и ресурсите е [6]:

a. По отношението на системата към обкръжаващата среда:
- отворена – системата има обмен на ресурси с обкръжаващата среда;
- затворена - системата няма обмен на ресурси с обкръжаващата среда.

b. По произход на системата (елементи, връзки, подсистеми):
- изкуствени – оръжия, механизми, роботи, транспортни срдства и т.н.;
- естествени – живи, неживи, екологични, социални и т.н.;
- виртуални – въображаеми и независимо че в действителност те реално не съществуват,но функционират така, все едно че съществуват реално;
- смесени – икономически, биотехнически, организационни и др.

c. По описанието на неизвестните (променливите) в системата:
- с качествени променливи – имащи само съдържателно описание;
- с количествени променливи – имащи дискретно или непрекъснато количествено описание;
- смесено описание – количествено-качествено.

d. По типа на законите, който описват функционирането на системата:
- тип „черна кутия” – напълно неизвестни закони по който функционита системата, известни са само входните и изходните данни;
- непараметизиран – законите не са описани, а са известни само някои априорни негови свойства;
- параметризиран – законуте са известни с точност до параметрите му и техните зависимости;
- тип „прозрачна кутия” – напълно известни закони за функциониране на системата.

e. По способа на управление на системата (в системата):

- управляема отвън – без обратна връзка, регулируема, със структурно управление, функционално или информационно;
- с вътрешно управление – самоуправляваща (саморегулираща) се, програмно или автоматическо управляема, самоорганизираща се, адаптируема, и др.;
- с комбинирано управление – автоматическо, автоматизирано, организационно и др.

От своя страна системите на критичната инфраструктура по характера на своето поведение могат да бъдат класифицирани като:

- детерминирани – поведението им е известно по определени правила и закони. Множеството от състояния на всеко елемент и на системата като цяло са известни;
- вероятностни – поведението им може да бъде описано с методите на теорията на вероятностите;
- хаотични – характеризират се с това, че не големи изменения в тяхното текущо състояние могат да доведат към непредсказуеми и значителни изменения в последващите състояния.

Класифицирането на дадена система на критичната инфраструктура по нейното поведение определя в голяма степен и методите за нейната оценка.

Характерното за детерминирания анализ е, че при него не се използват количествени вероятностни данни за описание на събития или тяхното съчетание. Определят се възможни сценарии включващи базовото множество от събития и последствията от тях върху критичната инфраструктура. Сценариите обиновенно се описват с стествен език с песимистичен уклон на изразяване – ориентирани са към най-лошия сценарий на развитие на събитието. Обикновенно се планират по-голямо количество средства от необходимото и не се отчитат неопределенностите в ситуацията, което прави този подход неефективен от гледна точка на управлението. Когато поведението на системата не може да бъде описано с набор определени правила, за оценка на риска се използва подход характеризира се с използването на веоятностни оценки. Основата на вероятностния подход е системния анализ на възможните сценарии с отчитане на количествения анализ на надеждността на системата. Когато управлението на безопасността на критичната инфраструктура протича в условията на неопределеност и неяснота на информацията, свързана с нейното функциониране, се налага използване на метода на така наречените „меки изчисления". Този метод се основава на теорията на нейронните мрежи (Neural Network), логиката на неясните събития (Fuzzy Logic) и вероятностното описание (Probabilistic Reasoning).

Основните характеристики на методите за анализ на безопасността в критичната инфраструктура са показани в Таблица 1.

Таблица 1 *Основни характеристики на методите за анализ на безопасността в критичната инфраструктура*

МЕТОДИ:	Детерминиран анализ	Вероятностен подход	„Меки изчисления"
Входни данни:	Детерминирани	Вероятностно разпределение	Неясни случайни значения на параметрите
Множество на разглежданите събития	Само с най-лошите последствия	Всички прогнозни събития	Всички прогнозни събития
Честота	Достоверни събития	Вероятността се оценява в съответствие с приетия закон за разпределение	Лингвинистични оценки, числа с неопределена стойност
Тежест на последствията	Предполага се известна	Предполага се известна	Лингвинистични променливи
Оценка на риска	Качествен анализ	Количествен анализ	Анализ на неточни числа
Оценка на неопределеността	Не се разлежда	Стохастическа неопределеност, неопределеност от първи род	Нестохастическа неопределеност, неопределеност от втори ред

Поради това, че в повечето случаи разходите по създаване и експлоатация на системите за защита са относително добре дефинирани в теоретичен аспект те не представляват интерес. От друга страна критериите за качество, базирани на единични и групови показатели са непълни и биха могли да се използват или за решаване на частни задачи, или чрез комбинирането им в система от критерии. Ето защо в доклада се предлага адаптиране на известни критерии за качество, базирани на обобщаващи показатели за качество, отчитащи особеностите на системите за защита на обекти с използването на вероятностния подход за анализ на безопасността на критичната инфраструктура.

Основното предназначение на системите за защита на обекти е да се предотвратят атаките срещу тях или да се намали ефектът от тях. Това можа да се постигне чрез предотвратявана на атаките посредством унищожаване или повреждане на атакуващите средства, както и чрез възпрепятстване на достъпа им до зони, от които те могат да извършат атака. В общия случай описването на тези характеристики включва вероятностите и степента на поразявания нанасяни както на атакуващите средства върху защитаваните обекти и върху модулните системи за тяхната защита, така и тези, нанасяни от средствата и системите за защита върху атакуващите средства.

Нека приемем, че съществуват I възможни типа средства за атака върху J броя прикривани обекти. Нека освен това приемем, че съществуват M типа модулни системи за защита, като всяка от тях е предназначена да прикрива един или няколко обекта.

Нека въведем следните обозначения:

- P_{ij} - вероятност за това i-ти тип средства за атака да извърши реално въздействие върху j-ти прикриван обект ($i = 1 \div I,\ j = 1 \div J$);
- Qi/j - вероятност за товасистемата за защита да извърши реално въздействие върхуi-ти тип средства за атака, прикривайки j-ти обект;
- $R_{im/j}$ - вероятност за това i –ти тип средства за атака да извърши реално въздействие върху m-ти тип модул за защита при опита си за въздействие върху j-ти прикриван обект;
- a_{ij} - загуба нанесена от i-ти тип средства за атака при реално въздействие върху j-ти прикриван обект без върху него да въздейства m-ти тип модул за защита;
- $\gamma im/j$ - загуба нанесена от i-ти тип средства за атака при реално въздействие върху m-ти тип модул за защита, при опита си за въздействие върху j-ти прикриван обект;
- βi - загуба нанесена от системата за защита върху i-ти тип средства за атака.

При известни стойности на посочените параметри е възможно формулирането на следните основни групи от критерии за качеството на системите за защита:

а. Критерий за минималните средни общи загуби (на отбраняваните обекти и модулите за защита).

Критерият отчита средните загуби нанасяни от атакуващите средства върху всички собствени обекти - и защитаваните обекти и компонентите на системата за защита. Общият му вид е:

$$S_1=\Sigma\Sigma\Sigma\ P_{ij}\ R_{im}/j\alpha_{ij}\gamma_{im}/j = min, \qquad (1)$$

където сумирането е за $i = 1 \div I,\ j = 1 \div J$ и $m = 1 \div M$.

Известно е [3,4], че Qi/j може да се разгледа като зависеща от вероятността подсистемата за разузнаване да открие своевременно i-тото средство за защита (Qi/j_1), вероятността тази информация да се предаде с необходимото качество и на нейна база да се вземе решение за въздействие върху i-тия тип средства за атака (Qi/j_2) и от вероятността за това въздействието на системата за защита да е ефективно, т.е. да реализира загубата βi (Qi/j_3). Освен томаможе да се приеме, че в процеса на операцията стойността на Pijи Rim/jса с относително постоянни стойности - Pij_0 и Rim/j_0.Тези стойности могат да се променят съществено с коефициент Кij, зависещ основно от действията на системата за защита (Кij = 1 - $Qi/j\beta i$ = 1 - $Qi/j1Qi/j2Qi/j3\beta i$).

Въвеждайки гореописаните параметри, критерият за минимални средни общи загуби добива вида:

$$S_1 = \Sigma\Sigma\Sigma P_{ij_0} R_{im}/j_0 K_{ij}\alpha_{ij}\gamma_{im} = \Sigma\Sigma\Sigma P_{ij_0} R_{im}/j_0\alpha_{ij}\gamma_{im}/j(1 - \frac{\frac{Q_i}{j_1 Q_i}}{j_2 Q_i}/j_3\beta_i) = \Sigma\Sigma\Sigma V_{ijm}P_{\alpha ij}, \qquad (2)$$

където:

- $V_{ijm} = P_{ij_0}R_{im}/j_0\alpha_{ij}\gamma_{im}/j$ - коефициент на важност на i-то средство за атака при действието му срещу j-ти защитаван обект и m-ти модул от системата за защита;
- $P_{\alpha ij} = (1 - Q_i/j_1Q_i/j_2Q_i/j_3\beta_i$ - коефициент на противодействие на системата за защита срещу i-то средство за атака при действието му

срещу j-ти защитаван обект и m-ти модул от системата за защита.

Формула (2) характеризира средния риск не само чрез действията на атакуващите средства, а и чрез противодействието на системите за защита (Qi/j и βi). Следва да се отчита, че зависимостта между αij и $\gamma im/j$ от една страна и Qi/j и βi от друга страна е по-сложна и определянето и е целесъобразно да се осъществява за фиксирани ситуации, или чрез използване на теорията на игрите. Въпреки това използваното приближение не променя общата качествена зависимост между качеството на системата и параметрите участващи във Формула (2).

Очевидно минимума на средния риск се постига с отчитане както на важността на отделните средства за атака $Vijm$, така и на възможностите на системата за защита за противодействие срещу него $Paij$.

b. Критерий за минималните средни загуби

Критерият отчита само загубите на отбраняваните обекти и е от вида:

$$S_2 = \Sigma\Sigma\Sigma P_{ij}\alpha_{ij} = \min, \qquad (3)$$

където сумирането е за $i = 1 \div I,\ j = 1 \div J$.

Отчитайки използваните за Формула (2) параметри можем да запишем критерияза минималните средни загуби като:

$$S_2 = \Sigma\Sigma\Sigma P_{ij_0} K_{ij} \alpha_{ij} =$$

$$= \Sigma\Sigma\Sigma P_{ij_0}\alpha_{ij}(1 - \frac{\frac{\frac{Q_i}{j_1 Q_i}}{j_2 Q_i}}{j_3 \beta_i} = \Sigma\Sigma\Sigma P_{\alpha ij}, \qquad (4)$$

където $V_{ijm_0} = P_{ij_0}\alpha_{ij}$ е коефициент на важност на i –то средство за атака при действието му срещу j-ти защитаван обект.

c. Критерии за максимално допустими средни загуби

За преодоляване на слабостите на критериите за минималния среден риск, както и за осигуряване на определена степен на защита се използва метод за фиксиране на допустимите загуби. Методът предвижда средните загуби (общи или само на защитаваните обекти) при произволен сценарии на агресия да не превишават предварително зададени стойности, т.е.:

$$S_3 = S_1 < S_{1гр} \text{ или } S_3 = S_2 < S_{2гр} \qquad (5)$$

където $S_{1гр}$ и $S_{2гр}$ са граничните, допустими стойности на съответните средни загуби.

d. Критерии на максималните средни загуби на противника

Този критерии се базира на хипотезата, че зашитата на обектите следва да се постигне чрез намаляване в максимална степен на възможностите на атакуващите средства, т.е. критерият е:

$$S_4 = \Sigma\Sigma\Sigma \frac{Q_{mi}}{j\beta_{mi}} = \max, \qquad (6)$$

където сумирането е за $i = 1 \div I,\ j = 1 \div J$ и $m = 1 \div M$.

e. Критерий за осигуряване на минимално необходими средни загуби на противника

Критерият е модификация на критерия за максимални средни загуби на противника и е свързан с въвеждането на изискване за гарантиране на определена минимална стойност на тези загуби, т.е.:

$$S_5 = S_4 \geq S_{4гр}, \qquad (7)$$

където $S_{4гр}$ е гранична, допустима стойности на средни загуби на противника.

f. Критерий на максималното отношение между загубите

$$S_6 = \frac{S_4}{S_1} = max \text{ или}$$

$$S_6 = S_4 / S_2 = max \qquad (8)$$

Вероятните сценарии на приложение на предлаганите критерии за качеството на системите за защита и изключенията са показани в Таблица 2.

Таблица 2 *Вероятни сценарии на приложение на предлаганите критерии*

Критерий	Вероятен сценарий на приложение	Ограничения
S_1	- защитаваните обекти и модулните системи са със сравними по стойности важност; - запазване капацитета на системите за защитата.	- неподходяш за защита на особено важни обекти от критичната инфраструктура; - слабо приложим за епизодични агресивни действия.
S_2	- защитаваните обекти са с относително еднаква важност; - въздействия с единични или с малки групи ; - системите за защита са с висока степен на устойчивост - епизодични агресивни действия, след които системата за защита се възстановява	- при защита на единични особено важни обекти. - при невъзможност от бързо възстановяване на средствата за защита. - при цена на средствата за защита съизмерима с тази на защитаваните обекти.
S_3	Да не се допусне намаляване на остатъчната стойност под определена (допустима): - на защитаваните обекти; - на защитаваните обекти и системите за защита.	Когато приоритет е защитата на много важни единияни обекти. Когато има възможност за бързо възстановяване на обектите или на средствата за защита.

S_4	Намаляване в максимална степен на възможностите на атакуващите средства. Приоритет на психологическо, медийно и морално въздействие. Защита на територия	Нанасянето на значителни загуби на противника е самостоятелна цел, за изпълнението на която не е задължително да се защитават конкретни обекти.
S_5	Малка интензивност на конфликта. Създаване на условия за прекратяване на конфликта. Демонстрация на възможности за защита.	Нанасянето на предварително планираните загуби на противника не е пряко свързано със защитата на конкретни обекти.
S_6	При относителен паритет на силите в началото на конфликта и стремеж за повишаване на съотношението между възможностите на защитаваните обекти и средства спрямо атакуващите. При стремеж за демонстрация на превъзходство на защитата и доказване на несъстоятелността на агресията..	Постигането на максимално съотношение между нанесените и претърпените загуби не означава нито сриване на възможностите на противника, нито надеждна защита на конкретни обекти.

3. Заключение

Посочените критерии се базират на обобщени показатели за качеството на системите за защита. Използването им зависи от конкретния сценарии за развитие на агресията - напр. при очаквана агресия от терористични групи подходящ е критерия за минимални средни загуби или за максимално допустими такива[5]. При възможна кратка агресия от друга държава е подходящ критерия за максимални средни загуби нанесени на противника или критерия за максимално отношение между загубите. При очаквани продължителни агресивни действия би могъл да се използва критерия за минималните средни общи загуби. Възможно е използването и на други критерии, получени чрез различни комбинации от посочените, както и чрез групиране на определени съвкупности от обекти за защита, модулни системи и атакуващи средства и задаване на различни частни критерии за всяка отделна група.

ЛИТЕРАТУРА

1. http:/asq.org/glossary/q.html.
2. Dimitar Dimitrov, Valeri Panevski (2015) *The need for unformity of languange in security analysis, risk management and critical infrastructure protection-an overview* Пета национална конференция с международно участие „Металознание, хидро- и аеродинамика, национална сигурност“ ISSN:1313-8308, стр. 374-378.
3. Kiril Stoichev, Valeri Panevski, Dmitar Dimitrov (2016). *Contemporary approach for complex analysis and evaluation of hazardous environments (CAEHE),* International Journal of Economics, Commerce and Management, IV, 4, ISSN:2348 0386, pp. 500-516.
4. Кирил Стойчев, Димитър Димитров, Валери Пъневски (2016) *Интегрирана сигурност и защита на критична инфраструктура,* ИМСТЦХА-БАН, ISBN:978-619-90310-6-3, стр. 340.
5. Kiril Stoichev, Valeri Panevski, Dmitar Dimitrov (2016) *Contemporary approach for complex analysis and evaluation of hazardous environments (CAEHE),* International Journal of Economics, Commerce and Management, IV, 4, International Journal of Economics, Commerce and Management, ISSN:2348 0386, pp. 500-516.
6. Георгиев Стилиян (2016) *Сензорни системи за защита на обекти от критичната инфраструктура.* Научни известия на НТСМ, 1, 187, ISSN:1310-3946.

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НОВИ ПОДХОДИ ЗА ПОВИШАВАНЕ ПРОТИВОМИННАТА УСТОЙЧИВОСТ НА МОРСКИ ДЪННИ МИНИ

СТЕФАН ВОДЕНИЧАРОВ, АЛЕКСАНДЪР КОЛАРОВ, НИКОЛАЙ ГЕОРГИЕВ, ВЕНЦИСЛАВ ПЕХЛИВАНСКИ

Резюме: *При конструирането на съвременните морски дънни мини обикновенно се търси компромис между тактическите изисквания към този вид оръжие и изискванията за висока устойчивост срещу евентуални противоминни действия, например, правят се с цилиндрична форма когато трябва да се поставят на позиция от торпедни апарати на подводници, корпусът им се конструира в така наречената „стелт“ технология и се изработва от неметални материали, увеличава се количеството на взривното вещество когато дълбочината на района е по-голяма и т.н. В статията се предлага подход, който дава общо решение на всички тези изисквания и позволява конструирането на една моногофункционална, универсална и с висока противоминна устойчивост морска дънна мина, която няма аналог във военноморската практика.*

Ключови думи: *морска дънна мина, хидроакустична сянка, фрагментиране, дефрагментиране, подводен реактивен двигател, аербег, противоминен сонар.*

NEW APPROACHES TO INCREASE ANTI-MINING RESISTANCE TO SEA BOTTOM MINES

STEFAN VODENICHAROV, ALEKSANDAR KOLAROV, NIKOLAY GUEORGUIEV, VENCISLAV PEHLIVANSKI

Abstract: *In constructing the modern sea bottom mines usually seek a compromise between tactical requirements for this type of weapon and requirements for high resistance against possible mine-action e.g. make it a cylindrical shape when you need to put an item on the torpedo apparatus submarines, their shell is constructed in the so-called "stealth" technology and is made of non-metallic materials, increasing the quantity of the explosive when the depth of the region is greater, etc. The article proposes an approach that provides a common solution to all these requirements and allows the construction of a highly functional, versatile, high anti-mining resistance sea bottom mine that has no analogue in the naval practice.*

Key words: *sea bottom mine, hydro acoustic shadow, fragmentation, defragmentation, underwater jet engine, airbag, anti mining sonar.*

1. Въведение

Разработването на нови типове дънни морски мини е актуален проблем поради факта, че този тип средства за защита на пристанища и подстъпите към тях стават част от компонентите за защита на морска критична инфраструктура[1,2,3].

Съвременните противоминни системи за откриване и унищожаване на дънни морски мини представляват информационен комплекс организиран на няколко нива. Простото откриване на мината като локална хидролокационна цел на фона на обкръжаващата среда все повече се преобразува в мониторинг на подводната

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обстановка и създаване на детайлна хидролокационна картина на участъци от морското дъно с подробно обследване за всяка подозрителна цел и фиксиране на всички локални изменения.

Най-новите тенденции при конструирането на корабните подкилни противоминни сонари и тези от състава на буксируемите или автономни подводни апарати и роботи, свързани с обработването на отразените от целта хидроакустични сигнали, използват следните основни показателите за класификация, заложени в алгоритмите за откриване на дънна мина [4,5]:

1. Хидроакустична сянка на целта върху морското дъно - основно при използване на буксируеми сонари или на монтирани на автономни самоходни подводни апарати (Autonomous Underwater Vehicle – AUV);
2. Сила на целта – съотношение между падналата върху целта и отразената в направление към антената хидроакустична енергия (основно за подкилни сонари);
3. Оптическа забелижимост (контраст) върху морското дъно – при използване на оптико-електронни (оптически) средства за поиск и на сонари с много висока честота (над 600 kHz), които правят хидроакустична снимка на целта;
4. Пространствени размери на целта, които са заложени във филтрите за автоматична класификация на миноподобни тела.

Отчитайки изложеното, подходите за повишаване на противоминната устойчивост на морските дънни мини, наричани още „защитно оръжие на бедните държави” са свързани с намирането на технически решения, които да намаляват значително признаците за тяхната класификация като цел на фона на морското дъно.

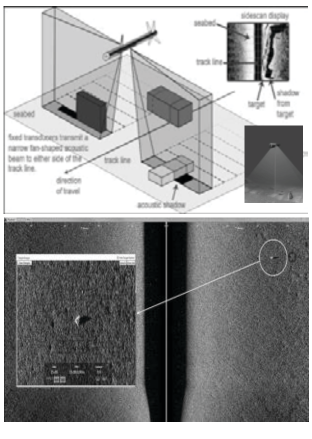
2. Изложение

С цел намаляване ефективността на противоминните сонари при откриване на дънни мини по големината и формата на хидроакустичната им сянка и по нивото на отразения сигнал, съвременна дънна мина трябва да отговаря на следните изисквания [6]:

- да има нисък вертикален профил, за да формира по-малка хидроакустична сянка върху морското дъно;
- да е с конструкция от материал, който поглъща и/или има малка отразяваща способност при облъчване с хидроакустични вълни в диапазоните на работа на съвременни минотърсещи сонари – 30 kHz ÷ 600 kHz;
- профилът на тялото на мината да отговаря на изискванията на “стелт” технологията за разсейване на звуковата енергия в направление, различно от ъгъла на падане;
- да има голяма отразяваща повърхост, която да води до маскиране на сянката, при което филтрите за големина на целта (относно габарити на известни мини) няма да я класифицират като миноподобна цел;
- да има симетричност на формата поради това, че обикновенно се извършва двукратен поиск на перпендикулярни галсове и се оценяват (изваждат) сигналите от целите;
- да има ниска отразаваща енергетична способност, защото се извършва оценка на центъра на тежестта, т.е. ако една маса е с по-голяма площ тя е по-слабо контрастна.

Влиянието на вертикалния профил на тялото на мината върху големината на хидроакустичната сянка е показано на Фиг.1, където:

- H [m] – отстояние на буксируемия сонар със страничен обзор (AUV) от дъното;
- h [m] – височина на дъната от дъното;
- D [m] – разстояние между сонара и мината;
- S [m] – дължина на хидроакустичната сянка.



$$\frac{(D+S)}{S} = \frac{H}{h} \Rightarrow S = \frac{(D \times h)}{H-h}$$

H	D	h	S	H	D	h	S
2	10	0.2	*1.1*	4	20	1.0	*6.67*
2	10	0.3	*1.8*	4	40	0.2	*2.13*
2	10	0.5	*3.3*	4	40	1.0	*13.34*
2	10	1.0	*10.0*	4	60	0.2	*3.16*
2	20	0.2	*2.2*	4	80	0.2	*4.25*
2	20	0.5	*6.7*	6	10	0.2	*0.34*
2	20	1.0	*20.0*	6	10	1.0	*2.0*
2	40	0.2	*4.4*	6	20	0.2	*0.69*
2	40	1.0	*40.0*	6	20	1.0	*4.0*
2	60	0.2	*6.7*	6	30	0.2	*1.03*
2	80	0.2	*8.8*	6	30	1.0	*6.0*
4	10	0.2	*0.53*	6	50	0.2	*1.72*
4	10	0.3	*0.81*	6	50	1.0	*10.0*
4	10	0.5	*1.43*	8	50	0.2	*1.28*
4	10	1.0	*3.33*	8	50	1.0	*7.14*
4	20	0.2	*1.06*	8	100	0.2	*2.56*
4	20	0.5	*2.87*	8	100	1.0	*14.28*

***Фиг. 1** Хидроакустична сянка на цел, позиционирана на дъното*

Вижда се, че големината на сянката от мина с височина 0.1 м е 10-15% от тази на най-разпространените дънни мини с височина около 1 м. Следователно формата на мината трябва да е с минимална височина.

За удовлетворяване изискването за симетричност е целесъобразно мината да има звездовидна форма във фрагментирано състояние (когато е на позиция на дъното), а за да отразява на звуковите вълни в странични направления е необходимо повърхността на фрагментите да сключва походящ ъгъл с равнината на дъното. Корпусите на отделните фрагменти трябва да са от материал с намалена отразяваща способност. При групиране на фрагментите (дефрагментиране) мината трябва да придобива цилиндрична форма с диаметър, позволяващ тя да бъде изстрелвана от торпеден апарат.

От гледна точка на бойната ефективност на дънна мина може да се приеме, че поразяващата и способност е обратно пропорционална на дистанцията до подводната част на кораба и право пропорционална на големината на заряда. В съответствие с методиката на разчет на налягането на ударната вълна, свързано с формата и размерите на газовия балон, се доказва, че зарядът трябва да е компактен с форма близка до сферичната (цилиндрична) и с минимален радиус. Известно е, че поразяващото действие на тротилов заряд може да се изчисли по формулата [7]:

$$\mathrm{P_{max}} = 23800 \left(\frac{\sqrt[3]{\mathrm{W}}}{\mathrm{R}}\right)^{1.16} \qquad (1)$$

където:

- $\mathrm{P_{max}}$ [dB] – акустично налягане на фронта на ударната вълна;
- W [lb] – тегло на тротиловия заряд;
- R [ft] – разстояние до корпуса на кораба.

Някои зависимости между $\mathrm{P_{max}}$, W и R са представение в Таблица 1, в която чрез к е обозначен пространствен коефициент на разпространение на енергията на газовия балон в пространството. От резултатите може да се направи извод, че пораженията, които могат да се очакват от дънна мина с тегло на заряда 500 кг на разстояние 30 метра от кила на кораба, са приблизително равни на пораженията от подводен заряд с тегло 10 кг на разстояние 5 м от корпуса на кораба.

P_{max} (Pa)	R (ft)	R (m)	W (lb)	W (kg)	K	Забележка
1455.6	131.23	40	1653.47	750	1	
2620	131.23	40	1653.47	750	1.8	дънна
1243.2	131.23	40	1102.31	500	1	
2237.8	131.23	40	1102.31	500	1.8	дънна
954.3	131.23	40	551.16	250	1	
1717.7	131.23	40	551.16	250	1.8	дънна
2032	98.43	30	1653.47	750	1	
3657.7	98.43	30	1653.47	750	1.8	дънна
1735.6	98.43	30	1102.31	500	1	
3124	98.43	30	1102.31	500	1.8	дънна
446.3	98.43	30	551.16	250	1	
803.4	98.43	30	551.16	250	1.8	дънна
2777.8	65.62	20	1102.31	500	1	
5000	65.62	20	1102.31	500	1.8	дънна
2132.2	65.62	20	551.16	250	1	
3838	65.62	20	551.16	250	1.8	дънна
4764.7	32.81	10	551.16	250	1	
3316.4	32.81	10	220.46	100	1	
2560	32.81	10	110.23	50	1	
5722.7	16.4	5	110.23	50	1	
3967	16.4	5	44.09	20	1	
3062.4	16.4	5	22.05	10	1	
25661	3.28	1	44.09	20	1	
19809.2	3.28	1	22.05	10	1	

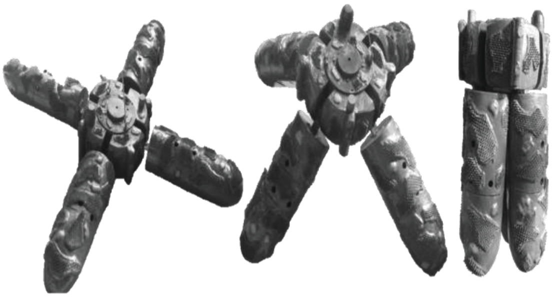
***Таблица 1** Поразяващо действие на тротилов заряд*

Следователно съвременната дънна мина трябва да е компактна и да се детонира на оптимална (минимална) дистанция до дъното на кораба-цел, което ще позволи тя да бъде позиционирана на дълбочини съответстващи на зоната на действие на неконтактните сензори – 100 ÷ 200 м, а не на зоната на действие на поразяващото действие на концентриран заряд – 30 – 40 м за заряд 1000 кг.

От гледна точка на тактиката на постановка на минни заграждения е целесъобразно дънните мини освен по традиционния способ на миноспускане – по релсови пътища от палубата или с подемно-пускови устройства, да могат да се поставят и през торпедните апарати на бойни кораби и подводници, т.е. да имат цилиндрична форма със съответния радиус. Най-разпространения калибър торпеда, а съответно и торпедни апарати, е 533 мм, но са известни и образци с диаметър от 254 до 660 мм.

За удовлетворяване на всички тези понякога противоречиви изисквания се предлага нова инженерна конструкция на фрагментираща се дънна мина /ФДМ/, която се състои от N на брой бойни тела, които са съединени посредством подвижни връзки с централно цилиндрично тяло - групиращ неконтактен взривател /ГНВ/, в което се намират сензорите, захранващия блок на мината и реактивен двигател и/или аербег (airbag), който служи за отлепване на корпуса от дъното и задвижване във вертикално направление и групиране на бойните тела.

Предназначението на ФДМ е да поразява подводната част на корпуса и за нанасяне на бойни повреди на кораби със средно и голямо водоизместване, на подводници и на десантни кораби, в това число и на въздушна възглавница.



Фиг. 2 *Конструкция на ФДМ*

Конструктивните особености при реализиране на идеята за ФДМ (Фиг.2), освен за удовлетворяване на изискванията за намаляване ефективността на противоминните сонари при откриване на дънни мини по големината и формата на хидроакустическата им сянка и ниво на отразен сигнал, я правят многофункционална защото:

- съставните елементи могат да бъдат профилирани с максимален полезен обем при вариант “мина” и с подходящи пускови контейнери за варианти “подводни реактивни снаряди” и “малогабаритни високоскоростни торпеда”;
- минната постановка може да се извършва със свободно спускане на изделието на вода от палубата на кораб или от торпедните апарати на бойни кораби и подводници, като подбраните геометрична форма на фрагментираното тяло и масогабаритни характеристики, съобразени с размерите на торпедните апарати, осигуряват плавно удълбочаване и заставане стабилно на дъното;
- процесът на дефрагментиране (групиране на елементите) на мината след сигнал от сензорната система и подизплаването й на оптимална дълбочина осигуряват ефективното използване на поразяващата сила на подводния взрив при минен вариант или подходящо положение на елементите при торпеден вариант.

Могат да бъдат реализирани следните варианти според изискванията за бойно използване на ФДМ в конкретна операция:

- ГНВ без реактивен взривател – за противодесантни морски минни заграждения на дълбочини до 10 м, когато не се налага групиране;
- ГНВ с реактивен двигател с малка мощност и/или с използване на аербег, който осигурява групирането в компактно състояние на бойните тела след повдигане на ГНВ на височина от дъното, равна на дължината им – стандартен вариант на дънна мина, позиционирана на дълбочини от 10 ÷ 40 м;
- ГНВ с реактивен двигател с голяма мощност, осигуряващ движение на мината към повърхността на морето и доближаване на целта;
- ГНВ с реактивен двигател с малка мощност и/или с използване на аербег, на която в обемите на бойните тела вместо взривно вещество са поместени ракетни подводни снаряди, които реализират зона на поражение с програмируеми характеристики;
- ГНВ с реактивен двигател с малка мощност и/или с използване на аербег, на която в обемите на бойните тела вместо взривно вещество са поместени малогабаритни високоскоростни торпеда.

Проведените експерименти показват, че за дълбочини в районите за минна постановка до 70 - 80 м, е целесъобразно използването на вариант на ФДМ с ГНВ с реактивен двигател с малка мощност, който да осигурява преодоляване на засмукващата сила на тинесто дъно, и аербег за осигуряване на групирането и изплаване към повърхността. В този случай е важно вертикалната скорост на движение да е достатъчна за да се реализира детонация под кила на кораба цел на оптимална дистанция или най-общо казано за времето, за което целта изминава дистанцията на откриване от сензорите, мината трябва да изплава под него на оптимално разстояние за поражение на подводната част. Значенията на средната скорост на изплаване на балон пълен с въздух при различни значения на неговия обем и напречно сечение са показани в Таблица 2 [8]:

	Сфера	
Обем [m^3] (литри)	Радиус [m]	Скорост [m/s]
0.02 (20)	0.168	3.31
0.03 (30)	0.193	3.55
0.04 (40)	0.212	3.72
0.05 (50)	0.228	3.86
0.07 (70)	0.256	4.09
0.1 (100)	0.288	4.34
	Цилиндрично тяло с радиус 0.095 m	
Обем [m^3] (литри)	Дължина [m]	Скорост [m/s]
0.02 (20)	0.714	5.88
0.03 (30)	1.07	7.2
0.04 (40)	1.43	8.318
0.05 (50)	1.78	9.3
0.07 (70)	2.5	11.0
0.1 (100)	3.57	13.15

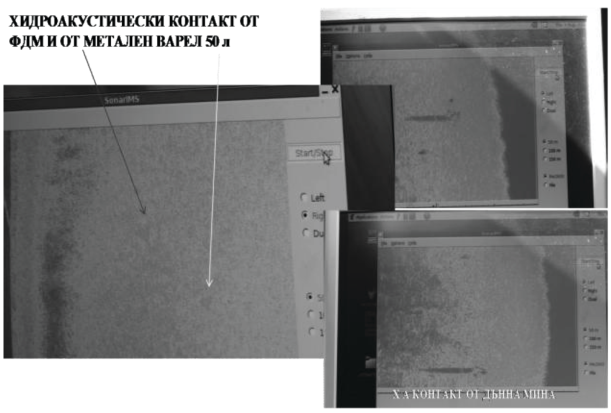
Таблица 2 *Средна скорост на изплаване на аербег в морска вода*

Разчетите показват, че е достатъчна скорост на изплаване от порядъка на 3 – 4 m/s, което е напълно достижимо при използване на аербег с обем 50 ÷ 100 литра и налягане на въздуха в него съответен на дълбочината на активирането му.

3. Заключение

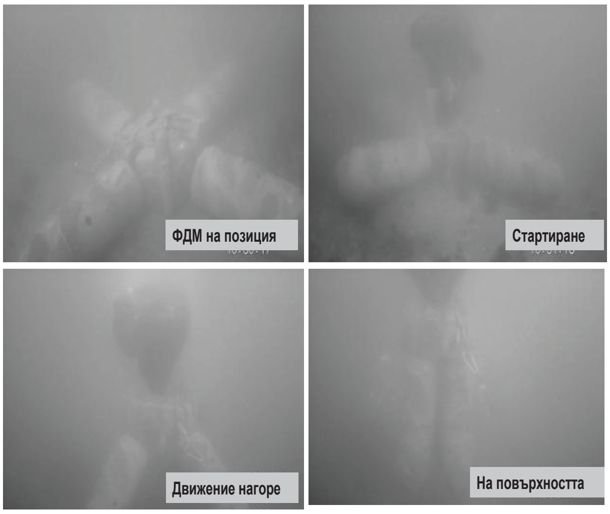
Проведените експерименти с прототип, изготвен под ръководството на доктор Стоян Делиев от ИМСТЦХ-БАН, за оценяване на новите технически решения при конструирането и функционирането на ФДМ показват, че те спомагат в значителна степен за повишаване ефективността и противоминната устойчивост на морските дънни мини в следните направления:

- универсалност – могат да се поставят на позиция на целия диапазон оперативни дълбочини на района на постановка от надводни кораби и подводници за въздействие практически срещу всички видове надводни кораби и подводници;
- многофункционалност – възможно е да бъдат използвани във оптимален вариант според изискванията за бойно използване в конкретна операция или комбинирано;
- в групиран вид ФДМ има формата на цилиндър с диаметър в съответствие с приетите на въоръжение торпедни апарати (прототипът е изработен за торпеден апарат за изстрелване на 533 мм торпеда), което позволява извършване на минна постановка както от кораби, така и от подводници;
- постига се значително намаляване ефективността на противоминните сонари при откриване на дънни мини по големината и формата на хидроакустическата им сянка и ниво на отразен сигнал. На Фиг. 3 се вижда, че хидроакустичната сянка от ФДМ е по-малка от тази на 50 литров метален варел и значително-помалка от тази на стандартна дънна мина със заряд с еднакъв тротилов еквивалент;



Фиг. 3 *Хидроакустичен контакт с ФДМ и с 50 литров метален варел*

- след пускане (изстрелване) на мината на вода бойните тела се разтварят като образуват звездообразно тяло, което осигурява плавно потъване на ФДМ и заемане на стабилно положение на дъното. Процесът на групиране на заряда и придвижването на мината към повърхността, съответно към целта, което е показано на Фиг.4, значително повишава нейната бойна ефективност.



Фиг. 4 *Активиране на ФДМ, групиране и движение към целта*

Реализираните в ФДМ нови технически решения я правят без аналог във военното производство на този вид оръжия.

ЛИТЕРАТУРА

1. Kiril Stoichev, Valeri Panevski, Dimitar Dimitrov. *Contemporary approach for complex analysis and evaluation of hazardous environments* (*CAEHE*). International Journal of Economics, Commerce and Management, IV, 4, pp. 500-516ISSN:2348 0386,
2. Кирил Стойчев, Димитър Димитров, Валери Пъневски (2016) *Интегрирана сигурност и защита на критична инфраструктура* ИМСТЦХА-БАН стр. 340, ISBN:978-619-90310-6-3.
3. Николова В., Г. Дамянов (2013) *Оперативен риск - оценка и предотвратяване в обекти от критичната инфраструктура.* Трета национална конференция с международно участие „Металознание, хидро- и аеродинамика, национална сигурност ’2013“, София стр. 294-298, ISSN 1313-8308.
4. J. A. Fawcett (2001) *Image-based classification of sidescan sonar detections*, Proceedings of CAD/CAC 2001, Halifax, Nov. 12-14,.
5. S.Reed, Y.Petillot, J.Bell (2004) *A model based approach to the detection and classification of mines in sidescan sonar*, Applied Optics, Vol. 43, Issue 2, p237-246.
6. G.J.Dobeck (2001) *Algorithm fusion for automated sea mine detection and classification*, Proc. MTS/IEEE Oceans Conf. and Exhibition, pp.130-134.
7. R. J. Urick (1983) *Principles of underwater sound*, McGraw-Hill, 3rd ed. Pp.401-412
8. Tyce, R., Coelho, E., Bovio, E. MREP (2003) *Maritime reconnaissance for NATO recognized environmental picture*, SACLANTCEN CD-7.

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DETERMINATION OF PROPELLER CHARACTERISTICS FOR MULTIROTOR DRONE DESIGN

HRISTIAN PANAYOTOV, STANIMIR PENCHEV

Abstract: *A methodology for determination of multirotor drone propeller characteristics is described. A special formula with correction coefficients is derived to calculate propeller thrust and power at different flight modes. The calculated theoretical results are compared with experimental data and thorough analysis is carried out.*

Key words: *multirotor drone, propeller, characteristics*

1. Basic theory

Like helicopter and airplane propellers, multirotor drone propellers are well described by momentum and blade element theory. However in multirotor drone design it is often necessary to assess the main propeller characteristics such as propeller thrust, power and efficiency in hover and translational non-axial flight. Hence the aim of the present study is to derive some approximate dependencies that could be useful in early multirotor design stage for determination of propeller characteristics.

For propellers in hover mode the main assumptions for the flow field are shown in Fig. 1.

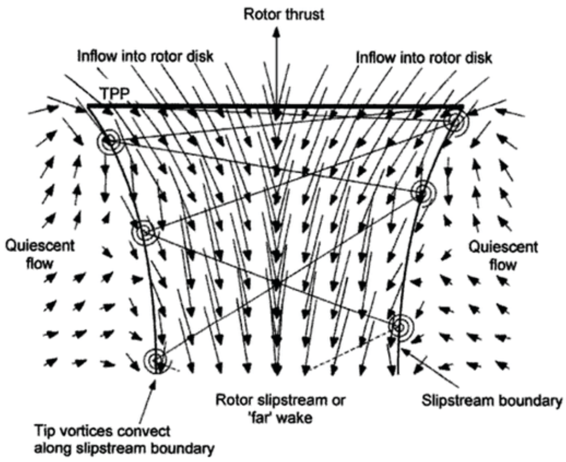

Fig. 1. *Propeller flow field*

Far upstream the air flow is undisturbed and passing through the propeller disc the flow induces speed – V_i. The airflow is further accelerated until it reaches the far wake at slipstream velocity or the jet velocity V_j [1]. The described control volume is shown in Fig. 2.

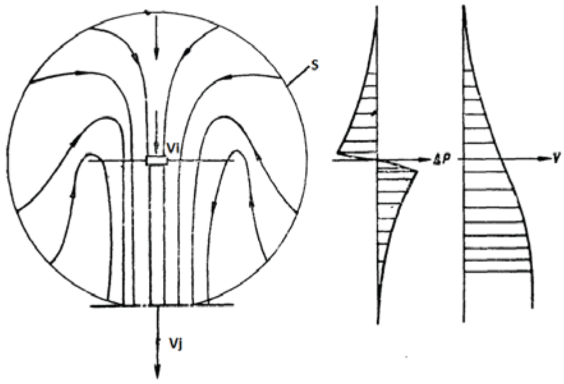

Fig. 2. *Propeller control volume*

Applying the governing conservation laws for the fluid mass and momentum to this control volume yields the following equations [2]:

$$\iint_S \rho\vec{V}.d\vec{S} = 0 \tag{1}$$

$$\vec{F} = \iint_S p d\vec{S} + \iint_S (\rho\vec{V}.d\vec{S})\vec{V}, \tag{2}$$

where $\vec{V}$ is the local velocity, ρ is the density of the fluid across the surface S, and $\vec{F}$ is the net force.

According to eq. (1) for the control volume in Fig. 2 the air mass flow at the station of the propeller disc is:

$$\dot{m} = \rho A V_i, \tag{3}$$

where $A = \pi R^2$ is the propeller disc area provided the propeller has a radius of R.

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Applying eq. (2) the thrust of the propeller is:

$$T = \dot{m}V_j = \rho A V_i V_j. \quad (4)$$

For hover mode (Fig. 2) the theory [1] yields that $V_j = 2V_i$, so finally:

$$T = 2\rho A V_i^2. \quad (5)$$

Additionally the power exerted to the flow from the propeller is [1]:

$$P = TV_i = T\sqrt{\frac{T}{2\rho A}} = \frac{T^{3/2}}{\sqrt{2\rho A}}. \quad (6)$$

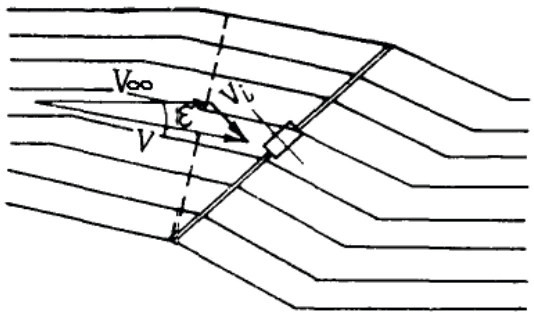

Fig. 3. *Propeller in translational flight*

In the case of translational non-axial flight the flow field assumption is given in Fig. 3. The disc is inclined at some angle of attack A and the resultant velocity across the propeller disc is $\vec{V} = \overrightarrow{V_\infty} + \vec{V_i}$. Hence the mass airflow in that case is $\dot{m} = \rho A V$ and propeller thrust in translational flight will be:

$$T = 2\rho A V V_i. \quad (7)$$

Alternatively from eq. (5) provided the thrust of the propeller is known the induced speed can be calculated:

$$V_i = \sqrt{\frac{T}{2\rho A}}. \quad (8)$$

2. Wind Tunnel Propeller Test Bed

The Department of Transport and Aviation Engineering in the Technical University of Sofia, Plovdiv Branch is equipped with state-of-the-art laboratory wind tunnel used for aerodynamic measurements both for fix-wing and rotary-wing aircraft. There is a specially developed propeller test bed, mounted in the open test area of the tunnel (Fig. 4) that allows orientation of the axis of the propeller at arbitrary inclination towards the vector of undisturbed velocity flow (the angle of attack of the propeller – A). The test bed is designed so that at a certain flow velocity, rotational speed and angle of attack of the propeller the measured properties are: propeller thrust, power and efficiency. Also at steady conditions with no wind tunnel flow the slipstream velocity of the jet (V_j) could be measured using calibrated pitot-static tube. According to eq. (4) and (5) the induced speed (V_i) could be calculated as well.

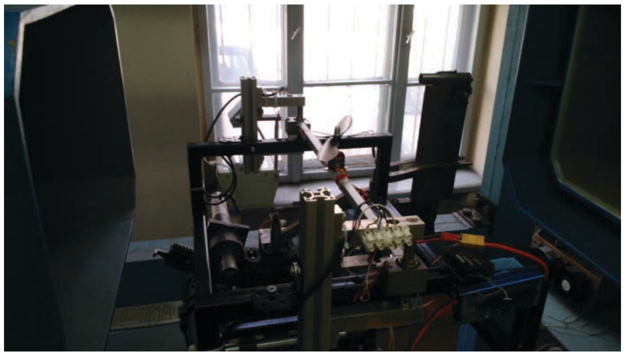

Fig. 4. *Propeller test bed*

Firstly the properties of a propeller are measured to validate the theoretical model from eq. (1) to (8). The chosen drone propeller is well known APC 10''x4,5'' (Diameter=10'', Pitch=4,5''). The propeller is shown in Fig. 5.

Fig. 5. *Propeller APC 10x4.5*

The results from the experiment are given in Table 1. Here the angle of attack of the propeller disc is zero ($A = 0$). The variables are propeller rotational speed in RPM and flow velocity. This represents the hover mode and translational non-axial flight. In hover mode ($V = 0$) thrust T, consumed electric power P_{el}, and jet slipstream velocity V_{jexp} are measured. Additionally using eq. (8) the induced speed (V_i) is calculated, based on the measured thrust. This is to compare the induced speed based on momentum theory and actual measured speed.

Table 1. *Propeller experimental data*

A=0	*n, rpm*	**4000**	**6000**	**7100**
V=0	T, N	3,15	7,20	9,45
	P_{el}, W	34,885	100,41	162,41
	$\frac{T}{P_{el}}, \frac{daN}{W}$	9,03	7,17	5,82
	$V_i, m/s$	5,07	7,66	8,78
	$V_{jexp}, m/s$	9,17	14,17	17,22
	$V_{iexp}, m/s$	4,58	7,08	8,61
V=10 m/s	T, N	4,05	9,00	10,35
	P_{el}, W	34,10	99,86	163,35
	$\frac{T}{P_{el}}, \frac{daN}{W}$	11,88	9,01	6,34
V=20 m/s	T, N	5,85	12,60	13,95
	P_{el}, W	34,78	102,41	164,80
	$\frac{T}{P_{el}}, \frac{daN}{W}$	16,82	12,30	8,46

For the other non-hover mode cases at flow velocity 10 m/s and 20 m/s (Table 1) the induced and jet velocities are not measured due to obvious difficulties.

It is apparent from Table 1 for the hover mode that the errors between the measured and calculated induced speeds from the propeller are acceptably small, and the assumptions from the momentum theory are reliable and applicable to early design phases.

3. Methodology for determination of propeller characteristics.

In Table 1 induced velocities in hover mode are easily measured and calculated provided the propeller thrust is a priori known. However the calculation of the induced velocities in translational flight at some angle of attack is a difficult task. In the case of translational flight eq. (7) is used to calculate propeller thrust. If we have correct measurements of the propeller characteristics in hover mode then the induced speed can be calculated using eq. (8) or measured directly. If we assume that in translational flight the induced speeds for a certain rotational speeds remain the same then eq. (7) should yield the propeller thrust for a given airspeed. However two problems arise that influence the thrust and power of the propeller in translational flight. First at a given airspeed at zero angle of attack the flow field around the rotor is not axisymmetric. There is a region with reversed flow defined by the regime coefficient:

$$\mu = \frac{V_\infty cosA}{\omega R} \quad , \tag{9}$$

where ω is the rotational speed in rad/s. The diameter of the reversed flow region is $d = \mu R$ [2]. So it is as if at higher airspeed the actual radius of the disc is reduced. This phenomenon has to be taken in account.

The second problem is that if the propeller disc were at a given angle of attack towards the undisturbed flow then the axial component of the resultant flow velocity decreases the angle of attack of the propeller blade elements, which reduces the actual induced speed. So if formula (7) is used to calculate propeller thrust in translational flight the abovementioned phenomena should be considered. As we can see from Table 1 with the airspeed increased the resultant speed V is increased and so the thrust is increased, however the reverse flow area is also increased and if the propeller is at some angle of attack (negative for forward flight) then the induced velocity should be decreased.

We can take advantage of the blade element theory in order to take in account the abovementioned problems. The propeller thrust and power are usually defined in terms of thrust and power coefficients – respectively C_T and C_P:

$$T = C_T \rho n^2 D^4 \\ P = C_P \rho n^3 D^5. \tag{10}$$

If we apply the first assumption that the effective diameter of the propeller is reduced due to reverse flow region with diameter μR and bear in mind that the momentum theory assumes even distribution of the induced velocity across the propeller disc then the following is true:

$$\frac{T\prime}{T} = \left(\frac{D-\mu R}{D}\right)^4 = \left(1-\frac{\mu}{2}\right)^4 \equiv k_\mu, \tag{11}$$

where T' is the thrust of the propeller due to reverse flow region. In other words the thrust in eq. (7) has to be corrected with coefficient k_μ equal to the ratio in eq. (11).

The second problem – the reduction of the induced velocity with the increase of axial component of the resultant speed is connected with the blade element angle of attack or with the thrust coefficient. If we assume that due to increased axial velocity the initial blade angle of attack at hover mode (φ_H) is decreased by $\Delta\varphi$ then:

$$\frac{T\prime}{T} = \frac{C_T\prime}{C_T} = \frac{C_{T\varphi}\varphi\prime}{C_{T\varphi}\varphi_H} = \frac{\varphi_H - \Delta\varphi}{\varphi_H} = 1 - \frac{\Delta\varphi}{\varphi_H}, \quad (12)$$

where $C_{T\varphi}$ is the derivative $\frac{\partial C_T}{\partial \varphi}$, which for a certain airfoil is accepted to be a constant.

The decrease of the blade angle of attack can be found if the velocity triangle for a blade element is viewed:

$$\tan\Delta\varphi \approx \Delta\varphi = \frac{\Delta V_i}{\omega R} = \frac{V_\infty \sin A}{\omega R} = \mu \tan A. \quad (13)$$

Finally the ratio in eq. (12) will take the form:

$$\frac{T\prime}{T} = 1 - \frac{\Delta\varphi}{\varphi_H} = 1 - \frac{\mu \tan A}{\varphi_H} \equiv k_A. \quad (14)$$

In other words provided we use the induced speed in hover mode to calculate the thrust in translation flight the formula in eq. (7) has to be corrected with k_μ *and* k_A and the corrected thrust will be:

$$T' = 2k_\mu k_A \rho A V V_i \quad (15)$$

Regarding to the propeller power from Table 1 it is obvious that the required electric power for all flight regimes including hover is almost identical so with some precision the power of the propeller in translational flight could be considered approximate to the power at hover mode for a given rotational speed (Fig. 7).

4. Results and discussion

To asses the accuracy of the hereby methodology, propeller characteristics can be evaluated using formula (15) with the corrections (11) and (14). Figure 6 shows experimental data for the thrust from Table 1 (solid lines) compared to momentum theory results, corrected with k_μ (dashed lines). The angle of attack of the propeller is zero and the k_A coefficient is zero respectively. It can be seen (Fig. 6) that with the increase of the flow velocity the thrust generated by the propeller is increased due to the increased mass airflow through the propeller disc. If uncorrected the predictions for the thrust are too high. In this case this is a satisfactory result.

Figure 7 shows the power of the propeller – both experimental (electric) and theoretical – according to momentum theory, calculated from the induced speeds, corrected with k_μ. The measured electric power (solid lines) is far bigger than the theoretical, which gives the time rate of change of the mechanical work exerted to the flow. In fact the ratio of the mechanical power to electric power gives the efficiency of the propulsion (propeller, electric motor and ESC) that is shown with the dotted line in Fig.7. In that manner the described methodology is capable to predict the overall efficiency of the propulsion.

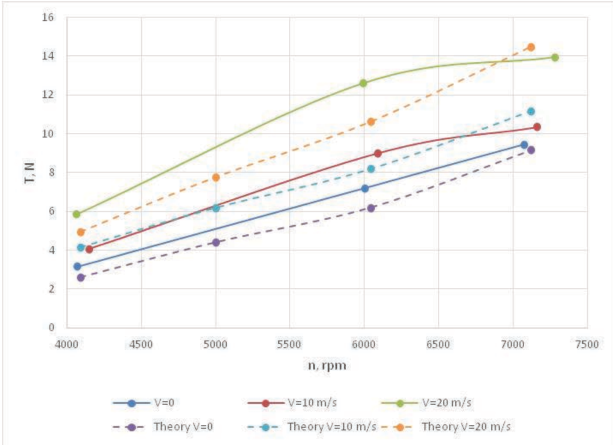

Fig.6. *Thrust vs RPM & Airspeed*

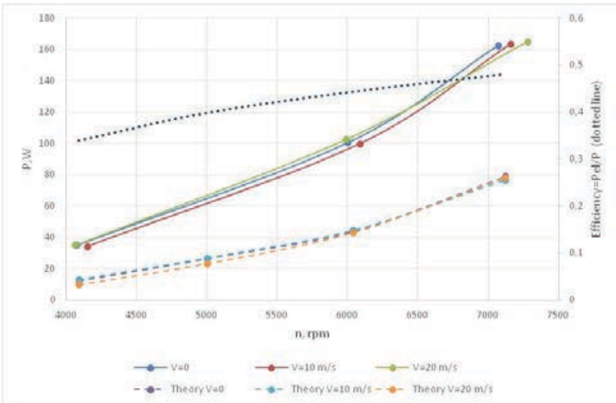

Fig.7. *Power vs RPM & Airspeed*

Once again Fig. 7 shows that the power consumed by the propeller at different flight modes is approximately the same.

So far the angle of attack of the propeller disk was considered to be zero. In order to check the assumption made in derivation of (14) additional experimental and theoretical research is done. Propeller characteristics are measured at angle of attack $A = -25\ deg$ (forward flight). The experimental data are compared to theoretical (Table 2). The corrected thrust, calculated using eq. (15) is shown in the last row, compared to the experimental in the first row. Here the hover induced speed are used (V_{ih}) to calculate the thrust. This is also plotted in Fig. 8. The results show acceptable convergence and accuracy.

Table 2. *Propeller experimental data at A=-25 deg*

A=-25 deg \ n, rpm		4000	5000	6000	7100
V=10	T_{exp}, N	2,70	4,05	4,95	8,55
	μ	0,18	0,14	0,12	0,10
	k_μ	0,69	0,74	0,78	0,81
	k_A	0,57	0,65	0,71	0,76
	$V_{ih}, m/s$	4,58	5,97	7,08	8,61
	T, N	6,22	8,59	10,71	14,03
	T', N	2,43	4,17	5,96	8,75

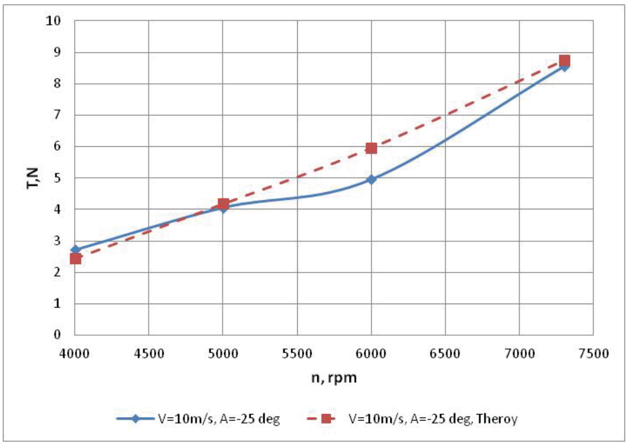

Fig. 8. Propeller thrust at V=10 m/s & A=-25 deg

5. Conclusion

The present paper deals with a methodology for determination of a multirotor drone propeller characteristics at different flight modes. Specially derived coefficients are proposed to correct the results from momentum theory. Theoretical results are compared with experiment.

LITERATURE

1. Leishman J. Gordon (2006), *Principles of Helicopter Aerodynamics*, 826 p., Cambridge Aerospace Series, USA.
2. W.Z. Stepniezki, C.N. Keys (1979). *Rotary-Wing Aerodynamics, Vol.1*, 380 p., NASA, Philadelphia, USA.
3. Homiao Huang, Gabriel Hofmann et al. (2008), *Aerodynamics and Control of Autonomous Quadrotor Helicopters in Aggressive Maneuvering,* Stanford, California

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СИСТЕМА ЗА ИЗМЕРВАНЕ НА НАЛЯГАНЕТО ПРИ РАБОТА И ПОСТРОЯВАНЕ НА ИНДИКАТОРНАТА ДИАГРАМА НА ДИЗЕЛОВ ДВИГАТЕЛ

КРАСИМИР АМБАРЕВ, ВЪЛЬО НИКОЛОВ

Резюме: *В настоящата статия е описана системата за индициране на дизелов двигател чрез измерване на налягането при неговата работа и компютърната обработка на получените резултати със създения софтуер в средата MATLAB. Представени са основните технически данни на всеки един от компонентите на системата и са дадени връзките между тях. Извършени са измервания на налягането при работа на дизеловия двигател и са получени индикаторни диаграми.*

Ключови думи: *дизелови двигатели, измерване на налягане, индикаторна диагарама*

SYSTEM FOR MEASURING THE PRESSURE AT WORK AND CONSTRUCTION OF INDICATOR DIAGRAM OF DIESEL ENGINE

KRASIMIR AMBAREV, VALYO NIKOLOV

Abstract: *This article describes the system for indicating of diesel engine by measuring the pressure in its operation and computing the results obtained with the created software in the MATLAB environment. The basic technical data of each of the components of the system are presented and the connections between them are given. Diesel engine pressure measurements have been made and indicator diagrams are obtained.*

Key words: *diesel engines, pressure measurement, indicator diagrams*

1. Основни положения

Въз основа на измерването на налягането на работното вещество по време на работа на ДВГ се построява така наречената индикаторна диаграма. От получените данни за налягането в цилиндъра могат да се изчислят аналитично мощностните показатели на изследвания двигател при различни режими на работа, както и да се анализира горивния процес в двигателя, да се изследват различни явления, свързани с етапите от протичане на горивния процес в ДВГ [2], да се провери адекватността на математични модели [3] и др.

2. Система за индициране на ДВГ

Системата за измерване налягането на работното вещество се състои от сензор за налягане *AVL QC43D*, едноканален усилвател и преобразовател *AVL FI PIEZO*, многоканален аналогово-цифров преобразовател (АЦП) *NI 6343*, софтуер за запис и визуализация на получените резултати, разработен в средата *MATLAB*.

Фиг. 1. *Общ вид на сензора за налягане QC43D*

Сензорът за налягане *QC43D* (фиг. 1) е производство на фирмата *AVL* и е от категорията сензори, предназначени за развойна дейност в

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областта на ДВГ [4]. Присъединяването на *QC43D* към цилиндровата глава на изследвания ДВГ се извършва посредством резбово съединение M14x1,25.

За защита на кварцовия елемент на *QC43D* от прегряване е необходимо да се охлажда чрез принудителна циркулация на охлаждащата течност. Това гарантира дълъг експлоатационен срок и висока достоверност на получените резултати.

Някои основни данни от техническата спецификация на сензора за налягане *QC43D* са представени в таблица 1.

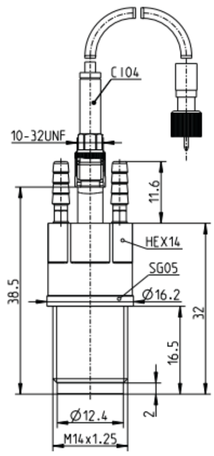
Таблица 1. *Техническа спецификация на AVL QC43D*

Диапазон на измерване	0...200 bar
Максимално допустимо работно налягане	250 bar
Чувствителност	71,32 pC/bar
Линейност	≤ ±0.2 %
Калибрирани диапазони на измерване	0 ... 80 bar 0 ... 140 bar 0 ... 200 bar
Собствена честота	50 kHz
Размер на присъединителната резба	M14 x 1.25
Присъединителен куплунг	10-32 UNF Micro-Dot
Дебит на охлаждащата течност	≥ 20 l/h
Маса	34 гр. (без кабел)
Необходим въртящ момент за затягане на сензора	20 Nm

Основните геометрични размери на сензора за налягане *AVL QC43D,* които трябва да се вземат в предвид при монтажа му са показани на фиг. 2.

Другият елемент от системата - *AVL FI PIEZO* (фиг. 3) в конкретния вариант *2P2E* включва едноканален усилвател и преобразовател на електрическия сигнал [4].

AVL FI PIEZO е снабден с течнокристален дисплей, на който се визуализира налягането в цилиндъра във функция от ъгъла на завъртане на коляновия вал за един работен цикъл или по-малък интервал (фиг.5), дефиниран предварително, както и други параметри.



Фиг. 2. *Размери на сензора за налягане AVL QC43D*

Възможността за динамична *drift* компенсация позволява безпроблемна работа с дължина на кабела от сензора до устройството до 20 m. От друга страна, здравата конструкция на устройството позволява монтирането му в непосредствена близост до изследвания двигател. Устройството може да се използва, както за стендови измервания, така и за измервания в пътни условия.

Фиг. 3. *Общ вид на AVL FI PIEZO*

Чрез ъпгрейд на фърмуера на *AVL FI PIEZO*, предлагащ се като опция е възможно отчитане на максималното налягане в цилиндъра при процеса горене. Тъка отчетената стойност се подава към *CAN* изхода на устройството.

Определянето на коефициента на усилване A става по формула (1).

$$A \le \frac{8000}{S.p_n} \qquad (1)$$

където S е чувствителността на сензора, *pC/bar*

p_n - максимална стойност на измервания сигнал, *bar*.

Формула (1) е в сила при *0V* офсет. При избор на *8V* офсет, константата 8000 във формула (1) се заменя с 16000.

Коефициентът на преобразуване от електрически заряд в напрежение *SCF* се изчислява по формула (2)

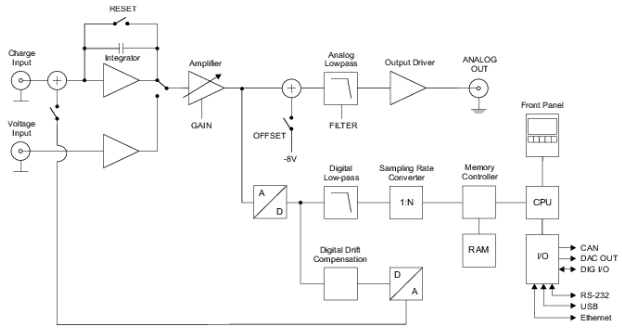
$$SCF \leq \frac{800}{S.A}, \frac{bar}{V}. \qquad (2)$$

Основни данни от техническата спецификация на *AVL FI PIEZO* са представени в таблица 2.

Таблица 2. *Техническа спецификация на AVL FI PIEZO*

Маса	1,6 kg
Размери	86x109x271 mm
Захранване	9.5 V ... 36 VDC или 100 ... 240 VAC чрез AC адаптер
Консумирана мощност	10 W (при работа) 20 W (при пускане)
Температурен диапазон на работа	-10°C...+60°C
SID (Идентификация на сензора)	не
Аналогови входове (ел. заряд/напрежение)	1 брой
Диапазон на измерване на електрически заряд	0 ... 14,400 pC
„Low-pass“ филтър	2 kHz, 5 kHz, 10 kHz, 20 kHz, 50 kHz или 100 kHz
Диапазон на измерване на напрежение	-10 ... +10 V
Резолюция на АЦП	12 bits
Drift компенсация	постоянна или циклична
Цифрово-аналогови изхода	1 брой
Аналоговите изходи на АЦП	-10 ... +10 V, BNC куплунг

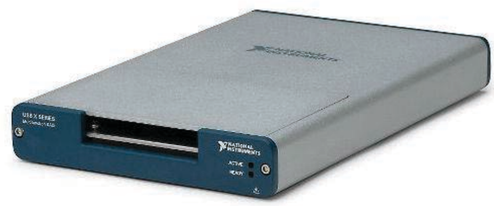
Настройките на *AVL FI PIEZO* се правят от компютър, свързан чрез *USB* интерфейс и инсталирано приложение *IndiSignal* или посредством бутоните и дисплея от лицевия панел на устройството.



Фиг. 4. *Блокова схема на AVL FI PIEZO*

Аналоговият сигнал от измерването на изхода на *AVL FI PIEZO* се подава към един от диференциалните входове на АЦП на мулти-функционалното устройство *NI 6343*, производство на фирмата *National Instruments* [7].

Връзката между *NI 6343* (фиг. 5) и компютъра се осъществява посредство USB интерфейс.



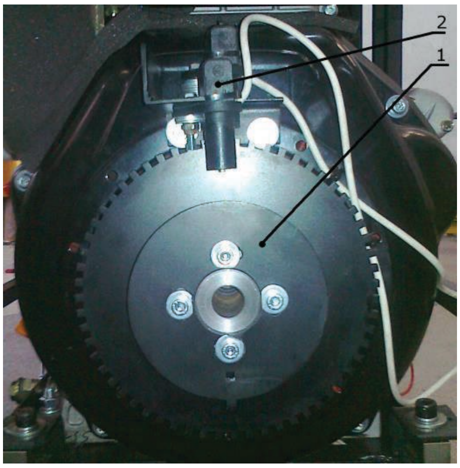
Фиг. 5. *Общ вид на NI 6343*

Основни данни от техническата спецификация на *NI 6343* са представени в таблица 3.

Таблица 3. *Спецификация на NI 6343*

Аналогови входа	32 еденични (16 броя диференциални)
Резолюция на АЦП	16 bits
Скорост на измерване	500 kS/s
Резолюция на измерване	10 ns
Диапазон на измерване	±0.2 V, ±1 V, ±5 V, ±10 V
Максимално вх. напрежение	±11 V

Елемент от системата е и закрепения към края на коляновия вал на изследвания ДВГ диск с един зъб, който при работа на двигателя генерира импулси в намиращия се в близост до диска индуктивен сензор (фиг. 6). Тези синхронизиращи импулси се подават към друг от аналоговите входове на *NI 6343* и служат за синхронизиране не измерванията по горна мъртва точка (ГМТ).



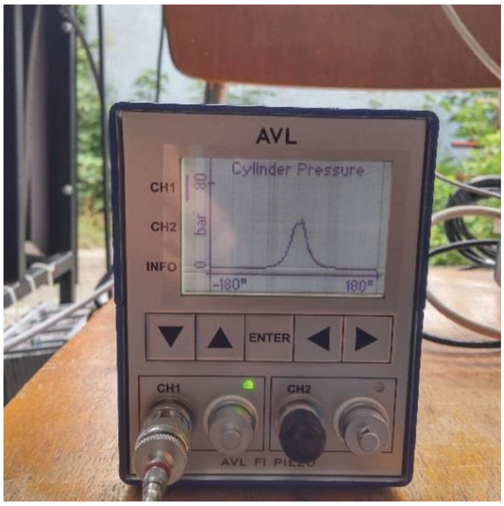
Фиг. 6. *Разположение на индуктивния сензор за ГМТ 1 – диск с един зъб; 2 – индуктивен сензор.*

Индуктивният сензор е свързани към *NI 6343* посредством високочестотен екраниран проводник - тип *RG58U* (с вълново съпротивление 50 Ω), което гарантира минимални загуби при преноса на високочестотния електрическия сигнал, както и минимални смущения в измервания сигнал. Техническите данни за индуктивния сензор са показани в таблица 4.

Таблица 4. *Техническа спецификация на индуктивния сензор*

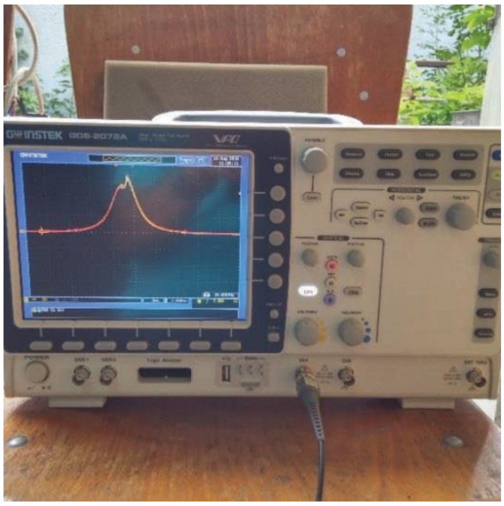
Производител	Автоприбор
Модел	191.3847
Минимална амплитуда на променливото напрежение при честота на въртене на вала 30±5 min-1 и разстояние от диска 1,4±0,05 mm	≤ 0,28 V
Максимална амплитуда на променливото напрежение при честота на въртене на вала 7000±30 min-1 и разстояние от диска 1,4±0,05 mm	≤ 250 V

Създадената програма в приложението *Simulink* в средата *MATLAB* [6] позволява визуализиране в реално време и възможност за съхраняване на данните от измерванията във файлове с разширение "mat". Чрез създадения скрипт в *MATLAB* е възможна обработка и визуализация на резултатите от измерването на по-късен етап.



Фиг. 7. *Визуализиране в реално време на налягането на работното вещество на течнокристалния дисплей на AVL FI PIEZO*

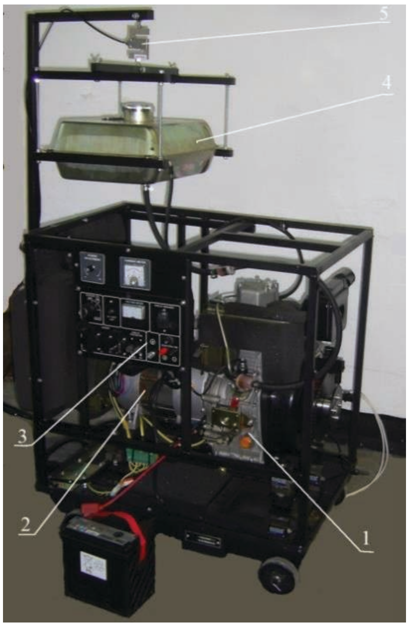
За допълнителна възможност за визуализация в реално време на сигнала на изхода на *AVL FI PIEZO* при измерванията служи свързан към аналоговия му изход цифров осцилоскоп (фиг. 8).



Фиг. 8. *Визуализиране на налягането на работното вещество за работен цикъл на цифров осцилоскоп*

3. Работа на системата

За проверка на работоспособността, системата за индициране е монтирана на експериментална уредба [1], състояща се от дизелов двигател и натоварващо устройство - генератор за променлив ток (фиг. 9). Стендът е разработен на базата на дизелов агрегат за променлив ток, производство на фирмата *KIPOR (Китай)* - модел *„KDE 6500T“* [5].



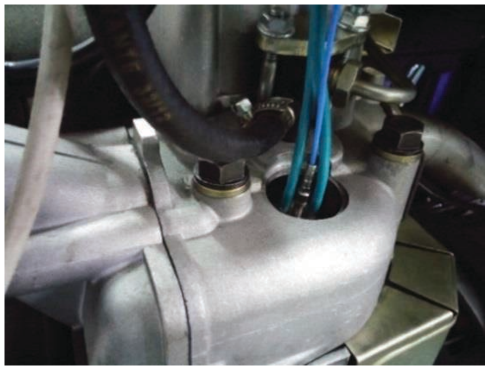
Фиг. 9. *Общ вид на експерименталната уредба*
1 - дизелов двигател; 2 - генератор;
3 - контролен панел; 4 – горивен резервоар;
5 – динамометър

За натоварване на електрическия генератор и свързания с него дизелов двигател се използва външен електрически товар, показан на фиг. 10. Електрическият товар представлява седем на брой нагреватели, свързани успоредно в две електрически вериги.

Фиг. 10. *Външен електрически товар*

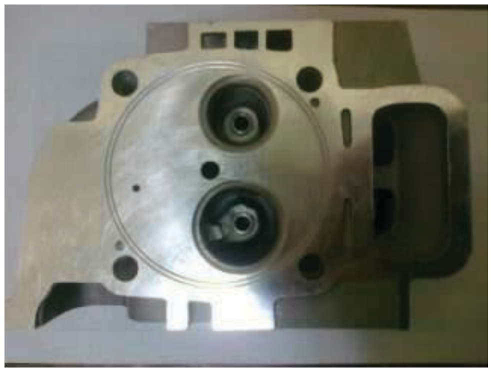
Регулирането на големината на тока през електрическия товар се осъществява чрез два регулатора на мощност. Потенциометърът на единия е разположен на контролния панел на стенда, а другият е външно разположен.

Сензорът за налягане *AVL QC43D* е монтиран на цилиндровата глава на двигателя в специално изработен за целта отвор (фиг. 11).



Фиг. 11. *Разположение на сензора за налягане AVL QC43D*

Местоположението на отвора към сензора за налягане е показано на фиг. 12.



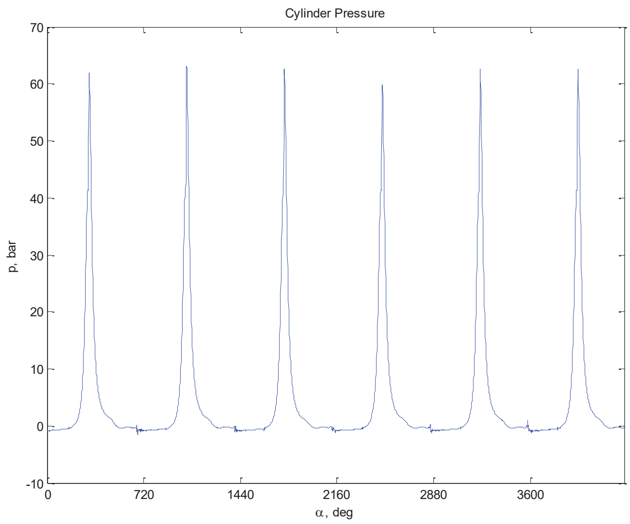
Фиг. 12. *Разположение на отвора в цилиндровата глава към сензора за налягане*

Снемането на индикаторните диаграми при този стенд се осъществява при стабилизирана честота на въртене $n=3000\ min^{-1}$, тъй като двигателят задвижва електрически генератор за променлив ток с честота на генерираното напрежение $f = 50\ Hz$.

За осигуряване на сравнимост на получените резултати при различна стойност на електрическия товар е необходимо индикаторните диаграми да се снемат при:

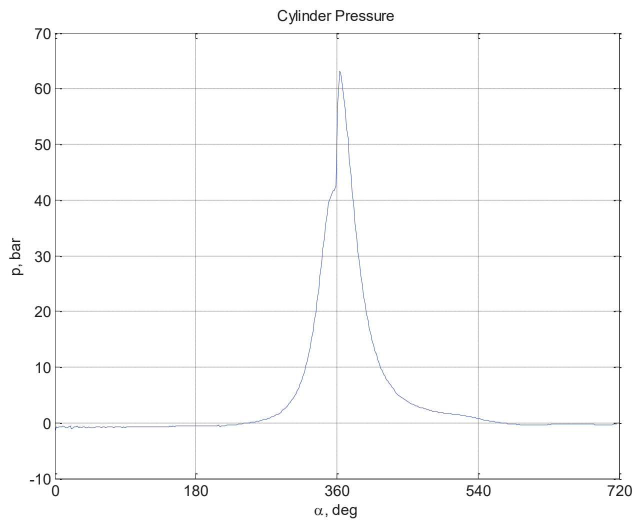
- еднаква регулировка (според предписанията на фирмата производител) на: газоразпределителния механизъм (хлабини в кинематичната верига) и горивната уредба на двигателя (началния ъгъл на изпреварване на впръскването и налягане на впръскване $p_{вп}$);
- еднакво топлинно състояние (температура на маслото в картера $T_м$) на двигателя;
- еднакви атмосферни условия (снемане на индикаторните диаграми в един ден).

Визуализация на резултатите от извършените измервания при големина на електрическия ток през товара *20A* за шест поредни измервания са представени на фиг. 13.



Фиг. 13. *Индикаторна диаграма на двигателя при пълно натоварване за шест последователни работни цикъла*

Усреднена стойност за налягането в цилиндъра на двигателя за 20 последователни работни цикъла при работа на двигателя са представени на фиг. 14.



Фиг. 14. *Индикаторна диаграма на двигателя при пълно натоварване за един работен цикъл*

Създадените програми позволяват избор на броя работни цикли при работа на двигателя на установен режим, за които се извършва измерването, записването и усредняване на стойностите на налягането в работното пространство и построяване на индикаторната диаграма.

4. Изводи

Представената система за индициране на ДВГ, изградена на основата на система за измерване на налягането в цилиндъра на двигателя на фирмата *AVL*, чийто възможности са разширени с опции за визуализация на резултатите от измерванията на екрана на компютър, възможност за запис на резултатите от измерванията и последваща тяхна обработка. Системата позволява изследване на бутални двигатели с вътрешно горене чрез снемане на индикаторна диаграма и автоматизирана обработка на резултатите от измерването. Представената система може да се използва, както за научни изследвания, така и при обучението на докторанти и студенти.

ЛИТЕРАТУРА

1. Амбарев К., Николов В., Димитров Е., Панчев С., Ташев А. (2014). *Уредба за експериментално изследване на дизелов двигател.* Научно списание "Механика на машините", год. XXII, кн. 2, бр. 106, стр. 8-12.
2. Zaccardi, J., Duval, L., and Pagot, A. (2009). *Development of Specific Tools for Analysis and Quantification of Pre-ignition in a Boosted SI Engine.* SAE Int. J. Engines 2(1):1587-1600, 2009, doi:10.4271/2009-01-1795.
3. Yousefi A., Birouk M. (2016). *Numerical study of the performance and emissions characteristics of natural gas/diesel dual-fuel engine using direct and indirect injection systems.* Proceedings of Combustion Institute - Canadian Section Spring Technical Meeting University of Waterloo, May 10-12.
4. https://www.avl.com
5. https://www.kipor.com
6. https://www.mathworks.com
7. http://www.ni.com/en-rs.html

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ПОКАЗАТЕЛИ ОЦЕНЯВАЩИ ГАЗООБМЕННИТЕ ПРОЦЕСИ ПРИ ДВИГАТЕЛИТЕ С ВЪТРЕШНО ГОРЕНЕ

РАДОСЛАВ КОСТОВ

Резюме: *В статията са анализирани, показателите оценяващи газообмения процес, по които се осъществява усъвършенстването на газообмена при двигатели с вътрешно горене с газотурбинно пълнене.*

Ключови думи: *двигател с вътрешно горене, газообмен, газотурбинно пълнене*

INDICATORS EVALUATING GAS EXCHANGE PROCESS IN COMBUSTION ENGINES

RADOSLAV KOSTOV

Abstract: *The article analyzes the main physical principles and indicator of gaseous exchange processes and leads to the improvement of the gas exchanges in the combustion engines turbocharged.*

Key words: *combustion engines, gas exchange, turbocharged*

1. Основни положения

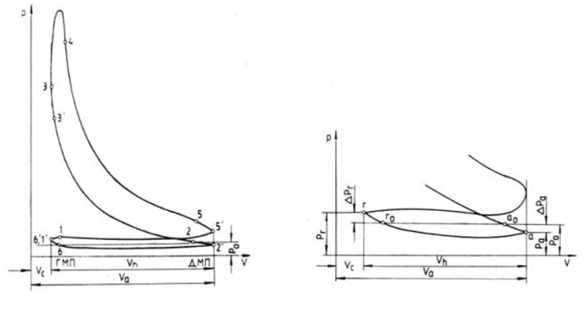
Основните критерии за подобряването на газообменните процеси са качеството на напълване и очистване на цилиндрите. Мощността на двигателя при равни други условия е толкова по-голяма, колкото количеството на прясно работно вещество, намиращо се в цилиндъра след завършване на напълването е по-голямо. Количеството на прясно работно вещество зависи от подобряването на очистването на цилиндъра от продуктите на горене. Част от обема на цилиндъра се заема от отработилите газове, които не са успели да напусната цилиндъра.

2. Цел на анализа

Целта на настоящата статия е да се разгледат показателите, по които да се оценят показателите на газообменните процеси при двигателите с вътрешно горене с газотурбинно пълнене.

3. Същност на проблема

На фиг. 1 е представена индикаторна диаграма на двигател с вътрешно горене и са отбелязани фазите на газоразпределение.



Фиг. 1. *Индикаторна диаграма на четиритактов двигател*

От представената индикаторна диаграма за начало на процеса изпускане се приема точката 5, а краят на процеса е точката 6. Началото на процесът пълнене е в точка 1, а края – в 2. Процеса на припокриване на пълнителния и изпускателния клапан обхваща 1-6.

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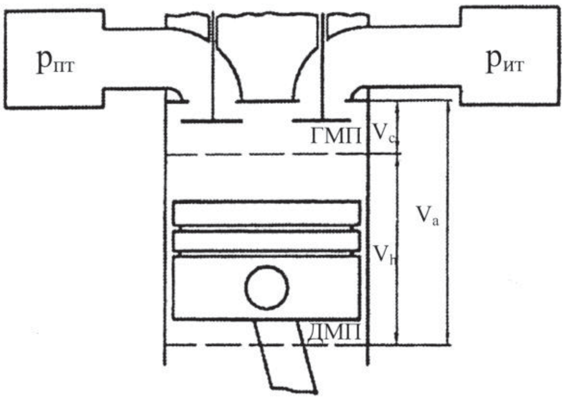
На фиг. 2 е изобразена опростена схема на газообменните процеси на четиритактов двигател.

При четиритактовите двигатели с вътрешно горене без свръхпълнене поради съпротивленията в пълнителния тракт (разяснения за символите) $p_{пт} \geq p_{ит}$.



Фиг. 2. *Схема на газообменните процеси в четиритактов двигател*

Очистването на цилиндъра се оценява чрез коефициента на остатъчните газове (γ_r) – отношението на количеството киломолове остатъчни газове M_r към количеството киломолове прясно работно вещество M_1:

$$\gamma_r = \frac{M_r}{M_1}. \tag{1}$$

Ако количеството на остатъчните газове и прясното работно вещество се изразят в килограми то:

$$\gamma_r = \frac{G_r m_1}{G_1 m_r}, \tag{2}$$

където: m_1, m_r са съответните молекулни маси;

G_r, G_1 – прясното работно вещество, действително постъпило в цилиндъра с параметри т.а – налягане p_a и температура T_a, т.е с плътност ρ_a.

Действителното количество прясно работно вещество, което постъпва в цилиндъра се отличава значително от теоретичното, защото налягането в края на напълването при всички четиритактови двигатели е по-малко от налягането в пълнителния тръбопровод p_a, в следствие на наличието на хидравлични загуби в пълнителния тракт. Температурата на прясното работно вещество в цилиндъра в края на пълненето е по-висока T_a, тъй като по време на напълването се загрява от стените на цилиндъра, чиято температура е по-висока от T_a.

Ако при четиритактовите двигатели се пренебрегне продухването на горивната камера поради незначително припокриване на клапаните около горно мъртво положение (ГМП), може да се приеме, че в края на процеса изпускане обемът на остатъчните газове $V_г$ при налягане p_r и температура T_r, е равен по обем на горивната камера V_c. Тогава от характеристичното уравнение за състояние на газовете се получава:

$$M_1 = \frac{p_0 V_0}{R T_o}; \tag{3}$$

$$M_1 = \frac{p_r V_г}{R T_r} = \frac{p_r V_c}{R T_r}. \tag{4}$$

Като се вземе под внимание определянето на коефициента на пълнене $V_0 = V_h \eta_v$, както и това, че $V_h = V_c(\varepsilon - 1)$ се получава формулата:

$$\gamma_r = \frac{1}{\eta_v(\varepsilon - 1)} \cdot \frac{p_r}{p_0} \cdot \frac{T_0}{T_r}. \tag{5}$$

Разсъждавайки върху получената формула може да се изкаже следното:

- с увеличаването на степента на сгъстяване, обемът на горивната камера се намалява и при други условия намалява и количеството на остатъчните газове - γ_r;
- с повишаване на налягането на остатъчните газове се увеличава и тяхната плътност, а следователно и количеството им, поради което γ_r се увеличава;
- налягането на остатъчните газове p_r нараства при увеличаване на съпротивлението в изпускателната система и на честотата на въртене на кояновия вал;
- при увеличаване на температурата на остатъчните газове T_r намалява тяхната плътност, а следователно и количеството им, поради което γ_r намалява;
- температурата на остатъчните газове зависи от степента на сгъстяване ε и от работния режим на двигателя. Като се увеличава ε, увеличава се и степента на разширяване на продуктите на горене, поради което T_r намалява. С увеличаване на натоварването и честотата на въртене на двигателя се повишава температурата на нагретите повърхнини, до които газовете в цилиндъра се допират, и температурата T_r се повишава.

При бензиновите двигатели, където регулирането е количествено, при намаляване на натоварването и има наличие на дроселна клапа - се притваря, количеството прясно работно вещество M_1 намалява, поради което γ_r се увеличава. При дизеловите двигатели регулирането е качествено и при намаляване на натоварването M_1 се увеличава, в резултат на което γ_r намалява. При двигателите със свръхпълнене с увеличаване на налягането p_k на прясното работно вещество γ_r се намалява.

При двутактовите двигатели коефициентът на остатъчните газове зависи главно от системата на продухване и честотата на въртене на коляновия вал.

Коефициентът на остатъчните газове е в следните граници:

- за четиритактови двигатели:

бензинови без принудително пълнене

$\gamma_r = 0{,}04 - 0{,}08$

дизелови без принудително пълнене

$\gamma_r = 0{,}02 - 0{,}06$

бензинови и дизелови с свръхпълнене

$\gamma_r = 0{,}02 - 0{,}04$

- за двутактови двигатели:

с картерно продухване

$\gamma_r = 0{,}25 - 0{,}40$

с правотоково клапанно продухване

$\gamma_r = 0{,}06 - 0{,}15$

с правотоково продухване през прорези

$\gamma_r = 0{,}03 - 0{,}07$

с възвратно продухване през прорези

$\gamma_r = 0{,}08 - 0{,}30$

В Таблица 1 са представени ориентировъчни зависимости на основните параметри на газообменния процес, определени експериментално при работа на двигателя на номинален режим [3].

Таблица 1

Показател	Четиритактов двигател с вътрешно горене (ДВГ)		Двутактов ДВГ с правотоково продухване през прорези
	Бензинов	Дизелов	
Коефициент на остатъчни газове	0,04…0,08	0,03…0,06	0,03…0,10
Налягане на остатъчните газове	0,105…0,120	0,105…0,120	0,105…0,120
Температура на остатъчните газове	900…1000	600…900	600…900
Коефициент на пълнене	0,75…0,85	0,8…0,9	0,75…0,85*
Налягане в края на пълненето	0,085…0,09	0,085…0,095	(0,85…0,105)$p_к$
Подгряване на прясното работно вещество	0…25	20…40	5…10
Температура в края на пълненето	320…380	310…350	320…400

* - отнесено към пълния обем на цилиндъра

Степента на запълване на цилиндъра с прясно работно вещество се характеризира с коефициента на пълнене η_v. При двигатели без свръхпълнене представлява отношението на количеството прясно работно вещество $M_1(G_1)$ (в kmol или kg), действително постъпило в цилиндъра (с параметри на т. a – налягане p_a и температура T_a, т.е с плътност ρ_a, към теоретичното количество $M_t(G_t)$, което може да запълни работния обем на цилиндъра, при условие е има параметрите на околната среда (налягане p_0 и температура T_0, и плътност ρ_0), т.е.

$$\eta_v = \frac{M_1}{M_t} = \frac{G_1}{G_t} = \frac{G_1}{V_h \rho_0}. \tag{6}$$

Количеството от прясното работно вещество, постъпило в цилиндъра през пълнителния клапан по време на продухването не остава цялото в цилиндъра. Част от него изтича през изпускателния клапан в изпускателния тръбопровод и не участва в осъществяването на работния цикъл на буталния двигател.

Коефициента на пълнен η_v може да се определи по два начина:

1. Определяне на η_v от уравнението за баланса на работното вещество в края на пълненето – т. a.

$$\eta_v = \frac{\varepsilon}{\varepsilon - 1} . \frac{p_a}{p_0} . \left(\frac{T_0}{T_0 + \Delta T + \gamma_r . T_r} \right) \text{ – без свръхпълнене} \tag{7}$$

и

2. Определянето на η_v от уравнението за баланса на топлината в края на пълненето

$$\eta_v = \frac{T_0}{T_0 + \Delta T} . \frac{1}{\varepsilon - 1} . \frac{1}{p_0} . (\varepsilon . p_a - p_r) \text{ – без свръхпълнене} \tag{8}$$

Отношението на количеството въздух $M_k(G_k)$ постъпило в цилиндъра по време на продухването и напълването, към количеството прясно работно вещество $M_1(G_1)$, се нарича коефициент на продухване - $\varphi_п$. Той отчита изменението на количеството остатъчни газове от забавянето на затваряне на изпускателния клапан:

$$\varphi_п = \frac{M_k}{M_1} = \frac{G_k}{G_1}. \tag{9}$$

Реципрочната стойност на коефициента на продухване се нарича коефициент на използване на продухвания въздух:

$$\eta_и = \frac{1}{\varphi_п} = \frac{M_1}{M_k} = \frac{G_1}{G_k}. \tag{10}$$

Този коефициент определя частта въздух останал в цилиндъра от цялото количество постъпило в цилиндъра по време на газообмена.

Коефициента на продухване се изменя в граници $\varphi_{п} = 0,8 \dots 1$ (при идеално продухване $\varphi_{п} = 0$), т.е. в цилиндъра няма остатъчни газове.

Максималните стойности на коефициента на пълнене се определят при пълно натоварване на четиритактовите двигатели без свръхпълнене (при честота на въртене, при която се постига максимален въртящ момент) се намират в следните граници:

- за бензинови двигатели $\eta_v = 0,75 \dots 0,90$
- за дизелови двигатели $\eta_v = 0,85 \dots 0,95$.

Факторите, които оказват влияние върху коефициента на пълнене са:

1. Влияние на степента на подгряване на прясното работно вещество и средната му скорост в проходното сечение на пълнителния клапан;
2. Влияние на фазите на газоразпределение;
3. Влияние на режимите на работа на двигателя;
4. Степен на сгъстяване;
5. Налягане в края на пълненето;
6. Продухване на горивната камера;
7. Температура на остатъчните газове;
8. Коефициент на остатъчните газове;
9. Загряване на прясното работно вещество.

Коефициент на въздушно отношение е отношението на разхода на въздух на двигателя към разхода на въздух, теоретично необходим за пълното изгаряне на горивото

$$\alpha = \frac{G_в}{l_0 G_h}, \tag{11}$$

където: $G_в$ е часов разход на въздух, kg/h;

G_h – часов разход на гориво, kg/h;

l_0 – количеството въздух, теоретично необходимо за пълното изгаряне на един килограм гориво, kg/kg.

4. Заключение

Оценката на газообмена, направена само по качеството на очистването и напълването е недостатъчна. Протичането на газообмена е неразривно свързано и с други процеси, съставящи действителния цикъл на двигателите с вътрешно горене.

Някой от коефициентите, характеризиращи газообмена са директно свързани с температурните напрежения в такива детайли на двигателя като изпускателни клапани, бутало и др. При избора на параметри и показатели за протичане на газообмена при съвременните високооборотни двигатели е необходимо да се отчитат и факторите на надеждност и дълговечност на двигателите.

ЛИТЕРАТУРА

1. Бояджиев К.Г. и др. (1990), *Автотракторни двигатели*, Техника, София;
2. Орлин А.С. и др. (1971), *Теория робочих процессов поршневых и комбинировоных двигателей*, Москва;
3. Орлин А.С. и др. (1973). *Системы поршневых и комбинировонных двигателей*, Москва.
4. Луканин В.Н. и др. (2007), *Двигатели внутреннего сгорания* – кн.1, Москва.

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ВЛИЯНИЕ НА КОНСТРУКТИВНИТЕ И ЕКСПЛОАТАЦИОННИ ФАКТОРИ НА ГАЗООБМЕННА ПРИ ДВИГАТЕЛИТЕ С ГАЗОТУРБИННО ПЪЛНЕНЕ

РАДОСЛАВ КОСТОВ

Резюме: *В настоящата статията са анализирани, конструктивните и експлоатационни фактори на газообмена при двигателите със свръхпълнене, които се явяват решаващи за повишаването на мощностите и икономичните показатели на двигателите с вътрешно горене с газотурбинно пълнене.*

Ключови думи: *двигател с вътрешно горене, газообмен, газотурбинно пълнене*

INDICATORS EVALUATING GAS EXCHANGE PROCESS IN COMBUSTION ENGINES

RADOSLAV KOSTOV

Abstract: *In this article have been analyzed, the design and operational factors of the gas exchange in the engine with turbocharging, which appear crucial for increasing the capacity and economical performance in the combustion engines turbocharged.*

Key words: *combustion engines, gas exchange, turbocharged*

1. Основни положения

Конструктивните и експлоатационни фактори на газообмена, характеризиращи газа при постъпването им в цилиндъра и при напускането му от него, влияят на газообменните процеси. Решаващ фактор за повишаване на мощностните и икономическите показатели на двигателя е доброто конструиране и експлоатация на двигателя. Това определя газообмена, като обект на непрекъснати изследвания. Чрез принудителното пълнене съществено се увеличава ефективната мощност на двигателя, повишава се горивната икономичност и се намалява отделянето на токсични вещества в отработилите газове. В същото време няма съществено увеличаване на масата и габаритите на двигателя.

2. Цел на анализа

Да се разгледат изискванията, които се предявяват към пълнителните и изпускателните тръбопроводи. Влиянието на фазите на газорезпределение оказващи влияние не само към показателите на очистване на напълване на цилиндрите. Охлаждането на въздуха след компресора и влиянието на някои експлоатационни фактори върху газообмена при двигателите газотурбинно пълнене.

3. Същност на проблема

<u>Конструктивни фактори</u>:

1. *Изисквания към пълнителните и изпускателните тръбопроводи*.

Сложността на газодинамичните процеси, протичащи в пълнителната и изпускателната система на двигателите с газотурбинно пълнене, затруднява определянето на необходимите размери на тръбопроводите само по аналитичен път. Проектирането на тези системи се извършва основно на базата на експериментални изследвания.

Пълнителните тръбопроводи на четиритактовите двигатели с газотурбинно пълнене по конструкция са аналогични на

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тръбопроводите на двигателите без принудително пълнене.

При проектирането на изпускателните тръбопроводи за двигателите със свръхпълнене, трябва да се отчитат следните изисквания:

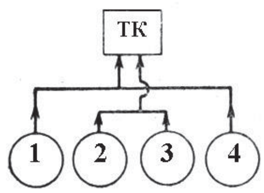
1. Загубите на топлина и кинетична енергия от отработилите газове в тръбопровода от изпускателните органи до направляващия апарат на газовата турбина, трябва да бъдат минимални;

2. Процесът на изпускане от един цилиндър на двигателя не трябва да затруднява газообмена в другите цилиндри;

3. Обемът на изпускателния тръбопровод трябва да бъде минимално допустим с цел намаляване влиянието на инертността на системата при работа на двигателя на преходни режими и за увеличаване на импулса на налягането при изпускане.

За изпълнението на тези условия, изпускателните тръбопроводи се проектират с минимална дължина без резки извивки и промени в сечението.

При използването на импулсна система на пълнене, газовете се изпускат в общ тръбопровод от не голямо число цилиндри. Изпускателния колектор се дели на части (сектори), които не са свързани помежду си. Всяка част обединява цилиндри, при които процесът на изпускане се редува без припокриване, т.е. отместени са по фаза на не по-малко от продължителността на изпускане (при четиритактовите двигатели 220° - 240° от завъртането на коляновия вал). При четирицилиндровия двигател една секция на колектора обединява два цилиндъра (фиг. 1).



Редуването на изпускателния: 1-3-4-2 или 1-2-4-3

Фиг. 1. *Схема на разпределение на изпускателен колектор при импулсно пълнене*

Фиг. 2. *Изпускателни колектори при импулсно пълнене* [5, 6]

Дефазирането е на 360°. В момента на отваряне на изпускателния клапан, налягането в секцията на колектора рязко се повишава, достига максимума и започва да пада до момента, в който започва изпускането от следващия цилиндър в същата секция. За да се намалят загубите от енергия при изтичане на газовете, обемът на секцията трябва да бъде възможно най-малък. Газовете от секцията на колектора се отвеждат към отделни канали в корпуса на турбината и така се осъществява парциално отвеждане на работното тяло в направляващия апарат на турбината.

За осъществяване на най-ефективното използване на разполагаемата енергия на отработилите газове, целесъобразно е турбокомпресора да бъде поставен в непосредствена близост с изпускателните клапани.

Размерите на изпускателния тръбопровод се избират по емпирични зависимости. Площта на напречното сечение на изпускателния тръбопровод при обединяване в една секция на колектора на две неприпокриващи се по фази изпускания, при изпълнените конструкции за четиритактов двигател с принудително пълнене е 1-1,3 от максималната площ на проходното сечение на изпускателния клапан. Площта на направляващия апарат на турбината на един тръбопровод е 0,4-0,5 от максималната площ на проходното сечение на изпускателния клапан.

Изменението на налягането в изпускателната система може да се установи ориентировъчно ако са определени конструкцията, разположението и размерите на тръбопровода и скоростта на изпускане на газовете. Средната скорост на газовете в изпускателния колектор за комбинирани двигатели е 70-100 m/s.

Изменението на налягането в изпускателния тръбопровод (MPa) е

$$\Delta p = \Sigma \Delta p_{mpi} + \Sigma \Delta p_m, \tag{1}$$

където: Δp_m е изменение на налягането, съответстващо на местните съпротивления, MPa:

$$\Delta p_m = \xi . \frac{\omega_i^2 . \rho}{2}, \tag{2}$$

ξ – коефициент на местни съпротивления за отделните участъци от тръбопровода;

ω_i – скорост в (m/s) на i-я участък;

ρ – плътност на газа, kg/m^3;

Δp_{mpi} – изменение на налягането на i-я участък на тръбопровода, MPa:

$$\Delta p_{mpi} = \lambda_i . \frac{l_i . \omega_i^2 . \rho}{d_{mpi}} \qquad (3)$$

λ_i – коефициент на триене на i-я участък;
l_i – дължина на i-я участък на тръбопровода, m;
d_{mpi} – диаметър на тръбопровода на i-я участък, m.

Обемът на изпускателния тръбопровод с газотурбинно пълнене обикновено е 0,8 – 2,0 от V_h. За да се избегнат резонансните колебания на стълба газове в тръбопровода, неговата дължина трябва да удовлетворява съотношението:

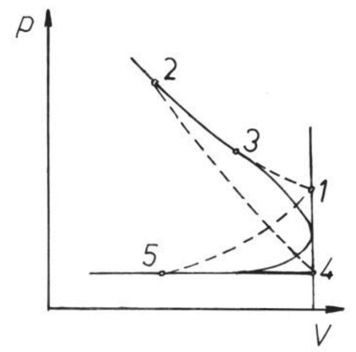
$$\frac{l.n_{\text{в}}}{a} \leq 2{,}5 \div 3{,}0, \qquad (4)$$

където: l е дължината на изпускателния тръбопровод, m;
$n_{\text{в}}$ – честота на изпускане в min;
a – скорост на звука при температура на газа в тръбопровода, m/s.

2. *Фази на газоразпределение*.

Фазите на газоразпределение оказват влияние не само на показателите на очистване и напълване на цилиндрите, но и на големината на работата, необходима за работа на газообмена, на температурата на детайлите, на условията на работа на турбината и компресора и т.н.

Предварителното отваряне на изпускателния клапан преди долно мъртво положение (ДМП), обезпечава ефективното очистване на цилиндъра по време на свободното изпускане, когато изтичането на газовете е в следствие разликата на наляганията в цилиндъра и изпускателната система. То се определя от изискването време-сечение на свободното изпускане да е достатъчно за необходимото понижаване на налягането в момента, когато буталото започва движение от ДМП към горно мъртво положение (ГМП). При правилно избран ъгъл на отваряне на изпускателния клапан (точка 3 фиг. 3) се намалява загубата на енергия, необходима за изтичането на газовете. От индикаторната диаграма на изпускането фиг. 3 се вижда, че при увеличаване на изпреварването (точка 2) загубената работа от разширението се увеличава (площ 1241). При отваряне на клапана в ДМП (точка 1) се увеличава работата за изтласкване на газовете (площ 1451). Показателите на двигателя ще бъдат оптимални, ако клапана се отваря в точка 3.



Фиг. 3. *Диаграма на изпускането на отработилите газове*

При закъсняването на затварянето на изпускателния клапан след ГМП от една страна се обезпечава достатъчно време-сечение за изтичането на газовете от цилиндъра в процеса на изпускане и от друга вследствие на това, че $\Delta p_r = p_r - p_p > 0$ количеството отработили газове може допълнително да изтече от цилиндъра, а това води до намаляване на остатъчните газове. При закъснението на затварянето на изпускателния клапан може да се използва и разреждането, образуващо се при наличието на ускорена маса газ, което създава благоприятни условия за по-пълно очистване на цилиндъра от продуктите на горенето.

От размерите на клапанната система, зависи характера на колебателните движения на отработилите газове и това трябва да се отчете при избора на момента на затваряне на изпускателния клапан.

Ъгъла на отваряне на пълнителния клапан се подбира така, че в момента, който налягането на остатъчните газове в цилиндъра стане по-ниско от това на пълнителната система, проходното сечение да бъде достатъчно за постъпване на прясното работно вещество. По тази причина пълнителния клапан се отваря с изпреварване – т.е. преди достигането на буталото в ГМП.

В комбинираните двигатели при $p_k/p_p > 1$, припокриването на клапаните е по-голямо в сравнение с това на двигателите, при които $p_k/p_p \leq 1$. Голямото припокриване в този случай се създава главно чрез увеличаване ъгъла на предварително отваряне на пълнителния клапан, тъй като по-високото налягане в пълнителния тръбопровод (p_k) в сравнение с налягането в изпускателния тръбопровод (p_p), непозволява при по-голяма част режимите връщане на отработили газове в пълнителния тръбопровод.

Затварянето на пълнителния клапан след ГМП т.е. със закъснение, подобрява напълването на цилиндъра с прясно работно вещество защото, първо проходното сечение на пълнителния клапан остава голямо до края на движението на буталото към ДМП и второ налягането в началото на хода сгъстяване в цилиндъра е по-малко от p_k и през отворения пълнителен клапан продължава постъпването на допълнително количество прясно работно вещество.

3. *Охлаждане на въздуха след компресора*.

Нарастването на температурата на въздуха в компресора зависи от степента на повишаване на налагането, КПД на компресора и топлообмена със стените, т.е. от конструкцията на компресора.

Прилагането на газотурбинно пълнене с променливо налягане в колектора може да се разгъне в областта на по-високите от средните ефективни налягане, посредством въвеждане на охлаждане на въздуха след компресора. Понижаването на температурата на въздуха при пълнене, довежда до увеличаване заряда на цилиндъра с въздух и понижаване на температурата в началото на сгъстяването. За напълването на цилиндъра определящ се явява плътността на заряда при пълненето

$$\frac{\rho_2}{\rho_1} = \frac{p_2.R.T_1}{p_1.R.T_2} = \frac{p_2}{p_1}.\frac{1}{\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}} = \left(\frac{p_2}{p_1}\right)^{\frac{1}{n}}. \qquad (5)$$

От тук се вижда, че повишаването на плътността при определени условия може да бъде значително по-малко от повишаването на налягането. Ориентировъчно може да се смята, че при еднакво налягане на пълнене и понижаване на температурата на въздуха след компресора с 10°С, плътността на въздуха се увеличава около 3%. Благодарение на това при постоянен коефициент на пълнене и при постоянен специфичен разход на гориво да се повиши мощността с 3%, а отчитайки останалите промени на различни параметри, произтичащи от понижението на температурата на въздуха, мощността може да се повиши и до 4,2%.

Използвайки вода в качеството си на охладител на въздуха след компресора в повечето случаи позволява без особено високи загуби да се осъществи охлаждане на въздуха до температура, превишаваща само няколко градуса средната температура на водата.

Може да направим извода, че охлаждането на въздуха на пълнене при равни други критерии, позволява да се осъществи значително по-висока степен на пълнене и се явява най-ефективно и евтин способ за увеличаване на мощността на двигателя с принудително пълнене. Трябва да се добави, че охлаждането на въздуха способства и за намаляване на съдържанието на вредните компоненти в отработилите газове.

<u>Експлоатационни фактори</u>:

При четиритактовите двигатели с голяма степен на сгъстяване ε, коефициентът на пълнене на цилиндъра е по-голям. Обяснява се с това, че с повишаването на сгъстяването, намалява обмена от камерата на горене V_c, който заемат остатъчните газове в края на изпускането. Коефициентът на остатъчните газове γ_r се намалява, а коефициентът на пълнене η_v се повишава. При голяма степен на сгъстяване температурата на стените е по-ниска вследствие на по-пълното разширение на продуктите на горенето, което увеличава също коефициента на пълнене.

Увеличаването на оборотите на коляновия вал при постоянно положение на регулираща орган, довежда до понижаване на коефициента на пълнене, тъй като се намалява отношението p_a/p_k и нараства p_r/p_k при едно и също p_k (вследствие увеличаване на загубите на енергия при протичането на газа през пълнителния и изпускателния тракт). Произтичащото намаляване на заряда, което повишава коефициента на пълнене, не компенсира намаляването му вследствие хидравличните загуби. Текущото изменение на налагането $\Delta p_{k'} = p_k - p_a$ е пропорционално на квадрата на оборотите n на коляновия вал и обратнопропорционално на квадрата на площта на проходното сечение f_1:

$$\Delta p_{k'} = k_0 \frac{n^2}{f_1^2}, \qquad (6)$$

където: k_0 е постоянна величина;

f_1 – площ на най-тясното проходно сечение на тръбопровода.

Влиянието на натоварването на двигателя и на коефициента на пълненето е различно в зависимост от начина на регулиране на двигателя. Съпротивлението на пълнителната система независи от натоварването (при n = *const*). При всички натоварвания на двигателя $(p_a/p_k) \approx const$, коефициентът на пълнене зависи от изменението на интензивността на подгряването на въздуха при напълване. В даден случай с увеличаването на натоварването на двигателя, коефициентът на пълнене η_v малко се понижава, тъй като отношението на температурата $\frac{T_k}{T_k+\Delta T}$ се намалява в резултата на по-интензивно подгряване от стените на цилиндъра.

4. Заключение

От организацията на газообменния процес, зависят мощностните и икономически показатели на двигателя. Влиянието на конструктивните и експлоатационни фактори върху газообмена, го правят обект на непрекъснати изследвания, независимо от наличието на трудност свързани с нестационарността на подходите. При двигателите с газотурбинно пълнене това е от значение за получаването на надеждни данни за процесите и за системата на принудително пълнене.

ЛИТЕРАТУРА

1. Цинер К., (1978), *Наддув двигателей внутреннего сгорания*, Ленинград;
2. Орлин А.С. и др. (1971), *Теория робочих процессов поршневых и комбинировоных двигателей*, Москва;
3. Орлин А.С. и др. (1973). *Системы поршневых и комбинировонных двигателей*, Москва;
4. Куросов В.С. и др. (2013), *Теория двигателей внутреннего сгорания*, КубГАУ;
5. www.full-race.com
6. www.turbozenturu.de

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АКТУАЛНИ ГРАЖДАНСКО-ВОЕННИ ПРОЦЕДУРИ В ОВД ПРИ ДЕЙСТВИЯ НА ВОЕННАТА АВИАЦИЯ ЗА ОСИГУРЯВАНЕ НА ВЪЗДУШНИЯ СУВЕРЕНИТЕТ. ЧАСТ 1

ДАНЧО КОЛИБАРОВ

Резюме: *Представени са гражданско-военните процедури и координация, като част от обслужване на въздушното движение, при действия на военната авиация, за осигуряване на въздушен суверенитет при различни видове вероятни терористични заплахи.. Разгледан е процеса на оценка на опасността и механизма на протичане на информационния поток.*

Ключови думи: *Гражданско-военни процедури и координация, обслужване на въздушното движение, управление на въздушното движение, вероятни терористични заплахи, въздушен суверенитет.*

CURRENT CIVIL-MILITARY PROCEDURES IN AIR AT THE ACTION OF THE MILITARY AIRCRAFT TO ASSURING AIR SURVEY. PART 1

DANCHO KOLIBAROV

Abstract: *Civic-military procedures and coordination are presented as part of air traffic services in military aviation activities to provide air sovereignty for various types of likely terrorist threats. The process of assessing the hazard and the mechanism of flow of the information flow is considered.*

Key words: *Civil-military procedures and coordination, air traffic services, air traffic management. possible terrorist threats, air sovereignty.*

1. Характеристика на гражданско-военната координация при управление на въздушното пространство и обслужване на въздушното движение.

Включва координация между упълномощени органи по въпросите на разделянето на ВП, за осигуряване на безопасно, ефективно и хармонизирано ползване на ВП. Стратегическата координация между граждански и военни органи представлява дефинирането и прегледа на държавната политика по ВП, като се вземат под внимание потребностите на държавните и чуждестранните потребители. Предтактическата координация между гражданските и военните органи е работата по оперативното управление на съществуващите структури и процедури – ежедневно разпределение на ВП. Координацията в реално време е активирането, деактивирането и преразпределението на ВП, както и по разрешаването на конфликти и проблемни ситуации.

1.1. Законова основа и регламентация на функционирането на двете подсистеми.

Функционирането на гражданската и военната подсистеми за УВД и ОВД се основава на член 2(а), ал. 2 на Закона за гражданското въздухоплаване и Наредба № 19 на министъра на отбраната и министъра на транспорта и съобщенията от 27 януари 1999 г., определяща реда за въвеждане и правилата за работа на единната система за гражданско и военно управление на въздушното пространство. С тази наредба се определят основната цел, задачите, съставът и организацията на работа на единната система за гражданско и военно управление на въздушното пространство в мирно време. В дейността си единната система за гражданско и военно управление на въздушното пространство ползва принципите, залегнали в програмата на Евроконтрол за хармонизация и интеграция на системите за управление на въздушното движение, Концепцията на Евроконтрол за гъвкаво използване на въздушното пространство и на препоръките на Регионалната инициатива на САЩ за модернизация на организацията и

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управлението на въздушното пространство в Централна и Източна Европа.

1.2. Система за разпространение на данни за ВП и гражданско-военна координация.

Разпространението на данни за ВП и гражданско-военната координация са двата главни компонента на системата. Гражданско-военната координация се подразделя на два компонента, които са обмен на гражданско-военни полетни данни и координация при пресичане на ВП.

Оперативните изисквания за системата произтичащи от концепцията за ГИВП могат да се разделят на две категории:

Първата категория изисква система за предтактическо УВП (денят преди деня на действието). Оперативните изисквания в тази област са за система за разпространението на данни за ВП към различните заинтересовани органи.

Националният план за използване на ВП, определящ как ВП ще бъде използвано през деня на полетите и неговата актуализация - актуализиран план за използване на въздушното пространство се изпраща до различните заинтересувани органи за УВД. Съобщение за действащите условни маршрути/трасета, включено в международно обединено съобщение, изброява тези от тях, които ще бъдат приложени в Националният план за използване на ВП. То също трябва да бъде изпратено до всички заинтересувани районни центрове за УВД, работните позиции за управление на потоците ВД и до всички центрове за УВП.

Целта на системата е да минимизира натоварването свързано с рутинни задачи. Тази цел може да се постигне чрез използване на система за съобщения, която позволява автоматична проверка и разпространение на данни и визуализация, както и обработващите подсистеми, където те могат да се използват (работни позиции, АТС съоръжения и т.н.).

Втората категория изисква система за тактическа (в деня на полетите) военно-гражданска координация. В тази област се определят два типа изисквания за системата: за обмен на полетни данни между гражданските и военни органи за ОВД и за координация при пресичане на ВП.

Практическата полза в тази област е намаляване на натоварването на ръководител полетите (РП), свързано с осигуряване на информация за ОВД, осъществявано от други органи за координация между съответните РП.

Инструкция №24 за реда за даване на заявки от ползвателите до Службата за планиране на военното използване на въздушното пространство (СП ВИВП) определя редът за заявяване намерение за използване на ВП от ползвателите.

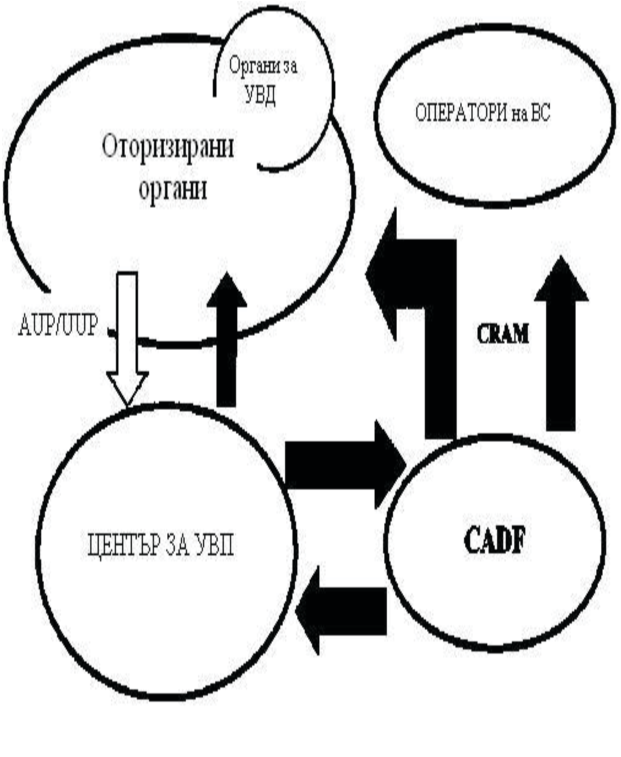
Тези ползватели на въздушното пространство, които дават заявки за използване на временно отделени зони в СП ВИВП, са: авиационните бази на военновъздушните сили и/или военноморските сили; щабът на отбраната на Българската армия и командванията на сухопътните войски, ВВС и ВМС; началниците на гарнизоните, в които се провеждат илюминации; ръководителите на местната изпълнителна власт, физически и юридически лица, отговорни за организиране и провеждане на взривни работи и/или илюминации.

СП ВИВП е структурна единица от военното „Ръководство на въздушното движение", която събира заявките от ползвателите за използване на ВОЗ.

Полетите и другите дейности във ВОЗ, заявени в СП ВИВП се планират и изпълняват само след осигуряване на безконфликтност с полетите на гражданската авиация, като безопасността на полетите и другите дейности във ВОЗ се осигуряват от органите на ВРВД. Заявките за ВП се събират от оторизираните органи и се изпращат до Центровете за УВП.

Плановете за използване на ВП се изпращат всеки ден в определено време от центъра за УВП до Централния орган за управление на потоците и до оторизираните органи. Актуализирания план за използване на ВП се изпраща всеки ден, във време определено от Централния Орган за Управление на Потоците ВД на адресите, на които е изпратен и плана за използване на въздушното пространство.

Актуализираният план за използване на ВП съдържа само изменения за гъвкавите структури на ВП, описани в съответния план за използване на ВП. На фиг. 1 е показано схематично как се осъществява обмена на данни и информация – плана за използване на ВП (AUP), актуализирания план за използване на ВП (UUP), съобщение за планиране използването на УМТ (CRAM) и др. между националните планиращи използването на ВП органи, органите за УВД, операторите на ВС (потребителите на ВП) и централизирания пункт за планиране на потоците ВД (CADF).



Фиг. 1. Схема на разпространение на информацията за ВП.

Съобщение с условни маршрути или трасета се изпраща всеки ден от централния орган за управление на потоците ВД /Централна функция за въздушна информация на ЕКГА до изброени оператори на ВС, до всички участващи районни центрове за УВД или работни позиции за управление на потоците ВД и до всички центрове за УВП. То съдържа всички условни трасета предоставени в областта на страните от ЕКГА по време на валидния период на плановете за използване на ВП.

Предтактическите съобщения за ВП се очаква да се получават до определено време всеки ден. Те не са време критични, следователно не се изисква потвърждение.

Информационната система за гражданско-военна координация изпълнява следните функции:

- Обмен на полетни данни;
- Координация при пресичане на ВП.

Обменът на полетни данни представлява предаването и приемането на базова група информация, когато полетът е навлязал в областта на приемащия орган, допълнена с подновена информация, докато полетът е през предаваното ВП. Допълненията могат да съдържат намерението на РП, когато това е регламентирано. Наличието на тази информация ще намали нуждата от словестна координация РП-РП. Обменът на данни преимуществено е автоматичен и в известни случаи се извършва чрез въвеждането на данни от определен РП.

Кординацията при пресичане на ВП се състои от обмен на съобщения между РП. Той има избора или да уведоми другия орган, под чийто контрол полетът ще премине през контролираното от него ВП или да изиска разрешение за пресичане на това ВП. Във втория случай РП към втория орган ще разчита да се въведе оперативен отговор за искането за пресичане на ВП.

Тези оперативни отговори могат да са или одобрения към искането, контра-предложения или отказ. Контра-предложението изисква одобрение или отказ от РП, който е предложил това искане.

Съответните области на пресичане може да са корегирани от РП, отговорен за полета или от РП, отговорен за ВП, което ще се пресича.

Целия обмен на полетни данни и на координацията при пресичане на ВП се потвърждават автоматично, ако могат да бъдат правилно получени и обработени в адресирания орган.

1.3. Нормативна база за преминаване под военен контрол.

Преминаването на националната система за УВД под военен контрол се основава на “Наредба № 23 за реда за използване на въздушното пространство при прехода към военен контрол и ръководство на въздушното пространство при повишаващи се нива на извънредни условия”.

В съответствие с посочената наредба, редът за използване на въздушното пространство при прехода към военен контрол и ръководство при повишаващи се нива на извънредни условия, се определя от СУВП по предложение на министъра на отбраната съгласувано с министъра на транспорта и включва последователността от дейности и правила за планиране, разпределение, предоставяне и контрол на използването на въздушното пространство и изпълнението на полетите.

Нивата на извънредни условия, при които се извършва преходът към военен контрол и ръководство на въздушното пространство, са:

- военно положение при заплаха от въоръжено нападение или война на територията на страната или на част от нея;
- положение на война при въоръжено нападение срещу страната;

- положение на война при необходимост от неотложно изпълнение на международни задължения;

- внезапно въоръжено нападение или нахлуване на чужди войски на територията на страната или на част от нея.

Повишаващите се нива на извънредни условия се обявяват с решение на Народното събрание или указ на президента на Р България по установения от Конституцията ред и се оповестяват чрез средствата за масово осведомяване.

За начало на прехода към военен контрол и ръководство на въздушното пространство при повишаващи се нива на извънредни условия се приемат часът и денят на обявяването на военното положение, на войната, ако не е предхождано от обявяване на военно положение или часът и денят на началото на внезапното въоръжено нападение.

За край на военния контрол се приемат часът и денят на отменянето на военното положение, часът и денят на обявяване края на военните действия или времето на тяхното фактическо прекратяване.

Продължителността на прехода към военен контрол се определя в директивата за бойната готовност на въоръжените сили на Р България.

При преход към военен контрол на въздушното пространство се извършва преструктуриране на системата за УВД.

Целта на прехода към военен контрол и ръководство на въздушното пространство при повишаващи се нива на извънредни условия е да осигури изпълнението на задачите на държавните въздухоплавателни средства, както и безопасността на полетите на гражданските въздухоплавателни средства.

От направената характеристика на функционирането на военната и гражданската подсистеми за УВП и ОВД и на системата за разпространение на данни за използването на ВП и осъществяване на гражданско-военна координация може да се направят следните изводи.

На първо място трябва да се отбележи, че системата дава възможност за гъвкаво реагиране както при управлението на ВП – отделяне на определени обеми ВП за специфични цели или използване на УМТ в зависимост от възможността за планиране, така и при обслужване на ВД – координация за полетите на гражданските и военните ВС.

От изключителна важност е своевременното оповестяване на централизирания орган за управление на потоците ВД на ЕВРОКОНТРОЛ в Брюксел за активирането и деактивирането на обемите ВП, отделени за специфични нужди – ВОЗ, ГЗП, ЗНК. Това позволява при възникване на определени ситуации или кризи, имащи продължителност повече от 24 часа да се осъществи надеждна сепарация на гражданския въздушен трафик, наричан още основен трафик от военния, или този, използван за специални и специфични задачи означаван като оперативен трафик.

Трябва също да се отбележи, че гражданско-военната координация и обмен на полетни данни и информация, осъществявани между гражданските и военните служби за ОВД осигуряват постигане на по-високи нива на сигурност и икономичност за гражданския въздушен трафик от една страна и изпълнението на учебните и бойни задачи от оперативния въздушен трафик

Друг важен извод е, че гражданско-военната координация се осъществява основно в две направления: първо – на принципа на резервиране и отделяне на ВП за специфични нужди и дейности; второ – по пътя на подобряване на т.н. "тиха координация". Тя може да се осъществява чрез въвеждане на ефективни комуникационни системи и системи за обмен на данни в реално време, както и с използването на еднозначна радиолокационна картина за всички потребители на радиолокационна информация за ОВД. Използването на такава автоматизирана система ще намали необходимостта от вербална координация и съответно ще редуцира времето за координация и вероятността от допускане на грешки.

2. Предотвратяване на конфликтни ситуации при УВД.

Ефективното функциониране на НС УВД се характеризира с намаляване на броя на конфликтните ситуации при опериране на военни ВС в гражданско ВП. Решаването на задачите по предотвратяване на конфликтни ситуации за осигуряване на безопасността на полетите на оперативното и основно ВД е една от основните функции на военните РП.

Към конфликтните ситуации при ОВД се отнасят:

- опасно сближение на ВС в полет;
- попадане на ВС в опасни за полета МТО условия;
- попадане на ВС в зони забранени за полети.

Решение за предотвратяване на създала се конфликтна ситуация се взема в случаите, когато величината и характера на текущите или екстраполирани параметри на движението на ВС застрашават безопасността на полетите.

В практиката по регулиране на ВД най-често се решава задачата по предотвратяване на опасно сближение между ВС. Ето защо задачата по предотвратяване на конфликтна ситуация може да се разглежда като опасно сближение между ВС.

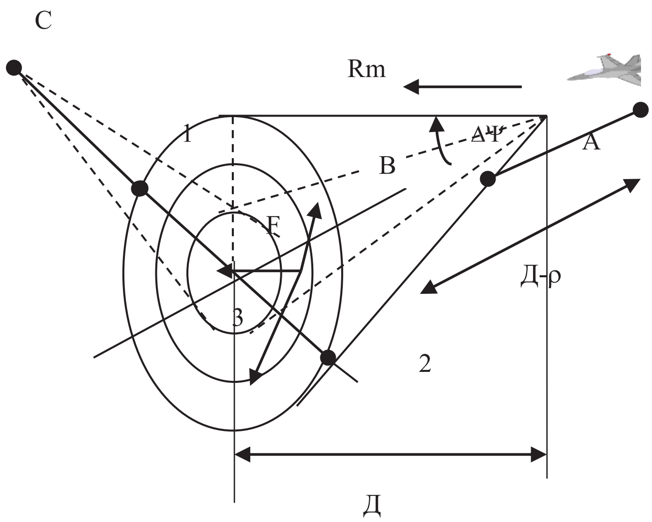
За решаване на задачата по отстраняване на конфликтна ситуация е необходимо да се знаят положенията на ВС, направлението на движението им, времето на полета и разстоянието до точката на пресичане на траекториите им с отчитане на вероятните отклонения за сметка на неточното поддържане на режима на полета и влиянието на вятъра.

Конфликтните ситуации се предотвратяват чрез:

- изменение на височината на полета на ВС;
- маневриране по скорост на едното или двете ВС;
- изменение на направлението на полета на едното или двете ВС при постоянни скорости.

Скоростта за маневриране на военното ВС се подбира така, че в момента на преминаване на едното ВС през изчислената точка на конфликтна ситуация (фиг. 2), разстоянието между двете ВС да не е по-малко от определения радиус на зоната на вероятни стълкновения ρ.

На фиг. 2 е показана схема на маневриране по скорост и направление на две ВС.



Фиг.2. Маневриране по скорост и направление от ВС

От фигурата се вижда, че скоростта на маневриращото ВС - *Vман* може да се опердели по следната формула:

$$V_{ман} = \frac{Д \pm \rho}{t} \qquad (1),$$

където: Д – разстояние от текущото място на ВС „А" до разчетната точка на среща;

ρ - радиус на зоната на вероятните стълкновения.

Следователно ВС, изпълняващо полет със скорост *Vман* и в момента на прелитане на конфликтната точка F, другото ВС ще се намира на границата на зоната на вероятните стълкновения, т.е. или в точка 1, или в точка 2.

За отстраняване на конфликтна ситуация чрез изменение на направлението на полета при постоянни скорост и височина, схемата на маньовъра се разчита и изпълнява така, че траекторията на маневриращото ВС да минава извън границите на зоната.

Ако областта на вероятните стълкновения е на голямо разстояние от изходната точка А, маньовъра по направление е целесъобразно да се изпълни чрез изменение на курса под ъгъл *ΔΨ,*определен от следната зависимост:

$$\Delta\psi = \arcsin\frac{\rho}{Д} \qquad (2),$$

където: Д – разстояние от текущото място на ВС „А" до разчетната точка на среща, ρ - радиус на зоната на вероятните стълкновения.

На ВС, намиращо се на по-голямо разстояние от точката F, се осигурява прелитане извън зоната.

Когато разстоянието до зоната е малко, необходимо е да се изпълни вираж от зададената траектория във възможно най-кратко време, (точка В).

Виражът трябва да се изпълни при известни ограничения. Минималният радиус на виража се определя по следното съотношение:

$$R\min = \frac{V^2}{g \cdot tg\beta_{mah}} \qquad (3)$$

При това е необходимо да бъде спазено следното условие:

$$R_{\min} \le Д - \rho \qquad (4),$$

където: Д – разстояние от текущото място на ВС „А" до разчетната точка на среща, ρ - радиус на зоната на вероятните стълкновения.

Предотвратяването на възможността за възникване на повторна конфликтна ситуация и осигуряване на безопасността на полета при разделяне на ВС е необходимо виража на ВС да се изпълни на страната на намаляване на курсовия ъгъл на визиране.

Един от пътищата за намаляване на броя конфликтните ситуации е представяне на по-високи изисквания към техническите средства за контрол и навигация, както на земята, така и на борда на ВС. Изпълнението на тези изисквания доведе до усъвършенстване на организацията на структурите на ВП и повишаване на капацитета на зоните и районите за ОВД.

В изпълнение на програмата на ЕВРОКОНТРОЛ за намален минимум за вертикална сепарация (RVSM) от 300 м (1000 ft) между полетни нива FL290 и FL 410, гражданските ВС бяха оборудвани със съвременни бордни системи за предотвратяване на сблъсквания.

Бордната система за предотвратяване на сблъсквания ACAS 7 е система, която анализира информацията за ВД през 300 м (1000 ft) до полетно ниво FL 410, а над него през 600 м (2000 ft).

Информацията се обменя чрез транспондерите на ВС в радиус от 50 мили. При наличие на потенциално конфликтна ситуация и след изтичане на време 45 s екипажа на ВС не предприеме мерки, то апаратурата подава команди на автопилота за отстраняване на конфликтната ситуация.

Следователно около ВС се описва цилиндър с радиус 6 км при обслужване по контрол на подхода и 18,5 км при обслужване по контрол на района и 300 м (1000 ft) под и над него до полетно ниво FL 410.

Възможно е получаване на препокриване на части от различни цилиндри, при което възниква риск от конфликтна ситуация.Съществуват следните четири нива на риска:

- риск от сблъскване;
- безопасността не е осигурена;
- отсъства риск от сблъскване;
- рискът не е определен.

Държавните ВС не са оборудвани с бордната система за избягване от сблъскване ACAS 7 . По тази причина е необходимо да се увеличи нормата за радарно сепариране между държавните и гражданските ВС.

ЛИТЕРАТУРА

1. Заеков В.С., Чилингиров Д. И., Теория за управление на въздушното движение, учебно пособие, ВИ, София, 1992.
2. Закон за гражданското въздухоплаване, Обн., ДВ, бр. 94 от 01.12.1972г., изм. и доп. бр. 30 от 1999г., бр. 16 от 1997г., бр. 85 от 1998г., в сила от 01.01.1999г., бр. 12 от 2000г.,в сила от 15.02.2000г., изм. доп.ДВ, бр.34 от 2001.Инструкция №24/01.11.1999г. за работа на Центъра за планиране и разпределяне на въздушното пространство на Република България, Обн., ДВ, бр.101 от 1999.
3. Инструкция №25/01.11.1999г. за структурата и правилата за работа на Центъра за координиране използването на въздушното пространство на Република България, Обн., ДВ, бр.101 от 1999.
4. Наредба №19/27.01.1999г. за реда за въвеждане и правилата за работа на единната система за гражданско и военно управление на въздушното пространство, Обн., ДВ, бр.13 от 1999.
5. Наредба №11/05.05.1999г. за обслужване на въздушното движение във въздушното пространство на Република България, Обн., ДВ, бр.50 от 1999.
6. Наредба №2/10.03.1999 г. Правила за провеждане на полети на Министъра на транспорта и съобщенията – Обн., ДВ, бр.50 от 1999.
7. Пенев П. Б., Ячев Р. Я., Основи на теорията и използването на авиационните навигационни системи и средства,учебник, ВА "Г. С. Раковски", 2004.
8. Унгорян С.Г., Маркович Е.Д., Волевач А.И, Анализ и моделирование систем управления воздушным движением, Транспорт, М., 1980.
9. Ячев Р. Я., Управление на въздушното пространство по време на кризи и военен конфликт, Лекция, ВА „Г. С. Раковски", С., 2002.
10. Procedures for air navigation services; Doc 8168-OPS/611, Vol II, IKAO.
11. Airspace Management Modernization for Central and Eastern Europe, Volume II – Annex K Air Sovereignty Modernization Recommendation for Bulgaria, sept. 1997.
12. Наредба № 23 от 1.11.1999 г. за реда за използване на въздушното пространство при прехода към военен контрол и ръководство на въздушното пространство при повишаващи се нива на извънредни условия, издадена от министъра на транспорта и министъра на отбраната, обн., ДВ, бр. 99 от 16.11.1999 г.

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АКТУАЛНИ ГРАЖДАНСКО-ВОЕННИ ПРОЦЕДУРИ В ОВД ПРИ ДЕЙСТВИЯ НА ВОЕННАТА АВИАЦИЯ ЗА ОСИГУРЯВАНЕ НА ВЪЗДУШНИЯ СУВЕРЕНИТЕТ. ЧАСТ 2

ДАНЧО КОЛИБАРОВ

Резюме: *Представени са гражданско-военните процедури и координация, като част от обслужване на въздушното движение, при действия на военната авиация, за осигуряване на въздушен суверенитет при различни видове вероятни терористични заплахи.. Разгледан е процеса на оценка на опасността и механизма на протичане на информационния поток.*

Ключови думи: *Гражданско-военни процедури и координация, обслужване на въздушното движение, управление на въздушното движение, вероятни терористични заплахи, въздушен суверенитет.*

CURRENT CIVIL-MILITARY PROCEDURES IN AIR AT THE ACTION OF THE MILITARY AIRCRAFT TO ASSURING AIR SURVEY. PART 2

DANCHO KOLIBAROV

Abstract: *Civic-military procedures and coordination are presented as part of air traffic services in military aviation activities to provide air sovereignty for various types of likely terrorist threats. The process of assessing the hazard and the mechanism of flow of the information flow is considered.*

Key words: *Civil-military procedures and coordination, air traffic services, air traffic management. possible terrorist threats, air sovereignty.*

1. Установяване на гражданско-военни процедури по управление на въздушното движение.

От изложеното в част първа възниква въпросът, дали така представената НС УВД ще бъде способна да поддържа и осигурява военните изисквания за организиране и провеждане на операции, и нарастването на гражданския трафик в едно и също време. За да удовлетвори тези изисквания НС УВД, трябва да осигури максимални нива на ефективност при ръководството и подобряване на стандартите за сигурност. Въпреки това в определени части от ВП и в определени периоди това може да не е възможно. Това налага стриктно спазване на сепарацията между основното и оперативното ВД, а при определени условия забрана за полетите на граждански въздухоплавателни средства в дадена част от ВП.

От ключово значение е да се установят националните правила по УВД при операции различни от война. Тъй като времето за реагиране и разпространяване на информацията до органите, които вземат решенията е от жизненоважно значение за последващите действия се приема, че националната система за УВД ще допълва интегрираната развърната система на НАТО за ПВО (NATO Integrated Extendent Air Defence System - NATINEA, DS), когато това е възможно.

Временното ограничено ВП за провеждане на хуманитарни, спасителни и др. операции различни от война, трябва да бъде осигурено с непрекъснат радиолокационен контрол и обмен на данни между гражданските и военните центрове. Границите му трябва да бъдат известни на гражданските органи за ОВД и координирани с ЕВРОКОНТРОЛ и съседните РЦ за ОВД.

При заявяване на височините на полетите, на които ще се изпълняват поставените задачи, сектора за ОВД може да бъде ограничен по височина (напр. в долното ВП). На фиг. 1 са показани минимумите за радарно сепариране осигуряващи безопасност между оперативния и основния трафик до полетно ниво FL410.

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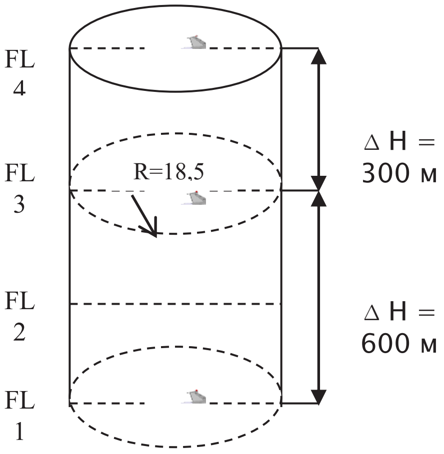


Фиг. 1. Минимуми за радарно сепариране.

Разгледаният пример на фиг. 1 показва,че граждански ВС летят на полетни нива FL3 и FL4.То следва военното ВС да лети на FL1. Това ще осигури безопасността на гражданското ВС и няма да се получи сигнал за опасно сближение от бордната система за избягване от сблъскване.

1.1. Установяване на гражданско военни процедури по УВД при терористична заплаха

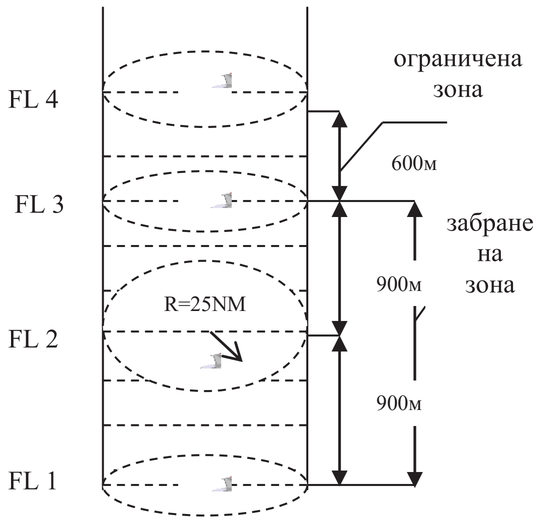
Анализът на събитията от 11.09.2001 г. в САЩ, наложи подобрения в гражданско-военните процедури за УВД при идентифицирането, воденето и внедряването на мерки на ПВО по отношение на въздухоплавателно средство, което се използва като оръжие за извършване на терористична атака. Това налага предварително да бъдат установени подходящи комуникационни връзки между гражданските и военните органи, както и между органите от предтактическото и тактическото ниво за УВД с органите от системата за ПВО. Необходимо е каналите да са със съответното ниво за защита.

Въздушното пространство около подозрителното ВС, трябва да бъде освободено от граждански въздухоплавателни средства, което би улеснило внедряването на мерките на ПВО, като прихващане, разузнаване, идентификация принудително кацане на определено летище.

Въвежда се ограничена зона около ВС, предмет на заплаха с размери R= 25 NM, а по височина до всички полетни нива от регулираното ВП над и под въздухоплавателното средство. В зависимост от развитието на инцидента и методите на прилагане на активните средства за ПВО, това ВП може да бъде ограничено по височина.

Отменят се всички УВД разрешения в ограниченото ВП и се вземат мерки за управление на потоците въздушно движение, а в контролираните летищни райони се прекратяват полетите в зоните за изчакване (ЗИ), отклоняване от маршрути и др.

За ефективното изпълнение на задачите си е необходимо да се осигурят по 1000 м по три полетни нива под и над подозрителното въздухоплавателно средство. Също така трябва да се отчита факта, че ВП може все още да не е освободено от другите въздухоплавателни средства. В този случай РП е длъжен да осигури тяхната безопасност и минималните норми за сепарация, както е показано на фиг. 2.



Фиг. 2. Зона за изпълнение на задачата.

Ако подозрителното въздухоплавателно средство лети на полетно ниво FL 2, то за изтребителната авиация се заделя ВП между полетни нива FL 1 и FL 3, в което то ще изпълнява задачата си. Това ВП е обявено като забранена зона за другите граждански въздухоплавателни средства. ВП между FL 3 и FL 4 е обявено за ограничено ВП за гражданските въздухоплавателни средства, когато на FL 4 лети такова.

ВП, което се осигурява за действие на активните средства на ЗРВ е с R=10 NM и без ограничения по височина. То се обявява като забранена за полети зона.

С оглед предотвратяване получаването на предварителна сигнализация на системата за алармиране и предотвратяване на конфликтна ситуация TCAS или ACAS, военният РП информира гражданския РП, че прехващащото въздухоплавателно средство може да ограничи информацията в режим С в ограниченото ВП.

Като част от процедурите по прехващането, подозрителното въздухоплавателно средство ще трябва да осъществи контакт с прехващащото, в съответствие с процедурите на Международната организация за гражданска авиация - ICAO. Единият от начините за осъществяване на контакти е на Международната аварийна честота 121,5 MHz или 243 MHz. Ако е възможно, за предпочитане е използването на отделна честота.

2. Участие на ВВС в програмите на НАТО “Air Policing” и “Ренегат”.

На 18.07.2002 г. Северноатлантическият съвет утвърди ръководни насоки за установяване на гражданско-военни процедури по управление на въздушното движение в светлината на новата обстановка по отношение на сигурността, което осигурява политиката на Алианса за подобряване на краткосрочните антитерористични мерки по УВД.

Събитията от 11.09.2001 г. в САЩ показват, че се разширява диапазона от опасности за националната сигурност на всяка държава, свързани с различните прояви на тероризма.

Една от основните задачи за въоръжените сили на НАТО, посочена в Коалиционната военна стратегия на съюза, е регулирането на кризи, включително и на тези, предизвикани от терористични действия.

От изключително значение за ефективността на работата на летателния състав и органите, ръководещи полетите, както и за адекватността на действията им в отговор на нестандартни ситуации е доброто познаване на структурата, принципите и подчинеността на системата за УВД, тяхното място в нея и евентуалните задачи, които биха им били поставени в съответните ситуации.

Новост в подготовката на летателния състав и на ръководителите полети е подготовката им за действие при терористичен акт на борда на ВС. Програма “Ренегат” съдържа ръководните насоки за политиката на НАТО за краткосрочни подобрения на гражданско-военните процедури за УВД в новата обстановка по отношение на сигурността.

2.1. Идентифициране на въздухоплавателно средство (ВС), представляващо вероятна терористична заплаха.

Ръководните насоки, посочени в програма “Ренегат” се концентрират върху две фази:

- Оптимизиране визуализацията на въздушната обстановка;
- Внедряване на дейности по УВД, свързани с осигуряване на ПВО срещу граждански ВС, използвани като оръжие за извършване на въздушна терористична атака (ВС-РЕНЕГАТ).

Цялата информация относно подозрително ВС трябва да се разпространи до съседните сектори за УВД и да се уведоми системата за ПВО (включително извън националните граници), а по командна линия и на съответните военни командири на НАТО и националните органи, за да се провокира своевременна реакция на ПВО.

В този процес от основно значение е установяването на подходящи комуникационни връзки между гражданските и военните органи, както и между по-висшите нива на органите за УВД и ПВО. В национален мащаб това налага установяване на съответни процедури и определяне на фразеология, за да се предотвратят евентуални недоразумения. Разпространяването на информация трябва да се осъществява при необходимост и да се използват канали със съответното ниво на защита.

От основно значение е да не се губи радиолокационната връзка (радарен трак) с подозрително ВС. Това означава резервиране на вторична радиолокационна информация чрез активна и пасивна радарна информация. Задължително е поддържането на първично радиолокационно покритие и обмен на данни между гражданските и военните центрове.

Препоръчва се установяването на телеконферентни връзки, за да се улесни постоянното, изчерпателно и еднакво познаване на въздушната обстановка от всички заинтересовани участници.

2.2. Прехват на гражданско ВС. Внедряване на дейности по УВД в резултат на усложнената обстановка и изпълнението на мерки по ПВО.

В интерес на безопасността на полетите въздушното пространство около подозрителното ВС трябва да бъде освободено, което би улеснило и внедряването на мерки на ПВО като прихващане за разузнаване, идентификация или принудително кацане на определено летище.

Въздухоплавателно средство, навлязло без разрешение във ВП на Р България или е нарушило правилата за полети, без държавен регистрационен отличителен знак или не се подчини на указанията на органите за управление на ВД, се счита за нарушител и се принуждава да кацне.

При маневриране за изпълнение на прехват трябва да се отчитат следните принципи:

а) прехват на гражданско ВС се предприема само като последна мярка;

б) ако се предприеме прехват, той се ограничава до идентифициране на ВС, с изключение на случаите, когато е необходимо ВС да бъде върнато на зададената пътна линия, да бъде изведено извън границите на въздушното пространство на Република България или извън забранена, ограничена или опасна зона, или да бъде принудено да извърши кацане на посочено летище;

в) забранени са прехватите на граждански ВС с тренировъчна и учебна цел;

г) насочването на прехванатото ВС и даването на свързана с това информация се извършва с помощта на радиотелефония, когато може да се установи радиовръзка;

д) прехванато гражданско ВС се принуждава да кацне, когато определеното за целта летище отговаря на изискванията за безопасно кацане на съответния тип ВС;

е) забранена е употребата на оръжие срещу граждански ВС, изпълняващи полет по смисъла на чл. 3, ал. 1 от Закона за гражданското въздухоплаване.

С цел осигуряване на необходимата безопасност на въздушната навигация и ограничаване до минимум случаите на изпълнение на прехват за опознаване на гражданските ВС, в района на държавната граница трябва да се използва вторичен радар, доколкото това е практически възможно.

2.2.1.Маневриране за изпълнение на прехват

При маневриране за изпълнение на прехват трябва да се отчитат следните фактори:

а) ограниченията в летателните характеристики на гражданските ВС;

б) необходимостта от поддържане на определена дистанция от прехващаното ВС с цел предотвратяване на опасността от сблъскване;

в) необходимостта от избягване пресичането на траекторията на полета на гражданското ВС или изпълнение на маньовър по такъв начин, че турболентната следа да представлява опасност, особено ако прехващаното ВС се класифицира като леко.

2.2.2.Маневриране за визуално опознаване

Визуално опознаване на гражданско ВС от прехващача се изпълнява, както следва:

а) Фаза I

Прехващачът приближава прехващаното ВС в задна полусфера. Прехващачът или водачът на прехващащата група заема позиция от лявата страна, малко по-високо и отпред спрямо прехващаното ВС, в границите на видимостта на пилота на прехващаното ВС и първоначално не по-близо от 300 m.

Другите ВС от прехващащата група трябва да поддържат безопасно отдалечение от прехващаното ВС, като заемат позиция в задна полусфера над прехващаното ВС. След достигане на необходимата позиция и скорост и при необходимост се преминава към Фаза II.

б) Фаза II

Прехващачът или водачът на прехващащата група започва бавно сближение с прехващаното ВС до отдалечение не по-малко от абсолютно необходимото за получаване на нужната информация, като поддържа нивото си. Прехващачът или водачът на прехващащата група трябва внимателно да избягва причиняването на уплаха на екипажа и пътниците на прехващаното ВС, като има предвид, че маньоврите, приемани за нормални от прехващача, могат да бъдат възприети като опасни от пътниците и екипажа на гражданското ВС.

Другите ВС от прехващащата група трябва да поддържат безопасно отдалечение от прехващаното ВС. След завършване на процедурата по опознаване прехващачът се отдалечава от прехващаното ВС съгласно Фаза III.

в) Фаза III

Прехващачът или водачът на прехващащата група започва бавно отдалечаване с плавно пикиране. Другите ВС от прехващащата група трябва да поддържат безопасно отдалечение от прехващаното ВС и да се присъединят към водача.

2.2.3.Маневриране за указване направлението на полета

След изпълнение на маньоврите за опознаване, описани във Фаза I и Фаза II, ако се счете, че е необходима намеса в навигацията на прехващаното ВС, прехващачът или водачът на прехващащата група заема позиция от лявата страна малко по-високо и отпред спрямо прехващаното ВС, позволяваща на пилота на прехващаното ВС да наблюдава подаваните визуални сигнали.

Командирът на прехващача е длъжен да се увери, че командирът на прехващаното ВС е разбрал за прехвата и потвърждава подаваните сигнали. Ако опитите да се привлече вниманието на командира на прехващаното ВС с помощта на сигналите, са неуспешни, могат да се използват други методи за подаване на сигнали за тази цел, включително, като крайна мярка, визуалният ефект, получаван при включване на форсажа, като не се създава опасност за прехващаното ВС.

Допустимо е поради метеорологични условия или релефа на местността прехващачът или водачът на прехващащата група да заеме позиция от дясната страна малко по-високо и отпред спрямо прехващаното ВС. В този случай командирът на прехващача е длъжен да предприеме всички необходими мерки, така че прехващачът да бъде наблюдаван постоянно от командира на прехващаното ВС.

2.2.4.Насочване на прехванатото ВС

Насочването на прехванатото ВС и даването на свързана с това информация се извършват посредством радиотелефония, ако може да се установи радиовръзка.

Насочване на прехванато ВС се изпълнява така, че насочваното ВС да не попадне в условия, при които видимостта може да бъде под изискваната за полет при ВМУ, и така, че изискваните маньоври от прехванатото ВС да не увеличават вече съществуващата заплаха за безопасността на полета, в случаите когато летателно-техническите характеристики на прехванатото ВС са влошени.

В изключителни случаи, когато прехванатото ВС се принуждава да кацне, се спазват следните изисквания:

- определеното за кацане летище да отговаря на изискванията за безопасно кацане на съответния тип ВС, особено ако това летище не се използва от граждански ВС;
- местността в района на летището да е подходяща за полет по кръга, подход и минаване на втори кръг;
- прехванатото ВС да има достатъчен запас от гориво за достигане до летището;
- за прехванато гражданско транспортно ВС ПИК на определеното за кацане летище да има дължина, еквивалентна на не по-малко от 2500 м дължина на ПИК, разположена на средното морско равнище;
- за кацане, когато това е възможно, се определя летище, за което е публикувана подробна информация в Сборника за аеронавигационна информация и публикация.

Когато гражданско ВС се принуждава да кацне на непознато летище, е необходимо да му се предостави достатъчно време за подготовка за кацане, като се има предвид, че само командирът на гражданското ВС има право да вземе решение за безопасността на кацането по отношение на дължината на ПИК и масата на ВС към този момент.

Особено важно е цялата необходима информация за изпълнението на безопасен подход и кацане да бъде предадена на прехванатото ВС посредством радиотелефония.

2.2.5.Действия на екипажа на прехванатото ВС

Екипажът на ВС, прехванато от друго ВС, е длъжен незабавно да:

- изпълнява инструкциите на прехващача, да интерпретира и отговаря на визуалните сигнали;
- уведоми при възможност съответния орган за ОВД;
- направи опит да установи радиовръзка с прехващащото ВС или със съответния орган за управление на прехвата, като се обади на аварийната честота 121.5 MHz и съобщи позивната си и вида на полета; в случай че не може да установи контакт и ако е възможно, да повтори това съобщение на аварийната честота 243 MHz;
- постави режим А, код 7700, ако ВС е оборудвано с транспондер, освен когато е получило други инструкции от съответния орган за ОВД.

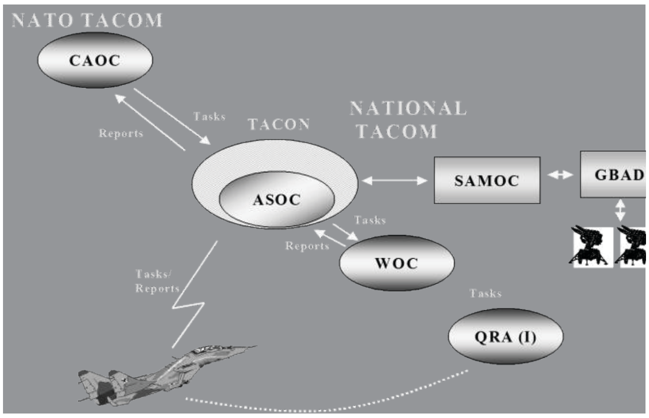
Когато инструкциите, получени по радиото от друг източник, противоречат на тези, подавани от прехващача посредством визуални сигнали, командирът на прехванатото ВС е длъжен незабавно да поиска разяснение, като същевременно спазва визуалните инструкции, подавани от прехващача.

Когато инструкциите, получени по радиото от друг източник, противоречат на тези, подавани от прехващача посредством радиотелефония, командирът на прехванатото ВС е длъжен незабавно да поиска разяснение, като същевременно спазва инструкциите, подавани от прехващача по радиото.

На процедурно ниво, между военното ведомство и министерството на транспорта и съобщенията съществува необходимост от договори за взаимодействие, протоколи за комуникация и планиране за внедряване на временно ограничено въздушно пространство

Анализирайки настоящите технически възможности за осигуряване на радиолокационна картина за нуждите на ПВО е необходимо да се извърши група от технически подобрения с цел улесняване координирането на мерките по УВД и ПВО. Това може да включи преразглеждане, в някои случаи, на настоящото планиране за спиране на граждански и военни първични радари и необходимостта от по-добър обмен на радиолокационна информация (филтрирана въздушна картина) между системата за командване и контрол на НАТО и системата за УВД.

Поставянето на задачи за бойно използване на активните средства за ПВО – дивизионите ЗРВ (GBAD) и ескадрилите изтребителна авиация (QRA), от многонационалния въздушен оперативен център (CAOC) и оперативния център за въздушен суверенитет (ASOC), чрез бригадните оперативни центрове (SAMOC) и базовите оперативни центрове (WOC) схематично е показан на фиг. 3.



Фиг. 3. Схема на процеса на протичане на информационния поток

Специално внимание трябва да се отдели на експортирането на УВД картината на въздушната обстановка до центровете за ПВО. Трябва да се установят защитени директни комуникационни връзки .

Не е изключено да възникне необходимост от централизирано събиране на УВД информация на ниво НАТО и/или ЕВРОКОНТРОЛ, както и от разврыщане на военен персонал при гражданските органи за УВД, както и на граждански РП в центрове на ПВО.

ЛИТЕРАТУРА

1. Заеков В.С., Чилингиров Д. И., Теория за управление на въздушното движение, учебно пособие, ВИ, София, 1992.
2. Закон за гражданското въздухоплаване, Обн., ДВ, бр. 94 от 01.12.1972г., изм. и доп. бр. 30 от 1999г., бр. 16 от 1997г., бр. 85 от 1998г., в сила от 01.01.1999г., бр. 12 от 2000г.,в сила от 15.02.2000г., изм. доп.ДВ, бр.34 от 2001.Инструкция №24/01.11.1999г. за работа на Центъра за планиране и разпределяне на въздушното пространство на Република България, Обн., ДВ, бр.101 от 1999.
3. Инструкция №25/01.11.1999г. за структурата и правилата за работа на Центъра за координиране използването на въздушното пространство на Република България, Обн., ДВ, бр.101 от 1999.
4. Наредба №19/27.01.1999г. за реда за въвеждане и правилата за работа на единната система за гражданско и военно управление на въздушното пространство, Обн., ДВ, бр.13 от 1999.
5. Наредба №11/05.05.1999г. за обслужване на въздушното движение във въздушното пространство на Република България, Обн., ДВ, бр.50 от 1999.
6. Наредба №2/10.03.1999 г. Правила за провеждане на полети на Министъра на транспорта и съобщенията – Обн., ДВ, бр.50 от 1999.
7. Пенев П. Б., Ячев Р. Я., Основи на теорията и използването на авиационните навигационни системи и средства,учебник, ВА "Г. С. Раковски", 2004.
8. Унгорян С.Г., Маркович Е.Д., Волевач А.И, Анализ и моделирование систем управления воздушным движением, Транспорт, М., 1980.
9. Ячев Р. Я., Управление на въздушното пространство по време на кризи и военен конфликт, Лекция, ВА „Г. С. Раковски", С., 2002.
10. Procedures for air navigation services; Doc 8168-OPS/611, Vol II, IKAO.
11. Airspace Management Modernization for Central and Eastern Europe, Volume II – Annex K Air Sovereignty Modernization Recommendation for Bulgaria, sept. 1997.
12. Наредба № 23 от 1.11.1999 г. за реда за използване на въздушното пространство при прехода към военен контрол и ръководство на въздушното пространство при повишаващи се нива на извънредни условия, издадена от министъра на транспорта и министъра на отбраната, обн., ДВ, бр. 99 от 16.11.1999 г.

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АКЦЕНТИ ПРИ ОБУЧЕНИЕТО ЗА ОПТИМАЛНО УПРАВЛЕНИЕ НА ЕЛЕКТРИЧЕСКИ РЕЛСОВ ТРАНСПОРТ С БЕЗСТЕПЕННО РЕГУЛИРАНЕ НА ТЕГЛИТЕЛНАТА СИЛА

ИЛКО ТЪРПОВ

Резюме: *Различните технически решения за управление на теглителната сила на електрическите транспортни средства до голяма степен определя поведението и стила на шофиране от страна на водача. В доклада ще бъдат разгледани някои акценти при обучението за оптимално управление с безстепенно регулиране на теглителната сила.*

Ключови думи: *оптимално управление, тренажор, обучение*

HIGHLIGHTS IN THE TRAINING FOR OPTIMAL CONTROL OF ELECTRICAL RAILWAY SMOOTH VARIABLE TRACTION

ILKO TARPOV

Abstract: *The various technical solutions to control the thrust of electric vehicles, largely determine the behavior and driving style of the driver. The report will be discussing some highlights in the training for optimal, smooth controlling of the thrust for constant acceleration*

Key words: *optimal control of smooth acceleration, simulator training*

1. Увод

Важен фактор при реализиране на оптимално управление на електрически транспортни средства (ЕТС) се оказва техният водач. Техническите знания, свързани с управлението на тяговото оборудване, съчетани с опита и отлично познаване характеристиките на пътния участък, гарантират реализирането на оптимално управление на транспортните средства. Постигане на конкретни умения у водача в тази посока, става чрез добро обучение и продължителна практика. По-бързото преодоляването на този дълъг процес може да бъде осъществено, чрез използването на технологиите за глобално позициониране, добавени към оборудването на транспортното средство и чрез обучение с тренажор.

Наред с придобиването на устойчиви познания и умения свързани с безопасността на превозите, чрез тренажорното обучение може да се постигне овладяване и натренирване на умения за оптимално управление на ЕТС. Според [1] фактора – психомоторика влияе около 24% от всички психологически фактори, разглеждани като възможности за намаляване на енергийния разход. Този подход със сигурност ще подобри енергийната ефективност на транспортните процеси.

2. Оптимално управление при безстепенно регулиране на теглителната сила

Фактори оказващи влияние върху разхода на електроенергия са теглителната сила на локомотива, скоростта на движение и коефициента на полезно действие на транспортното средство. При диодните транспортни средства органа за въздействие върху теглителната сила е контролера и

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неговото положение, което се определя от водача. Докато при напълно управляемите вентили максималният въртящ момент се поддържа от управляващата електроника. Водача определя само процента тяга.

След като разхода на електроенергия ни е основен критерий, определен от времето за придвижване, съгласно книжка разписание, то той придобива вида:

$$E = \int_{t_н}^{t_k} \frac{F_k V}{\eta} dt \quad , \qquad (1)$$

където $t_н$ и $t_к$ са начално и крайно време за движение;

$F_к$ - теглителна сила на локомотива;

η - среден коефициент на полезно действие на локомотива;

V - средна скорост на движение.

Според [2] „Прилагането на режим за водене на транспортното средство с подходящи скорости и ускорения, и ограничено използване на спирачните средства, намаляват разхода за енергия."

Оптимизирането на енергетичният разход за тягови нужди е целесъобразно да се направи, чрез аналитично изследване на различните стратегии за управление на транспортното средство. За да се постигне този вид управление на ЕТС е необходимо да се определят критериите, по които ще се прави оценка на енергетичния разход. От своя страна той зависи от две основни групи фактори - обективни и субективни.

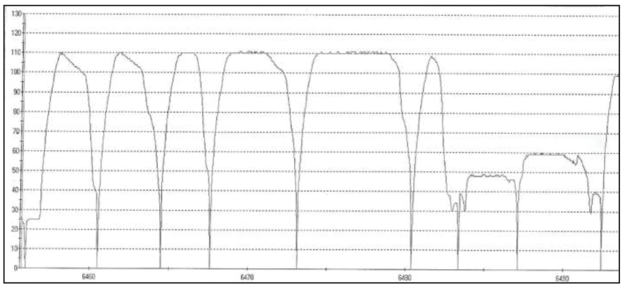
Към обективните фактори се отнасят профилът на пътя, допустимата скорост на движение, натовареността на ЕТС, пътната обстановка, условията на сцепление, нивото на напрежение в контактната мрежа и др.

Към субективните фактори се отнася стилът на управление, неговото съобразяване с техническите възможности на транспортното средство и усетът към използването на натрупаната потенциална енергия на състава по време на движение от страна на водача.

Влияние върху постигането на оптимално управление, както бе споменато, оказват коефициента на полезно действие на състава, намаляване на основното съпротивление на движение, намаляване на загубите при спиране и пускане както и подобряване на стратегията за управление на състава. В настоящия доклад ще се разглежда единствено въпроса свързан с правилно подбраните режими на движение на превозните средства с безстепенно регулиране на тяговите двигатели.

2.1. Режими на движение

При съставите с безстепенно регулиране на напрежението на тяговите двигатели водача избира процента тяга, който може да зададе посредством лоста за „движение –спирана". Поддържането на желаната скорост се осъществява автоматично, чрез устройство наречено темпомат. Тези технически особености предопределят до голяма степен малкото влияние на водача при ускоряване на транспортното средство. Движението на такъв състав е показано на Фиг. 1. На нея се наблюдават характерните четири основни фази на траекторията на движение на релсово транспортно средство във всяко едно междугарие. Специфичното тук, е, че ускоряването е максимално бързо и след достигане на максимално допустимата скорост ясно се очертава втора зона на така нареченото „трионовидно" движение, подсигурено от темпомата. Третата зона се характеризира с движение по инерция и се ограничава от



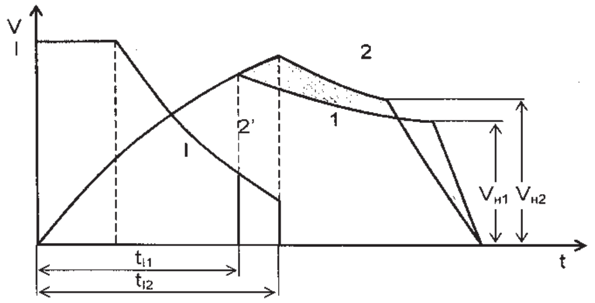
Фиг. 1. *Графично изобразяване движението на влак с диаграма V(s)*

стартиране на спирането, което представлява четвъртата зона. Именно в тези последни две зони водача може да влияе на енергийната ефективност, чрез определяне на тяхното начало и продължителност. Във втарата зона също може да се повлияе,чрез понижаване на скоростта, ака съществеват времеви буфери в разписанието и не е нарушен графика за движение. Съществуват и други стилове на движване, които са производни на описания по горе.

2.2. Фактори за ефективно управление

Основни фактори, оказващи влияние върху разхода на енергия са скоростта на движение, загубите при потегляне и спиране, както и увеличението на спирачното закъснение.

Увеличението на спирачното закъснение също води до намаляване на разхода за енергия. Както се вижда от Фиг. 2, на която крива 1 се отнася за по-голямо спирачно закъснение, а крива 2 - за по-малко, увеличението на закъснението позволява да се



Фиг. 2. *Увеличаване на спирачното закъснение*

намали скоростта на началото на спиране от $V_{н2}$ до $V_{н1}$. Поради това се намаляват и загубите за спиране и съответно намалява времето, през което двигателите работят под ток t_{i2} на t_{i1}. По-ранното изключване на ТД е отбелязано с индекса $t_{i1,}$ а по- дългата работа на ТД с индекса t_{i2}.Диаграмата на фигура 2 касае времетраенето на третата условна зона, движение по инерция. Скоростта на започване на спирането оказва голямо влияние върху общия баланс на консумираната енергия, особено при участъци с малка дължина, поради възможността за рекуперативно спиране при ЕТС с напълно управляемите вентили.

2.3. **Рекуперативно спиране**

Служебното спиране се задейства от водача на ЕТС посредством лоста "движение-спиране". Спирането се осъществява преимуществено, чрез електрическата спирачка с цел да се върне в мрежата рекуперативен ток и да се сведе до минимум нивото на шума и износването на накладките в процеса на спиране.

Размера на върнатата енергия при спускате по наклон- $E_{рк}$ се изразява чрез формула 2.

$$E_{рк} = K_И.У_{рк}.\eta_{рк}.\left(w_i - w_O - w_R\right).T_{спу}\ , \quad (2)$$

където $K_и$ - коефициент на използваемост на рекуперативната енергия;

$У_{рк}$ - частта от спирачната сила от рекуперация през целия процес на спиране;

$\eta_{рк}$ - среден коефициент на полезно действие на рекуперацията;

$T_{спу}$ - товаропоток при спускане

w_i-w_o-w_R – съпротивление на движение при наклон, основно съпротивление и съпротивление от криви.

След намиране на размера на рекуперативната енергия можем да определим нейното влияние върху общия разход чрез формула 3.

$$E_{об} = E_{дв} + E_{сн} - E_{рк}\,, \quad (3)$$

където $E_{об}$ е общ разход на енергия;

$E_{дв}$- разход за движение;

$E_{сн}$- разход за собствени нужди;

$E_{рк}$- енергия от рекуперация.

Определянето на ефективността на рекуперативното спиране става чрез коефициента $к_{рк}$.

$$K_{рк} = \frac{E_{рк}}{E_{об}}\,, \quad (4)$$

В планински участъци $K_{рк}$ може да достигне до 10-20 %, ако използваемостта на върнатата енергия е висока и ако товаропотока на спускане е по-голям от този на изкачване.

При спиране с рекуперация ефективността се характеризира с отношението на върнатата енергия към пълната, необходима за спиране на състава. Тук коефициента може да достигне до $K_{рк}\sim$ 0,49 [3], но благодарение на загубите от порядъка на 40÷60 % от цялата изразходвана енергия за рекуперация икономията на енергия достига до 15÷30 % от общата изразходвана.

$$K_{рк} = \frac{V_н^2 - V_k^2}{V_н^2}\eta_{рк}\eta_л K_и\,, \quad (5)$$

където $V_н$, $V_к$-начална и крайна скорост на рекуперативно спиране;

$\eta_{рк}$, $\eta_л$ – коефициент на полезно действие на рекуперацията и на локомотива.

Водача на ЕТС трябва да се стреми частта от спирачната сила от рекуперация през целия процес на спиране да е по-голяма от общата при използване и на друг вид спирачки.

Това показва, че рекуперацията е по-ефективна при спиране отколкото при спускане в надолнище или поддържане на максимално допустима скорост на движение поради по-голямата разлика на скоростите в началото и края на спирането.

Уменията за правилно определени и подбрани режими за управление на ЕТС от неговия водач, придобити след обучение с тренажор, ще гарантират повишена енергийна ефективност на транспортните процеси.

Отрицателно влияние върху икономията на енергия оказват още непредвидените спирания на състава, нарушаването на графика на движение, временните намаления на скоростта и др. Тези фактори няма да бъдат разглеждани подробно поради по-малкото им влияние върху електропотреблението и случайният им характер на възникване.

Намаляването на разхода на енергия за собствени нужди също е обвързан със стила на управление на железопътните състави и зависи, както от техническите решения за управление на електрическите устройства за собствени нужди, така и от начина на тяхното използване от локомотивния машинист. Правилната употреба и целесъобразното използване на системите за климатизация в мотрисните състави могат да доведат до оптимизиране на общият енергиен

Таблица 1. *Разход на електроенергия по направление Пловдив-Асеновград*

дата	маш. №	час начало	час край	енергия в kW	килом.	влак №
17.01	378	04:15	07:30	510	74	19201-19202-19205-19206
03.01	762	04:20	07:35	520	76	19201-19202-19205-19206
11.01	737	04:15	08:15	582	76	19201-19202-19205-19206
06.01	746	04:15	08:25	500	77	19201-19202-19205-19206
18.01	319	04:15	08:20	623	77	19201-19202-19205-19206

разход. Той може да се окаже значителен при пътническите влакове, които са снабдени с климатични системи, ако остават включени при служебните придвижвания и продължителни престои без пътници. При тези състави правилното регулиране на температурата, използването на автоматично управление на вратите, добрата топлоизолация и др., могат чувствително да намалят разхода на електроенергия.

За да се провери верността на получените теоретични резултати и дългогодишни наблюдения е направено експериментално изследване, чрез съпоставяне разхода на енергия на различни водачи, при управление на едни и същи влакове с мотриса № 31- 019, показани в Табл. 1.

Получената разлика от 20 % в реализирания разход на електрическа енергия доказват необходимостта от прилагане на предложената методика и внедряване на тренажорно обучение. Резултатите от проведеното изследване са потвърдени и в други направления. Те подчертават влиянието на субективния фактор върху разхода на енергия и необходимостта от обучение по енергийно ефективно управление.

3. Заключение

Получените теоретични резултати дават основание за въвеждане на трениробъчен стенд за обучение на водачи на релсови транспортни средства;

Получената икономия на енергия с въвеждането на тренажор ще е в порядък от 5 % ÷ 10 %;

Посочените предимства и доказания икономически ефект, дават основание да продължат изследванията в тази посока и от гледна точка на необходимите инвестиции за внедряване и използване на обучителен тренажор в железопътния транспорт.

ЛИТЕРАТУРА

1. Петров И., И. Лалов, С. Сребрекова, (2015), *Изследване на психофизическите показатели на локомотивните машинисти за подобряване на техниката на водене на влак и енергийната им ефективност,* Механика транспорт комуникации, том 13, Брой 3/3.
2. Ненов Н., (2008), *Движение на влаковете и оптимални режими на управление*, София 2008.
3. Българанов Л. и кол. (2009), *Електрически транспорт*, София.

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ПОВИШАВАНЕ ЕФЕКТИВНОСТТА ОТ РЕКУПЕРАТИВНОТО СПИРАНЕ ЧРЕЗ ПРОМЕНИ В ГРАФИКА ЗА ДВИЖЕНИЕ НА ВЛАКОВЕТЕ

ИЛКО ТЪРПОВ, СИЛВИЯ САЛАПАТЕВА

Резюме: *В доклада е разгледано рекуперативното спиране и възможностите за подобряване на коефициента за ефективност на този вид електродинамично спиране чрез промени в графика за движение на влаковете.*

Ключови думи: *рекуперация, график за движение на влаковете*

INCREASING THE EFFICIENCY OF THE RECUPERATIVE BRAKING BY ALTERING THE TRAIN SCHEDULES

ILKO TARPOV, SILVIYA SALAPATEVA

Abstarcts: *In the report the recuperative stopping and the possibilities of increasing the efficiency of this kind of electrodynamic braking, by changing the train schedules are analyzed.*

Key words: *recuperation, train schedules*

1. Въведение

От края на 2007 година в България се експлоатира тягов подвижен състав, които притежават електродинамична спирачка с рекуперативен ефект.

Рекуперативното спиране, като вид електрическо спиране се осъществява благодарение на обратимостта на електрическите машини. Натрупаната кинетична енергия в състава през периода на ускоряване и потенциалната такава при спускане се преобразува в електрическа по време на спиране. Тази енергия върната в контактната мрежа или съхранена в акумулаторни батерии, наричаме рекуперативна.

Значителен ефект от този вид спиране може да се наблюдава при продължителни стръмни спускания или в участъци с голям брой спирки. Размерът на върнатата енергия в мрежата, според някои автори [2], може да достигне до 30% от консумираната такава, в зависимост от стила на управление на транспортното средство. Пълното консумиране на енергията от рекуперация може да се осигури ако в същата фидерна зона има състав, който в този момент се намира в процес на ускоряване.

В доклада ще бъде обърнато внимание на възможността за повишаване на коефициента на рекуперация, чрез промени в графика за движение на влаковете (ГДВ).

2. Изследване на ефективността от рекуперация

За изследване на ефективността от рекуперативното спиране са проследени електрическите мотрисни влакове (ЕМВ) "Дезиро" на фирмата "SIMENS", собственост на БДЖ. На фиг. 1 са показани графичните изменения на трите вида мощности (активна – P, W, реактивна – Q, VAr и привидна – S, VA) на

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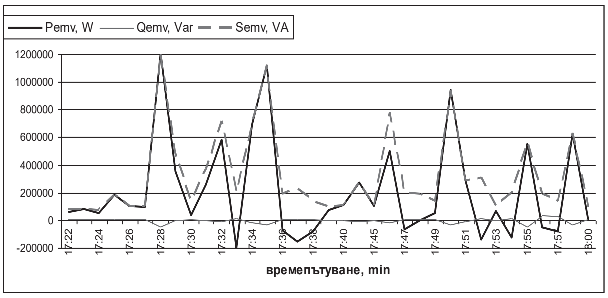
ЕМВ получени от експериментално измерване. Вижда се, че в няколко участъка активната мощност P сменя знака си, което показва, че състава реализира успешно рекуперация и връща енергия в мрежата.



Фиг. 1. *Изменение на активната P, реактивната Q и привидната S мощности на ЕМВ "Дезиро"*

Големината на върнатата енергия при спускане на състава по наклон $E_{рк}$ се определя чрез формула (1).

$$E_{рк} = K_u У_{рк} \eta_{рк} (w_i - w_o - w_R) T_{спу}, \qquad (1)$$

където K_u е коефициент на използваемост на рекуперативната енергия;

$У_{рк}$ - частта на рекуперацията за целия процес на спиране;

$\eta_{рк}$ - среден коефициент на полезно действие на рекуперацията;

$T_{спу}$ - товаропоток при спускане;

w_i, w_o, w_R - съответно съпротивление на движение при наклон, основно съпротивление и съпротивление от криви, kg/t.

От формула 1 се вижда, че може да се влияе на размера на върнатата енергия по два начина. Първият е чрез увеличаване коефициента на използваемост K_u на рекуперативната енергия, като се осигури консуматор, а втория чрез използване на рекуперацията $У_{рк}$ през целия процес на спиране без да се прилага друг вид спирачка. Методите за повишаване стойностите на останалите параметри от формула (1) са обект на разглеждане в други разработки.

Определянето на ефективността на рекуператевното спиране се извършва чрез коефициента $K_{рк}$:

$$K_{рк} = \frac{E_{рк}}{E_{об}}, \qquad (2)$$

където $E_{об}$ е общия разход на енергия, кWh;

$E_{рк}$ - енергия от рекуперация, кWh.

За да се повиши ефективността от рекуперативното спиране според формула (2), трябва да се повиши енергията от рекуперация $E_{рк}$, тъй като общата консумирана енергия зависи от свършената работа.

В планински участъци коефициента $K_{рк}$ може да достигне до 10-20 %, ако използваемостта на върнатата енергия е висока и товаропотока на спускане е по-голям от този на изкачване.

Това се установява от израза (3):

$$K_{рк} = \frac{V_н^2 - V_к^2}{V_н^2} \eta_{рк} \eta_л K_u, \qquad (3)$$

където $K_{рк}$ е коефициент на ефективност на рекуперативното спиране;

$V_н$, $V_к$, - съответно начална и крайна скорост на рекуперативно спиране, km/h;

$\eta_{рк}$, $\eta_л$ - коефициенти на полезно действие съответно на рекуперацията и на локомотива;

K_u - коефициент на използваемост на рекуперативната енергия.

Локомотивният машинист трябва да се стреми частта от спирачната сила от рекуперация $У_{рк}$ през целия процес на спиране да е по-голяма от общата при използване и на друг вид спирачки:

$$K_{рк} = \frac{T_2}{T_1} \frac{w_i - (w_o + w_R)}{w_i + w_o + w_R} \eta_{рк} \eta_л K_u У_{рк}, \qquad (4)$$

където T_1 и T_2 са годишните товаропотоци в двете посоки;

w_i - относително съпротивление на движение от наклона, kg/t;

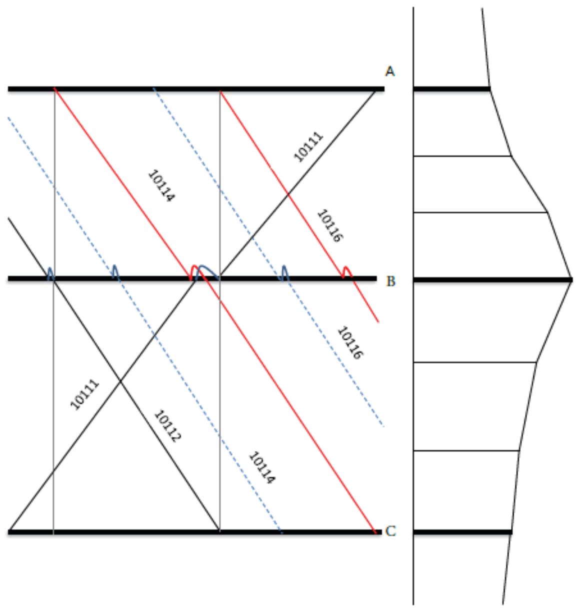
w_R - съпротивление от крива, kg/t;

w_o - основно съпротивление на движение, kg/t;

$У_{рк}$ - частта на рекуперацията от общия спирачен процес.

При $K_{рк}$ = 0,49 може да се достигне икономия на енергия от порядъка на 15÷30 % [2], необходима за движение по участъка. Създаването на подходящи условия, при които произведената енергия от рекуперация може да се консумира от друг състав в същия момент, води до увеличаване на коефициента на използваемост на рекуперативната енергия K_u, а от там и до реализиране на енергийно ефективен транспортен процес.

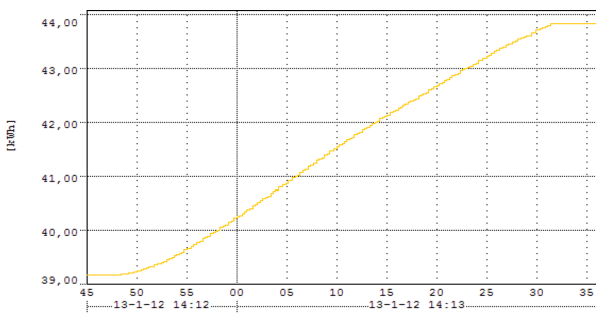
Това може да се постигне, чрез прецизно съставяне и изпълнение на ГДВ за всеки отделен участък. Изисква се още при съставяне на графика да се съобрази големината на железопътното трасе, захранвано от една подстанция и намиращите се в същата зона електрически подвижен състав (ЕПС), съгласно предварително подготвения график. Движението по наклон на един състав трябва да бъде съчетано с изкачването на друг състав по същото време, с цел да се използва произведената от рекуперация електрическа енергия. Също така е необходимо, спирането на един ЕПС да съвпада с процеса на ускорение на друг състав. Оптимизирането на ГДВ с цел повишаване коефициента на ефективност на рекуперативното спиране $K_{рк}$ е представен на фиг.2.



Фиг. 2. *Оптимизиране на ГДВ с цел повишаване коефициента на ефективност на рекуперативното спиране* $K_{рк}$

От лявата страна на фиг. 2 е представена част от ГДВ между три съседни гари А, В и С свързани с двойна железопътна линия. От дясната страна на фигурата е изобразен профила на участъка, като от гара А към гара В е в нагорнище, а от гара В към гара С в надолнище. Чрез отместване на влакове с номера 10114 и 10116, изобразени с червени линии, стремежът е влак №10116 да започне изкачване от гара А към гара В в момент, в който влакове №10111 и №10114 се спускат и произвеждат регенерирана електрическа енергия. С тази корекция в ГДВ влак №10116 ще оползотвори максимално енергията от рекуперация и така ще се повиши коефициента на използваемост $K_и$ на рекуперативната енергия.

Рекуперацията е по-ефективна при спиране отколкото при спускане в надолнище или поддържане на максимално допустима скорост на движение. На фиг. 3 е представено изследване, което показва нарастването на върнатата енергия в контактната мрежа. При рекуперативно спиране от 100 до 0 km/h нарастването достига до 4,8 kWh за 42 s. [3].



Фиг. 3. *Нарастване на върнатата в контактната мрежа енергия при спиране*

За нуждите на анализа в държавния железопътен превозвач се проведе измерване на доставената енергия от ЕМВ "Дезиро" за период от една година и върнатата такава от състава. Данните са отчетени от електромери LEM монтирани във всяко едно ЕМВ, съгласно справка [1]. Общо мотрисите са 25 броя, от които 15 са серия 30-00 (три вагонни) и 10 - серия 31-00 (четири вагонни). Резултатите от проведеното аналитично изследване са представени в таблица 1.

Таблица 1. *Анализ на консумираната и върнатата енергия от ЕМВ "Дезиро"*

ЕМВ	$E_{об}$, kWh	$E_{рк}$, kWh	L, km	$K_{рк}$	M, t
30	9827510	1922921	1688741	0,1956	133
31	9540453	2044247	1407681	0,2142	155

След сравняване на двете серии ЕМВ се констатира, че при серия 31-00 консумацията на електрическа енергия за километър е около 16% по-голяма от тази на серия 30-00. Също така рекуперираната електроенергия $E_{рк}$ за изминат километър е с 21,58% по-голяма при серия 31-00 [2]. Тези разлики се дължат на по-голямата маса M и завишените разходи за собствени нужди от допълнителния вагон.

3. Заключение

От направените експериментални измервания и анализ на получените резултати се вижда, че ефективността на реализираното рекуперативно спиране от ЕМВ “Дезиро” е значителна. Рекуперираната електическа енергия $E_{рк}$ е приблизително 20 % от общата консумирана енергия от състава.

При създаване на условия за максимално използване на енергията от рекуперация енергийната ефективност може да се подобри с 30 %. Такива стойности на ефективност могат да се наблюдават в „Метрополитен”- София поради свързването в паралел на захранващите подстанции.

Заинтересована страна от този вид оптимизация на ГДВ са превозвачите, които притежават ЕПС с рекуперативна спирачка и значително влаково движение в профилни участъци.

ЛИТЕРАТУРА

1. Генова С., М. Красимирова, (2011) *Месечни справки за отчетената енергия на “Дезиро”*, ППП София.
2. Ненов Н., (2008) *Движение на влаковете и оптимални режими на управление*, София.
3. Търпов И., (2015) *Оптимизация на експлоатационните и енергийни показатели на електрифицирания транспорт*, Дисертационен труд за продобиване на образователна и научна степен „доктор“, ВТУ „Т. Каблешков”, София.

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УДЪЛЖАВАНЕ НА РЕСУРСА НА ВОЕННА АВИАЦИОННА ТЕХНИКА В УСЛОВИЯТА НА ИКОНОМИЧЕСКА КРИЗА

ДОБРИН СЕЙЗИНСКИ, СТОЯН АВРАМОВ

Резюме: *Разглежда се въпросът за увеличаване на ресурса на военната авиационна техника в Българската армия в края на миналия и в началото на този век като основен начин за обосновано използване на заложения при проектирането и производството и запас от дълготрайност. Посочват се факторите, обуславящи удължаването на този ресурс. Анализира се удължаването на ресурса по време на авиационни изделия и преди всичко техническите аспекти на този въпрос.*

Ключови думи: *авиационна техника, авиационни изделия, ресурс, дълготрайност.*

MILITARY AVIATION EQUIPMENT LIFESPAN PROLONGATION IN ECONOMICAL CRISIS SITUATION

DOBRIN SEYZINSKI, STOYAN AVRAMOV

Abstract: *Analysis of the ways of increasing the Bulgarian militaryaviation equipment lifespan in the end of the last and at thebeginning of this century is shown as the main way of justifiable useof the full design and production limits. Indicated are the factorsunderlying the prolongation of this lifespan. It is analyzed theprolongation of the time lifespan mainly in the technical aspects ofthis issue.*

Key words: *Aviation equipment, aviation products, time resource, durability*

1. Основни понятия

Ресурсът е важна технико-икономическа характеристика за всички обекти, които имат висока производствено-експлоатационна стойност и от надеждната работа на които зависи живота и здравето на хора. Към този вид обекти спада и авиационната техника (АТ).

Тъй като съществуват различни тълкования на понятието ресурс, в настоящата работа под ресурс на авиационната техника ще разбираме сумарната наработка на АТ от началото на експлоатацията до прехода и в пределно състояние. Той се използва за количествена оценка на дълготрайността на АТ.

Най-общо ресурсът се дели на две основни групи: ресурс по наработка; ресурс по време, който се нарича още срок на служба.

Ресурсът по наработка се измерва се в пролетени часове, брой кацания, брой цикли, а този по време – в календарна продължителност от време.

Съществуват следните видове ресурс:

- ресурс до първи ремонт, който представлява наработката (календарното време) от началото на експлоатацията на обекта до постъпването му за първи ремонт;
- междуремонтен ресурс, който е наработката (календарното време) между два последователни ремонта на обекта;
- назначен ресурс, който представлява сумарната наработка или календарното време, при достигането на които експлоатацията на обекта трябва да се прекрати.

В настоящия доклад се прави опит да се анализира изминатия път при решаване на проблема с удължаване със собсвени сили на ресурса на военната АТ в Българската армия (БА) през последните 20 години, за които са

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характерни условията на икиономическа криза в страната. Поради ограничения си размер той разглежда само някои основни аспекти от този въпрос и няма претенциите да бъде обстоен и изчерпателен.

2. Проблеми на експлоатацията на авиационна техника в условия на икономическа криза в страната

В исторически план разглежданият период се характеризира с непрекъснато намаляване на финансовото осигуряване на екслоатацията на АТ във всичките и съставни елементи. Най-значително това намаление е в областта на нейната летателна и техническа експлоатация.

Затруднена е доставка на резервни части и окомплектовки. Възникват проблеми с лицензното производство на рективно гориво РТ в тогавашния „Нефтохим" – Бургас.

Пролетените часове непрекъснато намаляват, достигайки минимума за запазване на летателната годност на пилотите.

От друга страна, структурната реформа в армията се изрази в тотално ликвидиране на авиационните части и няколкократно намаляване броя на летателните апарати (ЛА).

В резултат на всичко това ЛА престояват на земята, ресурсът им по време се изразходва, без да се използва този по наработка.

При тези условия основният път за ресурсно осигуряване на АТ, експлоатирана по планово-предупредителната система, е технически обосновано и ефективно използване на заложената при проектирането и производството и дълготрайност, както и увеличаване на тази дълготрайност чрез удължаване на ресурса на АТ.

3. Фактори, от които зависи удължаването на ресурса на авиационна техника

Удължаването на ресурса на АТ зависи от множество фактори, които могат да се подразделят на следните: нормативно-правни; организационни; експлоатационни; научно-технически.

Нормативно-правните фактори са най-слабо проучени и изяснени.

През разглеждания период законовата основа за решаване на този въпрос липсва или не е достатъчно ясна. До средата на периода дейността на Главния инженер на авиацията е юридически защитена с промяната на НИАС-80 и на други документи, позволяващи удължаването на ресурса на АТ. През повечето време остават нерешени следните въпроси: по защита правата на производителя и свързаните с това негови задължения да предоставя на потребителя всякаква информация за експлотираните от него ЛА, включително и тази за удължаване на ресурсите; за спазване на изискванията на стандартите; за органите, осигуряващи този вид дейност и др.

Организационните фактори включват:

- провеждане на техническа, общоинженерна и специална подготовка на инженерно-техническия състав;
- спазване или промяна на стратегията и методите на техническо обслужване и ремонт и ритмичността на тяхното провеждане;
- своевременност в осигуряване на запасни части при поява на неизправности и при изпълнение на текущи ремонти;
- създаване на идеология на цялостния процес на удължаване на ресурса на АТ – от методиката до завършващия етап;
- използване на методи и средства за механизация и автоматизация на процесите на подготовка на ЛА за полет, за търсене на неизправностите и за тяхното отстраняване и, особено, използване на автоматизирани средства за контрол на техническото състояние на всички функционални системи и др.;
- информационно осигуряване; наличие на орган за контрол и узаконяване на разглежданата дейност.

Информационното осигуряване на удължаването на ресурса на АТ е един от основните проблеми за успешното решаване на тази задача. При изчислителния (разчетния) ресурс на конструкцията или на ЛА като цяло, например, се въвеждат коефициенти на запас от дълготрайност, които отчитат влиянието на различните неотчетени фактори и степен на достоверност на изходните данни. Тъй като тези коефициенти са приведени в конструкторската документация, то за удължаване на ресурса е необходима информация, свързана с проектирането и производството на ЛА. Такава своевременна и актуална информация може да бъде получена от заводите-производители, създаващи експлоатираната у нас АТ. Подобна информация може да бъде получена и чрез обмен със съответните органи във ВВС на страните, експлоатиращи еднотипни на нашите ЛА. Трябва да се отбележи, че в нача-лото на разглеждания период органите на АТВ във ВВС имат известни успехи, но в послед-ствие тази дейност няма никаква реализация.

Експлоатационните фактори включват:

- режимите на полета (скорост, височина, използвани маневри, полетна маса и др.);

- метеорологичните и климатични условия на полета, в това число турболентността на атмосферата, градиентите на температурата по височина, влажност и др.);
- индивидуалните особености на членовете на екипажите и тяхната професионална подготовка;
- квалификацията на инженерно-техническия състав, определяна, в частност, от знанието на конструкцията на ЛА, от пълнотата, с която се откриват неизправностите, своевременното и ефективно откриване, локализиране и отстраняване на пукнатини, корозии и др.;
- качеството и пълнотата на изпълняваните профилактични мероприятия, а също така и качеството на използване на техническите средства за контрол състоянието на ЛА.

Научно-техническите фактори включват:

- конструктивни, производствени и технологични особености;
- наличие на научноизследователска база за провеждане на уникални за целта изследвания;
- достижгения на научноизследователска дейност в разглежданата област – у нас и в световен мащаб.

Например, конструктивните, производствените и технологичните фактори при удължаване ресурса на планера се обуславят от концетрацията на напрежения в елементите на конструкцията, от остатъчните напрежения, възникващи поради несъвършенства в технологиите и за сметка на пластичните деформации при монтаж на сглобените единици или при ремонта. Те произлизат и от зависимостта на тези напрежения от свойствата на материалите и на тяхното изменение в процеса на експлоатация. Специфични са тези фактори за електрониката и елементната база.

В началото на разглеждания период у нас има сравнително добре развита научноизследователска база, която е предназначена за изследване на надеждността на различни технически системи и на техните елементи. Това е материално-техническата база на различни научни звена в институтите на БАН (Институт по металознание, Институт за космически изследвания), във висшите учебни заведения (тогавашното ВНВВУ „Г. Бенковски”, Технически университет – София, включително и филиала му в Пловдив), в тогавашния Военен научно-технически институт – МО, в бившите ведомствени институти и бази („Химатех” ООД – София).

Като проблем при удължаване на ресурса на АТ се оформи слабата научноизследователска работа у нас в дадената област. В миналото, преди 10.11.1989 г, тази дейност се игнорираше тотално, като ресурсната политика се свеждаше до безусловно изпълнението на изискванията на експлоатационно-техническата документация, на НИАС-80 и на изпращаните от заводите-производители бюлетини.

Липсата на целенасочена научноизследователска работа е причина и за ограничения брой специалисти, занимаващи се с разглежданата материя. Тези специалисти са преди всичко офицери, успешно защитили докторски дисертации в тогавашната ВВИА „Н. Е. Жуковски” – Москва. Това е изключително актуален проблем, тъй като скромният ни кадрови потенциал по това време не стига дори за следене и адаптация на чуждите научни постижения в тази област у нас. От друга страна, в тогавашния момент голяма част от разглежданите въпроси се решават на експертно ниво, за което също са необходими компетентни лица.

Основен изпълнител и координатор на работите и дейностите по удължаване на ресурса на АТ е отделението за анализ и контрол на АТ при Авиационноизследователска база – ВВС. За решаването на тази задача са привлечени специалисти и е използвана материално-техническата база на повечето от изброените по-горе научни звена.

Към нерешените чисто наши, български проблеми следва да добавим и тези, свързани с нерешените или недостатъчно изследвани задачи на теорията на надеждността на АТ в международен план. Сред тях можем да посочим следните: разработване на методи за прогнозиране на откази; оценка на надеждността на изделията, изработвани в неголеми серии; разработване на методи за ускорени изпитвания.

Независимо от множеството публикации у нас и в чужбина за разработване на методи за прогнозиране на отказите, не можа да се представи апробиран теоретичен метод, който да се приложи при удължаване на ресурса на която и да е комплексна група или подгрупа авиационни изделия. В световен мащаб разработването на математични модели за прогнозиране на отказите се намира на първоначално ниво и обхваща далеч не всички реално срещащи се ситуации. Например, има модел за развитие на корозията, но няма такъв за появата и в закрити и трудни за осъществяване на контрол отсеци от конструкцията на ЛА.

Разработването на такива методи е изключително трудно и изисква следното:

- дълбоко изучаване на физичните явления, водещи до отказите;
- изключително прецизно изследване на причините за всяка отделна аварийна ситуация;

- монтиране в конструкцията на ЛА на датчици за контрол на напрегнато-деформационното състояние на най-отговорните и елементи;
- натрупване на необходимия материал за разработване на правилата за поведение на АТ в процеса на нейната експлоатация.

За продукцията, произвеждана в големи серии и още повече за тази от масовото производство, са разработени добре действащи статистически методи на надеждността. Статистическите методи са непригодни, обаче, когата няма необходимия брой наблюдения. Например, отказите по самолета и двигателя са малко на брой, но за сметка на това решаващи при определяне нивото на безопасност на полета на ЛА. В такива случаи се спазват следните препоръки: да се използват знанията за физиката и механиката на процесите, в които работи авиационно изделие; да се въведе статистическо изпитване на елементите от изделията, изработвани в масови серии; да се използват данни за стари аналогични изделия.

Методите за ускорени изпитвания, които се използват доста отдавна, са особено важни за решаване на задачата за удължаване на ресурса. В тях е заложен принципът, че чрез прекомерно влошаване на условията на работа на изделията се ускорява изразходване на ресурса им. При такава по-напрегната работа тези изделия излизат по-бързо от строя и се получава необходимата информация за по-кратко време. Това, обаче, налага от своя страна предварително изучаване на закономерностите на ускоряване на процеса, в зависимост от влошаването на режима. Добре известно е, че до определени граници на изделието могат да действат едни закономерности, а при по-високи – други. Срещат се публикации, в които се привеждат изящни резултати и прости формули, по които трябва да се направят изчисленията на основата на ускорените изпитвания. Но организираните по специален начин проверки показват, че резултатите не се потвърждават.

Разгледаните досега проблеми биха се решили успешно у нас, ако има подкрепата на авиационния производител. Авиационното производство (самолетостроенето) осигурява удължаването на ресурса на АТ като създава следните предпоставки за това: притежава техническа документация (конструкторска, технологична и експлоатационна), чрез която в производството на АТ се залага и съответния назначен технически ресурс. Освен това разполага с якостните изчисления на произвеждания ЛА, което е изключително важно при каквото и да е изследване на напрегнато-деформационното състояние на неговата конструкция; служи за материално-техническа база на провеждането на уникални за целта изследвания; явява се основен потребител на създаваните със значителни финансови средства авиационни специалисти, пряко свързани с разглежданата задача; захранва се с множество научноизследователски разработки, част от които неминуемо засягат тези въпроси.

Практиката показва, че липсата на всяка една от изброените предпоставки е проблем за решаване на задачата за удължаване на ресурса на АТ.

4. Алгоритъм на удължаването на ресурса

Удължаването на ресурса през разглеждания период се извърши по алгоритъм, който се състои от следните елементи:

- разработване на методически указания за цялостното организиране на процеса;
- провеждане на организационни мероприятия;
- провеждане на инженерно-технически мероприятия (инженерен анализ на експлоатационната надеждност на конкретния тип ЛА, моделиране на някои процеси, изслед-вания на отделни елементи и системи на ЛА и др.);
- оформяне на регламентиращи документи (технически ръководства или програми за удължаване на ресурса и указания на Главния инженер на авиацията или на други ръководни лица, изпълняващи неговите функции).

Удължаването на назначения ресурс по наработка на ЛА като цяло е уникална и трудно решима за страната ни задача, поради което през последните 20 години не е решавана само с наши сили.

През разглеждания период удължаването на ресурса по време е реализирано за авиационни изделия (системи, агрегати, елементи), за които има създадена материално-техническа база и съответно научно осигуряване [1].

С над 120 указания и други ръководни документи е удължен ресурса на летателния апарат като цяло, на негови агрегати, блокове и функционални системи на почти всички типове ЛА (Миг-23, Миг-21, Миг-29, Су-22, Су-25К, Ми-8, Ми-14, Ми-17, Л-29, Л-39, Л-410, Ан-24 и др.), намиращи се на въоръжение в БА.

5. Удължаване на ресурса по време на авиационни изделия

Удължаване на ресурса по време (срока на служба) може да се приложи при авиационни изделия (АИ), чийто ресурс по наработка не може да се изразходва в назначения от производителя календарен срок.

Удължаването на срока на служба на АИ се извършва по методики, използващи различни методи, но включващи в най-общ план следните работи и дейности: изследователски работи; вземане на решение за удължаване на ресурса; работи и мероприятия, извършвани преди и след удължаването на ресурса; разработване и приемане на принципи на експлоатация на изделията с увеличен ресурс.

Изследователските работи зависят от вида на изследваното изделие т.е. от неговото предназначение, конструкция, използваните материали, технологични решения и т.н. При удължаване на срока на служба основно значение има изучаването на процесите на стареене в пластмасите, гумените изделия, херметиците, електронните елементи и др. От съществено значение е изучаването на корозионните процеси в конструкционните елементи на металните конструкции и тяхното влияние върху срока на служба на изделието.

През разглеждания период изследователската работа най-общо се свежда до следното: статистически и технически анализ на неизправностите на АИ в процеса на неговата експлоатация; анализ на условията на експлоатация и съхранение; анализ на техническото състояние; икономически анализ.

Статистическият и техническият анализ на неизправностите на изследваното АИ в процеса на експлоатацията му се извършват с цел отделяне на отказите, свързани с понижаване нивото на безопосност на полетите и определяне на елементите от изделието, оказващи съществено влияние върху това понижаване. Трябва да се отбележи, обаче, че чрез тези анализи се отделят само тези откази и свързаните с тях елементи, които се обуславят от процесите на стареене, корозия и др. т. е. от процесите, определящи назначаването на срока на служба. Анализът се извършва на базата на конкретни данни за всяко отделно изделие. При липса на такова се използва експлоатационната информацията за откази за дадения тип изделие, събирана от авиобазите.

Резултатите от анализа са толкова поправдоподобни, колкото по-пълна е информацията и колкото повече изделия от дадения тип подлежат на наблюдение. За повишаване достоверността на тези резултати към статистическите данни от експлоатацията се добавят и тези от ремонта на изделията.

Анализът на условията на експлоатация и съхранение се провежда от гледна точка на неблагоприятните въздействия на атмосферните условия върху неговата конструкция и елементи и свързаните с това процеси на стареене и корозиране. При извършване на този анализ особено внимание се отделя на създаването на адекватна представа за различните въздействия и следващите от тях последствия върху безотказността и дълготрайността на АИ.

В процеса на своята експлоатация АИ са подложени на въздействието на комплекси от фактори. Най-характерен е следният: температура на въздуха; относителна влажност; скорост на вятъра; слънчева радиация; химическо замърсяване на атмосферата.

Резултатите от пресмятането на коефициентите на корелация за този комплекс показват, че няма пряка зависимост между въздействията на различните фактори в различните климатични зони. Обаче, съвместното въздействие на няколко от тези фактори може да усили тяхното влияние върху изделието. Това се проявява изключително силно при действие на висока влажност заедно с химически фактори (съдържание на морски соли, на SO_2, H_2S, NH_3, NO_2). Влагата, попаднала на повърхността или проникнала във вътрешността на изделията и материалите може да предизвика: снижение на повърхностното или обемно съпротивление на изолация, снижение на електрическата якост на материалите и др.; изменение на физическите свойства на материалите, изменение на размерите и изкорубване на отделни неметални детайли и др.; ускорено стареене, окисляване и корозиране на материалите, повишаване износването на детайлите, покритията, изолациите, смазочните материали и т.н.; увеличение на нивото на относителните електрически загуби в материалите и изделията.

Трябва да се отчете, че анализът на условията на експлоатация и съхранение на военната АТ у нас показва, че тази техника е експлоатирана и съхранявана при строго спазване на изискванията на съответната за всеки тип експлоатационна документация. В резултат на това тя е възможно най-добре защитена от вредното въздействие на отделните външни фактори, както и на тяхната комбинация, което от своя страна я предпазва от възникването на изброените по-горе състояния.

Анализът на техническото състояние на АИ цели получаване на данни за определени техни параметри, на базата на които да се удължи ресурсът им. Този анализ се извършва индвидуално за всеки тип изделие и включва различни по вид и по обем лаборатории, имитационни и други изпитвания. Видът и обемът на изпитванията в голяма степен зависят от резултатите на статистическия и техническия анализи и на анализа на условията на експлоатация и съхранение. В повечето случаи това са сложни и специфични изследвания, които изискват използването на специална апаратура и методики. Коректността на тези изследвания в най-голяма степен определя правилността на решението за удължаване на ресурса.

Икономическият анализ позволява да се определи икономически критерий, въз основа на който да се вземе решение за реализация на работите, свързани с удължаването на ресурса на определен тип АИ.

Най-общо, икономичческият критерий за ефективността от удължаването на срока на служба на АИ е

$$E=C_2 - C_1 ,$$

където C_1 – стойност на разходите за удължаване на ресурса на изделието, както и за неговата експлоатация след това; C_2 – стойност на разходите за ремонт на изделието с изтекъл ресурс или на доставката на ново изделие, което да го замени, както и за неговата експлоатация.

Стойността на разходите за удължаване на ресурса на изделието се състои от стойностите на: елементите, подлежащи на подмяна; работите, които трябва да се изпълнят на изделието; изследователските работи, свързани с удължаването на ресурса; експлоатацията на изделието с удължен ресурс.

Понятно е, че при $E \geq E_{min} \geq 0$, удължаването на ресурса е икономически целесъобразно.

Вземането на решение за удължаване на ресурса на АИ е най-отговорния момент в целия комплекс от работи и дейности. За всеки тип изделие то става индивидуално. За някои АИ има апробирани методики, които позволяват да се оцени тяхната дълготрайност и да се прогнозира ресурса им. За повечето, обаче, решаването на този въпрос може да се осъществи само по експертен път. В този случай решението се взема от експертна комисия на базата на резултатите от изследователските работи и на определените от нея критерии за удължаване на ресурса. Правилността на взетото решение се определя в голяма степен от компетентността на експертите от комисията. Поради това, в качеството на такива се назначават най-добрите специалисти в дадените области. Например, в комисията за удължаване ресурса на гумените изделия в качеството на експерти са привлечени най-добрите учени и специалисти от нашите научни, научнопроизводствени и учебни звена в сферата на каучука.

Работите и мероприятията, извършвани преди и след удължаването на ресурса са осъществявани от съответните експлоатационни звена в системата на ВВС без или с помощта на авиационите военно-ремонти заводи. Обемът и периодичността на тези дейности са определяни както от решението, забележките и препоръките на експертната комисия, така и на базата на натрупания опит в експлоатацията на типовете АИ.

По методика [1,2], отчитаща горното, са удължени ресурсите на шлангове от горивната система на самолет МиГ-23 БН, на мекия горивен резервоар на самолет L-39 ZA, на мекия горивен резервоар на самолет МиГ-21, на противопретоварващите и височинните костюми на пилотите и др. Правилността на взетите решения се потвърждава от практиката.

ЛИТЕРАТУРА

1. Сейзински, (2012) Д. Анализ на удължаването на ресурса по време на авиационни изделия през последните две десетилетия. *Jubilee International Congress Sciens, Education, Tehnologies „40 Years Bulgaria – Space Country”,* стр. 342.
2. Сейзински, Д.Т. (1998). Удължаване на ресурса на гумени изделия от авиационната техника. *Сб. от докл. „Ресурсна политика, методи и програми за увеличаване на техническия ресурс на авиационната техника и въоръжение”,* стр.53.

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МЕТОДОЛОГИЧЕСКИ АСПЕКТИ НА БЕЗОПАСНОТО И ЕФЕКТИВНО ГАСЕНЕ НА ПОЖАРИ С ВЕРТОЛЕТ С ОКАЧВАЕМА СИСТЕМА ЗА ПОЖАРОГАСЕНЕ

ИВАЙЛО ГЕОРГИЕВ, ДОБРИН СЕЙЗИНСКИ

Резюме: *Гасенето на пожари в горски и планински райони с вертолет с окачваема система за пожарогасене е сложна задача. Настоящият доклад е посветен на този проблем и представя актулните в момента предимно практически аспекти на методологията на неговото изследване.Той цели разгледаната алгоритмизация на това изследване да бъде използвана за разработване на методика за провеждане на числени експерименти за определяне на най-съществените фактори, влияещи върху безопасността на полетите и ефективността на разглежданото гасене на пожари.*

Ключови думи: *вертолет, пожари, система за пожарогасене*

METHODOLOGICAL ASPECTS OF SAFE AND EFFECTIVE FIRE FIGHTING BY MEANS OF A FIRE FIGHTING SYSTEM ATTACHED TO A HELICOPTER

IVAJLO GEORGIEV, DOBRIN SEJZINSKI

Abstract: *Extinguishing fires in forest and mountainous areas by means of a fire fighting system attached to a helicopter is a complex task. This report focuses on this problem and presents the current, mainly practical aspects of the methodology applied in the research. The aim of this report is to use the described below algorithmics so as to develop methodology for conducting numerical experiments which will determine the most significant factors that affect flight safety and the effectiveness of the firefighting method in question.*

Key words: *helicopter, fire, firefighting systems*

1. Основни положения

Пожарите, възникнали и разпрострели се на голяма надморска височина, в гори и на трудно достъпни места, могат да бъдат овладяни и потушени предимно с използването на въздухоплавателни средства. Гасенето става или чрез изхвърляне на вода (пяна) в огнището на пожара, или чрез направата на заградителни полоси, препятстващи разпространението на огъня. Предимствата на вертолетите в тези случаи пред самолетите са тяхната маневреност, възможността за зареждане на вода от местни източници, извозване на пожарникари и стоварването им в района на пожара, както и по-ниските относителни разходи за доставка на 1 тон вода.

В България за първи път гасене на пожар с вертолет с окачваема система е извършено през 2010 г, като за период от шест години вертолетите са участвали в гасенето на десетки пожари на територията на страната.

Използването на вертолети Ми-8 и Ми-17 с окачваема система за пожарогасене (ОСП) е показало висока ефективност при гасене на пожари на неголеми площи и в труднодостъпни залесени местности, където използването на

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наземни сили и средства е много трудно или невъзможно. То има забележим ефект само в началните стадии на разгарянето на огнището на пожара. Ефективност на гасенето на разрастващ се интензивен пожар може да се достигне при изхвърляне на вода в режим на непрекъснато подлитане. Това изисква използването на голям брой въздухоплавателни средства, осигуряващи необходимата разчетна интензивност на подаване на вода и организация на защитни бариери на още незасегнатите от огъня площи пред фронта на разпространение на пожара. При голяма височина изхвърлянето на течността рязко намалява ефективността, тъй като значителна част от водата се изпарява и не достига до земната повърхност. При ниска височина на полета горещият въздух е беден на кислород, поради което съществува опасност от помпаж на двигателите и възникване на катастрофална ситуация. Това може да се отстрани като се увеличи дължината на въжето между вертолета и сливния резервоар, но и това има своята отрицателна страна – опасност от закачаване в електропроводи, клони на дърветата, при което точността и производителността са по-ниски, а вероятността от попадане на ОСП в опашния витло е доста голяма. Прокарването на заградителни полоси е много по-безопано, но е ефективно само при използване на пяна, което изисква допълнително специално оборудване. Като цяло гасенето на пожари с вертолет е крайно опасно.

Основният проблем при гасене на пожар в горски и планински райони с вертолет с ОСП е осигуряване на високи нива на безопасност и ефективност на летателната експлоатация. Актуалността на този проблем е обоснована от спецификата на летателната експлоатация на вертолета при извършване на тази екстренна авиационна работа, свързана с използването на опасни режими на малки скорости, с транспортиране на специални устройства на външно окачване, с полети в усложнени условия на експлоатация (на пределно малки височини, при намалена видимост, в сложни метеоусловия) и характеризираща се с извънредна срочност, непредвидимост и екстремални организационно-технологични условия.

Настоящият доклад е посветен на този проблем и представя актулните в момента предимно практически аспекти на методологията на изследване на гасенето на планински и горски пожари с помощта на вертолет с ОСП. Той цели разгледаната алгоритмизация на това изследване да бъде използвана за разработване на методика за провеждане на числени експерименти за определяне на най-съществените фактори, влияещи върху безопасността на полетите и ефективността на разглежданото гасене на пожари.

2. Постановка и задачи на изследването

Обект на изследването е вертолетът Ми-17 с външна окачваема система за пожарогасене Bambi Bucket при гасене на горски и планински пожари (фиг. 1).

Фиг. 1. *Гасене на горски планински пожар с вертолет с ОСП Bambi Bucket*

Предмет на изследването е процесът на летателна експлотация на вертолета при гасене на планински и горски пожари под въздействието на външни фактори в условията на извънредна ситуация.

Целта на изследването е методическото осигуряване на безопасността на полетите и ефективноста на гасене на планински и горски пожари от вертолет с окачваема система за пожарогасене.

За постигане на целта трябва да се решат следните основни задачи:

- определяне на характерните особености на изследвания обект;
- разработване на математичен модел на системата „вертолет – окачваема система за пожарогасене” (В – ОСП) с отчитане на особеностите на процеса на гасене на планински и горски пожари;
- разработване на математични модели за моделиране на отделните съставящи задачи (на потока от носещото витло на вертолета, на изтичането на течността от

системата за пожарогасене, на колебанията на външно окачената система за пожарогасене, на възходящия поток от огнището на пожара и др.);

- провеждане на числени експерименти с математичните модели на системата в различни ситуации при приетите условия;
- доказване адекватността на модела на обекта на изледването чрез съпоставяне на резултатите от числените и натурни експерименти;
- решаване на практически задачи за повишаване на ефективността на гасене на пожари с използване на предлаганите теоретични подходи при осигуряване на необходимото ниво на безопасност на полетите;
- разработване на нови изисквания, препоръки и предложения по летателната експлоатация на вертолета с окачваема система за пожарогасене при провеждане на дейности, свързани с гасенето на горски и планински пожари.

За решаване на тези задачи е необходимо добро познаване на физичните процеси, протичащи при разглежданото изследване, както и използваното на надеждно математично моделиране.

3. Средства и методи на изследването

За решаване на задачите на изследването като цяло се използва системният подход с използване на следните методи:

- аналитични;
- математично моделиране;
- за решаване на системи обикновени диференциални уравнения;
- за решаване на трансцедентни уравнения;
- от теорията на вероятностите и математическата статистика;
- на летателния експеримент;
- на лабораторния експеримент;
- на математичната обработка на резултатите;
- на системния анализ.

Анализът на резултатите, получени чрез приведените по-горе теоретичние и емпирични научни методи на изследване, позволява взаимно да се съпоставят качествените и количествените показатели.

При определяне на характерните особености на изследвания обект трябва да се отчита, че високата ефективност и безопасност на полетите на системата В – ОСП са неразривно свързани една с друга и непосредствено зависят от качествата на самата система и от качеството на пилотирането. Качествата на системата се характеризират с нейната динамика на полета при въздействие на външните фактори и съществено зависят от надеждната и безопасна работа на нейната конструкция, силова установка и функционални системи. От своя страна, качеството на пилотиране се определя от теоретичната и практическа подготовка на членовете на екипажа, управляващ системата, както и от тяхното разбиране за динамиката на полета в различни ситуации и знанието на съответните инструкции по експлоатация. Това налага чрез аналитични методи да бъдат обработени голям брой параметри и експлоатационни ограничения, влияещи на режимите на полета и изискващи повишено внимание от страна на пилотите. На базата на тази обработка трябва да се определят тези от тях, които определят ефективността и безопасността на системата при гасене на горски и планински пожари.

За изследване динамиката на полета на всеки летателен апарат в областта на пределните режими на полета, включително и на системата В – ОСП, най-рационално е използването на теоретичните методи и най-вече математическото моделиране. Достойнството на теоретичните методи е в следното: ниска себестойност; възможност да се моделират особени ситуации, включително катастрофални; възможност да се задават необходимите външни въздействия. Тези методи успешно се използват от всички автори [1...8], занимаващи се с изследване динамиката на полета на вертолет с товар на външно окачване, включително с ОСП при гасене на пожари.

При разработване на математичните модели на индуктивния поток от носещото витло на вертолета, на възходящия поток от огнището на пожара, на изтичането на течността от системата за пожарогасене, на колебанията на външно окачената система за пожарогасене може да се използват подходите и насоките, използвани в [1...6], като се изберат най-подходящите за постигане на поставената цел. Например, при моделиране на облака от водни капки, образуван след пускането на водата от ОСП Bambi Bucket и покриването на определената площ, може да се приеме, че газът е непрекъсната среда, а течността (водата) е дискретна среда, при изследването на която се прилага подходът на изучаване поведението на отделните капки (фрагменти) [1]. В този случай, за икономия на изчислителни ресурси се приема, че траекториите на големи групи от капки са еднакви т.е. не се отчита сблъсъкът между самите капки вътре в групата. За решаване на системата от уравнения се използва методът на крайните обеми.

Провеждането на числените експерименти с математичните модели на системата в различни ситуации при приетите условия може да се осъществи с използване на утвърдили своята работоспособност и ефективност програмни продукти. Например, численият експеримент с модела на облака от водни капки, образуван след пускането на водата от ОСП, може да се осъществи с помощта на програмния продукт Flow vision [9]. Този продукт позволява да се отчита цялото поле на течението без да се отделят особеностите и има подходящи възможности при задаване на движението на телата и граничните условия. За числения експеримент с моделите на движение на вертолета и взаимното положение на вертолета и ОСП може да се използва програмният продукт HeliCargo [6].

Доказването на адекватността на разработените математични модели става чрез съпоставяне на резултатите от числените и натурни експерименти.

Оценката на адекватността на математичния модел на движение на системата В – ОСП може да се направи с използване на следния подход. Първо се оценява адекватността на модела при полет на вертолета без ОСП чрез сравняване на резултатите от числения експеримент с тези от записите на параметрите на полета от летателния експеримент. След това същият модел преминава проверка на адекватност на моделирането на поведението на ОСП чрез сравняване на резултатите от числения експеримент и от летателния експеримент с празна окачваема система.

Летателните експерименти се провеждат с вертолет Ми-17 с ОСП – Bambi Bucket на летище Крумово (надморска височина 182 m), в района на Асеновград (надморска височина 1000 m) и в района на Баташки снежник (надморска височина 2000 m). Експериментите се извършват при хоризонтален полет със скорост $V_{пол}$= 60-180 km/h и при различно запълване с вода на резервоара на ОСП. Дължината на въжето от мястото на окачване на вертолета до ОСП се променя с цел постигане на най-добри резултати за пожарогасене с отчитане непопадането на празната ОСП в областта на опашното витло.

Лабораторните експерименти се провеждат в аеродинамичната тръба УЛАГ-1 на катедра Транспортна и авиационна техника при Технически университет – София, филиал Пловдив. Резултатите от лабораторния експеримент се съпоставят с тези, тези получени при численото моделиране с предварително изработения математичен модел.

При решаване на практически задачи за повишаване на ефективността на гасене на пожари при осигуряване на необходимото ниво на безопасност на полетите може да се използва следният подход. С използване на метода на математичното моделиране се получават параметрите на движение на ОСП за различни значения на интензивността и направлението на ветровия порив при различни скорости на полета вертолета. Определят се условията на възникване на явлението на динамична неустойчивост на ОСП при нейното транспортиране на вертолета-носител. На базата на това се формулират основните препоръки за използване на системата В – ОСП.

По аналогичен начин се разработват нови изисквания, препоръки и предложения по летателната експлоатация на вертолета с окачваема система за пожарогасене при провеждане на дейности, свързани с гасенето на горски и планински пожари.

4. Очаквани резултати

Като резултат от числените и натурни експерименти се очаква:

- отделяне на основните фактори, влияещи върху ефективността на използване на вертолета с ОСП за гасене на пожари (скорост и височина на полета, маньовър за пускане на водата, секунден разход на течност);
- пълно изследване на особеностите на вертолет с ОСП, както в нормални, така и в екстремни ситуации;
- осигуряване икономия на ресурси чрез използване на математически модели за сметка провеждане на ЛИ;
- провеждане на анализ на особените условия на експлоатация на В – ОСП на различни етапи на полета в рамките на ограниченията, с цел оценка пределните експлоатационни възможности на вертолета;
- използване и внедряване на получените резултати от изследванията в научни организации и експлоатационни предприятия във вид на лекции, учебни пособия, инструкции и методики по осигуряване безопасността на полетите;
- разработване на нови методи за съкращаване на работния цикъл с цел повишаване ефективността и надеждността на екипажа;

- използването на нови способи за пускане на вода, различни от хоризонтален полет (от горка или разворот на горка), да осигури необходимото безопасно отдалечение на вертолета от опасната конвективна зона на пожара;
- провеждане на разследване на АП и инциденти с помощта на решаване на обратната задача от динамиката на полета на вертолета с ОСП и на тази основа да се направят препоръки за недопускане в бъдеще подобни събития;
- разработване на препоръки и указания за обучение и тренировки на екипажите на вертолети при използване на ОСП в нормални и особени случай на полета.

5. Заключение

Използването на вертолети за гасене на планински и горски пожари е абсолютно необходимо. Местата, където може да се използва вертолетът, в повечето случаи са недостъпни за пожарникарите с техните мобилни средства. От друга страна бързо променящите се метеорологични условия в планината, липсата на достатъчно кислород вследствие на пожара или надморската височина, може да окажат влияние върху експлоатационните и аеродинамични характеристики на вертолета. Практическата значимост на изследванията се състои в това, че получените резултати могат да бъдат използвани за усъвършенстване на външната система за пожарогасене, технологията и тактиката за използването и, както и да се даде отговор за температурния диапазон в района на пожара, имащ пряко отношение върху работата на двигателите. Могат да се определят и факторите, оказващи най-голямо влияние върху ефективността и безопасността на полетите на системата В – ОСП. На тяхна основа могат да се разработят нови изисквания, препоръки и предложения по летателната експлоатация на вертолетите с ОСП.

ЛИТЕРАТУРА

1. Борисов, И.В., Паршенцев, С.А., и Ципенко, А.В. (2008). Моделирование слива жидкости из контейнера ВОП-3 на внешней подвеске вертолета с учетом потока от несущего винта. *Материалы VII международной конференции по неравновесным процессам в соплах и струях (NPNJ-2008), 24 – 31мая 2008 г,* стр. 98.
2. Борисов, И.В. и Ципенко, А.В. (2012). Вычислительный эксперимент для анализа работы вертолета с водосливным устройством. *Электронный журнал „Труды МАИ“*, № 53.
3. Володко, А.М. (1992). *Вертолет в особой ситуации,* 262с. Транспорт, Москва.
4. Володко, А.М. (2008). Влияние транспортируемого груза на эффективность управления вертолетом. *Научный вестник МГТУ ГА,* № 125, стр. 191.
5. Ефимов, В.В. (2012). Исследование условий возникновения особых ситуаций при транспортировке груза на внешней тросовой подвеске вертолета. *Научный вестник МГТУ ГА,* № 175, стр. 36.
6. Ефимов, В.В. (2012). Исследование автоколебаний вертолета с грузом на внешней тросовой подвеске. *Научный вестник МГТУ ГА*, No 177, стр. 65.
7. Козловский, В.Б., Паршенцев, С.А., Ефимов, В.В. (2008). *Вертолет с грузом на внешней подвеске,* 304с. Машиностроение-Полет, Москва.
8. Паршенцев, С.А. (2005). Надежность функционирования системы „экипаж - вертолет - груз на внешней подвеске“ в условиях развития неблагоприятного фактора. *Общероссийский научно-технический журнал „Полет“,* № 4, стр. 34.
9. Система моделирования движения жидкости и газа FlowVision. http://www.tesis.com.ru/software/flowvision/.

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PROBLEMS IN RECRUITING HUMAN RESOURCES FROM BULGARIAN INDUSTRIAL ENTERPRISES

TONI MIHOVA, VALENTINA NIKOLOVA - ALEXIEVA

Abstract: *The report is an attempt to analyze the problems associated with finding suitable human resources by industrial enterprises in Bulgaria***.** *For this purpose, the authors were based on two national surveys conducted by ManpowerGroup and Bulgarian Industrial Association, as well as its own investigation on the causes of this problem. Have been formulated conclusions and guidelines for improving the activity of selection of human resources in Bulgarian industrial enterprises.*

Keywords: *human resources, recruitment, motivation, remuneration, training and development*

1. Introduction

Modern industrial enterprises operate in an extremely dynamic development and application of new equipment, technology, communication and information systems. Nevertheless, the human factor occupies a leading position as the main productive and creative force in the enterprise.

The management of human resources is directly related to the competitiveness and efficiency of each company. Activities on recruitment and selection of staff play a leading role in attracting candidates who meet the requirements for education, experience, training, contributing to the achievement of organizational goals. This determines the **topicality of the theme** of the report.

The **subject** of research are the difficulties and problems faced by industrial enterprises in selecting the most appropriate human resources. The authors base their findings on two national studies as well as own research conducted in industrial enterprises in the Plovdiv region.

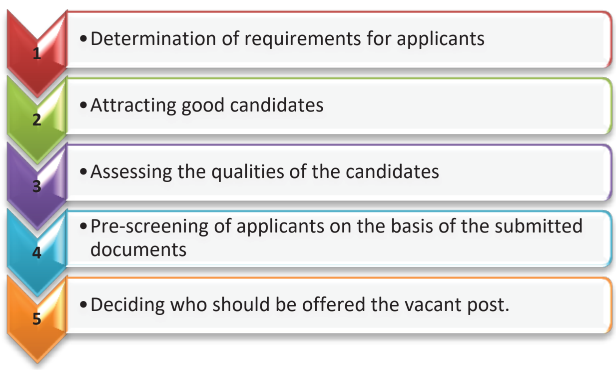
2. Definition of the recruitment and selection of human resources

In connection with the objective to understand what the problems and difficulties in recruitment and selection of human resources will be clarify in a systematic way the essence of this process. In the specialized literature has several publications about the nature of recruitment and selection of human resources. Extremely a thorough studies on this issue have been issued by Dimitar Shopov, Margarita Atanasova, Tatiana Hristova Dimitar Kamenov and Jordan Bliznakov.

According to the authors, definition that most accurately reflects the nature of the selection of human resources is: "The selection of human resources in the enterprise be an activity to attract suitable candidates for a post evaluation of their merits in terms of job requirements and then deciding whom to make a job offer. [1]

The main objective of selection is to ensure "the best man" for the job. It depends on the objective and accurate forecast of future job performance of candidates.

The selection process of candidates includes a number of activities that can be defined as its major stages:



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Basic methods and tools for contacting potential candidates for vacancies in the enterprise are:

- Advertise the vacancy;
- Oral advertising by relatives and friends;
- Attracting good candidates with the help of employees in the enterprise;
- Contacts with employment exchanges;
- Contacts through social networks;
- Contacts with students in their respective schools.

Business practices shows that this is an extremely complex and responsible process, which depends on the overall performance of the enterprise. Therefore it is necessary human resources specialists have appropriate training and competence to be able to effectively carry out activities in the selection and recruitment.

3. Contemporary tools in recruitment and selection of human resources

Besides the necessary training and competence recruiters also need to monitor emerging technological novelties on the process of recruitment and selection of staff. One such new challenge is recruitment through the use of so-called „social and mobile channels“. According to British electronic edition HRmagazine, "the market already has many social tools that allow you to quickly find people - this is not a problem" [2].

In this sense, the question is not only which channels to select are the most suitable for the needs of industrial enterprise, but also how to be used in the most effective manner. For example, according to marketing firm 4MAT, currently between 20% and 30% of traffic to websites for careers and recruitment is generated by users who visit mobile versions of the relevant pages [2].

We investigated various technologies and tools for selection, which we believe have the potential to change the face of the HR industry and provide a rating as follows:

➢ **Systems for tracking applicants (applicant tracking systems, ATS)**

The first such instruments appear early 90s of the last century and are among the earliest opportunities for online selection. At the very beginning their functionality is limited to tracking incoming company CV-s, but lately it offers opportunities to expand in various areas, including for example compliance checks skills, Analysis of CV-th and posting job advertisements through various communication channels, including social media. In practice, modern ATS is a platform that allows HR professionals to connect various tools and services used in the selection process, and thus streamline operations.

➢ **Instruments for mobile selection**

Rising sales of powerful smartphones and tablets will probably lead to a time when their use will overtake those of desktops. This in turn brings to the fore the question of mobile selection, and expectations are to become a major recruitment channel in the future.

➢ **Gamification**

According to one of the leading analytical companies in the world - Gartner, the so-called *gamification* is the trend of using different gaming mechanisms in the *non-gaming* situations, such as the selection of personnel. The idea is thus to increase the motivation of the people or to provoke change in their behavior. Gartner forecast that in the next five years the use of such methods will become "a pretty significant trend." Factor for this is the growing market of developers, offering opportunities for the use of game elements in processes like recruitment and management of staff. The use of such methods for example can allow more rapid identification of candidates who possess the necessary skills for a position. Game elements can be used also for better communication and build relationships between talent within an organization.

➢ **Collaboration tools**

Despite its great potential for sharing and exchanging information currently professional social networks are not as used by recruiters. However, if used effectively, this type of networks can contribute to a better integration of the processes of selection and management of human resources with other departments and activities within an organization, which ultimately contribute to increasing the efficiency of the selection process .

➢ **Technology to determine the location**

The idea of using this type of tool is that it allows both employers and HR professionals in an easy and inexpensive way to target jobseekers who are often on the move. The use of technology to determine the location (most often through the IP address of the mobile phone or the computer of a user) enables companies to provide potential employees information that is relevant to the area in which they are located. "When you ask people looking for work, what is important to them three things that always stated are salary, position and location",explains John Salt from the TotalJobs.com. According to him the possibility of receiving targeted ads depending on their location is already something jobapplicants seeking and HR professionals should be aware.

➢ **Video interviews**

In 2016, according to the head hunting company OfficeTeam UK, 45% of recruiters have increased their use of video to conduct job interviews compared to 2013. While it should not be taken entirely as an alternative to actual face to face meetings, interest in such tools grows and factors are speed and convenience they offer. Furthermore, the video channels are a natural environment for the majority of the representatives of the younger generations, which means that HR professionals will have to accept their increasing importance in the selection process.

- **Internet sources**

For a number of recruiters using social networks like LinkedIn, Twitter, Facebook etc. is now living part of their work. At a later stage in this category includes the use of a wider range of sources and head-hunting techniques for more difficult to detect talents. The challenge for HR professionals in this case is rather in how to optimize the use of such sources, so to maximize efficiency. Possible solutions to this effect are as applications that enable semantic search, where results are based on the meaning of search keywords rather than specific matches word for word. For now, however the use of such tools is not yet extensive, indicated by HRmagazine [2].

4. Results from research

To realize the goal of the report and to reveal the main difficulties and problems in the recruitment and selection of human resources from industrial enterprises, we can use three surveys.

The first study is a national survey of ManpowerGroup [3]. According to him, nearly two thirds (62%) of employers in Bulgaria have difficulties to fill their vacancies in 2016. In comparison, the percentage of Bulgarian employers shared these difficulties was 50% in 2015. About one-fifth (24%) of respondents consider that they are more difficult to find suitable candidates for the job in 2016. The situation has facilitated only in 6% of Bulgarian employers.

The main reasons for difficulties in filling the vacancies, cited by employers, are:

- first, with 32% - lack of so-called required. hard skills (eg qualifications relating to certain tasks, IT skills, or language and mathematical skills);

- secondly with 30% - lack of candidates;

- third with 13% - lack of so-called required soft skills (professionalism, enthusiasm, interpersonal skills, flexibility / adaptability);

- 12% of employers indicate lack of experience and talent in candidates;

- 11% of employers indicate higher expectation than the remuneration offered.

The results of this study also indicate that:

Employers in Bulgaria suffer most from a lack of skilled workers, engineers and drivers.

To deal with difficulties in finding people Bulgarian employers use several strategies:

- the majority - 50% - provide additional training and development of current staff;

- second, employers indicated hiring people outside the traditional range of talent - older or younger than usual employees;

- one-third of employers (33%) use outsourcing activities;

- 30% of surveyed employers offer a larger salary to employees, and 29% - offer additional motivational packages.

- 22 percent say changing existing business models - such as flexible or teleworking;

- only 9% of respondents said they did not follow any strategies, and 2% said they did not know.

In 2016 most sought after by employers in Bulgaria are skilled workers - they change their place in the rankings with engineers who were most scarce last year. In 2016 IT talents are in 10th place to fourth position in 2015. Sales representatives and project managers were replaced by laborers and operators proceedings. In 2016 remained large imbalance between demand and supply of skills.

The second study was conducted by the Bulgarian Industrial Association (BIA) in 2015, whose results were announced at a round table with the participation of the World Bank and the "Open Society" Institute [4]. The conclusions from it are:

- Businesses looking for staff with interdisciplinary knowledge and skills hybrids - combinations of technical capabilities and marketing flair and entrepreneurial attitudes;

- Labor market is valued also skills in development, creation and implementation of new technologies, willingness to learn and improve;

- Required skills for teamwork, leadership, decision making, problem solving, communication, emotional intelligence, commitment to change;

- The advantages are quickness, flexibility, adaptability, organization, personal effectiveness, courage to assume responsibility, reliability, attention to detail and focus on the customer. Important to many areas are also ability to work under pressure and stress, self-control and time management.

According to this study do not reach professionals in the software industry, nanotechnology, mechatronics, mobile communi-cations, applied sciences, energy, chemistry, construction, mechanical engineering.

The third study was conducted by the authors of the report during the period February 2016 - December 2016 into industrial enterprises in the Plovdiv region. In particular industrial enterprises are from the "Trakia economic zone" and the collection of empirical material is accomplished with the help of students from

Technical University - Sofia, Plovdiv branch and the University of Food Technologies and pupils from two vocational schools in Plovdiv. It covers 65 managers (from middle and operational level), 587 employees (121 - 466 engineers and skilled workers) and 332 students (175 students and 157 pupils).

The methods used are interview and questionnaire. We'll point out some highlights from the survey.

The main problem that indicate 92% of the managers is the difficulty in finding quality and skilled human resources. Only 3% do not think there is a problem to find what specialists, and 5% did not answer the question of selection of human resources (fig. 1).

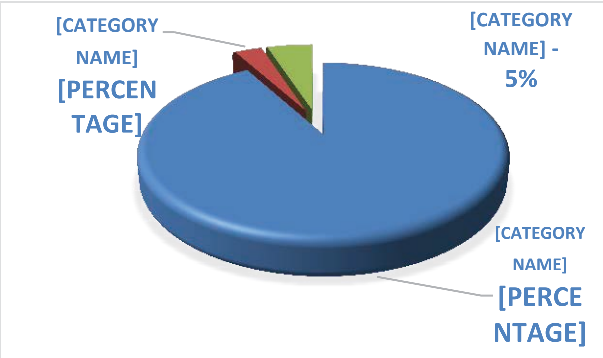

Fig. 1. *"What kind of problems are you experiencing in the staff selection?"*

On question of job satisfaction, the results are as follows:

- 78% of engineering professionals are largely motivated for the most effective job performance. They are satisfied with the remuneration, training opportunities and career development and working conditions;
- 16% are not motivated due to stress at work, poorly constructed teams and ineffective communication;
- 6% of respondents did not answer the question.

Highly skilled workers meet the same issues as follows:

- 67% are highly motivated to work effectively. Satisfied are from the salary, benefits, training opportunities and working conditions.
- 24% have expectations for higher remuneration;
- 9% did not answer the questions in the survey.

Study analysis of the results conducted with students enables to point out the following:

- 17% would apply for a job at the declared vacancy into industrial enterprises from "Trakia economic zone";
- 53% do not believe they will apply for jobs in these companies (do not feel sufficiently prepared; have other plans for their development; do not like the location of businesses; they do not think that they will receive the expected salary);
- 19% do not have information about these companies and cannot decide;
- 11% did not answer the survey questions.

On the same question (fig.2), students from vocational schools have responded as follows:

- 13% would apply for a job at the declared vacancy;
- 61% share the opinion that it would apply (they have other plans for their development; they are not convinced that will handle the job; have expectations for higher remuneration from the alleged);
- 21% are unaware of these enterprises;

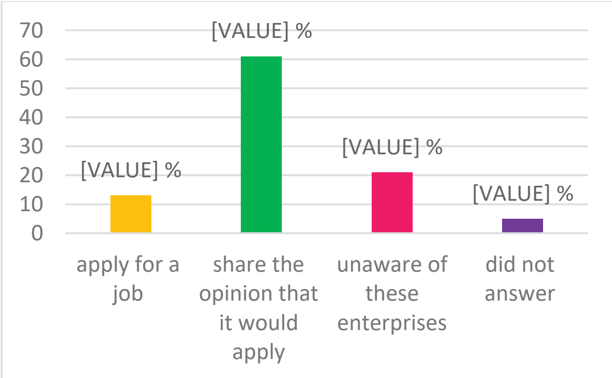

Fig. 2. *"Are you interested to work in the industrial enterprises from "Trakia industrials zone"?"*

- 5% did not answer the poll question.

What are the specific findings of the present studies?

- major problem for industrial companies is finding quality and skilled human resources;
- for the most part, employees are motivated the most effective job performance and are satisfied with the remuneration, opportunities for training and career development and working conditions in industrial enterprises;
- the majority of potential job applicants (students from vocational schools and students of universities) are not sufficiently confident in their professional employability in the industrial enterprises, and they lack the necessary information about.

The findings are reason enough to formulate some guidelines to solve the problem - the difficulty of finding the most appropriate human resources.

Above all, it is necessary to build mechanisms for extremely strong connection between business on the one hand and vocational schools and universities - on the other. The training of engineers and technical specialists creates a serious potential for recruitment for industrial enterprises in the Plovdiv region.

The problem with insecurity of the students in their preparation is solvable also with the direct involvement of business representatives who can actively participate in updating curricula, visits enterprises to conduct practices, offering training programs, organizing various joint events to increase the practical orientation of the training.

Moreover, this relationship between the two parties will produce information for industrial enterprises will construct attitude and willingness to work in them.

The other direction is the activities of HR specialists who can use more advanced and modern techniques to attract staff as discussed in the previous section of this report.

The use of social networks is also an important factor in relation to students and students who had been thoroughly studied in contemporary publications [5].

Last but not least is the use of various motivational techniques by the management of industrial enterprises detained successful staff – more attractive payment, flexible system of bonuses for stimulation, opportunities for training and career development. The analysis of the relationship between motivation of human resources and commitment to the business organization is thoroughly investigated problems in modern scientific works. [6]

This is a summary of some of the basic guidelines for dealing with problems with finding the most appropriate human resources that the effective functioning of industrial enterprises will depend on.

5. Conclusion

The report is an attempt to explain the essence of one of the major problems of industrial enterprises, the difficulty in finding qualified and quality human resources.

The dynamic development of these enterprises will make this problem even more acute and limiting the activity in the event it does not prepare adequate strategies, policies and tactics of human resources management.

The analysis of publications shows that the management of these companies is making effective efforts in the right direction. Proof of this are the meetings at universities and vocational schools, as well as the formation of a joint partnership with the economic cluster and educational board between Plovdiv Municipality, Ministry of Education, "Trakia Economic Zone" and "Industry Watch".

This will create conditions for young people to see alternative for its development as a highly qualified human resources in Bulgarian industrial enterprises.

Bibliography

1. Shopov, D. and co., How to manage human resources in the enterprise, Sofia, 2013
2. Seven tool selection that you need, https://www.capital.bg/
3. Firms increasingly difficult to find qualified staff, https: //technews.bg/article-94426.html
4. Businesses seeking employees with hybrid skills, https://technews.bg/article-80429.html
5. Tepavicharova, M., Boykova, L., Social networking in the context of increasing student motivation in Modern Education, Scientific Works of the Union of Scientists in Bulgaria - Plovdiv, Serie A: Social Sciences, Arts and Culture, Volume II, 2015
6. Tepavicharova, M., Analysis of correlation between the motivation of human resources and their commitment to business organizations: Scientific papers of the Union Scientists, Volume II, Serie A, Plovdiv, 2016

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CHALLENGES AND OPPORTUNITIES FOR FLEXIBLE CREDITING OF SMALL AND MEDIUM-SIZED ENTERPRISES IN BULGARIA

MINA ANGELOVA, DANIELA PASTARMADZHIEVA

Abstract: *The small and medium-sized enterprises (SMEs) play an important role in the economic processes and in this sense the optimization of their functioning is extremely important for raising the competiveness of the Bulgarian economy as a whole. The purpose of this study is to analyze, generalize and systematize challenges and opportunities for flexible financing of SMEs by European funds. A particular focuses of the study are challenges related to political instability and opportunities coming from European Union (EU) funding. The major goal of this study is subordinate to a major project, namely to create a useful model of an information platform that enables SMEs to get information about the best options for European funding in a quick and accurate manner.*

Key words: *business financing, credit instruments, small and medium-sized enterprises, smart information platform, human resources, European financial programs, political instability*

1. Introduction

The maturing of markets and market relations lead to intense competition and increasing consumer requirements, turning the quality into a factor for the success and survival of organizations. The significance of the studied topic is central to the discussions, research and organizational activities in the field of manufacturing and services, because the opportunities for flexible financing of organizations are preconditions for growth of quality and competitiveness.

The topicality of the study is grounded in the current situation in the global market. Dynamically changing economic and political environment requires more flexibility in the companies and willingness to change in accordance with the new conditions. Organizations face the challenge to "fight for survival" in a rapidly changing and uncertain environment. This process is enhanced in terms of the continuing economic crisis.

Optimizing the performance and opportunities for flexible financing of SMEs is extremely important to increase the competitiveness of the organizations and hence to the Bulgarian economy as a whole.

Despite the circumstances mentioned above, the development of small and middle sized enterprises (SMEs) has been an important area of EU's policies [1]. The recent measures under "Juncker plan" (such as COSME) and the reaffirmation of SMEs as priority in the Rome declaration from 26 March 2017 [2] give ground for further examination of capabilities for optimizing their role and functioning and the effect of political instability on their growth.

In these terms, the objects of the analysis are SMEs and the particular focus is on main theoretical concepts regarding SMEs and the conceptualization of correlation political instability-economic growth.

The purpose of this study is to analyze, generalize and systematize challenges and opportunities for flexible financing of SMEs by European funds. But the existence of opportunities is not enough for the growth of SMEs. The latter need accurate, accessible and easy to use information in order to put the possibilities into effect. Thus, the major goal of this study is subordinate to a project, namely to create a useful model of an information platform that enables SMEs to get information about the best options for European funding in a quick and accurate manner.

In this sense, the research tasks of this analysis are:

1) To systematize the theoretical concepts regarding SMEs;

2) To conceptualize the effect of political instability on the growth of SMEs;

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3) To study empirical data related to access to finance of SMEs;

4) To list some general options for financing from EU.

2. Role of SMEs in the national economy

According to Commission Recommendation 2003/361/EC, as published in the Official Journal of the European Union L 124, p. 36 of 20 May 2003 "The category of micro, small and medium-sized enterprises (SMEs) is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million." [3]

This definition was transposed in Bulgarian legislation and in particular in article 3 of Bulgarian Law on Small and Medium-Sized Enterprises.

At European level SMEs are seen as drivers of growth, employment and innovation. According to European Investment Bank they represent over 90% of businesses in the EU and also two thirds of the active working population is employed in them. [4]

SMEs play an essential role in economic processes and therefore optimization of their operation is extremely important to enhance their competitiveness and sustainable development. They are not only the backbone, but they are nearly the entire economy of Bulgaria, as according to NSI data for 2015 they represent 90.3% of all business organizations [5]. SMEs are a major source of added value and the largest employer in the country, but at the same time are experiencing serious difficulties in many areas. Undoubtedly, management must focus on the opportunities for flexible business financing, and access to various financial instruments that could help to overcome the main difficulties and discover horizon for innovation and investment.

According to Bulgarian National Strategy for Small and Medium-sized Enterprises 2014-2020 a main weakness regarding the state of SMEs in Bulgaria is underdeveloped information environment in terms of opportunities to provide affordable services and project financing. This also leads to another weakness - support programs for SMEs funded by the EU, remain largely underutilized [6]. In this sense, the increase of awareness among SMEs about EU funding should be a priority and specific measures should be taken.

3. Political instability as a challenge faced by SMEs

There are number of studies dedicated to the effects of political instability on economic growth and particularly on the growth of SMEs. Considering the unstable political environment in many European countries and in European Union at large it is an up to date issue for Bulgaria as well.

According to a recent analysis in the opinion to the companies worldwide there are five main obstacle of their growth: access to finance, electricity, political instability, competition and tax rate [7]. The relationship between political instability and economic growth has been examined in numerous scientific studies over a long period of time. This correlation is bilateral. If an economy works poorly this may cause "government collapse and political unrest". And when a political environment is unstable usually this leads to decrease of "investments and the speed of economic development" [8]. In fact national political instability may cause some kind of positive effect. It can be a factor for internationalization of SMEs, because when national political environment is unreliable business is motivated to go abroad. [9]

Some major factors of political instability are "political motivated violence", "mass civil protest", "instability *within* the political regime", and "instability *of* the political regime" [10]. Nevertheless, it may be caused by various factors but Alesina et al measure political instability as "propensity of government changes" [8]. The latter is a major factor of political instability in Bulgaria in recent years. In the period January 2013 – March 2017 there have been six governments, three of which were caretaker governments. The frequent change of governments has affected the economic environment and caused difficulties in financing of the SME's.

4. EU instruments supporting SMEs

According to analysis commissioned by Bulgarian Small and Medium Enterprises Promotion Agency (BSMEPA) the access to finance is a major problem for SMEs in Bulgaria.

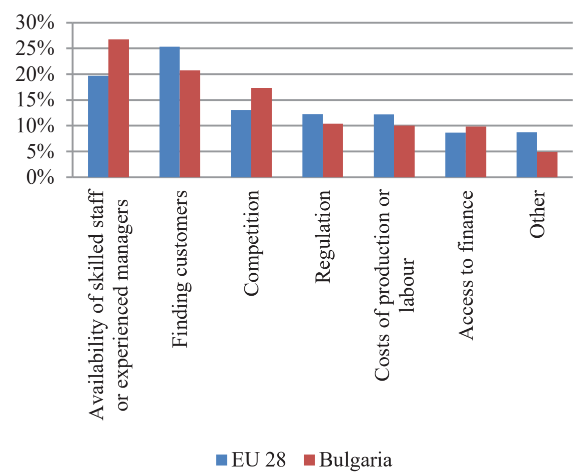

Fig. 1. Most important problems for the firms, 2016

Most commonly utilized sources of funding are banking instruments, government funding and international programs to support SMEs and the use of resources of the owner's family and his/her relatives. [11] Access to finance is a major issue at European level as well. Empirical data from Survey on the Access to Finance of Enterprises shows that in 2016 "access to finance" is challenge for 8,7% of SMEs at European level and for 9,8% companies in Bulgaria (Fig. 1.). [12]

The results on Fig. 2 indicate that there is a decrease in the significance of this problem in the period 2013-2015, but in 2016 there is a slight increase. [12]

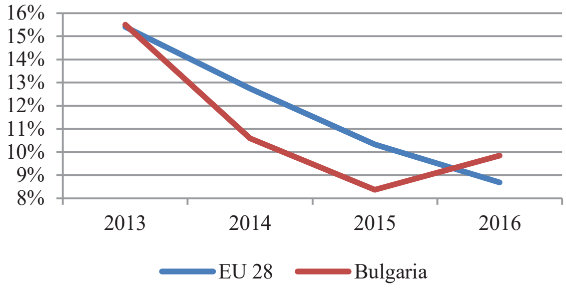

Fig. 2. Dynamics in "access to finance" as a problem to the firms

The European Union provides many opportunities for grants, loans and guarantees available for small and medium enterprises. The financing options often are not direct funding. Usually various national and sub-national institutions are intermediaries in this process. These can be authorities or financial institution such as banks. [13]

Two major programs under "Juncker plan" can be mentioned. One of them is Program for the Competitiveness of Enterprises and small and medium-sized enterprises (COSME) (2014 - 2020). It aims at "strengthening the competitiveness and sustainability" of the companies in EU with emphasis on SMEs. The program has potential to support the access to finance for the firms but also to widen their access to foreign markets (in EU and outside). Alongside COSME is expected to encourage the formation of new SMEs and they can assure economic growth in the European Union. [14]

COSME is a mechanism for guaranteeing loans financed by the European Union and managed by the EIF. It can contribute to reducing structural weaknesses in the financial market for SMEs and to become more diverse and accessible. Financial intermediaries in Bulgaria for loan/guarantee under COSME programme are CIBANK and Raiffeisenbank.

Another option is InnovFin SME Guarantee Facility. This program is specially designed for research-based and innovative SMEs and Small Mid-caps. It also is carried out through intermediaries who can be banks, leasing companies, guarantee institutions, etc. The type of support that SMEs can receive is loan/guarantee. Bulgarian partners of the programme are DSK Bank, CIBANK, ProCredit Bank, Piraeus Bank, Eurobank Bulgaria, UniCredit, Raiffeisenbank, United Bulgarian Bank, Deutsche Leasing and European Investment Bank [15]

The options shortly reviewed above can only be effective if the SMEs in Bulgaria are informed about them in an accurate and accessible manner.

5. Expected results and effects

The study of opportunities for flexible crediting of small and medium-sized enterprises in Bulgaria can generate new knowledge of the studied economic and socio-political phenomena and the relationship between socio-political environment and funding opportunities for SMEs. Challenges that might be faced are associated with the ability to propose alternative, improved versions of existing information tools concerning opportunities for European funding organizations. The research interest was provoked by the possibility of the application of new methods and technologies to detect dependencies between unexplored phenomena of economic, social and political spheres.

The expected results of the continuing research work this area are as follows: creating lasting and sustainable relationships with businesses and construction of model of an innovative information platform for flexible financing of SMEs. The results can be used in practice: management and control of business and public organizations; financial investments; development of marketing campaigns and social programs; business decisions with incomplete and inaccurate information and more.

6. Conclusion

In order to continue to carry out its role as the backbone of the economy SMEs need a special support. The changing international and national environment constitutes an obstacle to their access to finance. Although European Union provides various measures for promoting creation of SMEs and for support of their growth, the existence of such is not enough. First of all companies need to be inform about them.

A study on the topic will increase knowledge of mechanisms for financing SMEs. In this case the general purpose should be to develop an innovative information platform. It will work in favor of the business to quickly and easily orient them to the most appropriate financing option.

The research has the potential to enhance and develop the scientific knowledge in the following three areas:

1) Displaying the challenges facing SMEs in the Bulgarian context, providing opportunities to enhance their competitiveness and sustainable development and positioning in the global market.

2) Systematization of conceptual framework concerning the relationship and mutual influence of political instability and certain economic indicators concerning SMEs. In addition to systematization of scientific knowledge on the subject an empirical evidence based on Bulgarian political process and economic development in the period from 2013 onwards should be provided.

3) Enrichment of knowledge of Information and Communication Technology can be applied in favor of SMEs.

Future research effort will be focused on building innovative information platform for flexible financing SMEs to orient organizations in funding opportunities, grants, guarantees, etc. Furthermore, a "bank" with information on potential future employees in organizations (including CVs, experience, key competencies) can be integrated in such platform.

The tasks that should be fulfilled in order to realize such objective are:

1) to further analyze, summarize and systematize opportunities for flexible SME financing from European funds;

2) to conduct a survey among representatives of small and medium-sized organizations and to identify problem areas in connection with flexible financing;

3) to study the experience of EU Member States in building such information platforms.

REFERENCES

1. https://ec.europa.eu/growth/smes_en
2. http://www.consilium.europa.eu/en/press/press-releases/2017/03/25-rome-declaration/
3. European Commission (2015) *User Guide for the SME Definition*, Luxembourg: Publications Office of the European Union;
4. http://www.eib.europa.eu/projects/priorities/sme/index.htm
5. http://www.nsi.bg/
6. National Strategy for Small and Medium-sized Enterprises 2014-2020 - Small Business Act, adopted by Decision № 37 of the Council of Ministers of 23 January 2014;
7. Wang, Y. (2016) What are the biggest obstacles to growth of SMEs in developing countries? e An empirical evidence from an enterprise survey, Borsa Istanbul Review 16-3, pp. 167-176
8. Alesina, Alberto, Sule Ozler, Nouriel Roubini, and Phillip Swagel. (1996) Political instability and economic growth. Journal of Economic Growth, 1(2), pp. 189-211
9. Shirokova G. and T. Tsukanova (2014) *Internationalization of SMEs from transition economies: institutional perspectives*, In: Etemad, H, T. K. Madsen, E. S. Rasmusen, P. Servais (eds.) Current Issues in International Entrepreneurship, Cheltenham: Edward Elgar Pub;
10. Jong-A-Pin, R. (2008). Essays on political instability: Measurement, causes and consequences Enschede: Print Partners Ipskamp B.V., Enschede, The Netherlands, pp. 4-5
11. Vladimirov, Zh, K. Ganev, R. Simeonova-Ganeva (eds) (2013) *Study of entrepreneurship and development prospects of innovation in SMEs (2012-2013)*, Sofia: Bulgarian Small and Medium Enterprises Promotion Agency (BSMEPA);
12. http://ec.europa.eu/growth/access-to-finance/data-surveys
13. https://ec.europa.eu/growth/access-to-finance_en
14. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R1287
15. http://www.eif.org/what_we_do/guarantees/single_eu_debt_instrument/innovfin-guarantee-facility/

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ПРИЛОЖЕНИЯ НА ИМИТАЦИОННОТО МОДЕЛИРАНЕ ПРИ ИЗСЛЕДВАНЕ НА КРЕДИТОРСКАТА ЗАДЛЪЖНЯЛОСТ В БЪЛГАРИЯ

АНТОНИЯ ЛАЗАРОВА

Резюме: *Целта на доклада е да покаже използването на имитационното моделиране при изследване на кредиторската задлъжнялост.*

Ключови думи: *кредиторска задлъжнялост, имитационно моделиране, счетоводни отчети, Закон на Бенфорд*

APPLICATIONS IMITATION MODELING IN INVESTIGATION OF A LENDER LEVERAGE IN IN BULGARIA

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Abstract: *The purpose of the report is to demonstrate the use of imitation modeling in the study a lender's debt.*

Key words: *lender's debt, imitative modeling, accounting records, Benford's Law*

1. Имитационно моделиране

Имитационното моделиране е изследователски метод, при който системата на изследване се заменя с модел с достатъчна точност. Целта е да се експериментира с модела, за да се получи информация за реалната система. Имитационното моделиране е формализирано описание на изучаваното явление.

2. Кредиторска задлъжнялост – определение

Общото разбиране за кредиторска задлъжнялост е сумите, които принадлежат на доставчиците за закупени от тях на кредит стоки или услуги.[**Error! Reference source not found.**]

От гледна точка на търговските банки - те предоставят кредити при спазване на условията на кредитиране, регламентирани в посочената нормативна база, даващи възможност за правилното обслужване на кредита и нормалното му погасяване. При отпускане на кредит, кредитоискателят трябва да отговаря на следните най-общи условия: да отговаря на определението за действащо предприятие, съгласно Закона за счетоводството и да е вписан в Търговския регистър, да е кредитоспособен, да се ползва с добра репутация. И не на последно място да има необходимата за кредитиране гаранция - за възможността да си погаси кредита. Тя изразява способността му да посреща задълженията си към контрагентите и кредиторите, в това число към банките своевременно при настъпване на падежа на кредитите.

3. Възможности за имитационно моделиране при изследване на кредиторската задлъжнялост в България

От дефинираните условия става ясно, че се касае за действащо предприятие по смисъла на Закона за счетоводството, но при прилагане на различните показатели за ликвидност от страна на банките, не се създават възможности в цялост да се илюстрира наличието и

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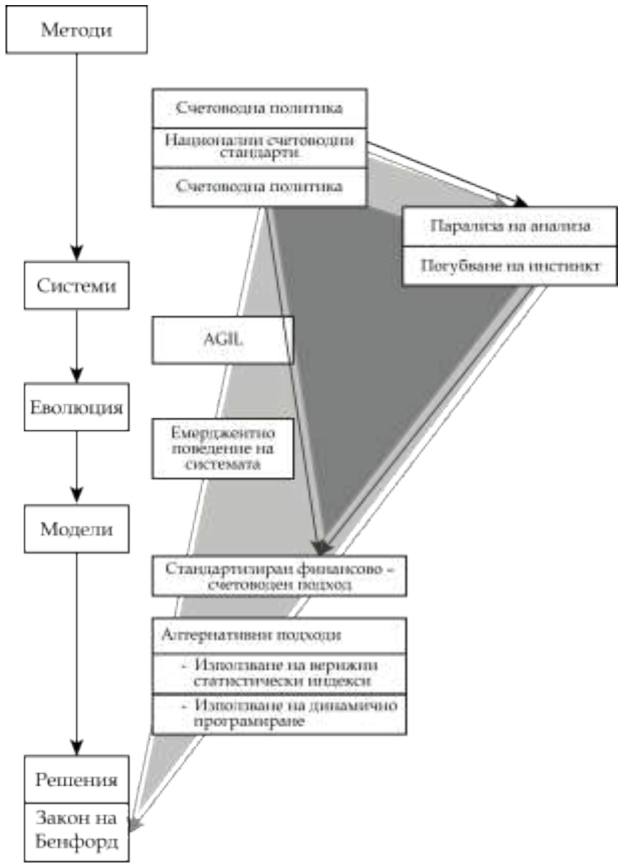
нарастването на кредиторската задлъжнялост в следващ времеви период. Поради тази причина предлагаме един теоретичен подход, които предстои да се апробира, чрез прилагането на който:

- Ще е възможна синхронизация при работа със СС 13 - Отчитане при несъстоятелност и ликвидация [1] и при общите разпоредби на МСФО е предвидено дружествата да прилагат стандартите само при сигурни индикации за "действащо предприятие", ето защо такъв стандарт липсва в МСФО. Съгласно хипотезата на чл. 35, ал. 1 от Закона за счетоводството СС 13 се прилага и от предприятия, които като действащи предприятия са прилагали МСФО.
- Ще се създаде възможност за изглаждане на някой разлики при отчитане на и представянето във финансовите отчети, като например - МСС 1 Представяне на финансови отчети Регламент [12] предприятието представя в баланса в състава на текущите (краткосрочни) пасиви статия "текуща част от дългосрочен дълг", съдържаща подлежащата на погасяване през следващата година част от дългосрочни заеми и други финансови пасиви СС 1 - Представяне на финансови отчети не налага такова изискване.
- Ще се сведе до минимум възможността за намаляване на допуснати в хода на счетоводното отчитане грешки, които по – късно ще намерят отражение в баланса и Отчета за приходи и разходи на дружествата.
- Ще се създаде възможност за устойчивост на счетоводната политика на дружествата и ще се създадат необходимите условия на съпоставимост на получените данни.
- Ще се създадат обективни възможности за метрирано представяне на данните и съпоставимост с оповестяванията в рамките на отчетите.

4. Имитационно моделиране при изследване на кредиторска задлъжнялост

При приложение на имитационно моделиране за изследване на кредиторската задлъжнялост, счетоводството се разглежда като единна система от взаимосвързани елементи на отчитане. Ще предложим модел на база на имитационното моделиране за изследване на кредиторската задлъжнялост.



Фиг. 1. *Модел на база на имитационното моделиране за изследване на кредиторската задлъжнялост*

От фигура 1става видно, че нормалното и законово установеното отчитане на кредиторската задлъжнялост се извършва в рамките на възприетата от предприятието счетоводна политика и изключително много зависи от факта дали предприятието използва Националните или Международните счетоводни стандарти. Подходът е изцяло стандартизиран и не предлага алтернативи. На практика, обаче при промяна и задълбочаване на кредиторската задлъжнялост на дружествата или при промяна на счетоводното обслужване в рамките на текущата година, доста често започва да работи паралелният алгоритъм, който доста често е съпътстван с първоначална парализа на анализа.

a. "Парализа на анализа" още е наричана „информационно претоварване". Често „парализа на анализа" възниква и тогава, когато ние прекалено усложняваме всичко и се опитваме да анализираме онези действия, които трябва да се правят автоматически.[**Error! Reference source not found.**] Оказва се, че независимо колко време и по кои стандарти се отчита кредиторската задлъжнялост на дружеството, грешките, които се допускат в неговите рамки нараства, което най-често се дължи на прекомерно вглеждане в първичната счетоводна информация. На практика се случва така, че само се стига до обсъждане на проблема, а не до реални действия по отношение на задлъжнялостта към кредиторите.

б. Погубване на инстинкти – Обикновено това се случва в края на счетоводната година, когато се установи, че при анализа на динамиката на показателите, третиращи кредитната задлъжнялост, показват отклонения от нормите. Страхът от обявяване на несъстоятелност и изпадане в ликвидация доста често блокира адекватните действия не само от страна на счетоводният отдел, но и от страна на ръководството. За преодоляване на парализа на анализа и потенциалната възможност за погубване на инстинкти следва да се използва AGIL.

„Парализа на анализа“ и „погубването на инстинкти“ много често се свързват с човешкия фактор в счетоводния процес и им се предава оценъчна психологическа характеристика. Не бива да се забравя, че именно счетоводителите са онази връзка между данните от счетоводните отчети и мениджмънта, на който тези данни се предоставят. Поради тази причина наличието само на едно от тези психични „блокатори на анализа“ е възможно да деформира не само преценката по отношение на данните, които да се предоставят на трети лица, но и да компрометира анализа в неговата цялостност.

в. AGIL – Това е една цялостна система на действие, чрез която се стремим да отговорим на въпроса – Как да се избегне информационното натоварване и да се сведе до минимум страха от обявяване в несъстоятелност на дружеството при наличие на висока кредиторска задлъжнялост?

AGIL е неразделна част от системата за действие при наличие на високи нива на кредиторската задлъжнялост и по този начин се проявява само като подсистема в рамките на по-голямото цяло на системи в рамките на счетоводната отчетност. Тя създава възможност за нагаждане, постигане на целите, интеграция, следване на модела на интеграция .[3]

г. Емерджентно поведение на системата – Възникване на нови свойства на системата, различаващи се от сбора на въздействията на отделните елементи.[4] Емерджентните свойства могат да бъдат овладени и използвани при алтернативните подходи, така че системата да придобие и нови, допълнителни свойства. Това на практика може да се случи на база на едновременното използване на стандартизирания и добре познат подход при използването на финансово – счетоводния анализ на рентабилността, задлъжнялостта и т.н. и алтернативните подходи – анализ на база на верижни статистически индекси и динамично програмиране.

д. Алтернативни подходи при изследване на кредиторската задлъжнялост

- Използване на верижни статистически индекси за изследване на кредиторската задлъжнялост

  След отпадане на НСС 13 – Показатели за финансово - счетоводен анализ на предприятието [5] все още е възможно в рамките на оповестяванията в годишният финансов отчет и като част от вътрешнофирменият счетоводен анализ да се изградят верижни индекси, като стойностите на интересуващите ни коефициенти се изградят като текущата година към базисна година. Използването на познатите коефициенти, приложими при финансово – счетоводен анализ, счетоводителите прилагат повече по навик, отколкото на база на реално взети управленски решения. Така предложеният модел способства за интеграция на реално приложимите до момента показатели за финансово – счетоводен анализ и статистическите методи за оценка. Този интегриран подход подпомага вземането на управленски решения във връзка с кредиторската задлъжнялост на дружествата като разкрива следните три важни елемента – падеж на задължението, стойността му и вероятната безнадеждност по отношение на това задължение.
- Използване на динамично оптимиране при изследване на кредиторската задлъжнялост

В много случай процесът на вземане на управленско решение се разделя на няколко етапа в зависимост от характера на разглежданата система. Тъй като процеса на вземане на решение е разложен на отделни етапи, разположени във времето и взетите решения трябва да доведат до оптимален резултат разделът от математиката, който дава методите за решаване на такива задачи се нарича динамично оптимиране. В него се разглеждат широк кръг от екстремални задачи, по-голямата част от които имат динамичен характер в смисъл, че при тяхното решаване трябва да се отчита фактора време или последователност на операциите. Възприето като самостоятелно съществуваш елемент в системата, той изпълнява двете функции на AGIL – интеграция и следване на модела на интеграция.

Системата може да действа в дискретни моменти от времето к=1,2,3...n, (n-етапен процес). На всеки етап или момент с-мата се характеризира с някакъв елемент P (състояние на системата), принадлежащ на множеството P(pP). Множеството P може да има различна природа:

- множество от реални числа;
- P може да бъде векторно пространство. Тогава състоянието на системата се определя от параметрите на вектора.

Дискретни процеси, при които променливите, характеризиращи състоянието на системата приемат стойности само в определени интервали от време. Непрекъснати процеси когато интервалите между отделните етапи клонят към 0. Процес на вземане на решения, при който изборът на решение определя еднозначно резултата от решението, се нарича детерминиран процес. На практика често се срещат задачи на многоетапно планиране, в които важна роля играят случайни фактори. При тях резултатът от решението не е напълно определен. Изходът от приетото решение е определен само във вероятностен смисъл. Такива процеси се наричат стохастични (вероятностни) (6)

На практика чрез динамичният анализ при изследване на кредиторска задлъжнялост се създава и възможност за точно, ясно и конкретно дефиниране на емерджентното поведение на счетоводната система на дружеството.

5. Решения на база на фраксипариален анализ

Фраксипариалният анализ дава възможност върху вече съществуващият класически финансово – счетоводен модел за изследване на кредиторската задлъжнялост да се интегрират и други модели, чрез които да се изследват всички емерджентни промени на поведението на системата.

Най-често фракталът се генерира от повтаряща се схема, обикновено рекурсивен или итерационен процес. Това позволява представяне на неговите характерни особености - самоподобността и възпроизвеждането на цялостната структура независимо от увеличението.[7]

На практика тук става дума за статистическа самоподобност на фракталите при кредиторската задлъжнялост.

Фракталът има числени или статистически характеристики, които се запазват в различни мащаби, което може да доведе до прецизна преценка от страна не само на вътрешните анализатори на дружеството, но и от външните ползватели на счетоводна информация за промените на кредиторската задлъжнялост.

Решенията само на база на фраксипариален анализ за нивото на кредиторска задлъжнялост, обаче са изключително трудни са математическо дефиниране, защото:

- специфичните характеристики на фракталите са интуитивно разбираеми;
- няма точно значение на „прекалено неравномерен”;
- няма единствено определение на „размерност”;
- има много начини, по които един обект може да бъде самоподобен;
- не всеки фрактал е дефиниран рекурсивно.[8]

Чрез рекурсия е възможно да се достигне до решение, когато назад в рамките на счетоводното записване на първични данни се открият грешки, които следва да бъдат коригирани. Прилагането на пряка рекурсия създава обективни възможност за сторниране, коригиране на стойности и обективизиране на процеси, без това да е в разрез с действащата счетоводна политика на предприятието и актуалната нормативна уредба в България. Важно условия е, че на практика прилагането на пряка рекурсия може да се случи само със счетоводни записвания, които са в рамките на текущата година и поради тази причина пряката рекурсия следва да се прилага изключително внимателно.

На практика се работи с индиректна, косвена рекурсия, която създава възможности за връщане и прецизиране на счетоводната информация до три години назад. Това, обаче означава, че е възможно да възникне най-слабата форма на самоподобност, а именно – статистическата. От гледна точка на реалността днес, в България, това е изключително масово прилагане на фраксипариален анализ в рамките на използвания счетоводен софтуер, който обаче е с индиректна рекурсия.

6. Приложение на Закона на Бенфорд при имитационното моделиране при изследване на кредиторската задлъжнялост

Строго математически погледнато в дефиниционно отношение Закона за Бенфорд може да се представи като: съществуват такива случайни величини, при които вероятностното разпределение на дробната част на логаритъма клони към единица в границите на разпределение от нула до едно.

Съществуват математически обекти, които отговарят на изискванията на Закона на Бенфорт:

- Числата на Фибоначи, известни и като Прогресия на Фибоначи;[9]
- Факториелите - Факториел е функция на цялото число n, равна на произведението на всички естествени числа, по-малки или равни на n.[10] Факториел може да бъде определена и чрез пряка и чрез индиректна рекурсия.

Приложението на Закона на Бенфорд [11] при имитационното моделиране при изследване на кредиторската задлъжнялост следва да се използва и при класическият финансово – счетоводен подход по отношение на публичните отчети на дружествата. Истината е, обаче че това се случва изключително рядко.

Чрез Закона на Бенфорд се създава обективна възможност в рамките на имитационното моделиране да се установят отклонения при изготвяне на междинните счетоводни отчети, при показаните данни за кредиторската задлъжнялост и при анализа на показателите за рентабилност, платежоспособност и задлъжнялост на дружеството.

7. Изводи

Основните изводи могат да бъдат направени от две различни гледни точки. От гледна точка на действащата в момента нормативна уредба в България имитационното моделиране при изследване на кредиторската задлъжнялост е възможност за по-пълно прилагане на Международните стандарти за финансово отчитане 8. Оперативни сегменти (12). От друга страна чисто математическият подход към проблема за кредиторската задлъжнялост на дружествата способства за многостранни и различни по задълбоченост анализи, които рано да откроят тревожни тенденции, ако съществуват такива.

8. Заключение

В заключение може да се каже, че отпадането на НСС 13 създава обективни възможности за по-пълно използване на възможностите, които дава имитационното моделиране при изследване на кредиторската задлъжнялост в България.

ЛИТЕРАТУРА

1. СС 13 - Отчитане при несъстоятелност и ликвидация Обн. ДВ. бр. 30 от 7.04.2005 г., изм. ДВ. бр. 86 от 26.10.2007 г.
2. Регламент (ЕС) № 475/2012 на Комисията от 5 юни 2012 година за изменение на Регламент (ЕО) № 1126/2008 за приемане на някои международни счетоводни стандарти в съответствие с Регламент (ЕО) № 1606/2002 на Европейския парламент и на Съвета по отношение на Международен счетоводен стандарт (МСС) 1 и Международен счетоводен стандарт (МСС) 19 (текст от значение за ЕИП)
3. Talcott Parsons, On the Concept of Value-Commitments. Sociological Inquiry. Vol.38. Issue 2. pp.135-160. April 1968.
4. Дянков, А. Методи, модели и метафори за мениджъри, 2010, ПОВВИК АД, pp.26
5. НСС 13 – Показатели за финансово - счетоводен анализ на предприятието ,приет с ПМС No 65 от 1998 г. - обн., ДВ, бр. 36 от 31 март 1998 г.; издание на Народното събрание - притурка към ДВ, бр. 36 от 1998 г.
6. Дюлгерова, Г. Икономическо моделиране, научна статия, 2010, София, с. 5-6.
7. Mandelbrot B., (1967). How Long Is the Coast of Britain? Statistical Self-Similarity and Fractional Dimension, Science, New Series, Vol. 156, No. 3775. (May 5, 1967), pp. 636-638.
8. Манделброт Б., Фракталните обекти: Форма, случайност и размерност (прев. от фр. ез. Петър Лазаров и др.) София: Унив. изд. К. Охридски, 1996, ISBN 954 07 0469-3)
9. Черноокий, А. Закон Бенфорда и распределения под него попадающие, 2014. с. 4

10. Николов,Т. Естествени, цели и рационални числа. Математическа логика и анализ, София, 2011, с. 2
11. Theodore P. Hill. The First Digit Phenomenon. A century-old observation about an unexpected pattern in many numerical tables applies to the stock market, census statistics and accounting data, pp. 358-363
12. Регламент (ЕО) № 1347/2007 на Комисията от 16 ноември 2007 година за изменение на Регламент (ЕО) № 1725/2003 относно приемането на някои международни счетоводни стандарти в съответствие с Регламент (ЕО) № 1606/2002 на Европейския парламент и на Съвета във връзка с Международен стандарт за финансово отчитане (МСФО) 8
13. Young, C. (2001) English Heritage position statement on the Valletta Convention, [Online], Available: http://www.archaeol.freeuk.com/EHPostionStatement.htm [24 Aug 2001].

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МОДЕЛ ЗА ИЗБОР НА ДОСТАВЧИЦИ

ОТМАН АХМЕД, СВЕТОСЛАВ ДИМКОВ

Резюме: *Настоящата работа се занимава с проблема за избор на доставчици. Цел на работата е разработване на пределно прост и практически приложим подход за избор на доставчици като се отчита променливата резултатност на дейността им. На база на контакти с мениджъри са избрани показатели за оценяване на резултатността на дейността на доставчиците. Разработени са модели за оценяване на максималната и минималната производителност на доставчиците. Извършено е апробиране на моделите на база на предварително набавени реални данни за мебелна компания в Либия и шест нейни доставчика в Италия, Турция, Испания и Португалия.*

Ключови думи: *Избор на доставчици, Показатели за резултатност, Макс-Мин подход.*

A MODEL TO SOLVE THE SUPPLIER SELECTION PROBLEM

OTMAN AHMED, SVETOSLAV DIMKOW

Abstract: *This work deals with the problem of choice of suppliers. Aim of the work is to develop a very simple and practicable approach to selecting suppliers taking into account the variable performance of their activity. Based on contacts with managers indicators to assess the performance of providers are selected. Models for assessing the maximum and minimum performance of suppliers are developed. There has been committed approbation of the models based on real data previously supplied from furniture company in Libya and six of its supplier in Italy, Turkey, Spain and Portugal.*

Key words: *Supplier selection; Performance measures; Max-min approach.*

1. Въведение

Понастоящем разходите за закупуване на материали и компоненти от доставчици имат ключово значение, защото в много индустриални сектори формират значима част от себестойността на крайните продукти. Изборът на доставчици има два основни подхода. Първият е определяне на оптимален брой доставчици и вид на взаимоотношенията с тях съобразно мащабите на организационната дейност, характеристиките на продуктите и на пазарите се избира оптимален брой доставчици. Вторият подход се основава на избор на най-добрите доставчици между познатите. В настоящата работа се взема под внимание този втори подход като се счита, че броят на доставчиците предварително е набелязан.

В литературата са познати множество модели за избор на доставчици, но тези модели не включват показатели за отчитане на различната резултатност на дейността на доставчиците. За една компания купувач е от критично значение да дефинира и използва такива показатели в процеса за избор на доставчици. Това ще спомогне за получаване на точна представа за възможностите на всеки доставчик.

Настоящата работа запълва тази празнина като предлага подход за оценяване на доставчици, отчитащ максималната и минималната резултатност на дейността на всеки от тях. Основното предимство на такъв подход е, че осигурява на купувача избор на алтернативни доставчици в идентифицирани групи от доставчици.

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2. Показатели за резултатност на доставчици

Въпреки изобилието от публикации върху избора на доставчици, малцина автори разглеждат въпроса за показатели за оценяване на резултатността на дейността на доставчиците. Но и в ограничения брой публикации се забелязва значително разнообразие от показатели. Доминиращи показатели са цените и качеството заедно с навременността на доставките и гъвкавостта на доставките. В публикациите през 70-те и 80-те години на 20-век основно се акцентира върху цените, докато в началото на 90-те години на 20-век акцентът пада върху цикъла за доставка и реакцията на потребителските изисквания. В края на 90-те години на 20-век акцентът се премества върху гъвкавостта на доставчиците. Понастоящем освен всички тези показатели се добавя и екологичния аспект. В крайна сметка резултатността на дейността на доставчиците следва да се оценява като се използват различни показатели в зависимост от характеристиките на създаваните продукти, влаганите материали, възможностите за удължаване на живота на продуктите (рециклиране, многократно използване, повторно производство и др.) и др. Тенденцията е към разработване на всестранни и по-детайлни показатели за резултатността на дейността на доставчиците.

Така например Холмберг [1] изгражда всестранен поглед върху управлението на взаимоотношенията с доставчици и идентифицира проблемите свързани с липсата на системно третиране на логистиката. Той счита, че липсата на синхрон между системите за оценяване на доставчиците и общо организационните бизнес цели на купувача води до дефиниране на изолирани и несъвместими показатели. Освен това акцентирането върху финансови показатели води до предоставяне на непълни данни на мениджмънта относно слабостите на взаимоотношенията с доставчиците. Бимън [2] констатира, че показателите трябва да притежават четири характеристики – всеобхватност (отчитане на всички аспекти); универсалност (възможност за сравнение при различни условия за дейност); измеримост (предоставяне на количествени данни); адекватност (съответствие с организационните цели).

Ремко [3] предлага модел във формата на матрица, който свързва конкурентността на логистични вериги с мястото на доставка в рамките на цялостната логистична верига. Ван Амстел и Дхерт [4] установяват, че типът на показателите за резултатност, използвани за оценяване на дейността на доставчиците варира според нивото на оценяване (отделна дейност, функционална област, множество функционални области, организации). Извършеното от Канън и Перо [5] изследване доказва, че в различни ситуации следва да се използват различни показатели. Харланд [6] счита, че ролята и приносът на определена връзка между доставчик и купувач за достигане на крайните бизнес цели е основен фактор при избора на показатели за резултатност. Това още повече увеличава сложността за стандартизиране на моделите за оценяване на резултатност.

Добре познатият SCOR модел спомага за разрешаване на проблемите между бизнес организации като спомага за обективно оценяване на резултатността и за идентифициране на възможностите за подобряването й [7]. Това е йерархичен модел на четири нива. Ниво 1 дефинира пет типови мениджърски процеси. Ниво 2 декомпозира типовите процеси в 26 категории базови процеси, които могат да се използват за конфигуриране на логистични вериги. Ниво 3 дава детайлно описание на елементите на базовите процеси от 26-те категории заедно с показатели за диагностика, целеви стойности (бенчмарки), добри практики и др. Ниво 4 е реализационно ниво, на което всяка бизнес организация къстомизира своите операционни практики. Понастоящем ниво 1 включва 13 показателя в пет категории – надеждност на доставките, реактивност, гъвкавост, разходи, ефикасност на управлението на управлението на активите.

3. Max-min подход за оценяване на доставчици

В настоящата работа авторите предлагат оригинален подход за избор на доставчици чрез използване на непостоянството на резултатността на доставчиците в процеса на оценяване. Max-min подходът, представен в настоящата работа, позволява всестранно оценяване на резултатността на доставчиците чрез отчитане на техните максимална и минимална ефикасност спрямо поставени от купувача целеви стойности. Друг значим елемент при този подход е, че могат да се идентифицират групите от сходни доставчици, което предоставя на купувачите възможност да правят алтернативни подбори при вземане на окончателно решение.

Концепцията върху която се базира Max-min подходът се заключава в максимизиране и минимизиране на резултатността на доставчиците спрямо възможни екстремни стойности, дефинирани от купувача. Съчетанието от модели, което се използва при този подход спомага да се получат по два показателя за резултатност на всеки доставчик, като по-високите стойности показват по-добра степен на резултатност. Първият модел е структуриран по начин да идентифицира областите, в които доставчиците показват превъзхождаща резултатност, а вторият служи за идентифициране на областите, в които доставчиците показват слаба резултатност. Двата показателя се използват съвместно за постигане на цялостна представа за резултатност на всеки доставчик.

Ако са дадени n доставчици с m характеристики купувачите са в състояние да идентифицират най-добрите стойности за всяка характеристика сред всички доставчици. Купувачите използват тази група от оптимални стойности като целеви стойности при оценяване на резултатност на алтернативните доставчици. Също така купувачите могат да използват свои стойности за добра практика (бенчмарки) при дефиниране на целевите стойности, които са различни от намерените оптимални стойности.

За всеки случай резултатността на доставчиците, която се дефинира като отношение между претеглени изходни параметри спрямо претеглени входни параметри, се максимизира и минимизира за получаване на двоични групи от стойности за резултатност. Случаят за максимизиране е показан по-долу като Модел (1).

$$
\begin{aligned}
&\max \frac{\sum_{s=1}^{v} a_r y_{rp}}{\sum_{s=1}^{u} b_s x_{sp}} \\
&s.t. \frac{\sum_{s=1}^{v} a_r y_{r^*}}{\sum_{s=1}^{u} b_s x_{s^*}} = 1 \\
&s.t. \frac{\sum_{s=1}^{v} a_r y_{ri}}{\sum_{s=1}^{u} b_s x_{si}} \leq 1 \quad \forall i, \\
&a_r, b_s \geq 0 \quad \forall r, s,
\end{aligned}
$$

Където p показва доставчика, който се оценява, v изобразява броя на изходните параметри на доставчика, u изразява броя на входните параметри на доставчика, y_{ri} изразява стойността на r-тия изходен параметър на r-тия доставчик, x_{ri} изразява стойността на r-тия входен параметър на r-тия доставчик, y_{r*} изразява най-добрата стойност за r-тия изходен параметър между всички доставчици, x_{r*} изразява най-добрата стойност за r-тия входен параметър между всички доставчици, a_r изразява тегловния коефициент на r-тия изходен параметър, b_r изразява тегловния коефициент на r-тия входен параметър.

В модел (1) целевата функция изразява производителността на доставчик p , която е максимизирана целева стойност, която може да се постигне при отчитане на група от ограничения. Първата група ограничения изразява стойността на производителността на база на дефинирани от купувача най-добри стойности (стойност 1). Това показва, че дейността на доставчика по отношение на дефинирани от купувача най-добри стойности е ефикасна, тъй като нито отделен доставчик или група доставчици не могат да доминират [8]. Втората група ограничения предотвратява стойностите за ефикасност на всички доставчици да не надхвърлят стойност 1, което е повече от нормализиране на ограничение. На последно място за модела са дефинирани ограничения за избягване на отрицателни стойности.

Модел (1) лесно може де се приведе в нормализирана форма, което е показано с представения по-долу Модел (2):

$$
\begin{aligned}
&\max \sum_{r=1}^{v} a_r y_{rp} \\
&s.t. \sum_{s=1}^{u} b_s x_{sp} = 1 \\
&\sum_{r=1}^{v} a_r y_{r^*} - \sum_{s=1}^{u} b_s y_{s^*} = 0 \\
&\sum_{r=1}^{v} a_r y_{ri} - \sum_{s=1}^{u} b_s y_{si} \leq 0 \quad \forall i, \\
&a_r, b_s \geq 0 \quad \forall r, s
\end{aligned}
$$

Модел (2) се решава за всеки доставчик за да се получат стойности за производителността. Моделът отчита тегловните коефициенти на отношенията „входни параметри / изходни параметри", което не само спомага за поддържане на максимална ефикасност по отношение на дефинираните от купувача група от целеви стойности, но и максимизира ефикасността на доставчика, който се оценява. Накратко, този модел спомага за идентифициране на силните страни на доставчиците, които също са силни страни спрямо групата от целеви стойности, дефинирани от купувача. Така доставчик, който постигне високи стойности на ефикасност се счита за добър контрагент при сравняване с изискванията на купувача.

Втората част от Max-min подхода е свързана с минимизиране на стойности за ефикасност на доставчиците спрямо същата система от ограничения, която се използва при Модел (2). Това е изразено в представения по-долу модел (3):

$$\min \sum_{r=1}^{v} a_r y_{rp}$$

Модел (3) определя тегловните коефициенти на отношенията „входни параметри / изходни параметри”, което не само спомага за поддържане на максимална ефикасност по отношение на дефинираните от купувача група от целеви стойности, но и минимизира ефикасността на доставчика, който се оценява. Накратко, този модел спомага за идентифициране на слабите страни на доставчиците. По този начин доставчици, които постигат високи стойности за ефикасност се считат за добри контрагенти.

За пълно решаване на проблема е необходимо прилагането на статистически метод за идентифициране на групи от показатели на база на двете групи резултати за ефикасност.

В настоящата работа се използва непараметрична статистическа процедура, позната като „Тест на Кросъл-Уолис” за тестване на хипотезата, че поне един доставчик е в състояние да постигне по-високи резултати за ефикасност от поне един друг доставчик. Тестът на Кросъл-Уолис, който е базиран на рангове, се използва за анализиране на различията в две или повече независими извадки [9]. Базовите единична и нулева хипотези са:

H_0: Функциите на разпределение на всички к съвкупности са идентични.

H_a: Поне една от съвкупностите проявява склонност за по-високи стойности на наблюденията от поне една друга съвкупност.

Статистическа проверка:

$$T = \frac{12}{N(N-1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1)$$

Където: N е пълният брой на наблюденията; k е броят на групите; n_i е броят на наблюденията в *i-тата* група, където i = 1 до k; а R_i е сумата от ранговете на наблюденията във всяка група

Правило за вземане на решение:

Ако $T > \chi^2(k-1, 1-\alpha)$ тогава се отхвърля нулевата хипотеза H_0, в противен случай се елиминира отхвърлянето на H_0, където α е вероятността за допускане на грешка от първи тип.

За идентифициране на за различията между групите се извършват множество сравнения. Групите i и j са различни ако е удовлетворено неравенството:

$$\left|\frac{R_i}{n_i} - \frac{R_j}{n_j}\right| > t_{1-(\alpha/2)} \left(S^2 \frac{N-1-T}{N-k}\right)^{1/2} \left(\frac{1}{n_i} + \frac{1}{n_j}\right)^{1/2},$$

Където:

$$S^2 = \frac{1}{N-1}\left(\sum_{allranks} R(X_{ij})^2 - N\frac{(N+1)^2}{4}\right),$$

$R(X_{ij})$ е рангът, присвоен на наблюдението j в *i-тата* група; стойността t е $(1-\alpha/2)$ квантилът на t разпределение с $N — k$ степени на свобода. Стойността α се използва както при теста на Кросъл-Уолис.

4. Апробиране на модела

Извършва се оценяване на доставчиците на либийско мебелно предприятие. Това са шест доставчици на метален обков за мебели от Италия, Испания, Португалия и Турция. Данните за доставчиците са взети чрез непосредствени контакти с мениджъри от мебелното предприятие. Мениджърите на мебелното предприятие са счели за ключови фактори при избора на доставчици цените на компонентите; качество на компонентите; коректността на доставките. Цените на компонентите са изразени като единична цена за всеки компонент. Качеството на компонентите се изразява чрез процент на върнатите компоненти при доставката. Коректността на доставките се оценява чрез процент на закъснелите доставки на компоненти. Първичните данни са представени на Таблица 1

В извършените анализи цената се използва за входен параметър, а качеството на компонентите и коректността на доставките – като изходни параметри. Цената се взема за входящ параметър, защото изразява разходите, които прави купувача. Качеството на компонентите и коректността на доставките се считат за изходни параметри защото изразяват ползите за купувача. Изхождайки от тези постановки на модела, по-високите стойности на изходящите параметри и по-ниските стойности на входящите параметри са индикатори за желаните характеристики.

Таблица 1. *. Данни за доставчиците*

Променлива	Доставчик 1	Доставчик 2	Доставчик 3	Доставчик 4	Доставчик 5	Доставчик 6
Цена ($/брой)	0.1958	0.1881	0.2204	0.2081	0.2118	0.2096
Откази (%)	1.2	0.8	0.0	2.1	2.3	1.2
Закъснения (%)	5.0	7.0	0.0	0.0	3.0	4.0

За да се спази този принцип е извършено линейно трансформиране на двата изходни показателя в изследването. Вместо да се използват процент на върнатите доставки и процент на закъснелите доставки се използват разликите от 100%. Така трансформираните показатели изразяват процент на приетите доставки и процент на навременните доставки. Тъй като по-високите стойности на тези производни показатели изразяват по-високи нива на резултатност, така се постига съгласуваност с дефинирания модел. Таблица 2 представя данните за доставчиците след извършената трансформация на показателите.

Таблица 2. *Трансформирани данни за доставчиците*

Променлива	Доставчик 1	Доставчик 2	Доставчик 3	Доставчик 4	Доставчик 5	Доставчик 6	Целева стойност
Цена ($/брой)	0.1958	0.1881	0.2204	0.2081	0.2118	0.2096	0.1881
Приети (%)	98.8	99.2	100	97.9	97.7	98.8	100
Навременни (%)	95	93	100	100	97	96	100

В таблица 2, като е използван модел (2), са изчислени стойности за максимална за ефикасност. Целевите стойности използвани в модела се получават чрез избиране на най-добрите стойности за всеки от трите показателя за резултатност между всички доставчици. В таблица 2 целевите стойности са 0.1881 $/брой за цена; и 100% за показателите за качество и навременност. След шесткратно проиграване на Модел (2) се получават резултатите за максималната ефикасност, които са представени в Таблица 3.

Таблица 3. *Резултати от max-min оценяването*

Ефикасност	Доставчик 1	Доставчик 2	Доставчик 3	Доставчик 4	Доставчик 5	Доставчик 6
Max. еф.	0.949	0.992	0.853	0.904	0.868	0.887
Min. еф.	0.913	0.930	0.853	0.885	0.861	0.862

От таблица 3 се вижда, че доставчик 2 постига най-високи резултати за ефикасност 0.992 следван от доставчици 1, 4, 6, 5 и 3 с резултати 0.949, 0.904, 0.887, 0.868, и 0.853, съответно. Тези резултати изразяват максималните ефикасности, които се постигат от всеки доставчик, когато се сравняват с целевите стойности, дефинирани от купувача. При оценяване на тези стойности модел (2) избира тегловни коефициенти, които правят всеки от шестте доставчици да изглежда възможно най-добре при поддържане на целевата стойност за ефикасност 1. Така в определен смисъл модел (2) представлява средство за акцентиране върху силните страни на всеки от шестте доставчици. Следващият етап от процеса за вземане на решение включва оценяване на стойностите за минимална ефикасност.

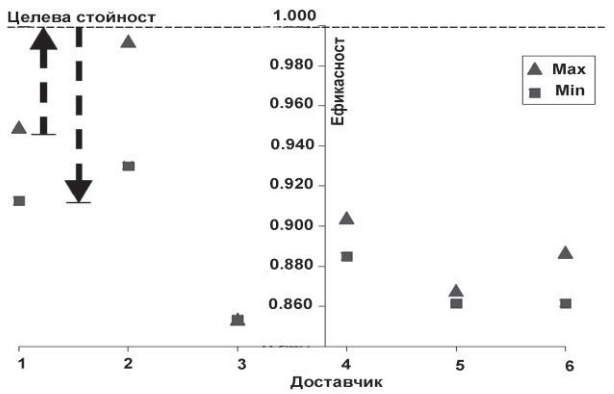
С цел да се получат стойностите за минимална ефикасност за всеки доставчик, модел (3) се прилага за данните от таблица 2. резултатите от анализа са показани в таблица 3 на ред „Min. еф.". на база на тези резултати може да се направи извода, че доставчик 2 отново се представя най-добре с резултат 0.930 следван от доставчици 1, 4, 6, 5 и 3 с резултати 0.913, 0.885, 0.862, 0.861, и 0.853, съответно. В контраст на Модел (2), Модел (3) може да се определи като модел, който идентифицира тегловните коефициенти, които правят всеки от шестте доставчика да изглежда най-слабо при поддържане на целевата ефикасност 1. Така този модел акцентира върху слабите страни на всеки от доставчиците. Фигура 1 изобразява графично резултатите от двата модела. На фигурата е взет за пример доставчик 1.

Двойките резултати за ефикасност за всеки доставчик се използват за извършване на теста на Кросъл-Уолис. Тъй като тестът се базира на рангове резултатите в таблица 3 се преобразуват в рангове, както е показано на таблица 4.

Таблица 4. *Рангове за ефикасност*

Ефикасност	Доставчик 1	Доставчик 2	Доставчик 3	Доставчик 4	Доставчик 5	Доставчик 6
Max. еф.	11	12	1.5	8	5	7
Min. еф.	9	10	1.5	6	3	4

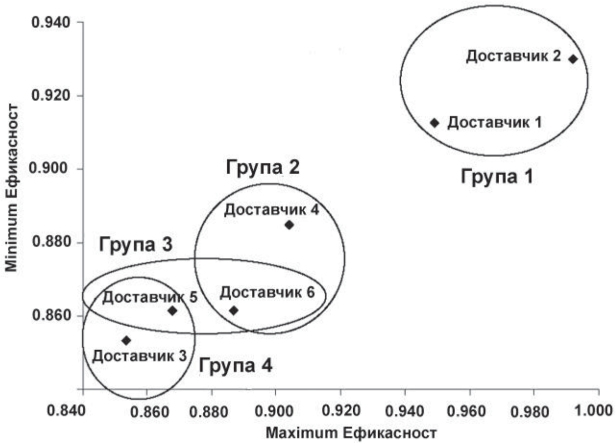
Присвояването на рангове се извършва като се започне с ранг 1 за най-ниския резултат, ранг 2 за следващия по големина и т.н. Осреднен ранг се присвоява при наличието на връзки. При стойност на теста 0.1 нулевата хипотеза се отхвърля, което показва, че поне един от доставчиците е склонен да постига ефикасност по-висока на поне един от останалите доставчици.



Фиг. 1. *Резултати от моделите*

Извършени са множество сравнения и резултатите са представени графично на фиг. 2.

От фигура 2 е видно, че доставчиците от група 1 (доставчици 1 и 2) се представят най-добре, следвани от групи 2, 3 и 4. Въз основа на извършения тест на Кросъл-Уолис се констатира, че не съществуват значими различия на резултатността на доставчиците в групите. Купувачите могат да използват тази информация за ефективно вземане на решение при избор на доставчици.



Фиг. 2. *Групиране на доставчиците*

5. Заключение

Въпреки, че бе разработен и успешно апробиран в практиката Max-Min подход за оценяване на алтернативни доставчици според показаната от тях резултатност на дейността, е необходимо в бъдеще да се извърши експериментално изследване за намиране на ефективни начини за отчитане на непостоянството на параметрите на резултатността на дейността им. Разумно е да се приложи итеративен подход при използване на разработения модел за да се идентифицират онези доставчици, които показват най-добра резултатност.

В бъдеще трябва да се работи и върху практическото приложение на разработения метод. За целта следва да се проведат множество срещи с мениджъри от различни индустриални сектори за идентифициране на специфични проблеми (входящи и изходящи параметри за модела). В крайна сметка трябва да се определи оптимален брой на параметрите за модели и да се идентифицират параметрите с най-силно влияние. Разумно е да се използват предпочитанията на мениджърите при оценяването на значимостта на параметрите. Самите мениджъри следва внимателно да оценят и подберат факторите, които ще използват с модела съобразявайки се със своите приоритети, цели и конкретни задачи. Използването на предпочитанията на мениджъри ще направи разработения модел по-реалистичен и по-универсален.

ЛИТЕРАТУРА

1. Holmberg, S., 2000. A systems perspective on supply chain measurements. International Journal of Physical Distribution & Logistics Management 30 (10), 847-868.
2. Beamon, B., 1999. Measuring supply chain performance. International Journal of Operations and Production Management 19 (3), 275-292.
3. Remko, I.V.H., 1998. Measuring the unmeasurable—measuring and improving performance in the supply chain. Supply Chain Management: An International Journal 3 (4), 187-192.
4. van Amstel, R.P., D'hert, G., 1996. Performance indicators in distribution. The International Journal of Logistics Management 7 (1), 73-82.
5. Cannon, J.P., Perreault Jr., W.D., 1999. Buyer-seller relationships in business markets. Journal of Marketing Research 36 (4), 439-460.
6. Harland, C, 1997. Supply chain operational performance roles. Integrated Manufacturing Systems 8 (2), 70-78.
7. Stephens, S., 2001. Supply Chain Council and Supply Chain Operations Reference (SCOR) Model Overview. Supply Chain Council, Inc.
8. Talluri, S., 2002. A buyer-seller game model for selection and negotiation of purchasing bids. European Journal of Operational Research 143 (1), 171-180.
9. Conover, W.J., 1980. Practical Nonparametric Statistics. Wiley, New York.

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МАРКЕТИНГОВИЯТ МИКС И СЪВМЕСТИМОСТТА МУ С МАРКЕТИНГА НА ВЗАИМООТНОШЕНИЯТА ПРИ БАНКОВИТЕ УСЛУГИ

МАЯ ДИЛКОВА-ПАВЛОВА

Резюме: *Настоящият доклад има за цел да разгледа доколко класическата концепция за маркетингов микс, използвана при транзакционния маркетинг, е приложима при маркетинга на взаимоотношенията в сектора на услугите и конкретно при банкирането. Освен основната концепция 4P са представени още два варианта на маркетинг микса – 7P и 4C, които по някои свои аспекти се доближават до маркетинга на взаимоотношенията.*

Ключови думи: *маркетингов микс, концепция 4P, концепция 7P, концепция 4C, маркетинг на взаимоотношенията, сектор услуги, банков сектор*

MARKETING MIX AND ITS COMPATIBILITY WITH RELATIONSHIP MARKETING IN BANKING SERVICES

MAYA DILKOVA-PAVLOVA

Резюме: *This paper aims to examine whether the classic concept of marketing mix used in transactional marketing is relevant to relationship marketing in the services sector and especially in banking. Besides the main concept (4P) two more variants of the marketing mix are presented – 7P and 4C. They in some aspects are close to relationship marketing.*

Ключови думи: *marketing mix, concept 4P, concept 7P, concept 4C, relationship marketing, services sector, banking sector*

1. Предпоставки за избор на сектора на банковите услуги

По данни на НСИ [1] секторът на услугите продължава да е водещ с най-голям дял на БДС. От Фиг. 1 се вижда, че за 2015г. БДС в сектор услуги е 2/3 от целия за страната. Голямата по обем добавена стойност, бързото развитие на сектора и специфичните характеристики на банковите услуги - неосезаемост, неделимост, хетерогенност, несъхраняемост, доверителна отговорност и двупосочност на информацията са едни от главните причини да се фокусираме именно върху него.

Фиг. 1. *БДС по икономически сектори в млн.лв. за 2015г.*

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2. Концепции за маркетингов микс

2.1. Класическа концепция 4Р на проф. Джером Маккарти

Концепцията за маркетинговия микс е една от основополагащите теории в маркетинга. За нейните поддръжници оспорването ú е равносилно на критиките, които е понесъл Коперник за твърдението си, че Земята се движи [2].

Въпреки това към нея са отправяни много нападки от различен характер, основните от които ще бъдат представени по-долу.

Маркетинговият микс представлява набор от взаимосвързани контролирани променливи, чрез които организацията се стреми да задоволи изискванита на потребителите от целевите пазари и по този начин да постигне своите цели.

Концепцията за маркетинговия микс в **производствена** фирма за пръв път е представена от Нейл Бордън [3] и оригинално включва 12 елемента: планиране на продукта (product planning); ценообразуване (pricing); брендинг (branding); канали за дистрибуция (channels of distribution); лични продажби (personal selling); реклама (advertising); промоции (promotions); опаковане (packaging); дисплей (display); обслужване (servicing); физическа работа (physical handling); откриване на факти и анализ (fact finding and analysis). Самият Бордън е на мнение, че предложените от него елементи на маркетинговия микс могат да се допълват или някои от тях да отпадат в зависимост от конкретната ситуация.

Приетият за класически модел на маркетинговия микс е разработен от проф. Е. Джером Маккарти [4]. Той редуцира елементите, на които организацията пряко може и трябва да влияе чрез разработване на съответните стратегии и политики, до четири на брой:

- Продукт – включващ елементи като качество, опаковка, асортимент, сервиз и др.
- Цена – включваща отстъпки, намаления, условия за кредитиране, състав на цената, ценови фактори и др.
- Дистрибуция – обхваща каналите за доставка, складови наличности, транспорт и др.
- Промоция / комуникация – разработват се комуникационните политики: реклама, насърчаване на продажбите, лични продажби, връзки с обществеността.

2.2. Критики към концепцията 4Р

Moller [5] отправя няколко основателни критики към разработения от проф. Маккарти маркетинг микс. Концепцията на Дж. Маккарти разглежда инструментите от гледна точка на организацията и е вътрешно ориентирана. Миксът е разработен за масови продукти и не предлага помощ за персонификация на маркетинговите дейности. Потребителите се възприемат като пасивна категория и не се предлагат подходи за взаимодействие и изграждане на трайни взаимовръзки с тях. Тези аспекти правят класическия маркетинг микс неприложим при разработване на маркетинга на взаимоотношенията.

2.3. Други концепции за маркетинговия микс

Критиките към класическия 4Р модел на маркетинговия микс и измененията в бизнес средата налагат предлагане на нови варианти на микса. В литературата се срещат много различни вариации на базовия модел - комбинации от думи с първи букви C, E, P, R, V, акронимът SAVE и др.

В настоящата разработка са обхванати две от тях, които имат връзка с маркетинга на взаимоотношенията в сектора на услугите, за да се изследва дали и доколкото тези две концепции са съвместими:

Маркетингов микс при услугите 7Р [6] – традиционните елементи са допълват от още 3 – хора (people), процеси (processes) и материални свидетелства (physical evidence)

От гледна точка на потребителите – концепция 4С [7] – пречупване на променливите през погледа на купувачите. Елементите в нея са потребителска стойност (customer value), цена за потребителя/разходи (cost), удобство (convenience), комуникации (communication).

3. Маркетингов микс при услугите (на примера на банковия сектор) – концепция 7Р

Услугите по своята същност се отличават от физическите продукти с няколко свои присъщи качества – неосезаемост, неделимост от дейността, която ги създава, хетерогенност, несъхраняемост плюс две характерни за банковите услуги черти – доверителна отговорност и двупосочност на информацията. Това създава специфични изисквания и открива нови възможности пред маркетинга на услугите. Именно тези особености на услугите водят до създаването на нови варианти на класическия маркетинг микс, така че да се отчитат присъщите им свойства.

На Фиг. 2 са представени елементите на 7Р концепцията за маркетинговия микс и как те си взаимодействат с основните характеристики на услугите и в частност банковите услуги.

Особености на услугите в банковия сектор

1. Неосезаемост
2. Неделимост
3. Нееднородност
4. Несъхраняемост
5. Доверителна отговорност
6. Двупосочност на информацията

Елементи на 7P концепцията

1.Продукт
2.Цена
3.Комуникация
4.Дистрибуция
5. Хора
6. Материални свидетелства
7. Процеси

Фиг. 2. *Връзка между характеристиките на банковите услуги и елементите на концепцията 7P*

Необходимостта от добавяне на хората, материалните свидетелства и процесите към елементите на маркетинговия микс произтича от характеристиките на услугите.

Услугите са **неосезаеми** и съответно основната задача на маркетинга е да намали тази неосезаемост. Това може да се постигне чрез ефективна комуникация на персонала с клиентите, „предоставяне на информация за лицата, ангажирани с осъществяването на услугата, в т.ч. за броя, квалификацията" [8], както и чрез подходящи материални свидетелства за извършените/извършващите се услуги – кредитни и дебитни карти, договори, рекламни материали и други. Пример от банкирането на дребно е превод на работна заплата по сметка. Докато преди години работната заплата се изплаща на каса и човек може да пипне и усети парите, при преводите се работи с абстракции. С цел намаляване на неосезаемостта банките изпращат напр. уведомителни смс-и, e-mail-и и др, в които се визуализира изплатената сума.

Услугите са **неделими от дейността, която ги създава**. Финансовите услуги първо се купуват (сключва се договор) и след това се произвеждат. В процеса по тяхното осъществяване пряко се включва персоналът. Хората имат ключова рола за приближаването на услугата до изискванията на отделния клиент. За да се създаде в максимална степен полезния ефект продавачът (банката в лицето на своите служители) и клиените трябва максимално да си взаимодействат. Тук отново имаме препратка към прилагане на маркетинга на взаимоотношения, изградени на система от доверителни отношения.

Хетерогенността на услугите води до невъзможността всеки път да се предлага услуга с едно и също качество. При услугите в банковия сектор качеството им силно зависи от компетенциите на персонала и процесите при осъществяване на услугата.

Несъхраняемостта на услугите или невъзможността им да се поддържат като запаси е предизвикателство пред банките. Тъй като част от предлаганите услуги са със сезонен характер – изплащане на работна заплата, данъчни плащания и др. един от начините за преодоляване на сезонноста е да се влияе върху предлагането чрез наемане персонал на непълно работно време. Друга мярка е „увеличаване участието на клиентите за ускоряване на транзакциите" [8], което отново ни насочва към маркетинга на взаимоотношенията.

Специално внимание заслужават двете допълнителни характеристики на услугите при банкирането – **доверителната отговорност и двупосочността на информацията**. Двупосочният обмен на информация и изграждането на доверие са два от основните елементи на МВ. Именно те са препратки към прилагане на маркетинг на взаимоотношенията.

4. Концепция 4 С – маркетингов микс през погледа на потребителите

Класическата концепция на четирите Р на проф. Маккарти и представената концепця 7Р са подложени на основателна критика поради факта, че те представят гледната точка на производителя/продавача, а не на клиента. Погледнато от страната на клиента, тези елементи на маркетинговия микс придобиват други измерения.

Докато компаниите предлагат продукти/услуги, клиентите търсят решение на свои проблеми и купуват стойност – напр. при една от най-разпространените банкови услуги, кредитирането, потребителят получава не толкова пари, колкото напр. средства и възможност за инвестиране.

Потребителят се интересува от удобството при намиране и получаване на услугата, а не от дължината на дистрибуционните канали. Именно затова някои „активни" банкови компании използват по-гъвкави канали за дистрибуция като посещения на място при корпоративните клиенти [8].

Важен за клиента е разходът, който той прави, за да бъде извършена услугата, а не компонентите на цената. Тук се включват всички разходи – по примера с кредитирането: от привличане на вниманието към ГПР, а не само на лихвите по кредита, към разходите по придвижване до банковия клон и не на последно място отделеното време за получаване на услугата.

Промоцията, разбирана като еднопосочно предаване на информация от фирмата към клиентите, отстъпва място на процес на двустранна комуникация.

Поставянето на клиента, а не на продукта в центъра, предлагането на стойност, отчитане усилията и разходите на клиента и разбирането за двупосочна комуникация, а не за едностранно предаване на информация прави концепцията 4С една стъпка по-близо до ориентирането на фирмата към маркетинг на взаимоотношенията.

5. Маркетинг на взаимоотношенията

Маркетингът, използван до сега, се базира главно на отделната сделка и представя една транзакционна перспектива, в чиято основа е концепцията за маркетинговия микс. Това ясно се вижда от определението за маркетинг на Американската организация по маркетинг от 1985г.: „Маркетингът представлява процес по планиране и реализиране на замисъла, ценообразуването, придвижването и реализацията на идеи, стои и услуги посредством размяна, удовлетворяващи целите на отделни лица и организации."

В последните години глобалната конкуренция, бързото технологично развитие, хетерогенните пазари, все по-изискващите потребители и други фактори водят до „промяна на ударението от транзакционно-ориентрана размяна към изграждане на отношения"[7].

Основата на маркетинга на взаимоотношенията е в ефективната комуникация между двете страни, поемането на отговорност от страна на фирмата и предоставянето на стойност за клиента, изграждане на доверие във фирмата, което води до лоялност на клиентите, и като резултат осъществяване на партньорство между двете страни.

Такава глобална промяна в цялостната дейност на фирмата налага използването на нови методи и подходи и прави „старите" такива неподходящи, особено в сферата на услугите. Маркетинговият микс се разработва за масов продукт, насочен към целева група потребители. Доколкото маркетингът на взаимоотношенията използва съответнте политики от микса, то те се разработват спрямо изискванията на конкретния клиент и предложенията са силно персонализирани. Маркетинговият микс отстъпва своето място на нови концепции. Фокусът се измества от продукта към клиента и по-конкретно не към масовия клиент, а към персонализация, комуникация и интеракции с точно определени клиенти.

6. Заключение

От тази гледна точно концепциите 7P, 4C могат да се разглеждат като преход от класическия транзакционен маркетинг, основан на 4P концепцията, към маркетинга на взаимооношенията, който има нови концептуални рамки като 30R [9] (разглеждаща 30 различни типа взаимодействия, илюстриращи ролята на маркетинга като смес от отношения, мрежи и взаимодействия) или като изцяло нова маркетингова парадигма [2].

ЛИТЕРАТУРА

1. http://www.nsi.bg/bg/content/2215/бвп-регионално-ниво
2. Gronroos, C. (1994). From Marketing Mix to Relationship marketing: Towards a Paradigm Shift in Marketing. *Management Decision*, vol. 32, no. 2, pp. 4-20
3. Borden, N. H. (1984). The Concept of the Marketing Mix, *Journal of Advertising Research*, vol 2, Septemberpp. 7-12.
4. Goi, C. (2009). A review of Marketing Mix: 4Ps or More?*International Journal of Marketing Studies*, vol. 1, no. 1, pp. 2-15
5. Möller, K. (2006). Comment on: The Marketing Mix Revisited: Towards the 21st Century Marketing by E. Constantinides. *Journal of Marketing Management*, vol. 22, pp. 439 – 450.
6. Booms, B. H., Bitner M. J. (1981). *Marketing Strategies and organization for Service firms. Marketing of Services*, James H. Donnelly and William R. George, eds. Chicago: American Marketing Association,pp. 47-51
7. Constantinides, E. (2006). The Marketing Mix Revisited: Towards the 21st Century Marketing. *Journal of Marketing Management*, vol. 22, pp. 407-438
8. Младенова, Г. (2007). *Маркетинг на финансовите услуги,* Университетско издателство „Стопанство", София
9. Gummesson, E. (2008). *Total relationship marketing*. 3rd edition, Butterworth-Heinemann, Oxford

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СЪСТОЯНИЕ НА ПАЗАРА НА ТРУДА В БЪЛГАРИЯ

ТАНЯ ГИГОВА

Резюме: *В статията се изследва състоянието на пазара на труда, като се анализират основните индикатори на пазара на труда.*

Ключови думи: *пазар на труда, заетост, безработни, работна сила*

STATE OF THE LABOR MARKET IN BULGARIA

TANYA GIGOVA

Abstract: *The article examines the state of the labor market by analyzing the main indicators of the labor market.*

Key words: *labor market, employment, unemployed, labor force*

1. Увод

Пазарът на труда е икономическото пространство, в което се намират и преговарят лицата, които предлагат и търсят работна сила. Пазарът на труда е фактор, които оказва влияние върху производството и върху икономическата активност на населението като цяло, затова данните за пазара на труда са особено важни за оценка на икономическото състояние. Световната финансово-икономическа криза се отрази особено тежко на заетостта. Целта на настоящата публикация е да се изследва състоянието и да се посочат основните проблеми и предизвикателства на пазара на труда, като използваните основни методи са сравнителен анализ и обработка на статистическа информация.

2. Изложение

Основните показатели за пазара на труда по статистически изследвания на Националния статистически институт (НСИ) [1], Статистическа служба на Европейския съюз (Евростат) [2] и Агенцията по заетостта [3], за периода 2010-2016 година са обобщени в Таблица 1.

Коефициента на икономическа активност се изчислява като отношение на броя на икономически активните лица към населението във възрастовата група 15-64 навършени години.

Икономически активните лица (работната сила) включва всички наети (заети) и безработни лица. Заети са лицата на възраст 15 и повече години, които през наблюдавания период са положили труд дори за едни час, за което са получили работна заплата или друг доход. Като заети се считат и лицата, които не работят, но имат работа, от която временно отсъстват поради болест, годишен отпуск, отпуск при раждане на дете, родителски отпуск, стачка или друг трудов спор и други.

Безработни са лицата на възраст от 15 до 74 навършени години, които през наблюдавания период нямат работа, както и тези които активно търсят работа през период от четири седмици или вече са намерили работа, която очакват да започнат до три месеца след края на наблюдавания период.

Коефициентът на заетост се изчислява като съотношение на броя на заетите лица към населението във възрастовата група 15-64г.

При коефициента на икономическа активност (Таблица 1) [1] за населението на възраст 15-64 навършени години за разглеждания период 2010-2016 г. се запазва тенденцията на нарастването му от 66,5 през 2010 до 69,3% за 2015 г., а за 2016 спрямо 2015 намалява с 0,6 пункта.

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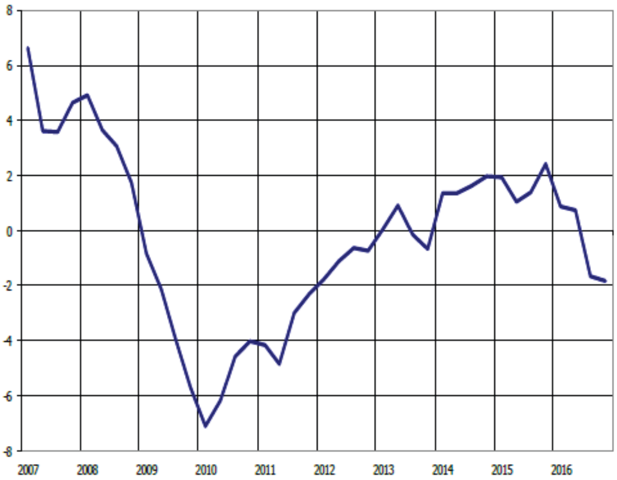
Таблица 1. *Основни показатели за пазара на труда в България*

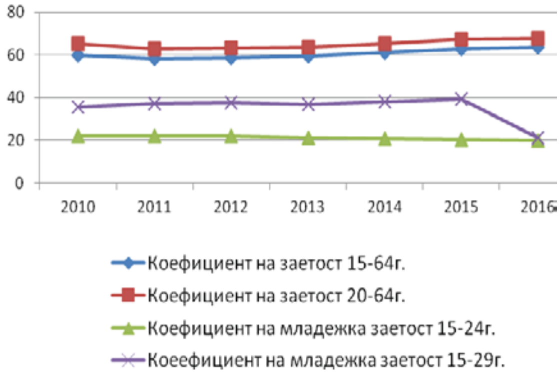
Показател	2010	2011	2012	2013	2014	2015	2016
Коеф. на икономическа активност 15-64, %	66,5	65,9	67,1	68,4	69,0	69,3	68,7
Заети лица на 15 и повече навършени години, бр. (хил.)	3052,8	2965,2	2934,0	2934,9	2981,4	3031,9	3016,8
Заети лица на 15-64г., бр. (хил.)	3010,4	2927,5	2894,9	2889,4	2927,4	2973,5	2954,3
Коеф. на заетост 15-64г., %	59,7	58,4	58,8	59,5	61,0	62,9	63,4
Безработни лица – общо, бр. (хил.)	348	376,2	410,3	436,3	384,5	305,5	247,2
Брой продължително безработни (над 1г.), бр. (хил.)	161,7	210	226,6	250,3	232,5	187,0	146,2
Коеф. на безработица, %	10,2	11,3	12,3	12,9	11,4	9,1	7,6
Коеф. На продължителна безработица (над 1г.), %	4,8	6,3	6,8	7,4	6,9	5,6	4,5
Обезкуражени лица на възраст 15-64г., бр. (хил.)	222,3	233,5	225,6	209,7	188,7	170	163,4
Безработни регистрирани в бюрата по труда, бр.	350944	332601	364537	371380	366470	330816	284707
Равнище на регистрирана безработица, %	9,5	101,1	11,1	11,3	11,2	10,1	8,7
Безработни лица с регистрация в бюрата по труда над 1г., бр.	110848	118135	118832	122738	138473	146010	118278
Равнище на безработица средно за ЕС-28, %	9,6	9,6	10,5	10,9	10,2	9,4	8,5
Недостиг на работна сила в промишлеността, %	6,5	7,5	8,7	8,6	11,2	15,8	21,7

Заетите лица (фиг.1) [4] и коефициентът на заетост (фиг.2) са идентични с коефициента на икономическа активност. Общият броя на заетите лица на възраст 15 и повече навършени години през 2016 г. е 3016,87 хил., като спрямо 2015 г. се наблюдава намаляване на общия броя на заетите лица с 15,1 хил.. Относителният дял на заетите лица от населението на 15 и повече навършени години за четвъртото тримесечие на 2016 г. е 49,2%, което е намаляване с 0,5 процентни пункта в сравнение с четвъртото тримесечие на 2015 г.. Като при мъжете този дял е 54,9%, а при жените – 43,9%. Увеличение на заетостта за 2016 спрямо 2015 г. се наблюдава в секторите: транспорт, складиране и пощи с 11,6 хил., професионални дейности и научни изследвания с 8,2 хил. и култура, спорт и развлечения с 5,1хил. За съжаление се наблюдава по-съществен спад на заетите лица в: образованието с 12,8 хил., преработваща промишленост с 8,8 хил. и с по 4,2 хил. в селско, горско и рибно стопанство, търговия, ремонт на автомобили и мотоциклети.



Фиг. 1. *Заети лица*

При коефициентът на заетост за населението на възраст 15-64 навършени години единствено за 2011г. спрямо 2010г. се наблюдава спад с 9,9 процентни пункта. През останалите години се запазва тенденцията на нарастване. За 2015 г. е 62,9%, като в сравнение с 2016 г. се увеличава с 0,5 процентни пункта и достига 63,4%. За жените е 60%, а за мъжете 66,7%. При останалите възрастови групи, също се наблюдава увеличение на коефициентите на заетост за населението (фиг.2). Коефициентът на заетост за населението на възраст 20 - 64 навършени години за 2016 г. е 67,7%, съответно 71,3% за мъжете и 64,0% за жените. Този коефициент се е увеличил с 0,6 процентни пункта спрямо 2015 г., като за мъжете е с 0,9 процентни пункта, а за жените с 0,2 процентни пункта. Коефициентът на заетост за населението на възраст 55 - 64 години за 2016 г. е 54,5%, т.е. се увеличава с 1,5 процентни пункта, като увеличението при мъжете и жените спрямо 2015 г. е 1,5 процентни пункта. През 2016 г. коефициента на младежка заетост (15-29 г.) намалява съществено с 18 процентни пункта и достига до 21,2%.



Фиг. 2. *Коефициенти на заетост по възрастови групи*

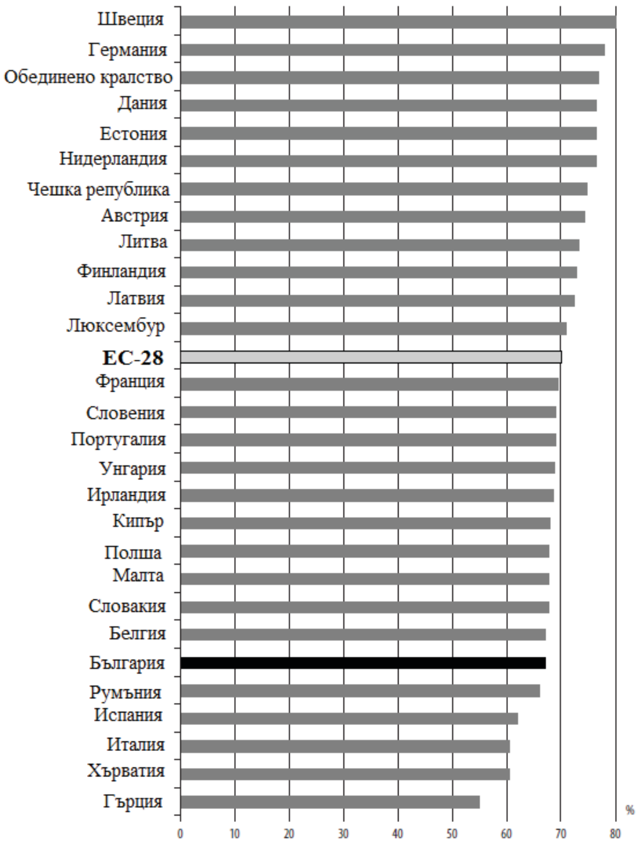
Равнището на заетост във възрастовата група от 15 до 64 години в ЕС-28 [5] е най-високо през 2008 г., когато достига равнище от 65,7%, като намалява през 2010г. с 1,6 процентни пункта и достига до 64,1%. Този спад по време на световната финансова и икономическа криза е последван от период на стабилност между 2010 и 2013 г., когато равнището на заетостта в ЕС-28 през 2010г. е 64,1 % и 64,2 % през 2013г. Равнището на заетост измерено в Наблюдението на работната сила (НРС) на ЕС [6] показва, че възходящата тенденция отпреди кризата се възобновява през 2014г., като равнището на заетостта достигайки 64,9 %, т.е. се увеличава с 0,8 процентни пункта в сравнение с 2013 г.. Равнището на заетост през 2014г. е високо и сред държавите членки на ЕС. Най-висока стойност е отчетена в Швеция, 74,9%, следвана от Германия, Нидерландия, Дания и Обединеното кралство, които се движат в интервала от 74% до 71%. На другия край на скалата, равнища на заетост под 60 %, са отчетени в четири от държавите членки на ЕС-28: Италия, Испания, Хърватия и Гърция, като най-ниската стойност е била в Гърция (49,4 % през 2014 г. и 54,9% през 2015г.) (фигура 3). Равнището на заетост за България през 2014 е 61%, а през 2015 нараства с 6,2 процентни пункта и достига до 67,2%, което отново е под средните стойности за държавите членки на ЕС (70%) и страната се нарежда отново в долните нива на скалата - пред Румъния.

Като продължително безработни се приемат лицата, които са безработни от една или повече години.

Коефициентът на безработица се изчислява като съотношение на броя безработни лица към населението във възрастовата група 15-64г.

Коефициент на продължителна безработица представлява относителният дял на продължително безработните лица от икономически активното население.

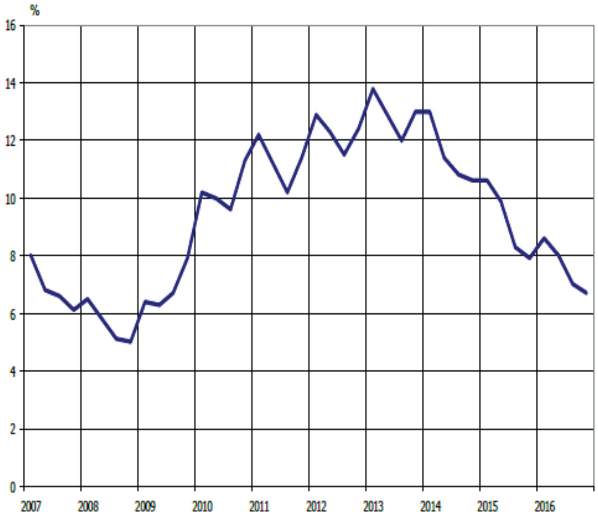
Обезкуражени са лицата извън работната сила, които не търсят активно работа, защото не вярват, че ще намерят, но желаят да работят.



Фиг. 3. *Равнище на заетостта във възрастовата група 20 — 64 години в държавите членки на ЕС, 2015 г.*

Броят на безработните лица показва устойчиво нарастване до края на 2013г.. През 2014г. се наблюдава спад с 51,8 хил. бр. спрямо 2013 г.. През 2016 г. безработните лица в страната са 247,2 хил., като в сравнение с 2015 г. броят на безработните е намалял с 57,9хил.. От общия брой на безработните лица през третото тримесечие на 2015 г. 57,0% (159,1 хил.) са мъже и 43.0% (120,1 хил.) са жени. 12,7% от всички безработни са с висше образование, 50,9% са със средно, и 36,4% са с основно и по-ниско образование. Броят на продължително безработни лица (от една или повече години) от 2010 до 2013 г. значително нараства, като от 2014г. се наблюдава намаляване на броя на продължително безработните, като 2016г. те са 146,2 хил. или 59% от всички безработни лица. Като цяло 2016г. приключва с намаляваща безработица спрямо предходната година.

За разглеждания период коефициентът на безработица следва тенденцията на безработните лица. За периода от 2010 до 2013г. коефициентът на безработица (фиг.4) [4] нараства от 10,2% до 12,9%, след което се наблюдава постепенното му намаляване, като 2014 намалява с 1,5 процентни пункта и достига 11,4%. През 2015 г. коефициентът на безработица е 9,1%, като в сравнение с 2014 г. е по-нисък с 2,3. През 2016 спрямо 2015 е по-нисък с 1,5 процентни пункта. През четвъртото тримесечие на 2016 г. коефициентът на безработица намалява както при мъжете, така и при жените, но стойността му се запазва по-висока при мъжете (6,8%), в сравнение с тази при жените (6,5%).



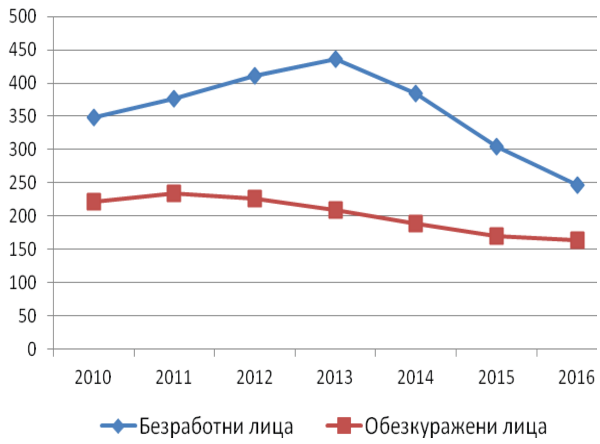
Фиг. 4. *Коефициент на безработица*

Коефициентът на продължителна безработица е идентичен с коефициента на безработица (фиг.5). За 2016 г. коефициентът на продължителна безработица е 4,5%, като в сравнение със 2015 г. намалява с 1,1 процентни пункта. Коефициентът на продължителна безработица намалява в по-голяма степен при мъжете, отколкото при жените.

Фиг. 5. *Коефициенти на безработица и коефициенти на продължителна безработица*

За разглеждания период 2010-2016г. най-висок е дела на обезкуражените лица на възраст 15-64 години през 2011г., когато достигат до 233,5 хил. бр. (фиг.6). От 2012 г.

до момента се наблюдава тенденция на намаляване на броя на обезкуражените лица. От населението на възраст 15-64 навършени години за 2016 г. 31,3% са икономически неактивните лица, като от тях 163,4 хил. са обезкуражени лица. В сравнение 2015 г. броят на обезкуражените лица намалява с 6,6 хиляди.



Фиг. 6. *Безработни лица и обезкуражени лица*

По данни на Евростат [5] в периода между 2010 г. и 2013 г. сезонно коригираният коефициент на безработица в ЕС-28 нарасна от 9,6 % на 10,9 %. През 2014 г. коефициентът на безработица спадна спрямо 2013 с 0,7 процентни пункта и достига до 10,2%. Безработицата в ЕС-28 се е понижила през 2016 г. до 8,5%, което е с 0.9%, като това е най-ниското равнище за разглеждания период от 2010г. Безработицата бавно намалява, но продължава да бъде на високи равнища в ЕС. Коефициентът на безработица в България остава по-висок за средното ниво на ЕС. Най-голяма безработица е регистрирана в Гърция, където повече от една четвърт от хората нямат работа, а най-ниска безработица в Германия и Австрия.

По данни на Агенцията по заетостта (АЗ) безработните регистрирани в бюрата по труда през 2011 спрямо 2010 намаляват с 18343 лица. В следващите 2012 и 2013г. се наблюдава нарастване броя на регистрираните безработни в бюрата по труда. През 2014 брой на безработните е намалял с 4910 души. През 2015 г. продължават да намаляват на годишна база регистрираните в бюрата по труда безработни – тенденция, която се наблюдава от 2014 г.. Безработните, регистрирани в бюрата по труда, през 2016 са 284 707 лица, като в сравнение с 2015 г. те намаляват съществено - с 46 109 лица. Въпреки, че започва да намалява равнището на регистрираната безработица е притеснителен факта, че безработните лица с регистрация в бюрата по труда над 1 година за периода от 2010 до 2014 запазват устойчива тенденция на нарастване, за 2014 г. са нараснали с 15735 лица спрямо 2013г., 2015 г. нарастват с 7537 лица. За 2016 са 118278 лица, като спрямо 2015 г. са намалели значително с 27732 лица.

Топ десет на най-търсените професии от работодателите в бюрата по труда през 2014 г. са: продавачи и посредници в търговията и продажбите; работници в шивашкото и текстилното производство; преподаватели в начално, основно и средно образование; неквалифицирани работници; работници в преработващата промишленост; градинари и растениевъди, животновъди и др.; готвачи и помощници при приготвянето на храни; работници в добивната промишленост и строителството; сервитьори и бармани; друг обслужващ персонал.

По данни на бизнес анкетите на НСИ [4] се наблюдава тенденция на нарастване на недостигът на работна сила в промишлеността за периода 2010-2016г., като нарастването за 2014г. спрямо 2013г. е с 2,6 процентни пункта. За 2016 г. спрямо 2015 г. нарастването е с 5,9 процентни пункта и достига до 21,7%. През март 2017 г. 23,5% от промишлените предприятия посочват недостига на работната сила като фактор, затрудняващ дейността им, т.е. трудовият пазар не отговаря на нуждите на работодателите.

Основните предизвикателства и проблеми на пазара на труда за 2016 г. са: висок дял на безработните, въпреки че безработицата продължава да намалява. Въпреки намалението, броят на неактивните лица, в. т.ч. обезкуражените, остава висок. Трудовият пазар не отговаря на нуждите на работодателите. Бавно е нарастването на броя на новоразкриваните свободни работни места. Влошена е ситуацията на пазара на труда в някои европейски страни, в които работят много българи – в т.ч. Гърция и Испания. Безработните в България остават повече от средното ниво за ЕС.

3. Заключение

Пазарът на труда постепенно се стабилизира. Безработицата бавно намалява, но продължава да бъде на високи равнища в ЕС. Безработицата в България намалява, а заетостта расте, но въпреки това безработните в страната остават повече от средното ниво за ЕС. Въпреки положените усилия държавната институция все още не успява да повлияе значително върху нивата на продължително безработните и недостига на работна сила и трябва да продължава да работи в тази насока, трябва да се търсят възможности за повишаване на конкурентоспособността на труда.

ЛИТЕРАТУРА

1. НСИ, www.nsi.bg/bg/,
2. Евростат, http://ec.europa.eu/eurostat/statistics-explained/index.php/Employment_statistics/bg
3. АЗ, www.az.government.bg/stats/1/
4. НСИ, *Ключови показатели за България*, 6стр., www.nsi.bg/sites/default/files/files/pages/KeyInd/KeyInd2017-04.pdf
5. http://appsso.eurostat.ec.europa.eu/nui/show.do
6. http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Labour_force_survey_(LFS)

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ИЗСЛЕДВАНЕ ХРАНИТЕЛНОТО ПОВЕДЕНИЕ НА ДЕЦА И ТИЙНЕЙДЖЪРИ В ЗАВИСИМОСТ ОТ ТИПА НАСЕЛЕНО МЯСТО, В КОЕТО УЧАТ

ЕЛЕНА ЗЛАТАНОВА-ПЪЖЕВА

Резюме: *В статията са описани основните логически конструкта, върху които е изградена методиката на изследване – разработване на представителна извадка, конструиране на въпросници и създаване на инструмент за събиране на информация. Представени са част от получените резултати от проведено емпирично онлайн изследване на потребителското поведение на деца и тийнейджъри по отношение на храни. Обсъдени са статистически доказаните връзки между изследвани аспекти от хранителното поведение на децата и тийнейджърите и типа населено място, в което учат.*

Ключови думи: *потребителско поведение, дете-потребител, хранителни предпочитания*

SURVEY OF FOOD BEHAVIOUR OF CHILDREN AND TEENAGERS IN DEPENDANCE OF THE TYPE OF POPULATED PLACE THEY STUDY

ELENA ZLATANOVA-PAZHEVA

Abstract: *The article explores the main logical constructs, on which basis is developed the methodology of research – development of representative sample, design of questionnaires and creating a tool for gathering information. Some of the obtained results from the empirical online study of the consumer behavior of children and adolescents in relation to food are presented. The statistically proven relations between the observed aspects of eating behavior of children and adolescents and the type of populated place they study are discussed.*

Key words: *consumer behavior, child-consumer, food preferences*

1. Основни положения

Научаването на децата на моделите на потребителското поведение представлява интерес за изследователите от 60-те години на XX век, когато за първи път през 1964 г. е публикувано изследване за развитието на моделите на потребителско поведение [1]. В последствие децата започват да бъдат признавани за пазар [2].

Маркетолозите и изследователите на потребителите дълго са пренебрегвали децата като пазарен сегмент, поради малкия им разполагаем доход. През последните десетилетия детският и тийнейджърски пазар е станал значителен, тъй като младите хора имат по-голям разполагаем доход от предишните поколения.

Поради факта, че покупателната сила на младите хора продължава да расте, маркетолози, производители и рекламодатели, са значително заинтересовани в изработването на ефективни методи, които да достигнат до пазара на младите хора [3]. Тъй като децата са потребители е уместно да се изследва тяхното покупателно поведение като се открият мотиваторите, които определят от къде пазаруват и какво купуват [4].

Днес интересът към децата и тяхното потребителско поведение е толкова голям не само защото формират значим пазарен сегмент и

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влияят на решенията на своите родители, но и защото сегашното им поведение в голяма степен ще формира и повлияе на бъдещото им поведение. Необходимо е да се разбере потребителското поведение на децата и как то се формира, за да могат да се създадат адекватни подходи към задоволяване потребностите на децата.

Въпросът с хранителните предпочитания и навици на българските деца и тийнейджъри е особено актуален, тъй като по данни на Европейски конгрес по затлъстялост в Прага от 2015 г. българските деца са класирани на пето място по степен на затлъстялост в Европа. Този факт изисква предприемане на сериозни мерки за изучаване на хранителното поведение на децата и тийнейджърите и на факторите, които им оказват влияние.

Детските хранителни предпочитания са силно свързани с техните модели на потребление [5]. Множество изследвания са открили, че хранителното поведение, формирано в ранно детство може да устои през периода на късното детство и дори в началото на зрялата възраст [6]. Именно това прави хранителните предпочитания на децата и тийнейджърите още по–важни за изследване.

Обект на проведеното изследване са две възрастови групи – деца на 7-9 години (1-3 клас) и тийнейджъри на 12-14 години (6-8 клас), идентифицирани чрез статистическа извадка от училища, териториално разположени в Южна България.

Предмет на изследване в настоящата статия са хранителните предпочитания на българските деца и тийнейджъри в Южна България.

Целта на настоящата статия е да се представят статистически доказаните връзки между хранителните предпочитания на децата и тийнейджърите и факторът - населено място, в което учат, като резултат от проведено емпирично изследване.

2. Методика на изследване

Три са основните логически конструкта, върху които се изгражда изследването:

- разработване на представителна извадка;
- конструиране на въпросници;
- създаване на инструмент за събиране на информация.

2.1. Разработване на представителна извадка

Обезпечаването на необходимите изходни данни за разработване на представителна извадка са предоставени от Министерство на образованието и науката, подкрепило провеждането на изследването.

Като признат метод, използван при международни оценъчно-диагностични изследвания, измерващи постиженията на учениците (Trends in International Mathematics and Science Study (TIMSS), Progress in International Reading Literacy Study (PIRLS), Progress in International Student Achievement (PISA) [7]) е избрано да се работи с много стъпкова стратифицирана клъстерна извадка.

Същността на възприетия метод за формиране на извадка може да се опише по следния начин:

- Извадката е много-стъпкова, тъй като последователно се избират най-напред училище и след това паралелки в тези училища;
- Стратифицирана е, защото предлага възможност за разделяне на училищата или учениците на групи в зависимост от съществен признак за измерването. За целите на изследването училищата са стратифицирани според признака – възрастова група. На тази основа са разработени две страти – Страта 1, включваща всички училища в Южна България, в които се обучават ученици от 1 до 3 клас, и Страта 2, съответно за училищата, включващи ученици от 6 до 8 клас;
- Клъстерна е, защото се избират цели клъстери, в случая паралелки.

Разработването на извадката е осъществено в две стъпки:

<u>Стъпка 1</u>: *Избиране на училища.*

Избирането на училище е извършено с метода PPS (Probabilities proportional to their size), при който вероятността дадено училище да попадне в извадката, е пропорционална на броя на учениците от разглежданата популация, които учат в това училище.

<u>Стъпка 2</u>: *Избиране на клъстери (паралелки) от избраните вече училища.*

Това е извършено посредством проста случайна извадка от списъка на всички паралелки в даденото училище. Във втората стъпка паралелката, а не отделният ученик, е самостоятелна единица за извадката. От избраната паралелка в изследването участват всички ученици.

В настоящето изследване използваната допустима грешка на извадката е 5%, а доверителния интервал 0,95, използвани при международни оценъчно-диагностични изследвания.

Полученият резултат от разработената извадка за всяка страта е, както следва:

- Страта 1 - попадат 2340 деца от 115 училища;

- Страта 2 – попадат 2310 тийнейджъра от 115 училища.

2.2. Конструиране на въпросници

Методът за събиране на данни, който е използван, е посредством въпросници в онлайн среда. Разработени са три възрастово съобразени въпросника – за деца, тийнейджъри и родители.

При конструиране на въпросниците, насочени към деца, се е изхождало от тезата, че „децата могат и предоставят надеждни отговори, ако са попитани по начин, който разбират и за събития, които значат нещо за тях” [8].

Някои основни характеристики на съставените два детски въпросника са:

- брой въпроси: въпросникът за деца е със застъпени по-малко въпроси в сравнение с този за тийнейджърите, поради различното ниво на когнитивно и езиково развитие;
- обръщение: и двата въпросника започват и завършват с обръщение към респондентите, което е различно за двете групи и съобразено с когнитивното им и умствено развитие;
- структура: еднаква е и за двата въпросника. Състои се от 7 части – любими храни, избор, знание, на училище, в къщи, любимо, ти и твоите приятели;
- скала за отговор: при децата са използвани биполярни скали от типа “да”–“не”, изобразени с емотикони и номинални скали. При тийнейджърите скалирането е отразено в ординални, биполярни, номинални и Ликърт скали.
- визуални стимули: При децата задаването на въпрос се извършва от „анкетьор”, който е компютърно създаден плод, зеленчук или друга храна, което има за цел предизвикване на интерес у децата и създаване на чувство за спокойствие (Фиг. 1).

Фиг. 1. *Изглед на въпрос от въпросник за „Дете”*

При тийнейджърите „анкетьорите” са адаптирани за малко по-големи деца, поради което са използвани компютърно създадени добронамерени и усмихнати емотикони (Фиг. 2).

Фиг. 2. *Изглед на въпрос от въпросник за „Тийнейджър”*

2.3. Създаване на инструмент за събиране на информация

Целта, която е поставена, е осъществяване на представително изследване в Южна България, което предполага събиране на голям обем информация.

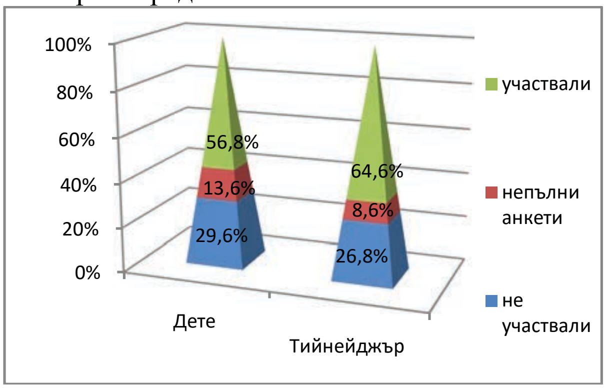
Проектът създаден за провеждане на изследването представлява уеб-базирано приложение, изградено с цел по-добро взаимодействие с потребителите. Приложението се характеризира със сравнително ниски разходи по изграждане и поддръжка. Този продукт позволява неограничен брой потребители да работят с него едновременно без това да утежнява нито сървъра, в който се намира продуктът, нито клиентските устройства, които се свързват с него.

Съвременното високо ниво на компютърна грамотност, както сред родителите, така и сред децата създаде възможност организацията на изследването да се извърши посредством кодове. По този начин се гарантира за обезпечаване на изследването с достоверна информация, за опазване на конфиденциалността на анкетираните деца и родители и за проследяване на получените отговори. Същността на организацията се състои в това, че администраторът генерира набор от кодове за всяко училище, което попада в представителната извадка. Всяко от тези училища, териториално разположени в Южна България, получава писмо по пощата, съдържащо обръщение към директорите, указания до децата и техните родители с наименованието на сайта и генерираните от администратора кодове. На следващия етап, за да посети онлайн базираното приложение, потребителят трябва да въведе наименованието на сайта **http://www.food-interests.eu/** (активен в периода 09.2015-12.2015 г.)в адресната лента на уеб браузъра на компютър, таблет или мобилен телефон, което го прави най-често срещания начин при изграждане на уеб-базирани приложения. [9]

3. Резултати

Инструментът, посредством който е извършвана статистическата обработка на получените данни, е статистическият пакет за социални науки на IBM SPSS Statistics Trial Software. Използваният метод за статистическа обработка е χ^2 тест, посредством който е извършвана проверка на поставена нулева хипотеза. Изборът на този статистически метод се обуславя от факта, че въпросниците, които се използват са независими и променливите, които се изследват са неметрични или категорийни.

При статистическа обработка непълни анкети (непопълнени до края на анкетата) са изключени. Възвръщаемостта на получените отговори е представена на Фиг. 3.



Фиг. 3. *Разпределение на участието в изследването на попадналите в извадката ученици*

Един от анализите, приложен при обработка на резултатите, е Анализ на връзките и зависимостите, имащ за цел да се открие какви зависимости съществуват между изследваните аспекти на хранително поведение за всяка възрастова група и избрани признаци. За целите на настоящия доклад от интерес представляват откритите връзки с териториалния признак. Именно този фактор е избран за обект на настоящия доклад, тъй като в проведеното цялостно изследване това е факторът, влияещ най-силно върху хранителното поведение на възрастова група „Дете".

Представянето на получените резултати е на база класифициране по ниво на значимост ($p < 0,05$) и сила на зависимостите (Cramers's V Value). Нулевата хипотеза (H_0), която се задава и подлежи на статистическа проверка е изградена на предположението за липса на статистически значима връзка между двете основания на класификациите – териториален признак и изследван аспект на хранително поведение. Алтернативната хипотеза (H_1) съдържа предположение за съществуване на статистически значима връзка между двете основания на класификациите и се противопоставя на H_0. За всички връзки, които ще бъдат представени в анализа, се отхвърля нулевата хипотеза и се приема алтернативната, тъй като за тях $p < 0,05$.

Необходимо е да се обърне внимание на обстоятелството, че при отхвърляне на нулевата хипотеза се приема алтернативната хипотеза за връзка между двете основания на класификациите, която се проявява поне за една клетка от кростаблицата. Но остава неизвестно това по отношение на кои именно клетки от кростаблицата връзката се проявява [10]. С други думи, възниква въпросът за *множествените сравнения*, поради което е направена допълнителна проверка - анализ по двойки или на кростаблици от вида 2х2.

3.1. Териториален признак – възрастова група „Дете"

Териториалният признак е изграден в зависимост от вида населено място, където учат децата, а не в зависимост от мястото на живеене. Това решение произтича от факта, че при разработване на представителната извадка децата са избирани в зависимост от училището, в което учат. Териториалният признак е определен на база четири типа населено място: столица, областен град, град и село.

<u>Най-високо ниво на значимост p=0,000</u>

Получените стойности за сила на зависимостите са степенувани съгласно Cramers's V Value.

Сила на зависимост $= 0,2 \div 0,3$

Децата, учащи в града предпочитат като любима храна „Домашно приготвена храна", повече от тези, учащи в столицата. Децата в столицата предпочитат като любима храна „Плодове" повече от тези в града.

Сила на зависимост $= 0,1 \div 0,2$

Установено е, че децата, учащи в града обичат да ядат хамбургер, повече от тези в столицата.

Децата в столицата предпочитат да ядат в голямото междучасие „Плод" повече от тези в града. Децата в града предпочитат да ядат в голямото междучасие повече „Солени тестени изделия" от тези в столицата.

<u>Високо ниво на значимост p<0,05</u>

Сила на зависимост $= 0,1 \div 0,2$

Децата, учащи в областен град обичат да ядат риба повече от тези, учащи в града.

Сила на зависимост $< 0,1$

Децата, учащи на село обичат да ядат зеленчуци повече от тези, учащи в столицата. От своя страна децата, учащи на село обичат да ядат чипс повече от връстниците им в столицата.

3.2. Териториален признак – възрастова група „Тийнейджър”

Най-високо ниво на значимост p=0,000

Сила на зависимост $= 0,1 \div 0,2$

Малки предпочитания за любима храна към „Домашно приготвена храна” имат както тийнейджърите, учащи в града, така и тези, учащи на село. Последните имат по-големи предпочитания за любима храна към „Нездравословна калорична храна” от тези, учащи в града.

Високо ниво на значимост p<0,05

Сила на зависимост $< 0,1$

Тийнейджърите, учащи на село обичат да ядат хамбургер повече от връстниците им в столицата.

4. Обсъждане

При прилагане на Анализа на връзките и зависимостите и на допълнителната проверка посредством анализ по двойки, са установени съществуващи зависимости, но не и конкретно тяхно проявление между представляващите интерес за изследването основания на класификациите. При последващ анализ има възможност да се изследва за кои клетки се проявява съществуващата връзка. На Таблица 1 и Таблица 2 са представени отговорите, за които е извършвана допълнителна проверка чрез анализ по двойки.

Таблица 1. *Изследвани основания на класификациите- група „Дете”*

		Населено място
	Отговори	
Храна, консумирана с приятели	Солени тестени изделия	Град
	Сладки тестени и шоколадови изделия	Областен град
Избор между вафла и банан	Вафла	Град
	Банан	Областен град

Таблица 2. *Изследвани основания на класификациите –група ”Тийнейджър”*

		Населено място
	Отговори	
Предпочитание към хляб	Да, много	Град
	Не, изобщо	Областен град
Любима реклама на храна	Сладки тестени и шоколадови изделия	Град
	Нямам	Областен град
Предпочитание към чипс	Да, много	Областен град
	Не, изобщо	Село
Храна, консумирана в голямо междучасие	Солени тестени изделия	Столица
	Нездравословна калорична храна	Град
Предпочитание към зеленчуци	Да, много	Столица
	Не, изобщо	Град
Избор между пържени картофи и картофена салата	Пържени картофи	Столица
	Картофена салата	Село

- Възрастова група „Дете”

Налице е статистически значима връзка между храната, която детето яде с приятелите си и населеното място, в което учи. Съществува статистически значима връзка между избора, който детето би направило между вафла и банан и населеното място, в което учи. Но анализа по двойки на избраните отговори показва, че конкретно за тях не се проявява връзка и би било некоректно да се правят заключения.

- Възрастова група „Тийнейджър”

Налице е статистически значима връзка между предпочитанието към хляб, любимата реклама на храна по телевизията, и населеното място, в което учи тийнейджърът. Съществува статистически значима връзка между предпочитанието към чипс и населеното място, в което учи детето. Открита е връзка между храната, консумирана в голямото междучасие и населеното място, в което учи детето. Открита е връзка между предпочитанието към зеленчуци, изборът, който детето би направило между пържени картофи и картофена салата, и населеното място, в което учи. Но анализа по двойки на избраните отговори показва, че конкретно за тях не се проявява връзка и би било некоректно да се правят заключения.

Анализът, извършен при обработка на получените резултати от цялостното изследване, показва, че при възрастова група „Дете“ факторът със статистически обосновани връзки с най-голяма сила на влияние (0,2-0,3), е териториалният признак. Това е и един от факторите, които влияят върху най-много аспекти от хранителното поведение на децата. За възрастова група „Тийнейджър” е установено, че териториалният признак не оказва силно влияние върху хранителното поведение на тийнейджърите.

5. Заключение

Представените статистически доказани връзки за двете изследвани възрастови групи дават информация за хранителните предпочитания на децата и тийнейджърите в зависимост от един важен фактор, влияещ върху потребителското поведение – географският критерии. Получените резултати за хранителните предпочитания на деца и тийнейджъри поставят редица въпроси, на които да се търсят отговори не само по отношение на хранителните предпочитания на обекта на изследване, но и по отношение на причините за изменение силата на влияние на изследвания фактор върху поведението на децата.

Може да се твърди, че поведението на децата-потребители в съвременния глобализиран се свят е сложен, многопластов и динамично развиващ се във времето проблем. Динамичността на факторите, влияещи върху децата потребители при избора им на храни, предопределя нуждата от задълбочаване на изследванията по този проблем, които в практико-приложен план ще дадат възможност на фирмите да постигнат по-добри икономически резултати.

ЛИТЕРАТУРА

1. Шадрина, С.В. (2009). Потребительское поведение подростоков: основные факторы влияния. *Вестник Санкт-Петербургского Университета*, Сер. 8, Вып. 2, стр.53-91.
2. McNeal, J.U. (2007). *On becoming a consumer: Development of consumer behavior patterns in childhood*, p. 429. Butterworth-Heinemann, an imprint of Elsevier Inc, USA.
3. Михова, Т., Бочева, М. (2013). Техники за привличане на българските потребители. *V Национална Научна Конференция за студенти, докторанти и млади учени*, Сборник доклади, стр. 356-360
4. Sidin, S.Md., Abdul Rahman, M.K. (2008). Effects of social variables on urban children’s consumption attitude and behavior intentions. *Journal of consumer Marketing*, Emerald Group Publishing Limited, 25/1, p. 7-15.
5. Jansen, P. et al. (2012). Children's eating behavior, feeding practices of parents and weight problems in early childhood: results from the population-based Generation R Study, *International Journal of Behavioral Nutrition and Physical Activity*, 9:130.
6. Owen, S. et al. (1997). Food choice: how to assess attitudes of pre-adolescent children, *Nutrition & Food Science*, Number 1, January/February, p. 5–11.
7. Банков, К. (2012). *Широко мащабни оценъчно-диагностични педагогически изследвания*, стр. 287. Хабилитационен труд за академичната длъжност професор, Софийски университет „Св. Климент Охридски”, Факултет по математика и информатика, София.
8. Kellet, M. (2011*). Engaging with children and young people*, p.23. Centre for children and young people: Background Briefing Series, Southern Cross University, Lismore, Australia.
9. Zlatanova–Pazheva, E et al. (2016). The web-based application as an instrument for collecting information when conducting online surveys with children, *European Journal of Scientific Research*, Paris University Press. № 1 (13), (January-June). Volume II. p. 728-734.
10. Наследов, А. Д. (2004). *Математические методы психологического исследования: анализ и интерпретация данных,* 392 стр. Изд. Речь, Санкт Петербург, Русия.

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КАЧЕСТВО И УДОВЛЕТВОРЕНОСТ ПРИ ПРЕНОСИМИ КОМПЮТРИ

КРИСТИАН ЦВЕТКОВ[1], ВЛАДИСЛАВ ГЕРАСИМОВ[1], ЕЛЕНА КОЛЕВА[1,2], ЛИЛЯНА КОЛЕВА[1]

Резюме: *Проведено е изследване за удовлетвореността на потребтелите от преносимите компютри. За характеризиране на гореупоменатата са използвани индикатори, като ефективност, използваемост, качество и ефикасност. Анкетираните са разделени в две групи, до и над 36 годишна възраст.*

Ключови думи: *удовлетвореност, ефикасност, ефективност, качество, използваемост, потребители, преносими компютри.*

QUALITY AND SATISFACTION FOR PORTABLE COMPUTERS

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Abstract: *A study about complacency of portable computers. For characterization on complacency were used indicators witch efficiency, usability, effectiveness and quality. Respondents were split into two groups, up to and over 36 years of age.*

Key words: *satisfaction, efficiency, usability, effectiveness, quality, user, portable computers.*

1. Въведение

Преносим компютър (портативен компютър, ноутбук, нетбук) или често наричан лаптоп, е компютър с малки размери и същата функционалност, като персоналния компютър. Думата лаптоп идва от lap- скут. Идеята за мобилните устройства от този тип възниква около 70те години на 20 век. През 1973 година компанията IBM демонстрира проекта SCAMP (Special Computer APL Machine Portable). След две години компанията предлага IBM 5100, който е първия преносим компютър. Първоначално те били с 8 битови процесори, работели с 5.25 инчови (13.335 см.) флопидискови устройства и с малки CRT дисплей. С развитието на технологиите търсенето на тези устройства става все по- голямо, заради своите известни предимства, едно от които безспорно е тяхната мобилност. Съвременните модели преносими устройства са с плоски LCD-TFT монитори, вградени оптични устройства, мрежова карта, безжична комуникация, сензорни екранни, възможност за включване на външни устройства, които разширяват функционалността на компютъра [1].

В днешно време поради своята функционалност те се използват широко по целия свят от милиарди потребители, което поражда интерес към спецификата, коя от техните характеристики е най- важна за задоволяване нуждите на клиента. Удовлетвореността от мобилното устройство е функция, която зависи от ефективността, ефикасността, използваемостта и не на последно място от качеството на продукта.

Ефективността характеризира само отношението на постигнатия резултат спрямо поставената цел, тя не отчита разхода бил то пари, време и други, а само постигнатата цел.

Използваемостта изразява честотата на ползване на даден продукт.

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Фиг. 1. *Диаграма на Ишикава*

Качеството в нашия случай е показател определящ изследваната удовлетвореност, който е свързан с характеристиките на разглежданото устройство, като например размер, марка, материал на изработка и други.

Ефикасност- показва отношението на вложените разходи спрямо постигнатия резултат.

2. Методика

Диаграмата на Ишикава е един от класическите примери и най-широко разпространен инструмент за решаване на управленски задачи, свързани с управлението. Причинно-следствената диаграма помага не само да елиминира даден проблем, но и да се предприемат действия за неговото отстраняване. Причинно-следствена диаграма на Ишикава тип „рибена кост“ е наречена така, заради структурата си, която наподобява рибена кост. За целите на изследването е използвана диаграма на Ишикава, която е разклонена и разделя причините, които характеризират проблема на 4 категории: ефективност, ефикасност, използваемост и качество [2, 3].

На Фиг. 1 е представена диаграма на Ишикава тип рибена кост, на която са представени разглежданите показатели по които ще се съди за удовлетвореността от преносимите компютри. Основните разклонения са:

- ефективност – свързана е с хардуерните компоненти изграждащи разглеждания продукт;

- използваемост- показва, колко често и по каква причина потребителите използват интернет;

- качество – според ISO то е съвкупност от свойства и характеристики на обектите, които определят пригодността им да удовлетворяват установени и предполагаеми потребности;

- ефикасност – показва колко е определяща цената, като вложен ресурс за удовлетворението на потребителите.

На базата на определените чрез диаграмата на Ишикава основни причини за удовлетвореността е съставена анкетна карта с 42 въпроса. На диаграмата е показан, като подразклонение всеки един от въпросите със съответния му номер. Анкетираните са хора от всяка възраст. За попълването на анкетата анкетираните са използвали петстепенна скала на оценяване: Да; По-скоро Да; Нито Да, нито Не; По-скоро Не; Не. При проведеното запитване са събрани 138 валидни анкети, които са обработени за целите на статията. Анкетата е проведен онлайн.

3. Определяне на удовлетвореност-та на потребителите

Всеки от отговорите е разпределен в петстепенна скала. На всяка оценка се присвоява съответния коефициент, който е в граница от 0 до 1. В Таблица 1 са представени възможните отговори и съответните им коефициенти.

Таблица 1. *Коефициенти на удовлетвореност*

Оценки	**Да**	**По-скоро Да**	**Нито Да, нито Не**	**По-скоро Не**	**Не**
Коефициент	1	0.75	0.50	0.25	0

В Таблица 2 са показани отговорите групирани с помощта на допълнителен критерий, възраст. Потребителите са разделени под и над тридесет и шест годишна възраст с цел по-голяма информативност. В тях са дадени произведенията на съответните коефициенти по броя на анкетираните отговорили със съответния отговор. В последната колона е дадено нивото на удовлетвореност според съответния критерии в проценти. За да се получи тази удовлетвореност са сумирани положителните отговори за даден критерий, след което този сбор е разделен на броя на анкетираните и е умножен по 100 за бъде в проценти.

Таблица 2. *Отговори от анкетата, групирани по възраст: до 36 г. / над 36 г.*

Въпроси	**Да**	**По-скоро Да**	**Нито Да, нито Не**	**По-скоро Не**	**Не**	**Удовлет-вореност (%)**
1.При покупка на лаптоп от какво значение са параметрите и марката на процесора му?	73/33	13/14	3/0	1/0	0/1	95.55/97.91
2.При покупка на лаптоп от какво значение е с колко RAM - памет разполага?	68/32	17/14	3/1	2/0	0/1	94.44/95.83
3.При покупка на лаптоп от какво значение е големината на HARD-диска?	43/23	28/20	14/4	5/0	0/1	78.88/89.58
4.При покупка на лаптоп от какво значение е с каква видеокарта разполага?	45/23	29/21	13/4	3/0	0/0	82.22/91.66
5.При покупка на лаптоп от какво значение е марката на дъното?	28/18	24/20	19/8	15/2	4/0	57.77/79.16
6.При покупка на лаптоп от какво значение е издръжливостта на батерията му?	39/29	30/10	11/3	7/2	3/4	76.66/81.25
7.При покупка на лаптоп от какво значение е да има инсталирана операционна система?	11/12	23/17	6/7	13/2	37/10	37.77/60.41

8.Използвате ли Интернет за обучение?	60/19	21/16	5/10	4/2	0/1	90/72.92
9.Използвате ли Интернет за комуникация?	85/47	4/0	0/0	1/0	0/1	98.88/97.92
10.Използвате ли Интернет за търсене на информация?	90/46	0/1	0/0	0/0	0/1	100/97.92
11.Използвате ли Интернет за работа?	68/31	8/7	5/2	4/3	5/5	84.44/79.16
12.Използвате ли Интернет за общуване чрез социалните мрежи?	76/38	6/4	3/2	3/1	2/3	91.11/87.5
13.Използването на Интернет пречи на обичайния ми ритъм на живот.	7/4	10/2	20/13	25/6	28/23	18.88/12.5
14.Използването на Интернет редуцира времето, прекарано на живо с приятели.	20/5	22/7	11/7	16/12	21/17	46.66/25
15.Изпитвате ли нужда непрекъснато да имате връзка с Интернет?	16/15	20/9	14/8	16/7	24/9	40/50
16.Използването на Интернет разширява ли кръга от хора, с които редовно общувате?	28/20	20/10	12/7	19/5	11/6	53.33/62.5
17.Използвам Интернет основно по работа.	12/7	18/8	24/19	23/5	13/9	33.33/31.25
18.Използвам Интернет за получаване на информация за лични въпроси.	43/22	25/11	13/9	5/3	4/3	75.55/68.75
19.Използвам Интернет за забавление (филми, книги, онлайн игри и др.)	70/25	13/11	3/4	3/4	1/4	92.2/75
20.Използвам често електронната си поща.	54/32	14/7	7/4	4/4	1/1	75.55/81.25
21.Когато съм в Интернет, е основно, за да съм в социалните мрежи (Facebook, Twitter и др.).	12/13	18/1	18/11	23/6	19/7	33.33/50
22.Използвам интернет, за да пазарувам онлайн дрехи, продукти и услуги.	24/11	14/9	10/7	20/11	22/10	42.22/41.66
23.Поне веднъж в седмицата поръчвам храна през Интернет.	5/3	2/1	4/3	12/7	67/34	7.77/8.33
24.При покупка на лаптоп от какво значение за Вас е цената му?	33/11	25/20	25/15	4/0	3/2	64.44/64.58
25.При покупка на лаптоп от какво значение е марката му?	27/15	23/19	29/9	4/2	7/3	55.55/70.83
26.При покупка на лаптоп от какво значение е размера на монитора?	33/16	29/18	19/12	6/2	3/0	68.88/70.83
27.При покупка на лаптоп от какво значение е теглото му?	10/8	20/13	22/10	22/10	16/7	33.33/43.75
28.При покупка на лаптоп от какво значение е да се предлага с аксесоари (чанта, мишка, слушалки и др.)?	7/5	20/7	10/10	19/14	34/12	30/25
29.При покупка на лаптоп от какво значение е да има водоустойчива клавиатура?	4/3	18/17	16/3	27/13	25/12	24.44/41.66
30.До каква степен за вас качеството на продукта се определя от дългосрочното използване, без повреди?	63/32	21/15	5/0	0/0	1/1	93.33/97.92
31.До каква степен за вас качеството на продукта се определя от големината на гаранционното време?	20/20	34/17	21/8	7/2	8/1	60/77.08
32.До каква степен за вас качеството на продукта се определя от това гаранцията да е валидна и за чужбина?	13/10	15/13	17/11	20/5	25/9	31.11/47.92
33.До каква степен за вас качеството на продукта се определя от материалите, с които е изработен?	38/17	21/18	17/10	10/1	4/2	65.55/72.92
34.До каква степен за вас качеството на продукта се определя от външния му вид?	8/8	25/10	22/19	23/4	12/7	36.66/37.5
35.До каква степен за вас качеството на продукта се определя от наличието на допълнителни функции?	19/10	34/19	22/12	9/4	6/3	58.88/60.42
36.До каква степен за вас качеството на продукта се определя от високото ниво на изпълнение на стандартни функции?	48/22	27/18	11/6	4/0	0/2	83.33/83.33
37.До каква степен за вас качеството на продукта се определя от страната, в която е произведен?	15/14	24/14	18/12	14/3	19/5	43.33/58.33
38.До каква степен за вас качеството на продукта се определя от спазването на международни стандарти (ИСО-стандарт и др.)?	27/22	33/15	14/6	8/2	8/3	66.66/78.08
39.За да сте удовлетворен от направената покупка на устройство?	12/10	26/12	37/17	15/7	0/2	42.22/45.83
40.До каква степен за вас качеството на продукта се определя от цената?	16/16	58/16	21/14	10/0	5/2	60/66.66
41.До каква степен за вас качеството на продукта се определя от това платената цена да отговаря на полученото качество?	48/25	26/16	12/5	2/0	2/2	82.22/85.41
42.До каква степен за вас качеството на продукта се определя от съотношението цена-качество?	39/20	32/18	11/8	5/1	3/1	78.88/79.16

Следващата стъпка е определянето на важността на параметрите, което става по метода на Стоянов за определяне на тегловни коефициенти при многокритериално вземане на решения, чрез ранжиране на целевите параметри [4].

За всеки от посочените критерии y_i се изчислява сума от техните оценки:

$$\sum_{k=1}^{R} \alpha_{ki}$$

и сумата на теглата за всеки целеви параметър Δj.

Таблица 3. *Тегловни коефициенти, групирани по възраст: до 36 г. / над 36 г.*

	$\sum_{k=1}^{N} a_{ki}$	V_j	w_i
1	84.5/43.5	1.010/1.015	0.1386/0.1406
2	82.75/43	1.013/1.017	0.1391/0.1408
3	72.25/40	1.032/1.027	0.1417/0.1423
4	74/40.75	1.029/1.025	0.1413/0.1419
5	59.25/37.5	1.056/1.036	0.1450/0.1435
6	68.75/38.5	1.039/1.032	0.1426/0.1430
7	34.5/28.75	1.102/1.066	0.1513/0.1477
8	79.25/36.5	1.007/1.015	0.0616/0.0620
9	88.25/47	1.001/1.001	0.0611/0.0611
10	90/46.75	1/1.001	0.0611/0.0611
11	77.5/38	1.009/1.013	0.0616/0.0619
12	82.75/42.25	1.005/1.007	0.0614/0.0615
13	30.75/13.5	1.043/1.047	0.0637/0.0639
14	46/16.75	1.032/1.043	0.0631/0.0637
15	42/27.5	1.035/1.028	0.0632/0.0627
16	53.75/32.25	1.026/1.021	0.0627/0.0623
17	43.25/23.75	1.034/1.033	0.0632/0.0631
18	69.5/35.5	1.015/1.017	0.0620/0.0621
19	82/36.25	1.005/1.016	0.0614/0.0620
20	69/40.25	1.015/1.010	0.0620/0.0617
21	40.25/28.25	1.036/1.027	0.0633/0.0627
22	44.5/24	1.033/1.033	0.0631/0.0630
23	11.5/7	1.058/1.056	0.0646/0.0645
24	65.25/33.5	1.019/1.021	0.0661/0.0664
25	59.75/34.25	1.024/1.020	0.0664/0.0664
26	65.75/36	1.019/1.017	0.0660/0.0662
27	41.5/25.25	1.038/1.033	0.0673/0.0672
28	31.75/18.75	1.046/1.043	0.0678/0.0679
29	32.25/20.5	1.045/1.040	0.0678/0.0677
30	81.25/43.25	1.006/1.007	0.0652/0.0655
31	57.75/37.25	1.025/1.015	0.0665/0.0661
32	37.75/26.5	1.041/1.031	0.0673/0.0671
33	64.75/35.75	1.020/1.018	0.0661/0.0662
34	43.5/26	1.036/1.032	0.0672/0.0672
35	57.75/31.25	1.025/1.024	0.0665/0.0667
36	74.75/38.5	1.012/1.014	0.0656/0.0660
37	45.5/31.25	1.035/1.024	0.0671/0.0667
38	60.75/36.75	1.023/1.016	0.0663/0.0661
39	53.75/29.25	1.134/1.130	0.2584/0.2597
40	57.5/35	1.120/1.090	0.2552/0.2505
41	74/39.5	1.059/1.059	0.2413/0.2434
42	69.75/37.75	1.075/1.071	0.2449/0.2462

Определянето на тегловните коефициенти w_j става по следната формула:

$$w_j = \frac{V_j}{\sum_{j=1}^{m} V_j}$$

където V_j се определя като:

$$V_j = \frac{\left(R\times m - \sum_{k=1}^{R} a_{ki}\right)}{R\times m - R},$$

където R е броят на анкетираните хора, а m е броят на оценяваните критерии.

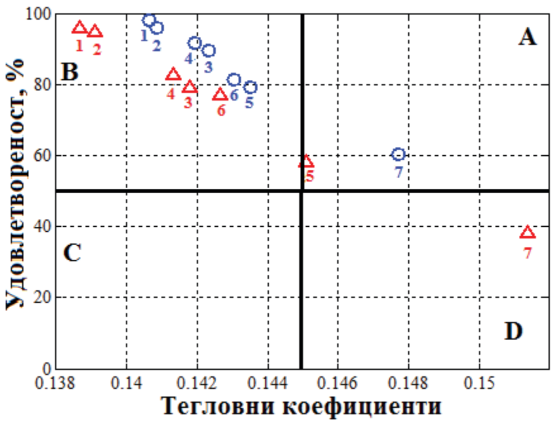
Получените резултати за сумата на оценките, тегловните коефициенти и коефициента V_j, които също са разделени на две групи от критерия възраст, са дадени в Таблица 3.

4. Анализ на резултатите

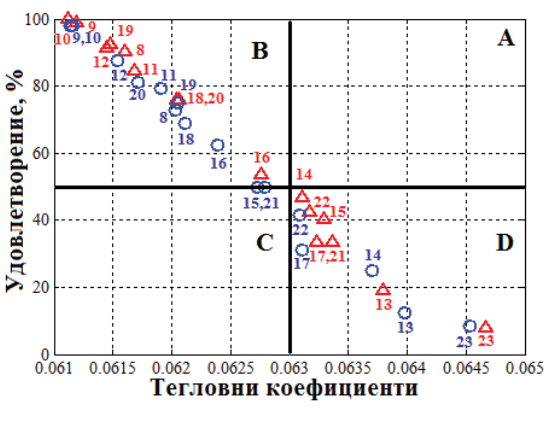
Фиг. 2-5 показват зависимостта между удовлетвореноста във проценти и тегловните коефициенти на всеки от основните четири критерии. Всяка от тях е разделена на четири квадранта, в които са групирани въпросите. Квадраните са означение с латинските букви: A, B, C, D:

- A – висока удовлетвореност и тегловни коефициенти;
- B – висока удовлетвореност и ниски тегловни коефициенти;
- C – ниска удовлетвореност и ниски тегловни коефициенти;
- D – ниска удовлетвореност и високи тегловни коефициенти.

Според ефективноста, за потребителите с най-голямо значение е продуктът да има инсталирана операционна система, въпрос № 7, но се вижда също и, че той носи най-малка удовлетвореност и на двете групи.

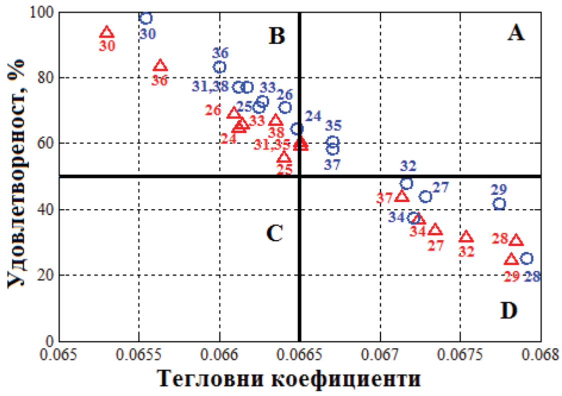


Фиг. 2. *Ефективност на преносимите компютри: ‘Δ’ – възраст до 36 г.; ‘о’ – възраст над 36 г.*



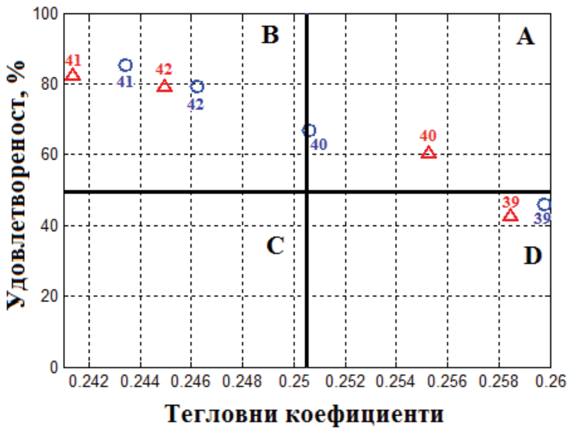
Фиг. 3. *Използваемост на преносимите компютри: ‘Δ’ – възраст до 36 г.; ‘о’ – възраст над 36 г.*

По въпроса за използваемостта с най-голямо „тегло“, но с най-малка удовлетвореност е въпрос № 23, поне веднъж поръчвам храна през интернет, а с най-голяма удовлетвореност са въпроси № 9 и 10 използвате ли интернет за търсене на информация и за комуникация.



Фиг. 4. *Качество на преносимите компютри: ‘Δ’ – възраст до 36 г.; ‘o’ – възраст над 36 г.*

При качеството се наблюдава разлика между тегловните коефициенти на различните възрастови групи, като за тези под 36 години с най-голям тегловен коефициент е въпрос № 29, важно ли е при покупка на лаптоп, той да има водоустойчива клавиатура, а за потребителите над 36 въпрос № 28, устройството да се предлага с допълнителни аксесоари. И двата въпроса носят най-малка удовлетвореност на съответните потребители. Най-важно според този критерий е дългосрочното използване без повреди, въпрос № 30.



Фиг. 5. *Ефикасност на преносимите компютри: триъгълник – възраст до 36 г.; кръг – възраст над 36 г.*

Според критерия ефикасност въпрос № 39 е с най-голямо тегло и най-малка удовлетвореност, а въпрос № 41 е негова противоположност.

5. Заключение

Няма съществена разлика между параметрите носещи удовлетворението на потребителите под и над 36 годишна възраст. С изключение на използваемостта, може да се обобщи, че потребителите над разделящата възраст са по-удовлетворени от изследваните параметри.

Единствено според основния критерий качество тези под 36 години са по-удовлетворени отколкото тези над тази възраст.

ЛИТЕРАТУРА

1. Тончев Милен, (2015) http://www.digital.bg/koga-e-sazdaden-parviqt-laptop-article435090.html
2. Todorova Maria, Koleva Lilyana, Koleva Elena, Iliev Veselin, (2015). Organization and optimization of e-learning at UCTM, Proceedings international scientific conference *“Post - crisis management in business”* November 27, 2015 Sofia, Bulgaria; Volume II; 438-446.
3. Koleva Lilyana, Koleva Elena, Dzharov Volodya, Todorova Maria, (2015). Investigation of the satisfaction from the education in UCTM - SOFIA, Proceedings international scientific conference *“Post - crisis management in business”* November 27, 2015 Sofia, Bulgaria; Volume II; 399-406.
4. Стоянов С. (2005), *Интелигентни методи за оптимизация. Въведение в оптимизацията*, Химико-технологичен и металургичен унверситет – София.

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АСПЕКТИ НА ОПТИМАЛНО ПРОЕКТИРАНЕ НА АВТОМАТИЧНИ ЛИНИИ

СТОЯНКА КАСАБАДЖАКОВА, ЕКАТЕРИНА ПЕРПЕРИЕВА

Резюме: *В предприятията с дискретно производство като правило се произвеждат изделия със сложна йерархична структура. Тези изделия обикновено са многовариантни на всички нива на производството. В настоящата статия са разгледани възможностите и критериите за оптимизация на автоматичните линии. За оптимален се счита този проект, който води да създаване на обект, най-добър от реално осъществените за дадени конкретни условия.*

Ключови думи: *автоматични линии, функционални схеми, целева функция, управляващи променливи*

PRINCIPLES OF AUTOMATIC LINES OPTIMAL DESIGN

KASABADZAKOVA S., PERPERIEVA EK.

Abstract: *The products with a complex hierarchical structure are generally produced in discrete manufacturing enterprises. These products are usually multivariate at all levels of the production. The opportunities and criteria for optimization of automated lines are examined in this paper. This project, which led to the creation of an object, the best of the actual set of specific conditions, is considered to be the optimal one.*

Key words: *Automatic lines, functional schemes, target function, control variables*

1. Въведение

Дискретното производство има редица специфични особености: огромно разнообразие на произвежданите детайли и изделия; голямо многообразие на прилаганите технологични процеси, производствени машини и съоръжения. В посоченото производство съществуват големи изискванията към точността на обработка на детайлите. За всеки конкретен случай са възможни огромен брой технически решения и това затруднява избора на най-подходящия вариант за даден обект в съответствие с поставените изисквания.

Бизнес процесът е организирана серия от действия, изпълнявани от системи и хора за постигане на даден резултат или цел. За ефективността на система (структурата) се изисква пълно равновесие между връзките, формиращи нивата на автоматизираното управление на индустриалната фирма. Създават се условия да се интегрират различните видове бизнес информационни потоци в йерархичните структури в дадена система, която вече е предмет на управление.

Обхватът на автоматизация на бизнес процесите се ограничава в зоната на описанието на процесите, което идентифицира различните

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функции на процесите, процедурни правила и съответстваща информация, необходима за управление на процеса.

2. Бизнес процеси в индустриалната фирма

Бизнес-процесът обединява на практика потока от дейности или функции, служителите и оборудването (ресурсите), нужната за вземане на решения информация (знания), както и правилата за изпълнение на тези дейности и функции. Една или няколко свързани помежду си процедури или операции (функции), които съвместно реализират определена бизнес задача и реализирането им води до конкретни резултати.

Рационалната им организация е решаващ фактор за превръщането им в конкурентно предимство за индустриалната фирма. За да бъде постигната такава обаче, е необходимо бизнес процесите да бъдат детайлно анализирани и постоянно оптимизирани.

Бизнес процесът е организирана серия от действия, изпълнявани от автоматизирани системи и хора за постигане на даден резултат или цел. Бизнес процесите по същество са типични за човека, но в днешния автоматизиран и свързан свят, използването на технологията за автоматизиране на процесите е неизбежно в индустриалната фирма.

Бизнес процесите са основния двигател на работа в една организация. Добрите бизнес процеси са гаранция, че нещата се случват бързо, качествено и надеждно. Процесите в една организация не е задължително да са формализирани. Колкото по-голяма е дейността обаче и колкото по-сложна е тя, толкова по-висока е нуждата от ясни и ефективни процеси на работа.

Координацията на сложни групи от дейности, извършвани от независими един от друг хора или машини, в никакъв случай не е просто. Бизнес процесите по същество са типични за човека, но в днешния автоматизиран и свързан свят, използването на технологията за автоматизиране на процесите е неизбежно. Технологията помага за автоматизирането на рутинни операции и динамично човешко взаимодействие.

Търсенето на оптимален процес е основна цел за всяка една организация. За постигането му могат да се използват различни средства- нови бизнес ИТ системи насочени към подобряване на дейността.

Първоначалният анализ и впоследствие промяната и подобряването на вътрешните процеси е почти винаги пренебрегван фактор при внедряването на всякакви бизнес ИТ системи. В същото време правилното му изпълнение е ключови както за успеха на внедряването на системата - анализът на процесите е особено важен за това, както и за по-добрата работа след внедряването на системата - промяната на начина на работа е факторът, даващ възможност организацията да се възползва от новата система.

В днешния бизнес нуждата от оптизация е постоян налага както поради постоянната промяна на бизнес среда технически средства, водещи до по-висока производителнос на индустриалната фирма.

Изборът на стратегия и средства за оптимизаци отношение на ИТ решенията. Факт е обаче, че ИТ системите дейностите, правейки процесите по

Вначалото на XXI век основният стремеж на всяка организация е да направи повече с по-малко ресурси. Постигането на тази цел изисква процесите и работните потоци да бъдат проектирани, така че да се осигурява максимална оперативна ефективност, а това е същността на концепцията управление на бизнес процесите Отделните бизнес дейности се привеждат в състояние да работят по-бързо, по-качествено и по-евтино, което води до общо подобряване на технико-икономическото състояние на индустриалното предприятие.

3. Управление на бизнес процесите

Добре дефинираните и безупречно изпълнени процеси в дадена компания са предпоставка за по-конкурентоспособни продукти и услуги, намалени разходи, по-добро обслужване на клиентите и бързи реакции при промяна на пазарните условия. Затова е необходимо вътрешните бизнес процеси да бъдат системно проверявани за проблеми и грешки, възникнали в резултат на ръчна обработка.

Съвременните средства за управление на бизнес процеси дават възможност на фирмата изцяло да оркестрира своите процеси от гледна точка на бизнес анализа и техническия дизайн. Обърнете внимание, че тук не става въпрос само за рутиране на документи във вътрешната ИТ инфраструктура. Решенията трябва да рефлектират не само върху техническата логика, но и върху целия работен поток.

Правилното решение трябва да позволява: извличане на максимална ефективност от процесите, като се дава възможност на крайните потребители директно да проектират, управляват, наблюдават и анализират бизнес процесите.

4. Ролята информационните технологии

Техническото и обществено развитие е изградено на базата на комуникационните и информационните технологии. От друга страна, стимулираните от глобалните приоритети технологични решения напълно разкриват своя потенциал, само в рамките на световното икономическо пространство.

Времето, в което живеем е период на големи икономически и социални промени. Създадоха се общи световни мрежи и системи от отделни части и елементи, при които глобалните интереси все повече преобладават над националните.

В резултат на това се формират точно определени международни приоритети, при които света се вижда като единно икономическо пространство, или единна сфера за осъществяване на технически и икономически растеж. Това се обяснява с „прехода от индустриално общество към общество на знанието, което още повече усложнява преплитащите се информационни бизнес процеси в сложната йерархична индустриална структура”[1].

В условията на съвременната глобална икономика много компании са изправени пред предизвикателството непрекъснато да прилагат нови стратегии, стремейки се да бъдат първи в пазарната надпревара за предлагане на нови продукти и услуги. Добре известен факт е, че първите на пазара получават по-висок процент от общия пазарен дял. В бъдеще най-голямо значение ще има не толкова увеличаването на броя и сложността на бизнес процесите, а създаването и използването на знания за подреждането им в система, дефинираща възможността за ефективното им автоматизирано управление.

5. Принципи на оптималното проектиране на бизнес процеси

За оптимален се счита този проект, който води до създаването на обект, най-добър от реално осъществимите при реални производствени условия. Процесът на оптимизация на всеки етап от проектирането включва следните основни етапа:

- Формиране на съвкупност от технически възможности и целесъобразни проектни варианти, които се различават по съчетаването на управляващите променливи – структурни, технологични, конструктивни и др.
- Избор на оптимален вариант по зададена целева функция.

Обикновено се прибягва до построяване на симулационни модели, даващи възможности за визуализация на бизнес процеса. Архитектурата на производствения процес се проектира на база разработен моделиращ алгоритъм и програма. Използват се универсални езици за програмиране.

Процесът на оптимизация се включва на всеки етап на проектирането Резултатът от симулационното моделиране е симулационният модел, служещ за изследване поведението на индустриалното предприятие при различни ситуации на работа и различни външни смущения.

6. Съвременни технологии за бизнес моделиране

Компаниите все повече се нуждаят от анализ на архитектурата на организацията, преди да внедрят каквито и било промени. За множество средни и големи компании използването на подобни средства е стандарт, а самите инструменти са се превърнали в част от информационните им ресурси. Реализацията на проекти, свързани с описание структурата на организацията, реинженеринг на бизнес процесите и др. Би било изключително трудно без използването на средства за бизнес за бизнес моделиране. По данни на Gartner Group през 2015 г. Обемът на продажбите на средства за бизнес моделиране е бил около 500 млн. долара с очакван годишен ръст около 15%.

7.Автоматизация на управлението на бизнес процесите

Автоматизираното управление на бизнес процесите може да се приеме като комплексно системно решение само от гледна точка на системния подход, защото отделни бизнес процеси са част или елементи от други подсистеми, или от общата автоматизирана система на индустриалното предприятие.

Обхватът на автоматизация на бизнес процесите се ограничава в зоната на описанието на процесите, което идентифицира различните функции на процесите, процедурни правила и съответстваща информация, необходима за управление на процеса. Автоматизирания процес пък е съвкупност от една или повече свързани помежду си процедури, които съвместно и автоматизирано реализират определена задача на бизнеса [2].

В автоматизираната система бизнес процесите се състоят от множество функционално зависими елементи, които са логически свързани така, че да осигурят автоматизираното управление на целия бизнес процес. Тогава функционалната зависимост на автоматизираното управление на бизнес процесите приема вида:

$$FS = \left(Br + Ba \right) \quad (1)$$

където:
FS - автоматизирано управление на бизнес процесите;
Br - ръчно управлявани бизнес процеси;
Ba - автоматизирани бизнес процеси.

Автоматизираните бизнес процеси включват цялата автоматизирана обработка на информацията в системата за управление на индустриалното предприятие. Нивото на автоматизирано управление, или степента на автоматизация на бизнес процесите ще определим по следния начин:

$$K = \frac{B_a + B_r}{B_a} \quad (2)$$

където:
K - степен на автоматизация на бизнес процесите.

Устойчивите тенденции към глобализация на икономиката създават добри предпоставки за ускорено въвеждане на решения за автоматизирана обработка на информацията и разширяване на възможностите за обхващане на по-голям брой бизнес процеси за автоматизирано управление.

4. Изводи

Изяснени са теоретичните въпроси, свързани с моделирането на работни потоци за автоматизирани производствени системи.

Формулирани са етапите за разработване на симулационни модели и са съставени симулационни модели за изследване работата на конкретни автоматични комплекси за дискретното производство.

ЛИТЕРАТУРА

1.Лесидренска С., С.Демирова, М.Маринова, Процесният подход – условие за автоматизирано управление на бизнес процесите в индустриалното предприятие, ТУ-Варна, 2011.

2.Чакърски, Д, Т. Вакарелска. Инженерни изследвания, ИК на ТУ - София, 2008.

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ПРОБЛЕМИ И РЕШЕНИЯ ПРЕД УПРАВЛЕНИЕТО НА ОТПАДЪЦИТЕ В ГЛОБАЛЕН И НАЦИОНАЛЕН АСПЕКТ

МАРИЯ ПЕТКОВА-КОЗОВСКА

Резюме: *Настоящият доклад има за цел да даде представа за проблемите и решенията пред управлението на отпадъците в глобален и национален аспект. На първо място, са разгледани проблемите, свързани с управлението на отпадъците в световен мащаб. Посочено е, че обемът на отпадъците в голяма степен се определя от два фактора – брой на населението и структура на потреблението, но увеличеното количество отпадъци не би имало толкова катастрофални последствия, ако не се наблюдаваше и промяна в състава им. На следващо място, се очертават политиката и инициативите в областта на управлението на отпадъците в България. Системата за разделно събиране и рециклиране на отпадъците в страната все още не функционира достатъчно добре, като превръщането им в полезна суровина е слабо разпространена практика и все повече изисква иновативни управленчески и технологични решения. В края на доклада е изтъкнато, че България разполага с много добри условия за въвеждане на иновативни методи за преработка на отпадъци, изразяващи се преди всичко в добра инфраструктура и подходяща законова рамка за управление на отпадъците.*

Ключови думи: *отпадъци, управление на отпадъци, рециклиране, околна среда*

PROBLEMS AND SOLUTIONS OF WASTE MANAGEMENT IN GLOBAL AND NATIONAL ASPECT

MARIYA PETKOVA-KOZOVSKA

Abstract: *The current report aims to provide insight into the problems and solutions of waste management in global and national aspect. First, the paper discusses the problems related to waste management worldwide. It is stated that the volume of waste is largely determined by two factors – the size of the population and the structure of consumption, but the increased volume of waste will not have such disastrous effects if it was not for the change in waste composition. Next, the policies and initiatives in the sphere of waste management in Bulgaria are outlined. The separate collection and recycling of MSW, however, is still not very popular in the country. Their transformation into useful raw materials is not a widespread practice and requires an increasing number of innovative management and technological solutions. At the end of the report, it is highlighted that Bulgaria offers very good conditions for introduction of innovative methods for waste recycling like good infrastructure and favorable legal framework for waste management.*

Key words: *waste, waste management, recycling, environment*

1. Въведение

Управлението на отпадъците е водеща комунална услуга и критичен елемент на инфраструктурата в подкрепа на обществото, но тя често не е призната като такава. Разходите за общественото здраве и свързани с щетите върху околната среда от безконтролното изхвърляне и открито изгаряне са далеч по-големи от разходите на разумното управление на

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отпадъците. Постигнат е значителен напредък през последните десетилетия, но от 2 до 3 млрд. души, често в най-слабо развитите страни, все още нямат достъп до редовно събиране на отпадъци и/или услуги за контролирано обезвреждане на битови твърди отпадъци. Това е глобален приоритет за общественото здраве, който изисква координиран подход, а не е само проблем на национално или местно ниво. Развитите страни също са постигнали напредък в повишаване на нивата на рециклиране и стабилизиране на растежа на отпадъци, но все още има много да се направи в целия свят при осъществяването на прехода от управление на отпадъците в линейна икономика към интегрирано и устойчиво използване на ресурсите и управление на отпадъците в кръгова икономика.

2. Проблеми, свързани с управлението на отпадъците

Глобалният проблем със събирането и извозването на отпадъците в световен мащаб спешно изисква иновативни решения. С въпросите, свързани с управлението на отпадъците, са ангажирани най-големите световни изследователски центрове и известни учени. През последните години става все по-очевидно, че съществуващата система за управление на отпадъци не може да се справи със задачата. Разразилата се през 2008 г. – 2009 г. финансова и икономическа криза само влошава ситуацията – преработката на отпадъци винаги е била изключително скъпа, и влошаващата се икономическа обстановка води до затваряне на много преработващи предприятия, най-вече в развиващите се държави. В същото време обемът на отпадъците стремглаво се увеличава, в резултат на което огромните депа за отпадъци в много страни неминуемо водят до екологична катастрофа.

Обемът на отпадъците в голяма степен се определя от два фактора – брой на населението и структура на потреблението. По данни на ООН населението в света, възлизащо на 7,3 млрд. души, се очаква да достигне 8,5 млрд. до 2030 г., 9,7 млрд. през 2050 г. и 11,2 млрд. през 2100 г. Повече от прогнозираното увеличение в глобален мащаб може да се отдаде на кратък списък от държави с висока раждаемост, най-вече в Африка, или на страни с вече многобройно население. С най-висок процент на нарастване на населението, Африка се очаква да осигури повече от половината от световния ръст между 2015 г. и 2050 г. През този период половината от увеличението на населението в света се очаква да бъде съсредоточено в девет страни: Индия, Нигерия, Пакистан, Демократична република Конго, Етиопия, Обединена република Танзания, САЩ, Индонезия и Уганда, изброени в зависимост от размера на техния принос към цялостния растеж [1].

Около 80 % от това нарастващо население ще живее в градове, повечето от които все още предстои да бъдат построени. От тези прогнозирани почти 9 млрд. души, 3 млрд. ще принадлежат към средната класа, с достатъчно разполагаем доход за закупуване на потребителски стоки, които другите вече употребяват по света, допълнително източвайки вече обтегнатите природните ресурси на планетата. Преминаването в кръгов модел на развитие, който работи за намаляване на отпадъците, преди те да се образуват и който ги третира като ресурс, когато те вече са станали отпадъци, е от съществена важност, като цялостното и интегрирано устойчиво управление на отпадъците ще бъде от решаващо значение [1].

В допълнение към пренаселеността се очаква БВП да се увеличи значително, особено в развиващите се страни, като до 2050 г. световното производство вероятно ще е четири пъти по-голямо от нивата си в началото на века. Значителният прираст на населението и глобалният растеж на БВП неминуемо ще доведат до увеличаване на обема на отпадъците. Според наблюдения, при увеличаването на националния доход с 1 % количеството на твърдите отпадъци нараства с 0,69 % [2]. Въпреки това са налице и положителни перспективи – известно е, че колкото по-голям е БВП на една държава, толкова по-сложна и ефективна е нейната система за управление на отпадъците. Въз основа на тази закономерност може да се твърди, че нарастването на БВП със сигурност ще принуди правителствата на новите членки на групата на развитите държави да предприемат мерки за подобряване на системата за събиране и управление на отпадъците. Настоящите икономически реалности обаче са такива, че за развитите страни е по-изгодно да изнасят отпадъците си към държавите от третия свят, отколкото да хвърлят огромни средства за тяхната преработка. Следователно са налице сериозни опасения, че усъвършенстването на технологиите без подкрепящи мерки няма да доведе до разрешаването на проблема. Възниква и въпросът доколко новите технологии ще са достъпни за развиващите се страни.

Увеличеното количество отпадъци не би имало толкова катастрофални последствия, ако не се наблюдаваше и промяна в състава им.

Преди началото на XX в. по-голямата част от изхвърляните от човечеството отпадъци естествено и лесно се разграждат от бактерии в почвата – храните в рамките на една година, хартията и дървото за няколко години, а металът за няколко десетилетия. С появата на нефта и синтетичните материали обаче ситуацията се променя коренно и към настоящия момент повече от 80 % от отпадъците не подлежат на естествено разлагане поради факта, че не съществуват бактерии, способни да разградят пластмасите. Проблемът се усложнява от огромните емисии на токсични вещества, изхвърляни при производството на този вид продукти, както и от съдържанието им в редица предмети от бита – живак в луминесцентните лампи и термометрите, тежки метали в батериите и акумулаторите и др.

Според различни оценки образуването на твърди битови отпадъци се оценява на около 2 млрд. тона годишно в световен мащаб. Въпреки вариацията на нивата на образуване в рамките на и между отделните страни, генерирането на твърди битови отпадъци на човек от населението се намира в силна корелационна зависимост с националния доход. В страните с високи доходи нивата на образуване на битови отпадъци сега започват да се стабилизират, или дори показват лек спад, което може да показва началото на „отделянето“ на ръста на отпадъците от икономическия растеж. Въпреки това, тъй като икономиките продължават да растат бързо в страните с ниски и средни доходи, може да се очаква генерирането на отпадъци на човек от населението да се увеличава постоянно. Органичните фракции представляват по-голям процент от образуваните твърди битови отпадъци в страните с ниски доходи (където органичните отпадъци са обикновено от 50 до 70 % от всички битови отпадъци), отколкото в страните с високи доходи (където органичните са обикновено 20 до 40 %). От своя страна, рециклирането може да осигури източник на доходи, да спомогне за опазването на оскъдните ресурси и да намали количествата на отпадъците, изискващи депониране. Нивата на рециклиране в държавите с високи доходи непрекъснато се увеличават през последните 30 години, дължащо се главно на законодателни и икономически инструменти. В страните с ниски доходи, неформалният сектор често постига нива на рециклиране от 20 % до 30 % за твърдите битови отпадъци [3].

В края на миналия и началото на настоящия век развитите държави започват да изпитват трудности при обезвреждането и рециклирането на всички произведени на тяхна територия отпадъци и започват да извозват голяма част от тях за преработка в развиващите се страни. Най-голям е делът на изнасяните електронни отпадъци, тъй като те съдържат тежки метали и вредни вещества и преработването им в съответствие с ограничителните норми за безопасност на националното законодателство се превръща в много скъп процес. За развитите страни е по-изгодно да извозват тези вид отпадъци към страни от третия свят, където те се сортират и обработват ръчно с помощта на най-примитивни методи. Въпреки че Конвенцията от Базел забранява износ на токсични отпадъци към развиващите се страни, нейните разпоредби често са пренебрегвани, като отпадъците се извозват под формата на хуманитарна помощ или друг „благороден“ претекст. Като се има предвид, че опасните отпадъци представляват потенциална заплаха за здравето на хората и за околната среда, един от водещите принципи на Базелската конвенция е, че за да се сведе до минимум тази заплаха, опасните отпадъци следва да бъдат третирани възможно най-близо до мястото, където се произвеждат. Въз основа на концепцията за предварително информирано съгласие трансграничното движение на опасни или други отпадъци може да се осъществява само след предварително писмено уведомление от страна на компетентните органи на държавата износител към същите на държавата вносител и на транзитните държави (ако има такива), като им се предоставя подробна информация за предвиденото движение. То може само да продължи, ако и когато всички засегнати страни са дали своето писмено съгласие. В някои страни съществуват и окончателни забрани за износ на тези отпадъци [4].

С настъпването на световната финансова и икономическа криза от 2008 г. – 2009 г. проблемът с извозваните за развиващите се държави отпадъци се влошава. Развитите държави вече не могат да си позволят да заделят огромните средства, необходими за рециклиране на отпадъци на тяхна територия, държавите от третия свят стават още по-силно зависими от значителните приходи в националния си бюджет от сортиране и преработка на отпадъци, а за местните жители работата на сметища често е единствена възможност за прехрана. По този начин, докато и двете страни имат интерес от „миграцията на боклуци“, справянето с тази порочна практика е невъзможно.

Посочените по-горе тенденции, свързани с проблема с отпадъците, ще се проявяват и занапред. Нарастването на количеството на отпадъците не може да бъде спряно поради ръста в световното население, като в допълнение навиците на консуматорското общество ще продължат да се разпространяват с увеличаване на просперитета в някои от развиващите се държави с многобройно население. Съвременната икономическа система изисква постоянен растеж, за който е нужно да е налице и постоянно нарастващо потребление. Стагнация в потреблението, съответно в растежа, би довела до рухването на много национални икономики, до безработица и глад. Стига се до затворен порочен кръг, който не би могъл да се прекъсне без иновации, водещи до кардинална промяна в потреблението на ресурсите и управлението и преработването на отпадъците.

Що се отнася до промяната в структурата на отпадъците, и тук перспективите не са окуражаващи. Опитите да се замени пластмасата с лесно разграждащи се в околната среда материали към настоящия момент не дават съществени резултати. Много изкуствени материали не могат да бъдат заменени, а при тези, при които това е възможно, разходите за производство на екологично чисти заместители са 4-5 пъти по-високи.

Извозването на отпадъците в развиващите се страни също ще продължи, поне в рамките на това десетилетие. За да бъде ограничено е необходимо значително да се повиши стандарта на живот във всички слоеве на населението на държавите от третия свят, а това е изключително трудна и дори непостижима за момента задача. Много от бедните страни не разполагат с природни ресурси, развита промишленост или качествено образование и няма какво да предложат на световния пазар, освен евтина работна ръка.

3. Политика и инициативи в областта на управлението на отпадъците в България

Проблемът за устойчивото управление на отпадъците е един от основните в съвременния свят. Развитието на технологиите в това направление дава широки възможности все повече отпадъци да се трансформират в нови ресурси и енергия. Заедно с това е налице необходимост от промяна в начина на мислене и културата на потребление, която да подтикне фирмите да внедряват и използват материали и продукти, незаплашващи екологичната сигурност. За разлика от останалата част на Стария континент, където за тези проблеми вече се намират множество адекватни решения, в югоизточна Европа и в частност в България се наблюдава сравнително слаба иновативна дейност в тази насока. Депонирането на отпадъци все още е „мръсна“ и неизгодна дейност, както в екологичен, така и в икономически план. То е източник на значителни емисии от парникови газове (главно въглероден диоксид, сероводород и метан), отделящи се в атмосферата при анаеробното разграждане на депонираните отпадъци, като в световен мащаб, приблизително 20 % от годишното количество емитиран метан в атмосферата се дължи именно на процеса депониране. В същото време в държавата продължават да се изразходват значителни средства за изграждане на регионални депа за битови отпадъци, поради недостиг на такива, изчерпване на лимита им или масовото закриване на тези, които не отговарят на екологичните изисквания на ЕС. Това противоречи на стратегията за устойчиво управление на отпадъците в страната, насочена към нулево депониране, максимално рециклиране, повторна употреба, ограничаване на енергийното оползотворяване до неподлежащите на рециклиране отпадъци и др. Основните трудности при изпълнението на тези цели са свързани главно с някои недостатъци на системата за разделно събиране, чието правилно функциониране е важен фактор за постигането им.

В България обезвреждането и преработката на твърдите битови отпадъци (ТБО) става чрез депонирането им на определени за целта площадки близо до населените места, както и на множество малки неконтролируеми сметища. Разделното събиране на ТБО в страната обаче все още не функционира достатъчно добре, като превръщането им в полезна суровина е слабо разпространена практика и все повече изисква иновативни управленчески и технологични решения. Във връзка с амбициозните цели на ЕС за устойчиво развитие, управлението на отпадъците и опазването на околната среда се превръщат в първостепенни задачи за общините. През 2013 г. около 60 % от отпадъците, постъпващи в сметищата, се състоят от употребени опаковки, като голяма част от тях са от бързооборотни стоки – хранителни продукти и стоки за бита. При това положение пред общините възниква проблемът как да се мотивират производителите на бързооборотни стоки да намалят превантивно отпадъците от опаковките на техните стоки. Така „битката с отпадъците“ и усвояването на съвременни опаковъчни технологии се явяват общ, комплексен проблем на общините и бизнеса на техните територии (без да се смятат търговските вериги и дистрибуторските системи, които са слабо заинтересовани). За да се справят с проблема, свързан с ТБО, българските общини се насочват към стимулиране и подпомагане на бизнеса на своите територии да обновява и внедрява опаковъчни системи с олекотени, рециклируеми, деградируеми и многооборотни опаковки.

През последните години вниманието на държавата и бизнеса в областта на ТБО се пренасочва в унисон със стратегическите цели на ЕС за управление на отпадъците – стремежът е те не само да се обработват ефективно, но и в самия производствен цикъл на преработка на суровините да се получават по-малки количества от тях. Всяко производство крие потенциална опасност от генериране на нови отпадъци, затова днес големият въпрос пред продуктовите дизайнери е какво ще се прави с новото изделие, когато то завърши жизнения си цикъл и се превърне в отпадък. В сферата на ТБО тази политика води до повишени изисквания към опаковките. Стремежът е те да имат минимален обем и размери, да са направени от рециклируеми и/или биодеградируеми материали, да се използват многократно и др.

България разполага с много добри условия за въвеждане на иновативни методи за преработка на отпадъци, изразяващи се преди всичко в добра инфраструктура и подходяща законова рамка за управление на отпадъците. Както бе отбелязано по-горе обаче, системата за разделно събиране и рециклиране на отпадъците все още не функционира достатъчно добре. Около 74 % от генерираните отпадъци през 2014 г. се транспортират към депата, при положение че голяма част от общото количество отпадъци са биоразградими. Площадките за депониране на отпадъци, както и броят на земеделските стопанства в България са достатъчни предпоставки за изграждане на централи за производство на биогаз от земеделски продукти, както и на вторични биопродукти (компост и течен органичен тор). Препоръчително е съоръженията за производство на биогаз да са в непосредствена близост до сметищата или в самите промишлени или земеделски цехове, като по този начин се ограничават транспортните разходи.

С интензивните усилия за гарантиране на енергийната сигурност и ефективност, които през последното десетилетие се полагат в глобален мащаб, все по-голямо значение се отдава на възобновяемите енергийни източници. [5] При добива на енергия от алтернативни източници особено място заема преработката на биомаса (селскостопански органични отпадъци) при която, използвайки процеса на ферментация се получава биогаз, съдържащ 70 % метан. Теоретичният потенциал за добив на биогаз в България се оценява въз основа на общото производство на биомаса. Селскостопанското производство и свързаните с него индустрии и потребление генерират значително количество изхвърляна органична материя. Тяхното използване за производство на биогаз е целесъобразно и препоръчително. В България най-голям потенциал за производство на биогаз от първични и вторични селскостопански отпадъци има в Североизточен и Южен централен регион на планиране, поради силно развития селскостопански сектор в тях. По отношение на твърдите битови отпадъци и отпадъчните води, най-значителни предимства при производството на биогаз има в югозападната част на България (най-вече столицата София), където гъстотата на населението е висока. Топлоенергийната промишленост е един от най-крупните генератори на твърди отпадъци в България. Ежегодно се генерират големи количества твърди отпадъци, от които само 25 % (основно гипс) биват оползотворявани като вторични суровини, а останалите се депонират.

Отпадъците от ТЕЦ могат да бъдат използвани като ценен ресурс в много производства с цел извличането на многобройни екологични и икономически ползи. Пепелите и сгуриите са подходяща суровина за производството на различни видове изкуствени добавки, с които се изготвят леки бетони. Използването им предоставя предимства като: по-добри кохезионни свойства; по-добра текстура; по-лесен контрол на влагата в изделията; по-голяма здравина на изделията и други. Пепелта и сгурията от ТЕЦ могат да се използват успешно и в пътното и уличното строителство самостоятелно като свързващо вещество или в смеси като инертен пълнител, както за долните слоеве на основите на всички категории пътни настилки, така и за горни слоеве на основите на пътна настилка на леко и средно натоварени пътища.

Сред иновационните технологии, прилагани в България, особено място заема активният демонтаж посредством т.нар. „умни материали”. Използването им прави възможно върху свързващите елементи да бъде приложена сила, така че продуктът да бъде разделен на съставните си части. На този етап с активен демонтаж могат да бъдат демонтирани подвъзли, основни възли (включително корпуси), PCB, LCD, антени, екрани, трансформатори, механични компоненти, дискови устройства, бутони, фитинги, различни видове винтови или други връзки. Тази технология ще бъде особено ефективна в следните случаи: когато замества ръчния демонтаж, което води до намаляване на демонтажното време, а оттам и до намаляване на разходите; когато се прилага вместо раздробяването и разделянето, като по този начин се повишава ефективността на рециклирането на материалите.

4. Заключение

Ресурсите на земята са ограничени, а това намалява и възможностите за развитие на постоянно нарастващото световно население. Отпадъците от една страна се образуват от използването на ресурси или продукти, а от друга – те имат негативни ефекти върху околната среда в резултат от тяхното преработване или обезвреждане. Прекъсването на връзката между икономическия растеж и нарастващото използване на ресурсите, което води до негативно влияние върху човека и природата, е основна цел в областта на политиката по околната среда. Този ръководен принцип за устойчиво развитие представлява не само ориентир за държавни действия, но е и мерило за решенията на икономиката и обществото. Отпадъците представляват икономическо, екологично и социално предизвикателство. Растящото потребление и развиващата се икономика продължават да произвеждат големи количества отпадъци, като все повече усилия са необходими за редуцирането и предотвратяването на образуването им. Макар в миналото отпадъците да са приемани като непотребни, днес те все повече се възприемат като ресурси. Това се вижда в смяната на фокуса при управлението на отпадъци от обезвреждане към рециклиране и оползотворяване.

Управлението на отпадъците е една от областите, в които въвеждането на иновативни технологии не е лукс, а необходимост, продиктувана от условията на съвременния живот. Нуждата от иновации не е породена единствено от нарастващото количеството отпадъци, в това число и такива, застрашаващи екологичното равновесие, нито само от замърсяването на въздуха с вредни вещества от изгаряне на отпадъците в инсталациите. Освен че би спомогнало за разрешаването на гореспоменатите проблеми, свързани с околната среда, ефективното и високотехнологично управление на отпадъците от човешката дейност би допринесло за формиране на нов възобновяем ресурс и алтернативен източник на енергия за националното и световно стопанство.

ЛИТЕРАТУРА

1. United Nations, Department of Economic and Social Affairs (2015). *World Population Prospects: The 2015 Revision, Key Findings and Advance Tables*. New York.
2. International Monetary Fund (IMF) (October 2013). *World Economic Outlook: Transitions and Tensions.* Washington. Available: http://www.imf.org/external/pubs/ft/weo/2013/02/pdf/text.pdf.
3. United Nations Environment Programme (2015). *Global Waste Management Outlook.* Available: http://unep.org/ietc/ourwork/wastemanagement/GWMO.
4. http://www.basel.int/.
5. Петков, В. (2014 г.). *„Енергийна сигурност и пазарите на енергоносители в страните от Черноморския регион“*. ГорексПрес, София, стр. 228.
6. Чкорев, Н. (2015 г.). *„Интегрираното управление на отпадъците в българските региони – предизвикателства и последици“*. БАН, Институт за икономически изследвания, София.
7. Закон за управление на отпадъците, Обн. ДВ, бр.53 от 13.07.2012 г.
8. Министерство на околната среда и водите, Изпълнителната агенция по околна среда. *„Национален доклад за състоянието и опазването на околната среда 2015“*. София. Available http://eea.government.bg/bg/soer/2013.
9. Министерство на околната среда и водите. Available: http://www.moew.government.bg/;
10. Евростат. Available: http://ec.europa.eu/eurostat/data/database.

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ЕДИН ПОДХОД ЗА МОДЕЛИРАНЕ НА СИСТЕМИ ЗА УПРАВЛЕНИЕ ПРИХОДА НА ХОТЕЛ

СВЕТЛАНА ВАСИЛЕВА

Резюме: *Социалните науки в България са слабо развити от гледна точка на експерименталната наука. С проекта, представен тук се цели внедряване на имитационното моделиране в мениджмънта и образованието за целта на развитието на устойчива туристическа индустрия както като отделен икономически отрасъл, така и от гледна точка на държавно управление. В представения GPSS World симулационен модел на Система за управление прихода на хотел входящите потоци GPSS транзакции могат да моделират различните видове туристически потоци, които ще се изследват симулационно, за да бъдат взети определени решения, касаещи мениджмънта на изследваните събития и организации от значение за целите на съответните изследователски дейности. Представени са резултати от изпълнението на GPSS модела в средата на Разширения редактор на GPSS World.*

Ключови думи: *Управление на прихода на хотел, моделиращ алгоритъм, GPSS World*

ONE APPROACH FOR MODELLING HOTEL REVENUE MANAGEMENT SYSTEMS

SVETLANA VASILEVA

Abstract: *Social sciences in Bulgaria are underdeveloped in terms of experimental science. The project presented here aims to introduce simulation modeling in management and education for the purpose of development of a sustainable tourism industry as well as a separate economic sector and from the perspective of governance. In the presented GPSS World simulation model of Hotel Revenue Management System GPSS transactions‘ inflows can model various types of tourist flow in simulation way will be explored to certain decisions concerning the management of the examined events and organizations relevant for the purposes of the relevant research activities. The results from the implementation of the GPSS model in the mid Extended editor of GPSS World are presented.*

Key words: *Hotel revenue management, modeling algorithm, GPSS World*

1. Основни положения

Една от актуалните задачи в Информатиката е проблемът за създаване на Методология на изследването на реални обекти със средствата на компютърната техника и наука. Т.е. това е проблем на създаването на информационни модели на основата на които може да се определи теоретичната значимост и практическата ценност на всяка (произволна) система в условията на въздействията на външната среда [1]. Това е изключително важно в началния етап на развитието на всяка иновация, особено ако тя касае развитието на икономически отрасъл в дадена географска област (и дори държава, а защо не и международни проекти и колаборации).

Според Девятков [1]: "Пазарът на приложенията на Имитационните изследвания на сложните икономически системи е потенциално огромен. Имитационните изследвания са изключително важни, а понякога

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са и единствен метод за оценка и анализ на иновации, оптимизация на разходите на предприятия и проекти, подобряване на производителността и увеличаване обема на продукцията…".

Методите на имитационното моделиране позволяват на изследователите да създават модели на сложни системи. Но това все още остава научна област [1]. Целта е внедряване на разработваните модели в бизнеса – реално използване на самостоятелни имитационни приложения в качеството на системи за поддържане вземането на решения. Затова в доклада се разглежда един пример за приложение на системата за имитационно моделиране (ИМ) GPSS World [2] в туристическата индустрия.

За да се развива една индустрия (в случая - хотелиерството) и да бъде ефективна е необходимо да се подготвят съответните специалисти – мениджъри. Едно от основните умения, които трябва да развиват всички бъдещи мениджъри на първо място в икономиката и всички нейни отрасли това е системното мислене. По характеристики то е: контекстно-обусловено, неемоционално, операционно. [3] Изключително силно средство за развиване на такъв тип умения предоставя имитационното моделиране. Появиха се много нови системи за (не просто) имитационно моделиране, а дори и „мултиподходно имитационно моделиране", обединяващо Системната динамика, Агентното и Дискретно-събитийното моделиране – в лицето на AnyLogic [4]. Обикновено тези системи са изключително скъпи, дори и пакетите с учебна цел.

Но с появата на т.нар. системи за автоматизация на имитационните изследвания има възможност имитационното моделиране да стане инструмент за обучение и експерти/специалисти в конкретна предметна област (като разглежданата тук Хотелиерство и Управление на туризма) да са активна част от екипа, разработващ симулационни приложения. Такива са Разширеният редактор [5] и Универсалният редактор на формите [6], разработени над системата GPSS World [2]. Системата за ИМ и нейните разширения създават възможност симулационните приложения да са много по-ефективни, защото логиката на експертите/обучителите се залага директно в разработваните продукти. Съществуващите симулационни приложения, разработвани от фирми не притежават гъвкавостта и „индивидуалната насоченост" каквато е целта на разглежданите имитационни приложения – моделиране на системи за управление на прихода на хотел (*Hotel Revenue Management* (*HRM*) *Systems*).

2. Концепция за моделиране на HRM системи

Всяка система (техническа, информационна, икономическа, социална и др.) и нейния алгоритъм на работа могат да бъдат описани в термините на Теорията за масовото обслужване като Система за масово обслужване [7]. Имитационното моделиране позволява да се изследват системи за масово обслужване при различни типове входни потоци и интензивности на постъпване на заявките на входовете на системите и определяне на основните характеристики на същите [7].

Една от най-използваните системи за ИМ – *GPSS World* [2] предоставя на потребителите средства за взаимодействие със системата в процеса на симулационните изследвания и програмни средства, реализиращи непосредствено процеса на изпълнение на модела. Като обекти на езика GPSS се използват аналози на такива стандартни компоненти на системите за масово обслужване, като заявки, обслужващи прибори, опашки и др. Достатъчният набор от подобни компоненти позволява да се конструират сложни симулационни модели, при запазване на привичната терминология на системите за масово обслужване.

Концепцията за (параметрични) имитационни модели на хотелски системи за управление на приходите е те да се използват първо за обучение на мениджъри в хотелския бизнес и на следващ етап да бъдат внедрени в хотелиерския бизнес и управление. Имитационното моделиране на *HRM* системи [8] включва решаването на следните задачи по [9]:

- Дефиниране и систематизиране на числените показатели, участващи в измерването на състоянието на един хотел. При което се отчита спецификата на: ареала, за който ще се разработва хотелския бизнес; на туристическите потоци, потребители на услугите, предлагани в ареала; външната по отношение на хотела среда, обект на интерес от различните туристически потоци

- Съставяне концептуалния модел на система за управление на приходите на хотел за целите на симулациите със средствата на средата GPSS World и определяне на входните параметри и изразите, в които участват;

- Моделиране на модулите, формиращи приход на хотел;

- Съставяне на алгоритми, моделиращи работата на система за управление на приходите на хотел. Настройка на моделите, валидация и верификация;

- Имплементация и апробация на имитационните модели ще се извършва със средствата на Разширения редактор и Универсалния редактор на формите на GPSS World. Универсалният редактор на формите предоставя изключително полезните за целите на имитационните проектни изследвания средства: Форма за въвеждане на данни; Форма за планиране на експеримента (единичен и множество експерименти); Форма за динамика на експеримента; Анимационна форма за представяне работата на модел;

- Формулиране на изводи за бъдещи разширения и приложения на методиката на параметричните имитационни GPSS World модели в областта на креативните и рекреативните индустрии.

3. Елементи на GPSS World модела на HRM системи

Разработеният в средата на GPSS World имитационен модел включва следните стъпки по [9]:

- Генериране на поток транзакти T_i, моделиращи заявките за резервиране на стаи в моделирания хотел. След постъпването на транзакт в модела (програмирано чрез GPSS блок GENERATE) на параметрите на транзакта се задават стойности – в тази част от алгоритъма се моделират желаните от туриста дата на първа нощувка, продължителност на престоя (дата на последна нощувка);

- Търсене в матриците, моделиращи базата от данни на хотелската информационна система дали има свободно количество стаи за желаните дати;

- При намиране на свободна стая/стаи, те се резервират чрез поставяне на съответните записи в матриците, моделиращи базата от данни, след което броячът на успешните заявки се увеличава с 1. Изчисляват се изразите, които показват за моделирания хотел прихода от резервации;

- Ако транзактът не е успял „да резервира“ стая/стаи, съответно не поставя никакъв запис. Увеличава се броячът на отказаните заявки с 1;

- Транзактът напуска модела (с GPSS блок TERMINATE).

3.1. Параметри на генерираните транзакти

На фиг. 1 е показан началният сегмент от моделиращия алгоритъм – постъпване на транзактите и задаване на стойности на параметрите на всеки постъпил транзакт по [9]:

P1, *P2* – Месец и ден от месеца „заявявани“ от транзакта за първа нощувка;

P3 – Продължителност на заявявания от транзакта престой;

P4, *P5* - Месец и ден от месеца „заявявани“ от транзакта за последна нощувка;

P6 – Номер на колоната в GPSS матрицата *MX$Booking*, моделираща базата от данни, където в реда с номера на резервираната стая ще се постави запис за първата нощувка;

P7 - Номер на колоната в GPSS матрицата *MX$Booking2*, където в реда с номера на резервираната стая ще се постави запис за последната нощувка. Разглежданият модел е на сезонен (морски) хотел;

P7 - Вероятност резервацията (моделирана от GPSS транзакта) да бъде канцелирана по-късно (в модела - след приблизително 1÷2 месеца). Стойност **0** – означава, че GPSS транзактът ще канцелира резервацията след изтичането на 62800±21600 моделни единици (В модела за моделна единица е приета 1 минута), т.е. след 43±15 дни. След успешно поставен запис за резервиране на стая в матриците *MX$Booking* и *MX$Booking2*, моделиращи базата от данни с резервации, транзактът излиза от опашката “Rezervacii”, но остава в общата опашка „TotalB“ в модела. И след посочения по-горе нормално разпределен интервал параметърът *P8* ще получи стойност **2** и се изпраща към съответния сектор в модела. Транзактът ще нулира записите за резервацията на стаята в матриците *MX$Booking* и *MX$Booking2* и ще напусне модела; Стойност **1** – Транзактът, ако успее да резервира стаята за датите, зададени в параметрите *P1*, *P2*, *P4* и *P5*, няма да канцелира резервацията и прихода, формиран от тази резервация ще остане добавен към общия приход на хотела.

В моделиращия алгоритъм се задават и други стойности за параметри на транзактите, които са помощни. Предвижда се за разширяването и параметризирането на модела да бъдат задавани и други стойности в параметрите на генерираните транзакти. Например, предвижда се моделирането на генериране на приход и от други услуги в хотела (ресторант, спа и други). Освен това се предвижда отчитането и на други параметри на туристическия поток като представените в [10]: Тип на престоя (бизнес, почивка и др.); Тип националност; Ниво на интерес към хотелските услуги; и други характеристики на туристическите резервации и туристическите потоци, които влияят на формирания приход на хотела.

```
PotokBook    GENERATE   60,FN$XPDIS
             ASSIGN     1,FN$MonthSumme                    ;month of the generat
                                          ; The value is determined by the functi
             QUEUE      TotalB
             QUEUE      Rezervacii
             GATE FV    SiteBook
             SEIZE      SiteBook
             FUNAVAIL   SiteBook
             DEPART     Rezervacii
             ASSIGN     2,V$DayBook1                       ;Day of the month P1
; in the interval [1, <last day of the month set in P1>] - The first date of request
             ASSIGN     3,7                                ;Length of the bookin
             ASSIGN     4,P1                               ;The month of the las
             ASSIGN     5,V$DayBook2                       ;Day of the month of
             TEST G     P5,V$DayMonths,ProverRoom
             ASSIGN     4+,1
             ASSIGN     5,V$DayMonths0
ProverRoom   SAVEVALUE  BookingsAll+,1
             ASSIGN     6,V$DayTabCol1                     ;Number of the column
; modeled by the matrix MX$Booking, where it is recorded the date of the first overn
             ASSIGN     7,V$DayTabCol2                     ;Number of the column
; modeled by the matrix MX$Booking1, where it is  recorded  the date of last night
             ASSIGN     Room,1                             ;Number of the booked
TestRooms1   TEST G     MX$RoomList(P$Room,2),0,DrugR
             TEST L     MX$RoomList(P$Room,1),X$WorkWeeks,DrugR
             TEST E     MX$Booking1(P$Room,P6),0,DrugR
             TEST E     MX$Booking12(P$Room,P7),0,DrugR
```

Фиг. 1. *Задаване стойности на параметрите на GPSS транзактите в модела на HRM*

3.2. Променливи и изрази

Някои от най-важните променливи, чрез които се изчисляват формирания приход и помощни стойности, участващи в различни изрази, а също и при определяне пътя на транзактите в GPSS модела [9] са (фиг. 2):

DayMonths – използва се за изчисляване на месеца на първата заявявана нощувка;

DayBook1 –за изчисляване на деня в месеца на първата заявявана нощувка;

DayBook2 – използва се за изчисляване на деня в месеца на последната заявявана нощувка;

Day1TabM1 – изчислява датата на първата заявявана нощувка от началото на календарната година в брой дни (като серийно число);

DayTabM2 – изчислява датата на първата заявявана нощувка от началото на сезона в брой седмици;

DayTabCol1 – определя номера на колоната в матрицата за резервации MX$Booking1, където ще се постави записа за първата заявявана нощувка;

DayTabCol2 – определя номера на колоната в матрицата за резервации MX$Booking2, където ще се постави записа за последната заявявана нощувка;

DayMonths0 – за определяне на деня от месеца за последната нощувка, когато датата е от следващ месец;

Krilo2, Krilo3 – изчисляват номера на първата стая от второто и третото достъпно „крило" на моделирания хотел;

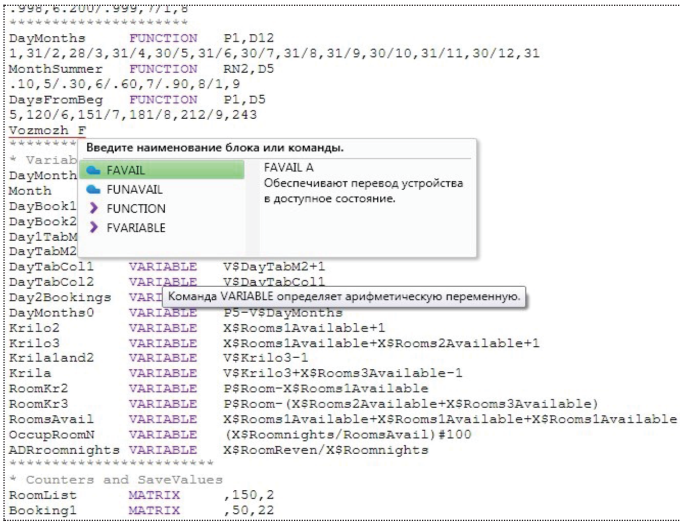
Krila1and2, Krila, RoomKr2, RoomKr3 – допълнителни променливи за изчисляване на броя на стаите при реализацията на цикъла за проверка на свободни стаи в достъпните крила на моделирания хотел;

OccupRoomN – изчислява заетостта на моделирания хотел Occupancy rate по формула (1) [8, с.43]:

$$Occupancy_{roomnights} = \frac{NumberOfRoomnights}{NumberOfRoomsAvailable} * 100\% \quad (1)$$

ADRroomnights – изчислява средната цена за една нощувка (*Average daily rate - ADR*) по формула (2) по [8, с.45]:

$$ADR_{roomnights} = \frac{Room\_revenues}{NumberOfRoomnights} \quad (2)$$



Фиг. 2. *Дефиниране на променливи в средата на Разширения редактор на GPSS с показана контекстуална подсказка*

3.3. Функции

Езикът GPSS предоставя много мощен инструмент за описание на (статистически) разпределения на случайни величини: равномерно, експоненциално, нормално и други [7]. За представения модел са определени следните функции: за описание на броя на дните във всеки календарен месец; вероятностно разпределение на резервациите по месеците от сезона; задаване броя на дните от началото на годината до всеки от месеците на летния сезон (фиг. 2, горе):

DayMonths – задава броя на дните във всеки месец от годината;

MonthSummer – разпределение на вероятностите, че генерирания транзакт (моделиращ заявка към хотела) ще бъде за месеца, присвояван на параметъра P1 (за месеци 5 и 9 – вероятността е 0.10, за месец юни - 0.20, и за месеците 7 и 8 - 30% вероятност).

Вероятностното разпределение, задавано от функцията може да се промени при наличие на други статистически данни за реалните туристически потоци;

DaysFromBeg – определя броя на дните от началото на календарната година до първия ден на месеца, чийто номер е записан в параметъра P1.

3.4. Клетки и съхранявани стойности

Освен променливи и изрази за определяне на различните метрики на *HRM* на моделирания хотел се използват и други средства, предоставяни от GPSS World, като клетки и съхранявани стойности [9]. На фиг. 3 е показан прозорецът на Съхраняваните величини в Стандартния отчет от симулация в средата на Разширения редактор на GPSS World със стойностите на началните „параметри“ и „броячите“, използвани в модела:

WeekOpen – Начална стойност 120 – брой дни от началото на годината до отварянето на хотела за туристи;

WorkWeeks – брой седмици (на сезона), в които хотелът е достъпен за туристи;

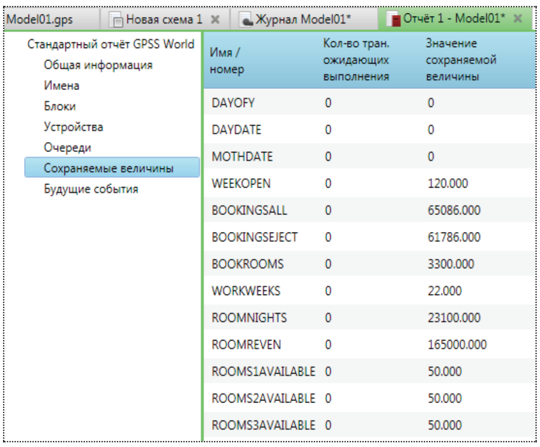
BookingsAll – брой на генерираните транзакти по време на моделирането;

BookingsEject – брой транзакти, не успели да резервират стая за датата, посочена в параметрите им P1 и P2;

BookRooms – брой транзакти, напуснали модела, успешно резервирали стая в GPSS матриците Booking и Booking2;

Roomnights – общ брой на резервираните нощувки;

RoomReven – Сума на прихода, генериран от резервации на стаи. На фиг. 3 може да се види формирания приход на хотела – стойността на RoomReven.



Имя / номер	Кол-во тран. ожидающих выполнения	Значение сохраняемой величины
DAYOFY	0	0
DAYDATE	0	0
MOTHDATE	0	0
WEEKOPEN	0	120.000
BOOKINGSALL	0	65086.000
BOOKINGSEJECT	0	61786.000
BOOKROOMS	0	3300.000
WORKWEEKS	0	22.000
ROOMNIGHTS	0	23100.000
ROOMREVEN	0	165000.000
ROOMS1AVAILABLE	0	50.000
ROOMS2AVAILABLE	0	50.000
ROOMS3AVAILABLE	0	50.000

Фиг. 3 *Прозорецът на Съхраняваните величини в Стандартния отчет от симулациите в средата на Разширения редактор на GPSS*

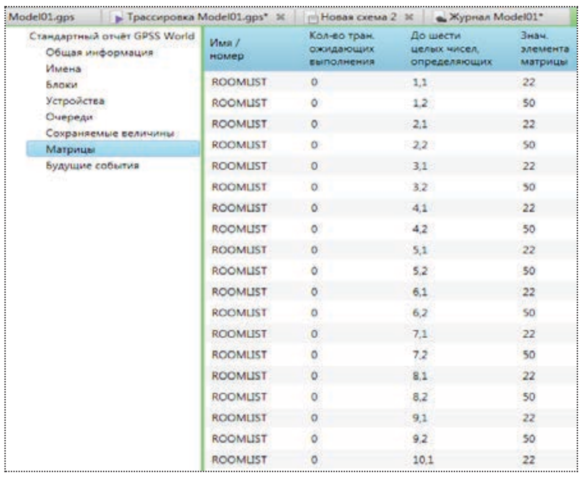
На фиг. 4 е показана част от моделиращия алгоритъм – цикъла на търсене на свободна стая в един сектор (в примера – първи сектор). Може да се види как се използват описаните променливи и съхранявани стойности при търсенето на свободна стая и поставянето на резервация в матриците, моделиращи базата от данни на информационната система на хотела.

```
            ASSIGN     Room,1                              ;Number of the booked hotel room
TestRooms1  TEST G     MX$RoomList(P$Room,2),0,DrugR
            TEST L     MX$RoomList(P$Room,1),X$WorkWeeks,DrugR
            TEST E     MX$Booking1(P$Room,P6),0,DrugR
            TEST E     MX$Booking12(P$Room,P7),0,DrugR
            MSAVEVALUE RoomList+,P$Room,1,1
            MSAVEVALUE Booking1,P$Room,P6,V$Day1TabM1      ;Booking  the room - 1st roomnight
            MSAVEVALUE Booking12,P$Room,P7,V$Day2Bookings  ;Record the 2nd roomnight
            SAVEVALUE  Roomnights+,P3                      ;Count of the roomnights
            SAVEVALUE  RoomReven+,MX$RoomList(P$Room,2)    ;Sumarize the room revenues
            TRANSFER   ,EndBookBook
DrugR       TEST L     P$Room,X$Rooms1Available,DrugoKrilo
            ASSIGN     Room+,1                             ;Looking for another room in the same sector
            TRANSFER   ,TestRooms1
*********************************
DrugoKrilo  ASSIGN     Room,V$Krilo2                       ;Room in 2nd sector
TestRooms2  TEST G     MX$RoomList(P$Room,2),0,DrugR2
            TEST LE    MX$RoomList(P$Room,1),X$WorkWeeks,DrugR2
            ASSIGN     RoomKr2,V$RoomKr2
            TEST E     MX$Booking2(P$RoomKr2,P6),0,DrugR2
            TEST E     MX$Booking22(P$RoomKr2,P7),0,DrugR2
            MSAVEVALUE RoomList+,P$Room,1,1
```

Фиг. 4 *Моделиране търсенето на свободна стая*

4. Изпълнение на моделиращия алгоритъм

Резултати от изпълнението на синтезирания алгоритъм, моделиращ HRM система могат да бъдат наблюдавани в прозорците на стандартния отчет от симулация в Разширения редактор на GPSS World, като показаните на фиг. 3 и фиг. 5. Средата на Разширения редактор, както и на GPSS World предоставят отчет от симулациите и прозорци, в които може да се наблюдават резултатите от симулацията (в отчета) и динамиката на изпълнението на модела в прозорците (Прозорец на съхраняваните стойности SaveValues Window (фиг. 3), Прозорец на блоковете Blocks Window, Прозорец на матрица Matrix Window и други).



Имя / номер	Кол-во тран. ожидающих выполнения	До шести целых чисел, определяющих	Знач. элемента матрицы
ROOMLIST	0	1,1	22
ROOMLIST	0	1,2	50
ROOMLIST	0	2,1	22
ROOMLIST	0	2,2	50
ROOMLIST	0	3,1	22
ROOMLIST	0	3,2	50
ROOMLIST	0	4,1	22
ROOMLIST	0	4,2	50
ROOMLIST	0	5,1	22
ROOMLIST	0	5,2	50
ROOMLIST	0	6,1	22
ROOMLIST	0	6,2	50
ROOMLIST	0	7,1	22
ROOMLIST	0	7,2	50
ROOMLIST	0	8,1	22
ROOMLIST	0	8,2	50
ROOMLIST	0	9,1	22
ROOMLIST	0	9,2	50
ROOMLIST	0	10,1	22

Фиг. 5 *Прозорец на матрицата RoomList в средата на Разширения редактор*

На фиг. 5 е показан прозореца на Матрицата RoomList, която е част от „базата от данни“ за резервации и моделира достъпността на стаите на хотела и цените им.

5. Заключение

Най-важната задача при разработването на всяка една индустрия е задачата за оценка на показателите на функционирането на системата, които накрая се използват за решаване на приложната задача. Имитационното моделиране дава възможност да се проведат предварителни изследвания и да се оценят: характеристики на работата на системата: пропускателна способност, вероятност за обслужване, време за обслужване; икономически показатели, като приходи и разходи и др. Дейностите по разработваните имитационни модели имат за цел не само Развитие на теорията, методологията и практиката на компютърния експеримент в рекреативните индустрии, но и в социално-икономическите изследвания и в задачите на управлението на България.

Работата по симулирането на HRM системи поставя като генерална цел създаването на експериментални комплекси и разработването на модели на експериментална икономика и определянето на ефективни направления за развитие.

ЛИТЕРАТУРА

1. Девятков, В.В. (2014). *Развитие методологии имитационных исследований сложных экономических систем*. Диссертация на соискание ученой степени доктора экономических наук, Москва, РФ. http://elib.fa.ru/avtoreferat/devyatkov.pdf/download/devyatkov.pdf
2. Minuteman Software. (2010). *GPSS World Tutorial Manual*. http://www.minutemansoftware.com
3. Каталевский Д. (2015). *Основы имитационного моделирования и системного анализа в управлении*, Изд.дом Дело, Москва.
4. AnyLogic. (2017). *Многоподходное имитационное моделирование*. http://www.anylogic.ru/overview.
5. Федотов, М. и Девятков, В. (2013) САИИ для профессионалов – развитие возможностей расширенного редактора GPSS World. *Сборник докладов шестой всероссийской научно-практической конференции «Имитационное моделирование. Теория и практика» (ИММОД-2013)*. Т. 1, Изд. «ФЭН» Академии наук РТ, Казань, с.356-360. http://simulation.su/files/immod2013/material/immod-2013-1-356-360.pdf.
6. Исаев, Ф. и Девятков, В. (2013). Основные возможности универсального редактора форм для GPSS World. *Сборник докладов шестой всероссийской научно-практической конференции «Имитационное моделирование. Теория и практика» (ИММОД-2013)*. Т. 2. Изд. «ФЭН» Академии наук РТ, Казань, 2013, с.149-154. http://simulation.su/files/immod2013/material/immod-2013-2-149-154.pdf.
7. Томашевский, В.Н., Жданова, Е.Г. (2003). *Имитационное моделирование в среде GPSS*. Бестселлер, Москва.
8. Ivanov, S.H. (2014). *Hotel revenue management – from theory to practice*. Zangador, Varna, Bulgaria.
9. Vasileva, S.Z. (2016). GPSS World Extended Editor's Opportunities to Simulate Hotel Revenue Management Systems. *International Conference Automatics and Informatics'16, Conference Proceedings*, October 4-5, Sofia, Bulgaria, p. 267-270.
10. Walek, B., Hosek, O., Farana, R. (2016). Proposal of Expert System for Hotel Booking System. *Proceedings of the 17th International Carpathian Control Conference (ICCC)*, IEEE, p.804-807

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ИЗПОЛЗВАНЕ НА ПЕКТИНОВИ ПОКРИТИЯ ЗА ПРЕСНИ ПЛОДОВЕ И ЗЕЛЕНЧУЦИ

РАДОСЛАВ РАДЕВ

Резюме: *Увеличеното потребителско търсене на висококачествени храни с продължителен срок на съхранение е основна предпоставка за разработване на иновативни технологии в хранително-вкусовата промишленост. Ядивните покрития представляват тънък слой съставен от биополимерни компоненти, който може да се консумира със стоката, върху която е нанесен. Той намалява загубата на влага, селективно контролира обмена на газове (кислород, въглероден диоксид и етилен), които участват в процеса на дишане. Ядивните покрития удължават съхраняемостта, поддържат свежестта, инхибират микробната развала на продукта, намаляват загубата на ароматични вещества и на други важни компоненти. Целта на настоящото изследване е да се проучи научната литература относно използването на пектинови покрития за пресни плодове и зеленчуци.*

Ключови думи: *пресни плодове и зеленчуци, пектинови покрития, ядивни покрития*

USE OF PECTIN COATINGS FOR FRESH FRUIT AND VEGETABLES

RADOSLAV RADEV

Abstract: *Increased consumer demand for high quality food products with a long shelf life is a fundamental prerequisite for the development of innovative technologies in the food industry. Edible coatings are thin layer composed of biopolymer components that can consume the goods to which they apply. This reduces the loss of moisture, selectively controls the exchange of gases (oxygen, carbon dioxide and ethylene). Edible coating to prolong the storage, maintenance of freshness, inhibit microbial spoilage of the product, reducing the loss of aromatic substances and other essential components. The aim of this study was to investigate the scientific literature on the use of pectin coatings for fresh fruits and vegetables.*

Key words: *fresh fruits and vegetables, pectin coatings, edible coatings*

1. Въведение

Увеличеното потребителско търсене на висококачествени храни с продължителен срок на съхранение е основна предпоставка за разработване на иновативни технологии в хранително-вкусовата промишленост. Те целят да запазят естествен и свеж външния вид на храните възможно най-дълго време, като основно изискване към тях е да са безопасни. Опаковката е важен елемент в концепцията за осигуряване на подходяща (механична и функционална) защита на различни храни и суровините, от които те се произвеждат. Тя предпазва от окисление и микробна развала, което оказва положително влияние върху съхраняемостта им. Увеличеното използване на синтетични опаковки, води до сериозни екологични проблеми, дължащи се на тяхната небиоразградимост. Потреблението на хранителни продукти и изхвърляните след консумация полимерни опаковки замърсяват околната среда. Това поражда необходимост от използването на биоразградими материали (възобновяеми източници), суровини от селското стопанство, морски отпадъци от хранително-вкусовата промишленост и др., които могат да се употребяват за създаването на биоразградими опаковки. Въпреки, че пълна

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подмяна на синтетичните опаковки е невъзможна, използването им може да бъде ограничено с разработване на подходящи по състав и свойства ядивни покрития за определени стокови групи [1,2].

Синтетичните филми се използват за опаковане на пресни плодове и зеленчуци, но те не са биоразградими и се натрупват в околната среда, което води до екологичен дисбаланс и замърсяване на нашата екосистема. Тези обстоятелства създават необходимост от разработване на алтернативни екологични опаковки, които са най-добрата екологично чиста алтернатива на пластмасите [3].

Целта на настоящото изследване е да се проучи научната литература относно използването на пектинови покрития за пресни плодове и зеленчуци.

2. Значение на ядивните покрития за пресните плодове и зеленчуци

Прилагането на ядивни покрития е един от най-иновативните подходи за повишаване съхраняемостта на пресните плодове и зеленчуци [4]. Най-често използвани основни суровини за създаването им са полизахарди, липиди и антимикробни агенти. Широк спектър от научни изследвания доказват, че ядивните покрития се използват за повишаване срока на съхраняемост и качеството на пресни плодове и зеленчуци чрез създаване на модифицирана атмосферна среда във вътрешността им поради техните бариерни свойства за газове, влага и микробно развитие. Те подобряват тяхната хранителна стойност и външен вид. Ядивните покрития се използват основно за пресни плодове и зеленчуци, за забавяне на зреенето по време на съхранение. Трайността при зеленчуците се удължава значително чрез добавяне на вещества, които потискат растежа на микроорганизмите, отделят или абсорбират подбрани компоненти. Способността на ядивните покрития да удължават съхраняемостта на пресни зеленчуци зависи от: техния химичен състав, структурата на филмообразуващия полимер, дебелината на покритието, начина на формиране и нанасяне, вида и свойствата на емулгаторите и пластификаторите, които се използват и от условията на съхранение. Добрите резултати на ядивното покритие за забавяне на промените при съхранение зависят от физиологията на пресните плодове и зеленчуци и присъствието на естествени покрития като восъци, кутикула на повърхността им [3,5].

Покритията забавят дехидратацията, потискат дишането, подобряват текстурата, задържат летливите съединения, с което се запазват вкусово-ароматичните свойства на пресните плодове и зеленчуци за по-дълъг период от време и се намалява микробното им замърсяване. С цел да се реши проблема свързан с намаляване загубата на влага при пресни плодове и зеленчуци, редица изследователи се стремят да разработят ядивни покрития с желаните бариерни свойства. В същото време се извършват проучвания за подобряване адхезията и трайността на покритието, нанесено върху повърхността на пресните плодове и зеленчуци, както и изследване на сензорните му свойства [6].

През последните години използването на ядивните покрития, които удължават съхраняемостта и подобрят качеството на пресните плодове и зеленчуци нарастна. Причините за това са свързани предимно с въпросите, отнасящи се до замърсяване на околната среда, дължащо се на използването на конвенционални синтетични опъковки за храни, които са трудно разградими.

Ефективността на ядивните покрития за защита на пресните плодове и зеленчуци зависи от мокрещата способност на покритието, което се отразява върху дебелината му. По този начин, те се разпространяват равномерно върху повърхността им и се изсушават, с което се постига необходимото сцепление [4].

Пресните плодове и зеленчуци притежават основни съставки, които са необходими за дневния хранителен прием на човешкия организъм. Те са важен източник на витамини, минерали, антиоксиданти, флавоноиди, диетични фибри и вкусови вещества. След прибиране на реколтата, в резултат на въздействието на микроорганизмите, дишането и загубата на влага пресните плодове и зеленчуци бързо намаляват своята трайност и хранителна стойност.

Най-важните фактори за качество на пресните плодове и зеленчуци, които допринасят за продаваемостта им са: текстура, цвят, външен вид, вкус, аромат, хранителна стойност и микробиологична безопасност. Качеството на пресните плодове и зеленчуци зависи от растителния сорт, етапа на зреене, степента на зрялост, условия на съхранение след прибиране на реколтата. Загубите след прибиране на реколтата на пресните плодове и зеленчуци са сериозен проблем, защото той бързо ги влошава по време на съхранение и транспортиране. Ядивните покрития нанесени върху повърхността на пресните плодове и зеленчуци се използват за подобряване на тяхното качество и срок на годност. [7].

3. Същност на ядивните покрития

Ядивните покрития се използват за удължаване на срока на годност на пресните плодове и зеленчуци. Те могат да бъдат консумирани като част от продукта върху който са нанесени без да му влияят неблагоприятно [7].

Ядивните покрития представляват тънък слой съставен от биополимерни компоненти, който може да се консумира със стоката, върху която е нанесен. Той намалява загубата на влага, селективно контролира обмена на газове (кислород, въглероден диоксид и етилен), които участват в процеса на дишане. Ядивните покрития удължават съхраняемостта, поддържат свежестта, инхибират микробната развала на продукта, намаляват загубата на ароматични вещества и на други важни компоненти [8, 9, 10].

4. Използване на пектинови покрития за пресни плодове и зеленчуци

Пектинът е полизахарид, изолиран от стените на растителните клетки. Получава се от кори на цитрусови плодове, ябълки, цвеклови резени и др. растителни суровини. Пектиновите покрития са с висока пропускливост за водна пара, а хидрофилния им характер може да бъде подобрен чрез добавянето на парафин или пчелен восък [11].

Пектинови покрития в комбинации с пчелен восък, сорбитол и моноглицериди намаляват промяната на цвета, омекването на тъканите и естествените загуби (фири) при манго. Те удължават съхраняемостта на изследвания продукт с над една седмица, след като в съчетание с другите компоненти осигуряват контролирано дишане и пропускливост за водна пара [12].

Авторски колектив доказва, че авокадо с нанесени на повърхността пектинови покрития забавя разпространението на болестта Lasiodiplodia theobromae, както и свързаните с нея промени в качеството (текстура и цвят). Получените резултати са много по-добри в сравнение с тези на контролната проба [13].

В проведено изследване са установени добри резултати при покритие с включен в състава си 3% пектин нанесено върху повърхността на домати. То запазва физико-химичните параметри, поддържа качеството по време на съхранение и зреене, с което се повишава съхраняемостта от 4 седмици при температура 30°C [14].

В друго изследване е доказано, че пектиновото покритие е с по-добри резултати от нишестено покритие с добавка на растителна смола. Нанесеното покритие върху два вида стафиди съхранявани при подходящи условия ги запазва непроменени в продължение на 6 месеца. Проведените микробиологични изследвания доказват, че по време на съхранение броя на микроорганизмите се понижава. Получените резултати по сензорните показатели цвят, текстура и вкус на стафидите покрити с пектин са с най-висока оценка [15].

Сложно покритие съставено от пектин (хидрофилен полимер), пчелен восък (хидрофобна фаза), сорбитол (пластификатор) и емулгиращ агент, нанесено върху повърхността на краставици ефективно намалява загубата на влага и удължава съхраняемостта. С покритието се запазват различни параметри на качеството: консистенция, цвят на кожата (хлорофил) и други. Всички промени в обекта на изследването намаляват при по-ниски температури на съхранение. Срокът на съхранение на краставиците при естествена атмосфера е удължен от 2 до 5 дни, а в хладилни условия до две седмици [16].

5. Заключение

Въз основа на проучената научна литература се установи, че изследванията за пектиновите покрития нанесени на повърхността на пресни плодове и зеленчуци не са много. Получени са определени положителни резултати при нанасянето на пектинови покрития върху повърхността на манго, авокадо, домати, стафиди и краставици. Това дава основание да се планират бъдещи научни изследвания на неизследвание до момента пресни плодове и зеленчуци с нанесени на повърхността пектинови покрития.

ЛИТЕРАТУРА

1. Maftoonazad, N., Badii, F. (2009). Use of edible films and coatings to extend the shelf life of food products. *Recent, patents on food, nutrition & agriculture*, Volume 1, Number 2, pp. 162 - 170.
2. Tharanathan, R. N. (2003). Biodegradable films and composite coatings: past, present and future. *Trends in food science & technology*, Volume 14, Issue 3, pp.71 - 78.
3. Mishra, B., Khatkar B. S., Siddiqui S., (2006). Edible coatings for postharvest preservation of fresh fruits and vegetables. *Advances in*

postharvest technologies for horticultural crops, pp. 131 - 172.

4. Scetar, M., Kurek M., Galic K., (2010). Trends in fruit and vegetable packaging - a review. *Croatian journal of food technology, biotechnology and nutrition*, 5, (3 - 4), pp. 69 - 86.
5. Kokoszka, S., Lenart, A., (2007), Edible coatings - formation, characteristics and use - a review. *Polish journal of food and nutrition sciences*, Vol. 57, No. 4, pp. 399 - 404.
6. Lin, D., Zhao, Y. (2007). Innovations in the development and application of edible coatings for fresh and minimally processed fruits and vegetables. *Comprehensive reviews in food science and food safety*, Vol. 6, pp. 60 - 75.
7. Raghav, P. K., Agarwal, N., Saini, M. (2016). Edible coating of fruits and vegetables: a review. *International Journal of Scientific Research and Modern Education (IJSRME)*, Volume I, Issue I, pp. 188-204.
8. Bourtoom, T., (2008), Edible films and coatings: characteristics and properties. *International food research journal, 15, (3), pp. 237 - 248.*
9. Kester, J. and Fennema O., (1986), Edible films and coatings: a review, *Food technology, 40, (12), pp. 47 - 59.*
10. Pavlath, A., and Orts W.., (2009)*, Edible films and coatings for food applications,* pp. 1 – 24. Publisher: Springer, New York, USA.
11. Baldwin, E., (2007). *Handbook of food preservation, second edition*, pp. 477 - 507 Publisher:,CRS Press Taylor and Francis Group, New York, USA.
12. Moalemiyan, M., Ramaswamy H., Maftoonazad N., (2012). Pectin - based edible coatings for shelf - life extension of Ataulfo Mango. *Journal of food process engineering*, Vol. 35, Issue 4, pp. 572 - 600.
13. Maftoonazad, N., Ramaswamy H., Moalemiyan M., Kushalappa, A. (2007), Effect of pectin - based edible emulsion coating on changes in quality of avocado exposed to Lasiodiplodia theobromae infection, *Carbohydrate polymers*, Vol. 68, Issue 2, 21, pp. 341 - 349.
14. Delina, E. and Mahendran, T. (2009), Physico - chemical properties of mature green tomatoes (Lycopersicon esculentum) coated with pectin during storage and ripening, *Tropical agricultural research & extension*, 12, (2), pp. 111 - 113.
15. Ghasemzadeh, R., Karbassi, A., Ghoddousi H., (2008), Application of edible coating for improvement of quality and shelf - life of raisins. *World applied sciences journal*, 3, (1), pp. 82 - 87.
16. Moalemiyan, M., and Ramaswamy, H. 2012, Quality retention and shelf - life extension in mediterranean cucumbers coated with a pectin - based Film. *Journal of food research*, Vol. 1, No. 3, pp. 159 - 168.

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ПРИЛОЖЕНИЕ НА ЛИПИДНИ ПОКРИТИЯ В ХРАНИТЕЛНИТЕ ТЕХНОЛОГИИ

РАДОСЛАВ РАДЕВ

Резюме: *Липидните покрития са гъвкави и устойчиви на счупване. Те притежават добри бариерни свойства срещу водна пара и кислород. Това са основните фактори влияещи върху промените на органолептичните свойства, на физико-химичните свойства и на микробиологичната развала на храните по време на съхранението. Целта на настоящото изследване е да се проучи научната литература относно приложението на липидните покрития в хранителните технологии. Въз основа на проучената литература се установи, че значително по-голямата част от научните изследвания за липидни покрития са насочени към приложението им за пресни плодове и зеленчуци.В заключение са посочени бъдещите направления за изследвания на липидните покрития.*

Ключови думи: *ядивни покрития, липидни покрития, храни*

APPLICATION OF LIPID COATINGS IN FOOD TECHNOLOGY

RADOSLAV RADEV

Abstract: *Lipid coatings are flexible and resistant to breakage. They possess good barrier properties against water vapor permeability and oxygen. These are the main factors influencing changes in the organoleptic properties, of the physicochemical properties and microbiological spoilage of food during storage. The main purpose of this study was to investigate the scientific literature about the use of the lipid coatings in food technology. Based on the research literature found that a significant majority of research on lipid coatings are focused on their application for fresh fruit and vegetables. In conclusion are set future directions for research on lipid coatings.*

Key words: *edible coatings, lipid coatings, food*

1. Въведение

Ядивните покрития са нанасяни върху повърхността на различни плодове в продължение на векове за предотвратяване загубата на влага, за създаване на лъскава повърхност и за подобряване на външния им вид. Тази практика е използвана дълго преди да се изяснят свързаните с нея биохимични процеси [1].

През XII и XIII в. в Китай пресни портокали и лимони са покривани с восък, който забавя изсушаването [2,3] и промените в плодовата тъкан [4]. Методът е най-добрия за този период от време и се използва дълго поради липсата на по-ефективен. В Европа процесът е известен като "larding" - съхранение на различни плодове чрез покриване с восъци или мазнини [1]. Восъчните покрития намаляват загубата на влага и забавят дишането на пресни плодове и зеленчуци, в резултат, на което се удължава съхраняемостта им. Различни восъци са нанасяни върху повърхността на пресни плодове и зеленчуци. Използвани са горещо топени восъци или емулсии. През Средновековието липидните покрития са прилагани, за да намалят естествените загуби и изсъхването на месо и сирена [5].

През XV в. са създадени ядивни покрития от варено соево мляко, които са използвани в Япония за поддържане качеството

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на храните и подобряване на външния им вид [1].

През XVI в. в Англия са предлагани храни с нанесени на повърхността мазнини за намаляване загубата на влага от продуктите [2], а през XIX в. в САЩ е издаден първия патент за запазване качеството на различни месни продукти [1].

През 1930 г. в търговската мрежа се предлагат пресни ябълки и круши с нанесени на повърхността восъци [3], а в САЩ парафина се използва за първи път за защита на цитрусови плодове [6]. Значителни изследвания за ядивни покрития започват през 1950 г. [2], но до 1967 г. употребата им се ограничава най-вече с восъчни слоеве предназначени за плодове. През изминалите години приложението на ядивните покрития нанасяни върху различни хранителни продукти значително се разраства. През 1986 г. в САЩ фирмите, които предлагат такива продукти са малко над 10, а до 1996 г. броя им е 600. Днес използването на ядивните покрития расте бързо, като основно се цели запазване качеството на разнообразни хранителни продукти с общи годишни приходи над 100 млн. $ [1].

В момента, ядивните покрития се използват най-вече за нанасяне върху пресни плодове и зеленчуци, месо и месни продукти, бонбони и някои ядки [5].

Целта на настоящото изследване е да се проучи научната литература относно приложението на липидните покрития в хранителните технологии.

2. Същност на ядивните покрития

Ядивните покрития представляват тънък слой съставен от ядивни биополимерни компоненти, който може да се нанесе върху повърхността на определени храни и да се консумира с тях. Той намалява загубата на влага, селективно контролира обмена на газове (кислород, въглероден диоксид и етилен), които участват в процеса на дишане. Ядивните покрития удължават съхраняемостта, поддържат свежестта, инхибират микробната развала на продукта, намаляват загубата на ароматични вещества и на други важни компоненти [1, 7, 8]. Ядивните покрития се нанасят върху повърхността на храната, обикновено чрез метода на потапяне в определен разтвор или чрез метода на напръскване с пулверизатор [9].

Биоразградимите ядивни покрития се създават предимно от естествени полимери и функционални съставки, които защитават бързо развалящи се хранителни продукти, запазват качество им и забавят промените при съхранение. Необходимо е да притежават приемливи сензорни характеристики, подходящи бариерни свойства (CO_2, O_2, вода), микробна, биохимична и физикохимична стабилност. Ядивните покрития трябва да бъдат безопасни и да се получават чрез бърза и лесна технология при ниски цени. Те могат да действат, като ефективен носител на антиоксиданти, вкус, цвят, хранителни или антимикробни компоненти [10].

3. Приложение на липидни покриия в хранителните технологии

Липидните покрития са гъвкави и устойчиви на счупване. Те притежават добри бариерни свойства срещу водна пара и кислород. Това са основните фактори влияещи върху промените на органолептичните свойства, на физико-химичните свойства и на микробиологичната развала на храните по време на съхранението [11].

3.1. Восъчни и парафинови покрития

Покритията нанасяни върху повърхността на пресни плодове и зеленчуци често се наричат "восъци", независимо дали някоя от съставките наистина е восък. С восък най-често се обработват ябълки, авокадо, цитрусови плодове, краставици, патладжан, праскови, сладък пипер и домати, което подобрява външният им вид. При проучване на връзката на восъците с процесите разваляне, нараняване и покафеняване е установено, че в повечето случаи плодовете покрити с восъци са с по-ниска честота на дишане, отколкото непокритите проби, което подобрява съхраняемостта им [12].

Восъците (минерални масла, парафин, канделилов и пчелен восък) се използват, като покрития нанесени върху плодове като портокал, лимон, грейпфрут, ябълка, круша, череша, банан, гуава, манго, кокосов орех, праскови, грозде, цяло и прясно нарязано авокадо. Нанасят се и върху някои зеленчуци като морков, краставица, тиква, пъпеш, сладка царевица, патладжан, пипер, домати, аспержи, целина, ряпа и картофи. Восъците и маслата, самостоятелно или в емулсия с хидроколоиди ефективно удължават срока на съхраняемост. Те подобряват защитните (бариерни) свойства на покритията за вода, което предотвратява естествените загуби (фири). Въпреки това, нанасянето на по-дебел слой восъци върху пресни плодове и зеленчуци силно променя обмена на кислород и въглероден диоксид, което създава анаеробни условия на съхранение [13,14].

Восъчните покрития са значително по-устойчиви на влага от повечето липидни. Въпреки това, покритията на восъчна и маслена основа имат определени проблеми във връзка с дебелина, хомогенност, мазна повърхност и органолептичните свойства. Малко са откритите научнати изследвания по отношение на ефективността на восъци, мазнини, и масла като защитни покрития за месо. Покритие от минерално масло и восък намаляват загубата на влага от замразени птици повече от покритие от царевично масло или свинска мас. В сравнение със синтетичните опаковки загубите са по-високи [15].

Пчелният восък е най-известния компонент, който засяга непрозрачността, която нараства с увеличаването му. Влага се в покрития за храни и е от решаващо значение за поддържане на свежестта, контролирането на микробния растеж и осигуряване на по-добра текстура на продукта. Покритията от пчелен восък контролират дейността на водата в продукта, като предотвратява загубата на влага или поемането й. Те защитават храната от физически наранявания и ограничават миграцията на мазнини, осигуряват бариера за газове, спомагат за запазване на вкуса и аромата, могат да съдържат антиоксиданти или антимикробни вещества [16]. Восъчните покрития намаляват загубата на влага и забавят дишането на покритите пресни плодове и зеленчуци, в резултат на което се удължава съхраняемостта им [5].

В проведено изследване е доказано, че запазването на качеството на някои (Generos, Starkrimson, Ionagold и Idared) сортове ябълки е възможно чрез нанасяне върху кожицата им на покритие от пчелен восък с концентрация от 1% [17].

Ядивно покритие от пчелен восък за храни е ефективна бариера за кислород, светлина и пара, която може да помогне за предотвратяване на окислението на мазнини, пигменти и загубата на вода. Изследвани са количествата на 2-тиобарбитурова киселина и водната активност (Aw) на италиански салам покрит с пчелен восък. Получените резултатите са корелирани с определяне на качеството чрез сензорна оценка. Нивата на на 2-тиобарбитурова киселина в италианския салам с нанесено ядивно покритие с пчелен восък са под 0.8 mg/kg^{-1} до 6 месеца и значително по-високи в непокритата контролна проба. Наблюдава се малка корелация между количеството на 2-тиобарбитурова киселина и водната активност (Aw) при колбасите с покритие от пчелен восък. След 7 месеца от съхранението на колбаса се наблюдава промяна във водната активност. Ядивното покритие от пчелен восък предотвратява втвърдяването и улеснява обелването на италианския салам.

Резултатите от това проучване доказват, че ядивно покритие от пчелен восък може да бъде полезна алтернатива на пластмасови опаковки за италиански салам. Този естествен материал за покритие може да се използва за увеличаване периода на съхранение на изследваната стока без да се нарушава структурата. Пчелният восък ефективно намалява развитието на липидната пероксидация в тези колбаси [18].

В друго изследване е извършен сравнителен анализ на ефектите на няколко концентрация на покрития от пчелен восък, които оказват влияние върху условията на съхранение, качеството и срокът на годност на мандарини. Получените резултати доказват, че комбинацията на 12% восъчно покритие (пчелен восък, олеинова киселина, триетаноламин) и съхранението на пробите при 5°C е с най-добри резултати относно поддържането на качеството и удължаване на срока на годност на мандарини. Разработеното покритие оказва благоприятно влияние върху честотата на гниене, титруемата киселинност, разтворими твърди вещества, аскорбинова киселина и общата сензорна приемливост пред контролната проба. Въз основа на получените резултати е доказано, че 12%-но восъчно покритие и съхранение при температура 5 °C най-ефективно поддържа качеството и увеличава срока на годност на мандарини [19].

Авторски колектив изследва влиянието на парафиново покритие (25, 50, 75, 100% -ен разтвор и контролни проби) върху качеството на краставици при различни условия на съхранение (5, 10 и 15 °C). Изследвани са показателите промяна на диаметъра и дължината, загуба на тегло, напълно разтворими твърди вещества, твърдост. Установено е че срокът на годност се увеличава с повишаване концентрацията на парафина и намалява с нарастване на температурата на съхранение.

Използваният парафин е восъкоподобно твърдо вещество с бял цвят, без вкус и мирис, с точка на топене между около 46 и 68 °C (115 и 154 °F), и с плътност от около 0.9 g/cm^3. Той е неразтворим във вода, но разтворими в етер, бензен, и някои естери.

Получените резултати доказват, че промените по показателите промяната на диаметъра и дължината, загубата на тегло, твърдостта, напълно разтворими твърди вещества намаляват с увеличаване на концентрацията на парафиновия разтвор, но се увеличават с повишаване на температурата на съхранение. При срокът на годност тази тенденция се запазва [20].

A. Purvis нанася различни восъци (повърхностно базирани восъци, восъци от натурални продукти, карнаубов восък, восъчна емулсия) по повърхността на краставици, които са съхранявани при два температурни режима 5 и 15°С. Получените резултати доказват, че восъчните покрития забавят загубата на влага и промените при охлаждане на краставиците. Това се запазва с повишаване концентрацията на восъка, а при намаляването й се наблюдава увеличаване изпарението на влага и вредите от охлаждане. Съхранението на краставици при ниски температури води до появата на пукнатини във восъците, което повишава загубата на влага [21].

Авторски колектив установява, че покритие от канделилов восък с елагова киселина подобрява качеството и удължава срока на съхранение на ябълки в продължение на 8 седмици, без да се променят органолептичните свойства на плодовете. Покритието доказва, че притежава противогъбични свойства, които инхибират растежа на определени гъбични щамове [22].

В друго изследване плодовете и зеленчуците са представени като бързо развалящи се селскостопански стоки с висока хранителна стойност. Акцентирано е на ядивните покрития и възможностите им да удължат срока на годност и поддържат качеството на пресни плодове и зеленчуци чрез създаване на модифицирана атмосфера във вътрешността на плода поради техните бариерни свойства за газове и влага. Разгледани са възможностите на покривните материали да бъдат носители на добавки за храни, антиоксиданти и/или антимикробни агенти.

В същото проучване е установено, че карнаубовото покритие с низин може да попречи на много микроорганизми, като удължава срока на годност на продуктите.

Доказано, е че покритието подобрява външния вид на продуктите, цвят, крехкост, вкус, хранителна стойност, сочност, текстура. То може да се използва за пресни плодове и зеленчуци, месни продукти, шоколади, различни ядки, вафли, пържени картофи, пиле, риба, царевичен чипс, ябълка, и лимон [23].

3.2. Ацетилглицеридни покрития

Ацетилираните моноглицериди притежават уникални свойства. Те могат да преминават от разтопено състояние в гъвкава подобна на восък твърда маса. Повечето липиди в твърдо състояние се удължават с около 102% от първоначалната им дължина преди да се счупят. Ацетилираният глицерол моностеарат може да се разтяга до 800% от първоначалната си дължина. Водопропускливостта на това покритите е много по-ниска от тази на полизахаридните покрития с изключение на целулозата и етилцелулозата. Покритията от ацетилирани моноглицериди се използват за забавяне загубата на влагата по време на съхранението [7].

Ядивните покрития на основата на ацетилирани моноглицериди намират приложение, нанесени върху различни видове месо [24], като изследвания на тези покрития върху пресни плодове и зеленчуци не са достатъчно изучени.

3.3. Покрития от смоли

Шеллакът е пречистен продукт на лак от естествени смолисти олигомери, който се секретира от паразитното насекомо „Kerria lacca” на различни дървесни видове в Индия и Тайланд. Съставът му варира в зависимост от вида на насекомите и дървото, от което се получава суровината [25].

Ябълки, покрити с шеллак са с по-добър гланц и твърдост. Шеллакови покрития или в съчетание с канделилов восък намаляват пропускливостта на O_2 и CO_2, с което се забавя дишането и естествените загуби (фири) [26].

Ядивно покритие от шеллак с добавен гел от алое вера се използва за удължаване срока на съхранение на домати в условия на естествена атмосфера (28±2°С). Включването на гел от алое вера в покритието подобрява пропускливостта за кислород, въглероден диоксид и водни пари. Ядивното покритие, което е нанесено върху повърхността на домати забавя промените при съхранение, твърдостта, ограничава дишането и синтеза на етилен [27].

В друго изследване е доказано, че покритите с арабска гума (20%-ен разтвор) краставици значително забавят естествените загуби (фири) и промените в консистенцията до 16 дни при температури на съхранение 10 и 25°С. Сензорната оценка по показателите вкус, цвят, консистенция, външен вид и приемливата оценка от потребителите доказва, че покритието от арабска гума запазва качеството на краставиците по време на съхранението [28].

3.4. Покрития от животински мазнини

Ядивно покритие от разтопени мазнини (говежда лой, свинска мас) нанесено на повърхността на прясно нарязани меса, постига по-добри резултати от контролните проби без покритие по отношение на цвета и загубата на влага по време на съхранение при температура от 2 до 4 °C. Замразени меса, домашни птици и риба не претърпят значителна дехидратация когато са покрити в маслено водна емулсия, приготвена при температура от 60 до 80 ° C чрез смесване на животински мазнини или растително масло с емулгатори, вода, подправки и консерванти.

Значително намаляване на загубата на влага се наблюдава при лиофилизирано месо с нанесено покритие съставено от говежда лой, свинска мас, с млечни триглицериди и растително масло [15].

4. Заключение

Въз основа на проучената литература се установи, че значително по-голямата част от научните изследвания за липидни покрития са насочени към приложението им за пресни плодове и зеленчуци. Някои от липидните покрития са нанесени на повърхността на месни продукти. В проучването се установи, че най-използваният липиден компонент е пчелният восък.

Бъдещите изследвания на липидните покрития могат да се извършват в две основни направления:

- научни изследвания насочени към нанасяне на липидни покрития върху неизследвани до момента пресни плодове и зеленчуци;
- научни изследвания насочени към нанасяне на неизследвани до момента месни продукти, хлебни и тестени изделия, захарни изделия.

ЛИТЕРАТУРА

1. Pavlath, A., and Orts W. (2009). *Edible films and coatings for food applications*, pp. 1 – 24. Publisher: Springer, New York, USA.
2. Ben, A., Kurth L. (1995). Edible film coatings for meat cuts and primals, Meat ’95. CSIRO *Meat industry research conference*, pp. 13 - 15.
3. Park, H. (1999). Development of advanced edible coatings for fruits. *Trends in food science & technology*, 10, pp. 254 - 260.
4. Muranyi, P. (2013). Functional Edible Coatings for Fresh Food Products. *Food processing & technology*, Volume 4, Issue 1, pp. 1 - 2.
5. Han, J., Gennadios A. (2005). *Innovations in food packaging*, pp. 239 – 262. Publisher: Elsevier science & technology books.
6. Kokoszka, S., Lenart A. (2007). Edible coatings - formation, characteristics and use - a review. *Polish journal of food and nutrition sciences*, Vol. 57, No. 4, pp. 399 - 404.
7. Bourtoom, T. (2008). Edible films and coatings: characteristics and properties. *International food research journal*, 15, (3), pp. 237 - 248.
8. Kester, J. and Fennema O. (1986). Edible films and coatings: a review. *Food technology*, 40, (12), pp. 47 - 59.
9. Falguera, V., Quintero J., Jimenez A., Munoz J., Ibarz. A. (2011). Edible films and coatings: structures, active functions and trends in their use. *Trends in food science & tehnology*, 22, pp. 292 - 303.
10. Maftoonazad, N., Badii F. (2009). Use of edible films and coatings to extend the shelf life of food products. *Recent, patents on food, nutrition & agriculture*, Volume 1, Number 2, pp. 162 - 170.
11. Milovanovic, M., Picuric - Jovanovic K. (2001). Lipids and biopackaging. Usage of lipids in edible films. *Joumal of agricultural sciences*, Vol. 46, No 1, pp. 79 - 87.
12. Hagenmaier, R., Shaw P. (1992). Gas permeability of fruit coating waxes. *Journal of the american society for horticultural science*, 117, (1), pp. 105 - 109.
13. Debeaufort, F., Quezada-Gallo J., Voilley A. (1998). Edible Films and Coatings: Tomorrow’s Packagings: A Review. *Critical reviews in food science,* 38, (4), pp. 299 - 313.
14. Rojas - Molina, R., León-Zapata M., Saucedo - Pompa S., Aguilar-Gonzalez M., Aguilar C. (2013). Chemical and structural characterization of Candelilla (Euphorbia antisyphilitica Zucc.). *Journal of medicinal plants research*, Vol. 7, (12), pp. 702 - 705.
15. Khan M. I., Adrees M. N., Tariq M. R. and Sohaib M. (2013). Application of edible coating for improving meat quality: A review. *Pakistan journal of food sciences*, Volume 23, Issue 2, page(s): 71-79.
16. Maftoonazad, N., Ramaswamy H., Marcotte M. (2007). Evalution of factors affecting barrier, mechanical and optical properties of pectin - based films using response surface methodology. *Journal of food process engineering*, Vol. 30, Issue 5, pp. 539 - 563.
17. Anghel, R. (2011). The influence of wax protection film on apple fruits, in order to maintain their quality during cold storage. *Lucrări ştiinţifice* - vol. 54, Nr. 1, seria Agronomie, 87 - 90.
18. Trevisani, M., Cecchini, M., Siconolfi, D. Mancusi, R. and Rosmini R. (2017). Effects of Beeswax Coating on the Oxidative Stability of Long-Ripened Italian Salami. *Journal of food quality*, pp. 5.

19. Hassan, Z. H., Lesmayati, S., Qomariah, R. and Hasbianto, A. (2014). Effects of wax coating applications and storage temperatures on the quality of tangerine citrus (Citrus reticulata) var. Siam Banjar. *International food research journal,* 21(2):641-648.
20. Bahnasawy A. H. and Khater E. G. (2014). Effect of wax coating on the quality of cucumber fruits during storage. *Food processing & technology,* 5 (6):339-346.
21. Purvis, A. (1994). Interaction of waxes and temperature in retarding moisture loss from and chilling injury of cucumber fruit during storage. *Proceedings of the Florida state horticultural Society*, 107, pp. 257 - 260.
22. Ochoa, E., Saucedo - Pompa S., Rojas - Molina R., Garza H., Charles - Rodríguez A., Noé Aguilar C. (2011). Evaluation of a candelilla wax -based edible coating to prolong the shelf - life quality and safety of apples. *American journal of agricultural and biological sciences*, 6, (1), pp. 92 - 98.
23. Puttalingamma.V. (2014). Edible coatings of carnauba wax — a novel method for preservation and extending longevity of fruits and vegetables - a review. *Internet journal of food safety*, Vol.16, pp. 1-5.
24. Пашова, С., (2011). *Приложение на растителните восъци в хранителните технологии*, Издателска къща „ Сафо ” - Ловеч, с. 65 - 90.
25. Farag, Y., Leopold C. (2009). Physicochemical Properties of Various Shellac Types, *Dissolution technologies*, pp. 33 - 39.
26. Alleyne, V., Hagenmaier R. (2000). Candelilla - shellac: an alternative formulation for coating apples. *Horticultural science*, 35, (4), pp. 691 - 693.
27. Chauhan, O., Nanjappa C., Ashok N., Ravi N., Roopa N., Raju P. S. (2013). Shellac and Aloe vera gel based surface coating for shelf life extension of tomatoes. *Journal of food science and technology,* 52(2): 1200–1205.
28. Al - Juhaimi, F., Ghafoor K., Babiker E. (2012). Effect of gum arabic edible coating on weight loss, firmness and sensory characteristics of cucumber (Cucumis sativus L.) fruit during storage. *Pakistan journal of botany*, 44, (4), pp. 1439 - 1444.

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SECTION 6 • СЕКЦИЯ 6

NATURAL SCIENCES

ПРИРОДНИ НАУКИ

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QUADRATURE ITERATIVE METHOD FOR A NUMERICAL SOLUTION OF A NONLINEAR HAMMERSTEIN FUZZY FUNCTIONAL INTEGRAL EQUATION

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Abstract: *In this paper, we obtain error estimation of the iterative method using a fuzzy trapezoidal quadrature formula to solve nonlinear Hammerstein fuzzy functional integral equations. Error estimation of the proposed method is given in terms of uniform and partial modulus of continuity. Finally, an illustrative numerical experiment confirms the theoretical results and demonstrates the accuracy of the method.*

Key words: *Hammerstein fuzzy functional integral equations, approximation solution, fuzzy trapezoidal quadrature formula, modulus of continuity.*

1. Introduction

The study of fuzzy integral equations begins with the investigations of Kaleva [1] and Seikkala [2]. The numerical methods for solving fuzzy integral equations involve various techniques. The method of successive approximations and iterative methods are applied in [3,4].

In this paper, we investigate the nonlinear Hammerstein fuzzy functional integral equation

$$x(t) = g(t) \oplus f\big(t, x(t)\big) \oplus (FR)\int_a^b k(t,s) \odot H\big(s, x(s)\big)ds\,,\ a \le s \le t \le b\,, \tag{1}$$

where $k(t,s)$ is a positive kernel function for $s,t \in [a,b]$. The fuzzy-number-valued functions g, f, H such that $g:[a,b] \to E^1$ and $f, H:[a,b]\times E^1 \to E^1$ are supposed to be continuous.

The convergence of the iterative numerical method proposed in [5] is based on error estimation in approximation of the solution of (1) that was derived using supplementary Lipschitz continuous for g, f, k and H .

The error estimate obtained in this paper is expressed in terms of the modulus of continuity for g and k .

2. Preliminaries

Definition 1. [6] *A fuzzy number is a function* $u:\mathbb{R} \to [0,1]$ *satisfying the following properties*

1. u *is upper semicontinuouson* $\mathbb{R}$ *,*

2. $u(x) = 0$ *outside of some interval* $[c,d]$*,*

3. there are the real numbers a *and* b *with* $c \le a \le b \le d$ *, such that* u *is increasing on* $[c,a]$*, decreasing on and for each* $[b,d]$*, and* $u(x) = 1$ *for each* $x \in [a,b]$*,*

4. u *is fuzzy convex set (that is* $(\lambda x + (1-\lambda)y) \ge \min\{u(x), u(y)\}$ *, for all* $x, y \in \mathbb{R}, \lambda \in [0,1]$).

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The set of all fuzzy numbers is denoted by E^1. The neutral element with respect to in E^1 is denoted by $\tilde{0}=\chi_{\{0\}}$. For any $0<r\leq 1$ an arbitrary fuzzy number is represented, in parametric form, by an ordered pair of functions $(\underline{u}(r),\overline{u}(r))$, which satisfies the following properties

1. $\underline{u}(r)$ is bounded left continuous non-decreasing function over $[0,1]$,
2. $\overline{u}(r)$ is bounded left continuous non-increasing function over $[0,1]$,
3. $\underline{u}(r)\leq\overline{u}(r)$.

Definition 2. [7] *For arbitrary fuzzy numbers* $u=(\underline{u}(r),\overline{u}(r))$, $v=(\underline{v}(r),\overline{v}(r))$, *the quantity* $D(u,v)=\sup\limits_{r\in[0,1]}\max\{|\underline{u}(r)-\underline{v}(r)|,|\overline{u}(r)-\overline{v}(r)|\}$ *is the distance between* u *and* v *and also the following properties hold*

1. (E^1,D) *is a complete metric space,*

2. $D(u\oplus w,v\oplus w)=D(u,v)$, *for all* u, v, $w\in E^1$,

3. $D(u\oplus v,w\oplus e)\leq D(u,w)+D(v,e)$, *for all* $u,v,w,e\in E^1$,

4. $D(u\oplus v,\tilde{0})\leq D(u,\tilde{0})+D(v,\tilde{0})$, *for all* $u,v\in E^1$,

5. $D(k\odot u,k\odot v)=|k|D(u,v)$, *for all* $u,v\in E^1$, *for all* $k\in\mathbb{R}$,

6. $D(k_1\odot u,k_2\odot u)=|k_1-k_2|D(u,\tilde{0})$, *for all* $k_1,k_2\in\mathbb{R}$ *with* $k_1k_2\geq 0$ *and* $u\in E^1$.

Definition 3. [8] *A fuzzy-number-valued function* $f:[a,b]\to E^1$ *is said to be continuous at* $t_0\in[a,b]$ *if for each* $\varepsilon>0$ *there is* $\delta>0$ *such that* $D(f(t),f(s))<\varepsilon$, *whenever* $t\in[a,b]$ *and* $|t-s|<\delta$. *We say that* f *is fuzzy continuous on* $[a,b]$ *if* f *be continuous for each* $t_0\in[a,b]$, *and denote the space of all such functions by* $C([a,b],E^1)$.

On the set $C([a,b],E^1)=\{f:[a,b]\to E^1; f \text{ is continuous }\}$, we define $D^*(f,g)=\sup\limits_{t\in[a,b]}D(f(t),g(t))$, for all $f,g\in C([a,b],E^1)$ and $D^*(.,\tilde{0})$ is denoted by $\|.\|_{\mathfrak{F}}$. It is obvious that $(C([a,b],E^1),D^*)$ is a complete metric space.

Definition 4. [4] *Let* $f:[a,b]\to E^1$, *be a bounded mapping, then the function* $\omega_{[a,b]}(f,\delta)=\sup\{D(f(t),f(t_0)):t,t_0\in[a,b],|t-t_0|\leq\delta\}$ *is called the modulus of oscillation of* f *on* $[a,b]$. *In addition if* $f\in C([a,b],E^1)$ *, then* $\omega_{[a,b]}(f,\delta)$ *is called uniform modulus of continuity of* f.

According to [4] the following properties hold

1. $D(f(t),f(s))\leq\omega_{[a,b]}(f,|t-s|)$ for any $t,s\in[a,b]$,
2. $\omega_{[a,b]}(f,\delta)$ is a non-decreasing mapping in δ,
3. $\omega_{[a,b]}(f,0)=0$,
4. $\omega_{[a,b]}(f,\delta_1+\delta_2)\leq\omega_{[a,b]}(f,\delta_1)+\omega_{[a,b]}(f,\delta_2)$ for any $\delta_1,\delta_2\geq 0$,
5. $\omega_{[a,b]}(f,n\delta)\leq n\omega_{[a,b]}(f,\delta)$ for any $\delta\geq 0$ and $n\in\mathbb{N}$,
6. $\omega_{[a,b]}(f,\lambda\delta)\leq(\lambda+1)\omega_{[a,b]}(f,\delta)$ for any $\delta,\lambda\geq 0$,
7. If $[c,d]\subseteq[a,b]$, then $\omega_{[c,d]}(f,\delta)\leq\omega_{[a,b]}(f,\delta)$ for all $\delta\geq 0$.

We consider the integral equation (1) and assume that k is continuous and therefore it is uniformly continuous and there exists $N_K>0$ such that $N_K=\max\{|k(t,s)|:t,s\in[a,b]\}$.

We introduce the following conditions:

(i) $g\in C([a,b],E^1)$, $f\in C([a,b]\times E^1,E^1)$, $H\in C([a,b]\times E^1,E^1)$;

(ii) there exist α_f, $\gamma_f\geq 0$ such that $D(f(t_1,u),f(t_2,v))\leq\gamma_f|t_1-t_2|+\alpha_f D(u,v)$ for all $t_1,t_2\in[a,b],u,v\in E^1$;

(iii) there exist $\alpha_H, \gamma_H \geq 0$ such that $D(H(t_1,u),H(t_2,v)) \leq \gamma_H |t_1 - t_2| + \alpha_H D(u,v)$ for all $t_1, t_2 \in [a,b], u, v \in E^1$;

(iv) $B = \alpha_f + N_K \Delta \alpha_H < 1$, where $\Delta = b - a$.

Theorem 1. [5] *Let the conditions* (i)-(iv) *are fulfilled. Then the integral equation* (1) *has unique solution* $x^* \in C([a,b],E^1)$ *and the sequence of successive approximations* $\{x_m\}_{m\in\mathbb{N}} \in C([a,b],E^1)$

$$x_m(t) = g(t) \oplus f(t, x_{m-1}(t)) \oplus (FR)\int_a^b k(t,s) \odot H(s, x_{m-1}(s))ds,\ t \in [a,b],\ m \in \mathbb{N} \tag{2}$$

convergences to x^* *in* $C([a,b],E^1)$ *for any choice of* $x_0 \in C([a,b],E^1)$. *In addition, the following error estimates hold*

$$D(x^*(t), x_m(t)) \leq \frac{B^m}{1-B} D(x_1(t), x_0(t)) \text{ for all } t \in [a,b],\ m \in \mathbb{N} \tag{3}$$

$$D(x^*(t), x_m(t)) \leq \frac{B}{1-B} D(x_m(t), x_{m-1}(t)) \text{ for all } t \in [a,b],\ m \in \mathbb{N}. \tag{4}$$

Choosing $x_0 \in C([a,b],E^1)$, $x_0 = g$ *the inequality* (3) *becomes*

$$D(x^*(t), x_m(t)) \leq \frac{B^m}{1-B}(M_0 + N_0 N_K (b-a)) \text{ for all } t \in [a,b],\ m \in \mathbb{N}, \tag{5}$$

where $D(f(t,g(t)),\tilde{0}) \leq M_0$ *and* $D(H(t,g(t)),\tilde{0}) \leq N_0$.

Remark 1. Let $\| f \|_{\Im} = \sup_{t\in[a,b]} D(f(t,\tilde{0}),\tilde{0})$ and $\| H \|_{\Im} = \sup_{t\in[a,b]} D(H(t,\tilde{0}),\tilde{0})$ then the inequality (5) has the form

$$D(x^*(t), x_m(t)) \leq \frac{B^m}{1-B}(B \| g \|_{\Im} + \| f \|_{\Im} + N_K \Delta \| H \|_{\Im}) \text{ for all } t \in [a,b],\ m \in \mathbb{N}\ . \tag{6}$$

Theorem 2. [4] *Let* $f : [a,b] \to E^1$ *be a continuous fuzzy –number-valued function. Then*

$$D\left((FR)\int_a^b f(t)\,dt, \frac{b-a}{2} \odot (f(a) \oplus f(b))\right) \leq \frac{b-a}{2}\omega_{[a,b]}\left(f, \frac{b-a}{2}\right).$$

3. Successive approximations and the iterative algorithm

Now, we introduce a numerical method for solving the fuzzy integral equation (1). We consider the uniform partition of the interval $[a,b]$, $a = t_0 < t_1 < ... < t_{n-1} < t_n = b$ with $t_i = a + ih$, $i = \overline{0,n}$, where $h = \frac{b-a}{n}$. Then the following iterative procedure gives the approximate solution of equation (1) on the point t

$$\begin{aligned} &\tilde{x}_0(t) = g(t), \\ &\tilde{x}_m(t) = g(t) \oplus f(t, \tilde{x}_{m-1}(t)) \oplus \sum_{j=0}^{n-1} \frac{h}{2} \odot \left[k(t,t_j) \odot H(t_j, \tilde{x}_{m-1}(t_j)) \oplus k(t,t_{j+1}) \odot H(t_{j+1}, \tilde{x}_{m-1}(t_{j+1}))\right], \end{aligned} \tag{7}$$

for $m \geq 1$.

Lemma 1. *Under the conditions* (i)-(iv) *we have*

a) $\omega_{[a,b]}(H(s, x_m(s), h) \leq \gamma_H h + \alpha_H \omega_{[a,b]}(x_{m-1}(s), h)$,

b) $\omega_{[a,b]}(x_m(s), h) \leq \frac{1}{1-\alpha_f}\omega_{[a,b]}(g,h) + \frac{\gamma_f}{1-\alpha_f}h + \Delta\left(\frac{\| H \|_{\Im}}{1-\alpha_f} + \frac{\alpha_H B^m \| g \|_{\Im}}{B-\alpha_f} + \frac{\alpha_H M}{(1-B)(1-\alpha_f)}\right)\omega_1$,

where $M = \| g \|_{\Im} + \| f \|_{\Im} + N_K \Delta \| H \|_{\Im}$ *and* $\omega_1 = \omega_{[a,b]}(k,\delta) = \sup_{t_1,t_2\in[a,b]} \{| k(t_1,s) - k(t_2,s) | : | t_1 - t_2 | \leq \delta\}$ *for all* $\delta > 0$.

Proof. a) For $s_1, s_2 \in [a,b]$ with $|s_1 - s_2| \le h$ and (iii)

$D(H(s_1, x_m(s_1)), H(s_2, x_m(s_2))) \le \gamma_H \, | s_1 - s_2 | + \alpha_H D(x_m(s_1), x_m(s_2)) \le \gamma_H h + \alpha_H \omega_{[a,b]}(x_m, h)$.

b) For $t_1, t_2 \in [a,b]$ with $|t_1 - t_2| \le h$, by using Theorem 2 and (2) we obtain

$$D(x_m(t_1), x_m(t_2)) \le D(g(t_1), g(t_2)) + D(f(t_1, x_{m-1}(t_1)), f(t_2, x_{m-1}(t_2))) +$$
$$+ D\left((FR)\int_a^b k(t_1, s) \odot H(s, x_{m-1}(s)\, ds, (FR)\int_a^b k(t_2, s) \odot H(s, x_{m-1}(s)\, ds \right) \le$$
$$\le \omega_{[a,b]}(g, h) + \gamma_f h + \alpha_f D(x_{m-1}(t_1), x_{m-1}(t_2)) + \int_a^b | k(t_1, s) - k(t_2, s) | \, D\left(H(s, x_{m-1}(s)), \tilde{0}\right) ds \le$$
$$\le \omega_{[a,b]}(g, h) + \gamma_f h + \alpha_f D(x_{m-1}(t_1), x_{m-1}(t_2)) + \omega_1 \int_a^b \left(D\left(H(s, x_{m-1}(s)), H(s, \tilde{0})\right) + D\left(H(s, \tilde{0}), \tilde{0}\right) \right) ds \le$$
$$\le \omega_{[a,b]}(g, h) + \gamma_f h + \alpha_f D(x_{m-1}(t_1), x_{m-1}(t_2)) + \omega_1 \Delta \left(\alpha_H \| x_{m-1} \|_{\Im} + \| H \|_{\Im} \right) \le$$

$\le \alpha_f D(x_{m-1}(t_1), x_{m-1}(t_2)) + \omega_1 \Delta \alpha_H \| x_{m-1} \|_{\Im} + P$, where $P = \omega_{[a,b]}(g, h) + \gamma_f h + \omega_1 \Delta \| H \|_{\Im}$.

So, we have

$$D(x_m(t_1), x_m(t_2)) \le \alpha_f D(x_{m-1}(t_1), x_{m-1}(t_2)) + \omega_1 \Delta \alpha_H \| x_{m-1} \|_{\Im} + P$$
$$D(x_{m-1}(t_1), x_{m-1}(t_2)) \le \alpha_f D(x_{m-2}(t_1), x_{m-2}(t_2)) + \omega_1 \Delta \alpha_H \| x_{m-2} \|_{\Im} + P$$

. . .

$$D(x_1(t_1), x_1(t_2)) \le \alpha_f D(g(t_1), g(t_2)) + \omega_1 \Delta \alpha_H \| g \|_{\Im} + P.$$

Multiplying these inequalities by 1, $\alpha_f, \ldots, \alpha_f^{m-1}$, respectively, and summing them, we have

$$\begin{aligned} D(x_m(t_1), x_m(t_2)) \le & \frac{1}{1-\alpha_f} \alpha_f^m \omega_{[a,b]}(g, h) + \frac{\gamma_f}{1-\alpha_f} h + \frac{\| H \|_{\Im} \, \Delta (b-a)}{1-\alpha_f} \omega_1 + \\ & + \omega_1 \Delta \alpha_H \left(\| x_{m-1} \|_{\Im} + \alpha_f \| x_{m-2} \|_{\Im} + \ldots + \alpha_f^{m-2} \| x_1 \|_{\Im} + \alpha_f^{m-1} \| g \|_{\Im} \right) \end{aligned}. \tag{8}$$

Now we calculate $\| x_{m-1} \|_{\Im} + \alpha_f \| x_{m-2} \|_{\Im} + \ldots + \alpha_f^{m-2} \| x_1 \|_{\Im} + \alpha_f^{m-1} \| g \|_{\Im}$.

$$\| x_{m-1} \|_{\Im} = D(x_{m-1}(t), \tilde{0}) \le D(g(t), \tilde{0}) + D(f(t, x_{m-2}(t)), \tilde{0}) + D\left((FR)\int_a^b k(t, s) \odot H(s, x_{m-2}(s)\, ds, \tilde{0} \right) \le$$
$$\le \| g \|_{\Im} + \alpha_f \| x_{m-2} \|_{\Im} + \| f \|_{\Im} + N_K (b-a) \left(\alpha_H \| x_{m-2} \|_{\Im} + \| H \|_{\Im} \right) \le B \| x_{m-2} \|_{\Im} + M .$$

So, we have

$$\| x_{m-1} \|_{\Im} \le B \| x_{m-2} \|_{\Im} + M$$
$$\| x_{m-2} \|_{\Im} \le B \| x_{m-3} \|_{\Im} + M$$

. . .

$$\| x_1 \|_{\Im} \le B \| g \|_{\Im} + M$$

Multiplying these inequalities by 1, $B, \ldots, B^{m-2}$, respectively, and summing them, we have

$$\| x_{m-1} \|_{\Im} \le B^{m-1} \| g \|_{\Im} + \frac{M}{1-B}.$$

Hence

$$\| x_{m-1} \|_{\Im} + \alpha_f \| x_{m-2} \|_{\Im} + \ldots + \alpha_f^{m-2} \| x_1 \|_{\Im} + \alpha_f^{m-1} \| g \|_{\Im} \le$$
$$\le B^{m-1} \| g \|_{\Im} + \frac{M}{1-B} + B^{m-2} \alpha_f \| g \|_{\Im} + \frac{\alpha_f M}{1-B} + \ldots + B \alpha_f^{m-2} \| g \|_{\Im} + \alpha_f^{m-2} M + \alpha_f^{m-1} \| g \|_{\Im} \le$$
$$\le \frac{B^{m-1}}{1 - \frac{\alpha_f}{B}} \| g \|_{\Im} + \frac{M}{(1-B)(1-\alpha_f)} = \frac{B^m}{B - \alpha_f} \| g \|_{\Im} + \frac{M}{(1-B)(1-\alpha_f)}.$$

From (8) we obtain

$$D(x_m(t_1),x_m(t_2)) \le \frac{1}{1-\alpha_f}\alpha_f^m\omega_{[a,b]}(g,h)+\frac{\gamma_f}{1-\alpha_f}h+\frac{\|H\|_{\Im}\,\Delta}{1-\alpha_f}\omega_1+\omega_1\Delta\alpha_H\left(\frac{B^m}{B-\alpha_f}\|g\|_{\Im}+\frac{M}{(1-B)(1-\alpha_f)}\right).$$

Hence,

$$\omega_{[a,b]}(x_m(s),h) \le \frac{1}{1-\alpha_f}\omega_{[a,b]}(g,h)+\frac{\gamma_f}{1-\alpha_f}h+\Delta\left(\frac{\|H\|_{\Im}}{1-\alpha_f}+\frac{\alpha_H B^m\|g\|_{\Im}}{B-\alpha_f}+\frac{\alpha_H M}{(1-B)(1-\alpha_f)}\right)\omega_1. \quad \square$$

Lemma 2. *Under conditions* (i)-(iv) *we have* $\|\tilde{x}_m\|_{\Im}\le B\|\tilde{x}_{m-1}\|_{\Im}+M$.

Proof.

$$\|\tilde{x}_m\|_{\Im}=D(\tilde{x}_m(t),\tilde{0})\le D(g(t),\tilde{0})+D(f(t,\tilde{x}_{m-1}(t)),\tilde{0})+$$
$$+D\left(\frac{h}{2}\sum_{j=0}^{n-1}k(t,t_j)\odot H\left(t,\tilde{x}_{m-1}(t_j)\right),\tilde{0}\right)+D\left(\frac{h}{2}\sum_{j=0}^{n-1}k(t,t_{j+1})\odot H\left(t_{j+1},\tilde{x}_{m-1}(t_{j+1})\right),\tilde{0}\right)\le$$
$$\le\|g\|_{\Im}+\|f\|_{\Im}+\alpha_f\|\tilde{x}_{m-1}\|_{\Im}+\Delta N_K\alpha_H\|\tilde{x}_{m-1}\|_{\Im}+\Delta N_K\|H\|_{\Im}\le B\|\tilde{x}_{m-1}\|_{\Im}+M. \quad \square$$

Theorem 3. *Under conditions* (i)-(iv) *the iterative method* (7) *converges to a unique solution* x^* *of* (1), *and its error estimate is as follows*

$$D^*(x^*,\tilde{x}_m)\le\frac{B^m}{1-B}\left(B\|g\|_{\Im}+\|f\|_{\Im}+N_K\Delta\|H\|_{\Im}\right)+$$
$$+\frac{3\Delta N_K\alpha_H}{4(1-B)(1-\alpha_f)}\omega_{[a,b]}(g,h)+\frac{3\Delta N_K}{4(1-B)}\left(\gamma_H+\frac{\alpha_H\gamma_f}{1-\alpha_f}\right)h+$$
$$+\frac{3\Delta^2N_K\alpha_H}{4(1-B)}\left(\frac{\alpha_H B^{m-1}}{B-\alpha_f}+\frac{M+(1-B)\|H\|_{\Im}}{(1-B)(1-\alpha_f)}\right)\omega_1+\left(\alpha_H mB^{m-1}\|g\|_{\Im}+\frac{\alpha_H M+(1-B)\|H\|_{\Im}}{(1-B)^2}\right)\Delta\omega_2,$$

where $M=\|g\|_{\Im}+\|f\|_{\Im}+N_K\Delta\|H\|_{\Im}$, $\omega_2=\omega_{[a,b]}(k,\delta)=\sup\limits_{s_1,s_2\in[a,b]}\{|k(t,s_1)-k(t,s_2)|:|s_1-s_2|\le\delta\}$.

Proof. Considering iterative procedure (7), for all $t\in[a,b]$ we have

$$D(x_m(t),\tilde{x}_m(t))\le D(g(t),g(t))+D(f(t,x_{m-1}(t)),f(t,\tilde{x}_{m-1}(t)))+$$
$$+D\left((FR)\int_a^b k(t,s)\odot H(s,x_{m-1}(s)ds,\frac{h}{2}\sum_{j=0}^{n-1}\left[k(t,t_j)\odot H\left(t,\tilde{x}_{m-1}(t_j)\right)\oplus k(t,t_{j+1})\odot H\left(t_{j+1},\tilde{x}_{m-1}(t_{j+1})\right)\right]\right)\le$$
$$\le\alpha_f D(x_{m-1}(t),\tilde{x}_{m-1}(t))+$$
$$+\sum_{j=0}^{n-1}D\left((FR)\int_{t_j}^{t_{j+1}}k(t,s)\odot H(s,x_{m-1}(s)ds,\frac{h}{2}\left[k(t,t_j)\odot H\left(t,\tilde{x}_{m-1}(t_j)\right)\oplus k(t,t_{j+1})\odot H\left(t_{j+1},\tilde{x}_{m-1}(t_{j+1})\right)\right]\right)\le$$
$$\le\alpha_f D(x_{m-1}(t),\tilde{x}_{m-1}(t))+$$
$$+\sum_{j=0}^{n-1}D\left((FR)\int_{t_j}^{t_{j+1}}k(t,s)\odot H(s,x_{m-1}(s)ds,\frac{h}{2}\left[k(t,s)\odot H\left(t,x_{m-1}(t_j)\right)\oplus k(t,s)\odot H\left(t_{j+1},x_{m-1}(t_{j+1})\right)\right]\right)+$$
$$+\sum_{j=0}^{n-1}D\left(\frac{h}{2}\left[k(t,s)\odot H\left(t,x_{m-1}(t_j)\right)\oplus k(t,s)\odot H\left(t_{j+1},x_{m-1}(t_{j+1})\right)\right],\right.$$
$$\left.\frac{h}{2}\left[k(t,s)\odot H\left(t,\tilde{x}_{m-1}(t_j)\right)\oplus k(t,s)\odot H\left(t_{j+1},\tilde{x}_{m-1}(t_{j+1})\right)\right]\right)+$$
$$+\sum_{j=0}^{n-1}D\left(\frac{h}{2}\left[k(t,s)\odot H\left(t,\tilde{x}_{m-1}(t_j)\right)\oplus k(t,s)\odot H\left(t_{j+1},\tilde{x}_{m-1}(t_{j+1})\right)\right],\right.$$
$$\left.\frac{h}{2}\left[k(t,t_j)\odot H\left(t,\tilde{x}_{m-1}(t_j)\right)\oplus k(t,t_{j+1})\odot H\left(t_{j+1},\tilde{x}_{m-1}(t_{j+1})\right)\right]\right)\le$$

$$\le \alpha_f D(x_{m-1}(t),\tilde{x}_{m-1}(t)) + N_K \frac{\Delta}{2}\omega_{[a,b]}(H(s,x_{m-1}(s)),\frac{h}{2}) + \Delta N_K \alpha_H D^*(x_{m-1},\tilde{x}_{m-1}) + \Delta\omega_2 D(H\left(t,\tilde{x}_{m-1}(t)\right),\tilde{0}) \le$$

$$\le BD^*(x_{m-1},\tilde{x}_{m-1}) + \frac{3\Delta N_K}{4}\omega_{[a,b]}(H(s,x_{m-1}(s)),\frac{h}{2}) + \Delta\omega_2\alpha_H \|\tilde{x}_{m-1}\|_{\Im} + \Delta\omega_2 \|H\|_{\Im}.$$

We denote $P = \frac{3\Delta N_K}{4}\omega_{[a,b]}(H(s,x_{m-1}(s)),\frac{h}{2}) + \Delta\omega_2 \|H\|_{\Im}$.

$D^*(x_m,\tilde{x}_m) \le BD^*(x_{m-1},\tilde{x}_{m-1}) + \Delta\omega_2\alpha_H \|\tilde{x}_{m-1}\|_{\Im} + P$

$D^*(x_{m-1},\tilde{x}_{m-1}) \le BD^*(x_{m-2},\tilde{x}_{m-2}) + \Delta\omega_2\alpha_H \|\tilde{x}_{m-2}\|_{\Im} + P$

. . .

$D^*(x_1,\tilde{x}_1) \le \Delta\omega_2\alpha_H \|g\|_{\Im} + P$

Multiplying these inequalities by 1, $B,\ldots,B^{m-1}$, respectively, and summing them, we have

$$D^*(x_m,\tilde{x}_m) \le \Delta\alpha_H\omega_2\left(\|\tilde{x}_{m-1}\|_{\Im} + B\|\tilde{x}_{m-2}\|_{\Im} + \ldots + B^{m-1}\|g\|_{\Im}\right) + \frac{P}{1-B}.$$

We use Lemma 2 and get

$$\|\tilde{x}_{m-1}\|_{\Im} + B\|\tilde{x}_{m-2}\|_{\Im} + \ldots + B^{m-1}\|g\|_{\Im} \le mB^{m-1}\|g\|_{\Im} + \frac{M}{(1-B)^2}.$$

Hence,

$$D^*(x_m,\tilde{x}_m) \le \Delta\alpha_H\omega_2\left(mB^{m-1}\|g\|_{\Im} + \frac{M}{(1-B)^2}\right) + \frac{1}{1-B}\left(\frac{3\Delta N_K}{4}\omega_{[a,b]}(H(s,x_{m-1}(s)),\frac{h}{2}) + \Delta\omega_2\|H\|_{\Im}\right).$$

From Lemma 1 we obtain

$$D^*(x_m,\tilde{x}_m) \le \frac{3\Delta N_K\alpha_H}{4(1-B)(1-\alpha_f)}\omega_{[a,b]}(g,h) + \frac{3\Delta N_K}{4(1-B)}\left(\gamma_H + \frac{\alpha_H\gamma_f}{1-\alpha_f}\right)h +$$

$$+\frac{3\Delta^2 N_K\alpha_H}{4(1-B)}\left(\frac{\alpha_H B^{m-1}}{B-\alpha_f} + \frac{M+(1-B)\|H\|_{\Im}}{(1-B)(1-\alpha_f)}\right)\omega_1 + \left(\alpha_H mB^{m-1}\|g\|_{\Im} + \frac{\alpha_H M + (1-B)\|H\|_{\Im}}{(1-B)^2}\right)\Delta\omega_2.$$

Considering the inequality $D^*(x^*,\tilde{x}_m) \le D^*(x^*,x_m) + D^*(x_m,\tilde{x}_m)$ and inequality (6) we prove the theorem.□

REFERENCES

1. Kaleva, O. (1987). Fuzzy differential equations. *Fuzzy Sets and Systems,* vol. 24, pp.301-317.
2. Seikkala, S.(1987). On the fuzzy initial value problem. *Fuzzy Sets and Systems*, vol. 24, pp. 319-330.
3. Bica, A. M. (2008). Error estimation in the approximation of the solution of nonlinear fuzzy Fredholm integral equations. *Inf. Sci.*178*,* pp. 1279-1292.
4. Bede, B. and Gal, S. G. (2004).Quadrature rules for integrals of fuzzy-number-valued functions. *Fuzzy Sets and Systems,* vol. 145, pp.359-380.
5. Enkov, S.,Georgieva, A. and Nikolla, R. (2016).Numerical solution of nonlinear Hammerstein fuzzy functional integral equations. *AIP Conference Proceedings* 1789*,* 030006, http://doi.org/10.1063/1.4968452, pp. 1551-7616.
6. Goetschel, R. and Voxman W. (1986).Elementary fuzzy calculus. *Fuzzy Sets and Systems,* vol. 18, pp.31-43.
7. Wu, C.and Gong, Z.(2001). On Henstock integral of fuzzy-number-valued functions. *Fuzzy Sets and Systems,* vol. 120 , pp. 523-532 .
8. Congxin Wu and Gong Wu (1997). The supremum and infimum of these to fuzzy-numbers and its applications. *J. Math. Anal. Appl.*, 210, pp. 499-511.

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RIEMANNIAN ALMOST PRODUCT MANIFOLDS GENERATED BY A CIRCULANT STRUCTURE

DOBRINKA GRIBACHEVA, DIMITAR RAZPOPOV

Abstract: *A 4-dimensional Riemannian manifold equipped with a circulant structure, which is an isometry with respect to the metric and its fourth power is the identity, is considered. The almost product manifold associated with the considered manifold is studied. The relation between the covariant derivatives of the almost product structure and the circulant structure is obtained. The conditions for the covariant derivative of the circulant structure, which imply that an almost product manifold belongs to each of the basic classes of the Staikova-Gribachev classification, are given.*

Key words: *Riemannian metric, circulant matrix, almost product structure.*

Mathematics Subject Classification (2010). *Primary 53B20, 53C15, Secondary 15B05.*

1. Introduction

The circulant matrices and the circulant structures have application to Vibration analysis, Graph theory, Linear codes, Geometry (for example [1], [2] and [3]). Riemannian manifolds equipped with a circulant structure, whose fourth power is the identity were considered in [4] and [5]. In particular case, such manifolds could be Riemannian almost product manifolds. The systematic development of the theory of Riemannian manifolds M with a metric g and an almost product structure P was started by K. Yano in [6]. In [7] A. M. Naveira classified the almost product manifolds (M,P,g) with respect to the covariant derivative of P. The Riemannian almost product manifolds (M,P,g) with zero trace of the structure P were classified with respect to the covariant derivative of P by $M.$ Staikova and K. Gribachev in [8]. The basic classes in this classification are W_1, W_2 and W_3. The class $W_0 = W_1 \cap W_2 \cap W_3$ was called the class of Riemannian P-manifolds. Our purpose is to obtain characteristic conditions for each of these classes according to the circulant structure. In the present paper we consider a 4-dimensional differentiable manifold M with a Riemannian metric g and a circulant structure Q, whose fourth power is the identity and Q acts as an isometry on g. This manifold we will denote by (M,Q,g). We study the Riemannian almost product manifold (M,P,g) where $P=Q^2$. The paper is organized as follows. In Sect. 1, some necessary facts about considered manifolds (M,Q,g) and (M,P,g) are recalled. In Sect. 2, the relation between the covariant derivative of P and the covariant derivative of Q is obtained. In Sect. 3, the conditions for the covariant derivative of Q, which imply that (M,P,g) belongs to each of the basic classes of the Staikova-Gribachev classification, are given.

2. Preliminaries

Let M be a 4-dimensional Riemannian manifold equipped with a metric g and an endomorphism Q in the tangent space T_pM at an arbitrary point p on M. Let the coordinates of Q with respect to some basis $\{e_i\}$ of T_pM form the circulant matrix

$$Q = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \end{pmatrix}. \tag{1.1}$$

Then Q satisfies the equalities

$$Q^4 = id,\ Q^2 \neq \pm id.$$

Let the structure Q be compatible with the metric g, i.e.

$$g(Qx,Qy) = g(x,y). \tag{1.2}$$

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Here and anywhere in this work x, y, z, u will stand for arbitrary elements of the algebra of the smooth vector fields on M or vectors in T_pM. The Einstein summation convention is used, the range of the summation indices being always $\{1, 2, 3, 4\}$.

Further, we consider a manifold (M, Q, g) equipped with a metric g and a structure Q, which satisfy (1.1) and (1.2). This manifold is studied in [4] and [5].

We denote $P = Q^2$. In [4] it is noted that the manifold (M, P, g) is a Riemannian manifold with an almost product structure P, because $P^2 = id$, $P \neq \pm id$ and $g(Px, Py) = g(x, y)$. Moreover $trP = 0$. For such manifolds is valid the Staikova-Gribachev classication given in [8]. This classification was made with respect to the tensor F of type $(0,3)$ and the Lee form α, which are defined by

$$F(x, y, z) = g((\nabla_x P)y, z),$$
$$\alpha(x) = g^{ij} F(e_i, e_j, x). \qquad (1.3)$$

Here ∇ is the Levi-Civita connection of g, and g^{ij} are the components of the inverse matrix of g with respect to $\{e_i\}$.

The basic classes of the Staikova-Gribachev classification are W_1, W_2 and W_3. Their intersection is the class of Riemannian P-manifolds W_0. A manifold (M, P, g) belongs to each of these classes if it satisfies the following conditions:

$$W_0: \quad F(x, y, z) = 0, \qquad (1.4)$$

$$W_1: \quad F(x, y, z) = \frac{1}{4}((g(x, y)\alpha(z) + g(x, z)\alpha(y) - g(x, Py)\alpha(Pz) - g(x, Pz)\alpha(Py)), \qquad (1.5)$$

$$W_2: \quad F(x, y, Pz) + F(y, z, Px) + F(z, x, Py) = 0, \quad \alpha(z) = 0, \qquad (1.6)$$

$$W_3: \quad F(x, y, z) + F(y, z, x) + F(z, x, y) = 0. \qquad (1.7)$$

It is well known that ∇ satisfies the equalities:

$$(\nabla_x Q)y = \nabla_x Qy - Q\nabla_x y \qquad (1.8)$$

$$(\nabla_x P)y = \nabla_x Py - P\nabla_x y \qquad (1.9)$$

Let the structure Q of a manifold (M, Q, g) be the covariant constant, i.e. $(\nabla_x Q)y = 0$. Then, from (1.8) we obtain successively $\nabla_x Qy = Q\nabla_x y$, $\nabla_x Q^2 y = Q\nabla_x Qy = Q^2\nabla_x y$, thus we get $\nabla_x Py = P\nabla_x y$.
Therefore, from (1.9) it follows $(\nabla_x P)y = 0$.
By using the latter equality and (1.3) we find (1.4). Hence the next theorem is valid.

Theorem 1.1. If the structure Q of the manifold (M, Q, g) satisfies $\nabla Q = 0$, then (M, P, g) belongs to the class W_0.

As it is known the curvature tensor R of ∇ is determined by

$$R(x, y)z = \nabla_x \nabla_y z - \nabla_y \nabla_x z - \nabla_{[x,y]} z.$$

The corresponding tensor of type $(0,4)$ is defined as follows $R(x, y, z, u) = g(R(x, y)z, u)$.

Proposition 1.2. [5] If the structure Q of the manifold (M, Q, g) satisfies $\nabla Q = 0$, then for the curvature tensor R it is valid

$$R(x, y, Qz, Qu) = R(x, y, z, u).$$

We substitute Qz for z and Qu for u in the latter equality, and using Theorem 1.1, we obtain

Corollary 1.3. If the manifold (M, P, g) belongs to W_0, then the curvature tensor R satisfies,

$$R(x, y, Pz, Pu) = R(x, y, z, u).$$

i.e. R is a Riemannian P-tensor.

3. Relation between F and $\overline{F}$

We consider manifolds (M, Q, g) and (M, P, g), where $P = Q^2$. We define a tensor $\overline{F}$ of type $(0,3)$, as follows

$$\overline{F}(x, y, z) = g((\nabla_x Q)y, z),$$
$$\overline{\alpha}(x) = g^{ij}\overline{F}(e_i, e_j, x), \qquad (2.1)$$

where $\overline{\alpha}$ is the Lee form associated to $\overline{F}$.

Theorem 2.1. For the tensors F on the manifold (M,P,g) and $\overline{F}$ on the manifold (M,Q,g) the following equalities are valid:

$$\overline{F}(x,y,z)+\overline{F}(x,Qy,Qz)=F(x,y,Qz), \qquad (2.2)$$

$$\overline{F}(x,y,Q^3z)+\overline{F}(x,Qy,z)=F(x,y,z). \qquad (2.3)$$

Proof. From (1.3) and (1.9), due to $P=Q^2$, we get

$$\begin{aligned}F(x,y,z)&=g(\nabla_x Py-P\nabla_x y,z)\\&=g(\nabla_x Q^2y-Q^2\nabla_x y,z),\end{aligned}$$

i.e. $F(x,y,z)=g(\nabla_x Q^2y-Q^2\nabla_x y,z)$.
Then

$$F(x,y,Qz)=g(\nabla_x Q^2y,Qz)-g(Q^2\nabla_x y,Qz),$$

from which, because of (1.2) we have

$$\begin{aligned}F(x,y,Qz)&=g(\nabla_x Q^2y,Qz)\\&\quad-g(Q\nabla_x y,z),\end{aligned} \qquad (2.4)$$

From (1.8) and (2.1) we obtain

$$\begin{aligned}\overline{F}(x,y,z)&=g(\nabla_x Qy,z)\\&\quad-g(Q\nabla_x y,z),\end{aligned} \qquad (2.5)$$

and consequently

$$\begin{aligned}\overline{F}(x,Qy,Qz)&=g(\nabla_x Q^2y,Qz)\\&\quad-g(\nabla_x Qy,z).\end{aligned} \qquad (2.6)$$

Taking the sum of (2.5) and (2.6) we get

$$\begin{aligned}&\overline{F}(x,y,z)+\overline{F}(x,Qy,Qz)\\&\qquad=g(\nabla_x Q^2y,Qz)-g(Q\nabla_x y,z).\end{aligned}$$

Then, having in mind (2.4), we find (2.2). Now we substitute Q^3z for z into (2.2) and using (1.2), we find (2.3). Hence the next theorem is valid.

Theorem 2.2. The manifold (M,P,g) belongs to W_0 if and only if Q satisfies

$$(\nabla_x Q)Qy=-Q(\nabla_x Q)y. \qquad (2.7)$$

Proof. Let $(M,P,g)\in W_0$, i.e. $F=0$. Then, due to (2.2), it follows

$$\overline{F}(x,Qy,Qz)=-\overline{F}(x,y,z).$$

The latter equality and (2.1) imply (2.7).

Vice versa. According to (2.1) and (2.7) we find $\overline{F}(x,y,z)+\overline{F}(x,Qy,Qz)=0$.
Then, due to (2.2), it follows $F=0$, i.e. the manifold $(M,P,g)\in W_0$.

4. Properties of $\overline{F}$

Theorem 3.1. For the tensor $\overline{F}$ on (M,Q,g) the following equalities are valid:

$$\begin{aligned}&\overline{F}(x,y,Q^3z)+\overline{F}(x,Qy,z)\\&=\overline{F}(x,z,Q^3y)+\overline{F}(x,Qz,y),\end{aligned} \qquad (3.1)$$

$$\begin{aligned}&\overline{F}(x,y,z)+\overline{F}(x,Qy,Qz)\\&+\overline{F}(x,Q^2y,Q^2z)+\overline{F}(x,Q^3y,Q^3z)=0,\end{aligned} \qquad (3.2)$$

$$\overline{F}(x,y,Qz)=-\overline{F}(x,z,Qy), \qquad (3.3)$$

$$\overline{F}(x,y,Q^3z)=-\overline{F}(x,Q^2z,Qy). \qquad (3.4)$$

Proof. It is known that the tensor F determined by (1.3) has the properties:

$$F(x,y,z)=F(x,z,y), \qquad (3.5)$$

$$F(x,Py,Pz)=-F(x,y,z). \qquad (3.6)$$

Equalities (2.3) and (3.5) imply (3.1).
From (2.3) and (3.6) we get

$$\begin{aligned}&\overline{F}(x,Qy,z)+\overline{F}(x,y,Q^3z)\\&+\overline{F}(x,Q^3y,Q^2z)+\overline{F}(x,Q^2y,Qz)=0.\end{aligned}$$

In the latter equality we substitute Qz for z, and we obtain (3.2). Further, we substitute Qz for z into (2.5) and we have

$$\begin{aligned}\overline{F}(x,y,Qz) &= g(\nabla_x Qy,Qz) - g(\nabla_x y,z)\\ &= xg(Qy,Qz) - g(Qy,\nabla_x Qz)\\ &\quad - xg(y,z) + g(y,\nabla_x z)\\ &= -g(\nabla_x Qz,Qy) + g(\nabla_x z,y)\\ &= -g(\nabla_x Qz,Qy) + g(Q\nabla_x z,Qy)\\ &= -g(\nabla_x Qz - Q\nabla_x z,Qy) = -\overline{F}(x,z,Qy).\end{aligned}$$

Therefore we get (3.3). From (3.3) directly follows (3.4). Using (1.5), (2.1) and (2.2) we obtain the following

Theorem 3.2. The manifold (M,P,g) belongs to W_1 if and only if the tensor $\overline{F}$ on (M,Q,g) satisfies the following conditions:

$$\begin{aligned}&\overline{F}(x,y,Q^3 z) + \overline{F}(x,Qy,z)\\ &= \frac{1}{4}(g(x,y)\alpha(z) + g(x,z)\alpha(y)\\ &+ g(x,Q^2 y)\alpha(Q^2 z) + g(x,Q^2 z)\alpha(Q^2 y),\end{aligned}$$

$$\overline{\alpha}(Q^3 z) + g^{ij}\overline{F}(e_i,Qe_j,x) = \alpha(z).$$

We apply (2.2) and (2.3) into (1.6) and we find

$$F(x,y,Pz) = \overline{F}(x,y,Qz) + \overline{F}(x,Qy,Q^2 z).$$

Therefore we arrive at the following

Theorem 3.3. The manifold (M,P,g) belongs to W_2 if and only if the tensor $\overline{F}$ on (M,Q,g) satisfies the following condition

$$\begin{aligned}&\overline{F}(x,y,Qz) + \overline{F}(x,Qy,Q^2 z)\\ &+ \overline{F}(y,z,Qx) + \overline{F}(y,Qz,Q^2 x)\\ &+ \overline{F}(z,x,Qy) + \overline{F}(z,Qx,Q^2 y) = 0.\end{aligned}$$

We apply (2.3) into (1.7) and we have

Theorem 3.4. The manifold (M,P,g) belongs to W_3 if and only if the tensor $\overline{F}$ on (M,Q,g) satisfies the following condition

$$\begin{aligned}&\overline{F}(x,y,Q^3 z) + \overline{F}(x,Qy,z)\\ &+ \overline{F}(y,z,Q^3 x) + \overline{F}(y,Qz,x)\\ &+ \overline{F}(z,x,Q^3 y) + \overline{F}(z,Qx,y) = 0.\end{aligned}$$

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References

1. S. I. R. Costa, J. E. Strapasson, M. M. S. Alves, T. B. Carlos: Circulant graphs and tessellations on at tori, *Linear Algebra Appl.*, 432(1) (2010) 369-382.
2. A. Kaveh, H. Rahami: Block circulant matrices and application in free vibration analysis of cyclically repetitive structures, *Acta Mech.*, 217 (2011) 51-62.
3. R. M. Tanner, D. Sridhara, A. Sridharan, T. Fuja, D. J. Costello: LDPC Block and convolutional codes based on circulant matrices, *IEEE Trans. Inf. Theory,* 50(12) (2004) 2966-2984
4. I. Dokuzova: Curvature properties of 4-dimensional Riemannian manifolds with a circulant structure. *J. Geom.* (2016). doi:10.1007/s00022-016-0356-9
5. D. Razpopov: Four-dimensional Riemannian manifolds with two circulant structures, In: *Proc. of 44-th Spring Conf. of UBM*, SOK "Kamchia", Bulgaria (2015) 179-185.
6. K. Yano: Differential geometry on complex and almost complex spaces. *Pergamont Press,* Oxford, (1965)
7. A. M. Naveira: A classification of Riemannian almost product manifolds, *Rend. Math.* 3 (1983) 577-592.
8. M. Staikova, K. Gribachev: Cannonical connections and conformal invariantson Riemannian almost product manifolds. *Serdica Math. J.* 18 (1992) 150-161.

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VARIATIONAL METHOD FOR A CLASS OF HIGHER ORDER HYPERBOLIC EQUATIONS

G.P.PASKALEV

Abstract. *For considered mixed problem for a higher order hyperbolic equation a Shalov-type symmetrizing operator[4] is build. Equivalence of the problem to the problem of minimization of quadratic functional is proved. Existence and uniqueness of the generalized solution are obtained.*

Key words: *higher order equation, mixed problem, variatonal method, Seeley's extension formula, anisotropic space.*

1. Introduction

Let $D \subset R^m, m \geq 1$ be a bounded domain with a boundary ∂D and $x = (x_1, ..., x_m)$, $\Gamma_0 = D \times \{0\}, \sigma = \partial D \times (0,T), G_T = D \times (0,T)$, $T > 0, n \geq 2$, $\xi' = (\xi_1, ..., \xi_n)$.

$$\sum_{|\alpha|=|\beta|=n-1} a_{\alpha\beta} (\xi')^\alpha (\xi')^\beta \geq C_1 \sum_{\xi'} (\xi')^2 \ \forall \xi',$$

$C_1 = const. > 0$, $a_{\alpha\beta}$ are real constants and

$$a_{\alpha\beta} = a_{\beta\alpha} \ \forall \alpha, \beta : |\alpha| = |\beta| = n .$$

Let $A \neq 0, \ C > 0.$

Consider in G_T the following problem. To find a solution to the equation

$$Lu = f(t, x), \tag{1}$$

where

$$Lu \equiv \sum_{|\alpha|=|\beta|=n} a_{\alpha\beta} D_x^\alpha D_x^\beta u - D_t^{2n} u + AD_t u + Cu,$$

satisfying the boundary conditions

$$D_x^\alpha u\big|_\sigma = 0, |\alpha| \leq n-1; \ D_t^l u\big|_{\Gamma_0} = 0, l = \overline{0,2n-1}. \tag{2}$$

2.Function spaces and definition

Let $\widetilde{C}^\infty(\overline{G_T})$ be the space of infinitely smooth in $\overline{G_T}$ functions, satisfying the boundary conditions (2). Define the space $\widetilde{H}^{2n-1,n}(G_T)$ as a closure of $\widetilde{C}^\infty(\overline{G_T})$ with respect to the norm

$$\|u\|^2_{2n-1,n,T} = \int_{G_T} \Big(\sum_{\frac{j}{2n-1} + \frac{|\alpha|}{n} \leq 1} D_t^j D_x^\alpha u \Big)^2 dtdx. \tag{3}$$

Let $G_{2T} = D \times (0,2T)$ and let by definition the space $\widetilde{C}^\infty(\overline{G_{2T}})$ be composed of extensions of the functions, belonging to $\widetilde{C}^\infty(\overline{G_T})$, obtained by the linear Seeley's extension formula [6]. Then there exists a positive constant C_1, non depending on u, such that

$$\|U\|_{2n-1,n,2T} \leq C_1 \|u\|_{2n-1,n,T} \ \forall u \in \widetilde{C}^\infty(\overline{G_T}),$$

where U is the extension, corresponding to u. Define $\widetilde{H}^{2n-1,n}(G_{2T})$ as a closure of $\widetilde{C}^\infty(\overline{G_{2T}})$ with respect to the norm (3). Denote by $L_2^{ref}(G_{2T})$ the closure of $\widetilde{C}^\infty(\overline{G_{2T}})$ by the L_2-norm and by F the corresponding extension to f.

If $\xi = (\xi_1, ..., \xi_{n+1}), \xi' = (\xi_1, ..., \xi_n)$, let we enter the operator

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$$KV=(2\pi)^{-\frac{n+1}{2}}\int_{R^{n+1}}B(\xi)e^{i(\sum_{j=1}^{n}x_j\xi_j+t\xi_{n+1})}\hat{V}(\xi)d\xi,$$

$$B(\xi)=\frac{\sum_{\frac{j}{2n-1}+\frac{|\alpha|}{n}\le 1}(-i)^{j+|\alpha|}(\xi')^{2|\alpha|}(\xi_{n+1})^{2j}}{\sum_{|\alpha|=|\beta|=n}a_{\alpha\beta}(\xi')^{\alpha}(\xi')^{\beta}+C+iA\xi_{n+1}},\qquad(4)$$

where $V\in C_0^{\infty}(R^{n+1}),V|_{G_{2T}}\in\widetilde{C}^{\infty}(\overline{G_{2T}})$,

and $\hat{V}(\xi)$ is the Fourier transform of V.

We note that for obtained extensions and some positive constant we have

$$\|V\|_{2n-1,n,R^{n+1}}\le C_2.\|V\|_{2n-1,n,2T}\quad\forall V\in\widetilde{C}^{\infty}(\overline{G_{2T}}).$$

Now for $U,V\in\widetilde{C}^{\infty}(\overline{G_{2T}})$,by integration by parts from (4) we have

$$(LU,KV)_{0,2T}=\int_{G_{2T}}(\sum_{|\alpha|=|\beta|=n}a_{\alpha\beta}D_x^{\alpha}D_x^{\beta}U-$$

$$D_t^{2n}U+AU+CU)KVdtdx=$$

$$\int_{G_{2T}}U[\sum_{|\alpha|=|\beta|=n}a_{\alpha\beta}D_x^{\beta}D_x^{\alpha}KV-D_t^{2n}KV+AD_t(KV)+$$

$$C(KV)]dtdx=\int_{G_{2T}}\sum_{\frac{j}{2n-1}+\frac{|\alpha|}{n}\le 1}(D_t^jD_x^{\alpha}U.D_t^jD_x^{\alpha}V)dtdx.$$

Hence

$$(LU,KV)_{0,2T}=[U,V]_{2n-1,n,2T}\forall U,V\in\widetilde{C}^{\infty}(\overline{G_{2T}}).$$

Changing the places of U and V, obtain

$$(LV,KU)_{0,2T}=[U,V]_{2n-1,n,2T}\forall U,V\in\widetilde{C}^{\infty}(\overline{G_{2T}}).$$

The last two equalities mean that the operator L is $K-symmetric$ [4].

For $U\equiv V$ we have

$$(LU,KU)_{0,2T}=\|U\|^2_{2n-1,n,2T}\quad\forall U\in\widetilde{C}^{\infty}(\overline{G_{2T}}),$$

which means that L also is $K-positive.$

Definition: *The function $u\in\widetilde{H}^{2n-1,n}(G_T)$ is called a generalized solution to the problem (1),(2) if there exists an element $U\in\widetilde{H}^{2n-1,n}(G_{2T}),\ U|_{G_T}=u,$ such that*

$$(F,KV)_{0,2T}=[U,V]_{2n-1,n,2T}\forall V\in\widetilde{H}^{2n-1,n}(G_{2T}).$$

3.Main results

Theorem 1: *The function $u\in\widetilde{H}^{2n-1,n}(G_T)$ is a generalized solution to the problem (1),(2) if and only if the corresponding element U (from above* ***Definition*** *) realizes the minimum of the quadratic functional*

$$D[U]=\|U\|^2_{2n-1.n,2T}-2(F,KU)_{0,2T}\qquad(5)$$

on the space $\widetilde{H}^{2n-1,n}(G_{2T})$.

Theorem 2: *For each function $F\in L_2^{ref}(G_{2t})$ there exists a unique solution to the variational problem to minimize the quadratic functional (5) on the space $\widetilde{H}^{2n-1,n}(G_{2T})$. The considered problem is correctly posed - to the small variance of the function F in $L_2^{ref}(G_{2T})$ corresponds a small variance of the solution in $\widetilde{H}^{2n-1,n}(G_{2T})$.*

4. Proofs

In order to prove the above theorems using the Theorem 1.3 from [7, p.367],we obtain the next estimate.

Lemma: *There exists a positive constant $C>0$, such that*

$$\|KV\|_{0,2T}\le C.\|V\|_{2n-1,n,2T}\quad\forall V\in\widetilde{C}^{\infty}(\overline{G_{2T}}).$$

The proofs follow the scheme, used in [1-3].

For elliptic equations the variational approach is well known but for hyperbolic equation (string equation) for the first time variational method for boundary value problem is constructed in [5]. For multidimensional parabolic and ultraparabolic equations the considered variational method is presented in [2,3].The present paper generalizes the results, obtained in [1].

REFERENCES

1. **Paskalev, G.P.** (2013) Shalov's variational method for the multidimensional wave equation. *Journal of the Technical University at Plovdiv,* "Fundamental Sciences and Applications", V.19, P.141-145.

2. **Paskalev, G. P.** (1999) Variational method for the multidimensional heat equation. *Journal of the Technical University at Plovdiv,* "Fundamental Sciences and Applications", V.8, P.69-78

3. **Paskalev, G.P.** (1992)On the investigation of boundary value problem for ultraparabolic type equation with constant coeficients using a variational method. (Russ.), *Diff. Uravnenia,* Minsk, V.28, no.9, P.1640-1641.

4. **Shalov, V.M.(**1963) A solving of non selfadjoint equations by the use the variational method. (Russ.), Dokl. A. N. SSSR, V.151, no.3, P.511-512.

5. **Shalov, V.M.** (1965**)** A principle of the minimum of quadratic functional. (Russ.),*Diff. Uravnenia,* Minsk, V.1,no.10,P.1338-1365.

6. **Seeley, R.T.** (1964) Extension of $C^{\infty}-$ functions, defined in a half space. , Proc. Amer. Math. Soc. 15, P.625-626.

7. **Taylor, M.** (1985) *Pseudodifferential operators*, (Russ.), Mir, Moskva.

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МАТЕМАТИЧЕСКИ МЕТОДИ ЗА ОЦЕНКА НА СРЕДНИЯ ДОБИВ НА СПАНАК В ДЪРЖАВИТЕ-ЧЛЕНКИ НА ЕВРОПЕЙСКИЯ СЪЮЗ ЗА ПЕРИОДА 1961-2014 Г.

НЕЛИ КЕРАНОВА

Резюме: *В настоящото изследване е направена математическа оценка на добива на спанак за периода 1961-2014 г. за всички страни-членки на Европейския съюз. Установи се, че Холандия (25,73 t/ha) и Белгия (20,8 t/ha) са страните с най-висок добив от тази култура. България (8,64 t/ha) и Румъния (7,53 t/ha) са страни, в които добивът от спанак е най-нисък. Средство за постигане на поставената цел е съставяне на математически модел, чрез който да се анализират статистическите данни и да се направи оценка на добива на спанак в отделните държави. Направена е класификация и групиране на държавите от ЕС чрез йерархичен клъстерен анализ според средния добив на разглежданата земеделска култура. Получена е оценка на добива за съответния период чрез еднофакторен дисперсионен анализ.*

Ключови думи: *среден добив, спанак, математически модел, йерархичен клъстер анализ, еднофакторен дисперсионен анализ ANOVA*

MATHEMATICAL METHODS FOR ESTIMATING THE AVERAGE YIELD OF SPINACH IN MEMBER STATES OF THE EUROPEAN UNION FOR THE PERIOD 1961-2014

NELI KERANOVA

Abstract: *This study made mathematical evaluation of the yield of spinach for the period 1961-2014 in all member states of the European Union. It was found that the Netherlands (25,73 t/ha) and Belgium (20,8 t/ha) are the countries with the highest yield of this crop. Bulgaria (8,64 t/ha) and Romania (7,53 t/ha) are the countries where the yield of spinach is the lowest. The means to achieve the set goal is generating a mathematical model for analyzing the statistical data and evaluating the yield of spinach in each country. There is a classification and grouping of the EU countries through hierarchical cluster analysis based on the average yield of the examined crop. There is an assessment of the yield for the relevant period by a single-factor analysis of variance.*

Key words: *average yield, spinach, mathematical model, hierarchical cluster analysis, single-factor analysis ANOVA*

1. Въведение

За родина на спанака се смята Югозападна Азия, по-точно Персия. Той води началото си още от средните векове. Първоначално се е отглеждал в Китай, а много по-късно и в Европа – Франция, Испания, Англия. Той е ценна зеленчукова култура, разпространена и у нас. Причина за това са качествата, които притежава: високо

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съдържание на много витамини от групите А, В и С, минерални соли, белтъчини, желязо, натрий, калий и протеини, което го превръща и в лечебно средство при редица заболявания.

В тази работа се анализира състоянието на производството на спанак, както в България, така и в страните от Европейския съюз. Периодът, който се разглежда, обхваща времето от 1961 г. до 2014 г. Основната цел на изследването е да се направи математическа оценка, основана на статистическите данни за среден добив на спанак за 28-те държави от ЕС.

2. Материали и методи

Настоящото изследване е разработено с данни за произведено количество спанак, както и за размера на засятите площи, извлечени от база данни FAOSTAT. Оценката на статистическите данни е направена на базата на размера на средния добив за съответната европейска държава за периода 1961-2014 г. Използван е методът за междугруповото свързване, а критерият, по който се осъществява той, е евклидовото разстояние. Известно е, че при метода на междугруповото свързване разстоянието между два клъстера А и В се дефинира като средната стойност на nA.nB на брой разстояния между nA точки от А и nB точки от В:

$$D(A,B) = \frac{1}{n_A n_B} \sum_{i=1}^{n_A} \sum_{j=1}^{n_B} d(x_i, x_j) \qquad (1)$$

където

$$d(x_i, x_j) = \sqrt{\sum_{m=1}^{p} (x_{im} - x_{jm})^2} \qquad (2)$$

$i, j = \overline{1,n}$ е обикновеното евклидово разстояние между два вектора $x_i(x_{i1}, x_{i2}, ..., x_{ip})$ и $x_j(x_{j1}, x_{j2}, ..., x_{jp})$. Построена е дендрограма, чрез която се представят графично образуваните клъстери. Направен е и еднофакторен дисперсионен анализ [1].

Обработката на данните е извършена чрез статистическата програма IBM Statistics SPSS 23 [2].

3. Резултати и обсъждане

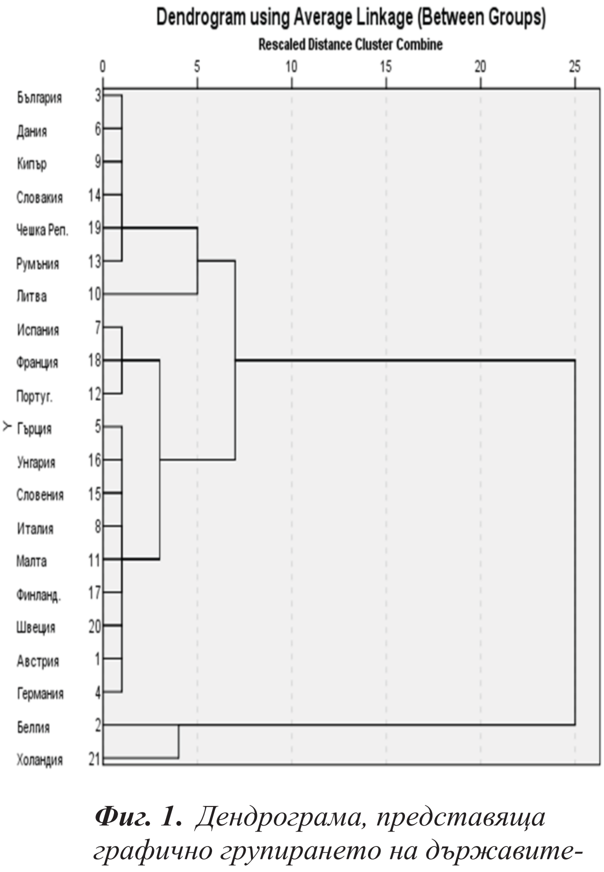
След направения клъстерен анализ става ясно, че според показателя „среден добив на спанак“ разглежданите държави от Европейския съюз могат да бъдат групирани в шест клъстера, които ясно се очертават на дендрограмата на Фигура 1.

Тъй като при клъстерния анализ не се правят никакви тестове за статистическа значимост, ще приложим еднофакторен дисперсионен анализ.

Според резултатите от теста за хомогенност на Ливин можем да твърдим, че данните за добив на спанак в разглежданите държави са с равни дисперсии и същите могат да бъдат сравнявани по избрания критерий. Изчислената стойност на критерия на Фишер е 62,903.

Общата статистическа оценка показва ниво на значимост, по-малко от грешката α = 0,05, което е достатъчно да считаме, че средните добиви от спанак на 28-те страни-членки на ЕС притежават статистически различия и че общият модел е статистически значим.

На Таблица 1 е представена оценката на средния добив на спанак по страни в зависимост от принадлежността им към съответния клъстер.



Фиг. 1. *Дендрограма, представяща графично групирането на държавите-членки на ЕС в клъстери според средния добив на спанак*

Клъстери 5 и 6 включват страните с най-висок среден добив от спанак – Белгия и Холандия. Тези два клъстера могат да бъдат обобщени в по-голям клъстер на евклидово разстояние 4 единици.

Клъстер 2 включва следващите по обем на производство със среден добив, статистически различен от средния добив на страните от клъстери 5 и 6. Това са Испания, Франция и Португалия.

С най-нисък добив на спанак са страните от клъстери 1 и 4.

Номер на клъстер	Държава	Среден добив	Станд. откло-нение
1	Дания	10,12 hij	2,44
	Кипър	8,73 jk	3,78
	България	8,64 jk	2,91
	Словакия	9,02 jk	2,9
	Чешка реп.	9,61 ij	2,69
	Румъния	7,53 k	1,08
2	Испания	16,7 c	2,01
	Франция	16,67 c	2,68
	Португалия	16,41 cde	1,49
3	Гърция	11,52 ghi	3,17
	Унгария	11,62 ghi	5,68
	Словения	11,3 ghi	2,01
	Италия	12,54 fg	1,1
	Малта	12,01 gh	0,68
	Финландия	13,17 efg	3,41
	Швеция	13,21 efg	3,42
	Австрия	14,77 cde	6,59
	Германия	14,46 def	2,67
4	Литва	3,68 l	1,84
5	Белгия	20,8 b	2,96
6	Холандия	25,73 a	5,67

Таблица 1. *Оценка на средните добиви на страни от ЕС по метода на Duncan, a,b,c,… – степен на доказаност при ниво на значимост α = 0,05*

Страната с най-висок добив на спанак е Холандия, но от Таблица 1 е видно, че статистическият показател за варирането е един от най-големите в сравнение с тези на останалите държави (5,67). Това означава, че получените добиви не са устойчиви във времето. Същевременно Литва е държавата с най-нисък среден добив, но има сравнително устойчиви добиви във времето.

На Фигура 2 са отразени действителните линии и трендовете за добива от спанак на България, Гърция и Кипър. За България се очертават четири периода, отличаващи се един от друг по посока на изменение на производството на спанак. Първият период обхваща 1961-1979 г. Характеризира се с неособено големи пикове и падове, но с лека тенденция на нарастване. Вторият период е 1980-1990 г., в който се наблюдават резки пикове и падове, но отново тенденцията е към задържане на производството.

В началото на третия период (1991-2000 г.) се наблюдава рязко спадане на производството и стабилизирането му до края на периода. Последният период обхваща 2001-2014 г.

Целият период се характеризира с резки спадове и пикове. Трендът за производството на спанак в България се описва с полином от втора степен:

$$y = -0{,}005x^2 + 20{,}103x - 20024 \qquad (3)$$

и показва намаляваща тенденция. Коефициентът на детерминация (23%) показва слабо изменение на добива във времето.

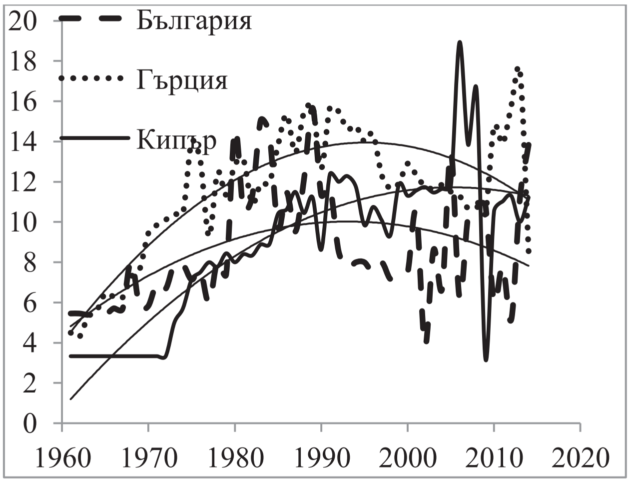
Производството на спанак в Гърция може да бъде разделено на три периода. Първият обхваща времето от 1961 до 1991 г. Началото на периода се характеризира с нарастваща тенденция на производството на спанак, със слабо изразени пикове и спадове.

Втората половина на този период е със силно изразени пикове и спадове, но отново с нарастваща тенденция на производството. Вторият период е 1992-2009 г. Той е с изразена намаляваща тенденция, със слаби пикове и спадове. Последният период е 2010-2014 г. Тук имаме силно изразена намаляваща тенденция. Трендът за производството на спанак в Гърция е описан с полином от втора степен:

$$y = -0{,}08x^2 + 32{,}109x - 32018\ . \qquad (4)$$

Изменението в добива на спанак е в силна зависимост от периода. Основание за това дава коефициентът на детерминация, който е 69%.

На представения тренд за производството на спанак в Кипър ясно се открояват три периода. Първият е от 1961 г. до 1972 г., когато количествата произведена



Фигура 2*. Графично представяне на изменението на средния добив от спанак за периода 1961-2014 г. за България, Гърция и Кипър*

продукция са с постоянни стойности. Вторият период обхваща 1973-2004 г. Като цяло периодът се характеризира с постепенно нарастване добивът на спанак, както и със слабо изразени спадове и пикове на добиваните количества продукция. Последният период започва от 2005 г. и продължава до края на 2014 г. В продължение на тези десет години има резки спадове и пикове на производство на спанак. Това се потвърждава и от коефициента на детерминация, който за Кипър е 72%. Както в България и Гърция, така и тук трендът за производство на спанак се описва с полином от втора степен:

$$y = -0{,}0054x^2 + 21{,}617x - 21661. \quad (5)$$

4. Заключение

След направения йерархичен клъстерен анализ се установи, че страните-членки на Европейския съюз се групират в шест клъстера. Разпределението на държавите в клъстерите се потвърждава и от проведения еднофакторен дисперсионен анализ. България е в първи клъстер, в който се намират държави с по-нисък среден добив на спанак. Оказва се, че в държавите от Източна Европа производството на спанак е ниско. Това би могло да се обясни както с водената държавна политика към производителите на тази култура, така и с географското разположение на съответната страна. Това се доказва и от графичното представяне на добива в България, Кипър и Гърция. При трите държави нямаме устойчива тенденция на нарастване на производството за целия период от 1961 г. до 2014 г., а са характерни спадове и пикове в кратки интервали от време.

ЛИТЕРАТУРА

1. Barov, V. (1982). Analysis and schemes of the Polish experience, NAPS, Sofia.

2. Haralampiev, K. (2009) *Working with data in SPSS*, Publishing House „St. Kl. Ohridski“, Sofia

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МОДЕЛИРАНЕ НА ДАННИ ОТ ЖИВОТНОВЪДНИЯ СЕКТОР В БЪЛГАРИЯ, СВЪРЗАНИ С ОТГЛЕЖДАНЕТО НА СЕЛСКОСТОПАНСКИ ЖИВОТНИ ЗА ПЕРИОДА 2000-2014 Г.

НЕЛИ КЕРАНОВА

Резюме: *Основната цел на настоящата работа е да се направи оценка и анализ на статистически данни от сектор „Животновъдство". Те се отнасят до брой отглеждани селскостопански животни /говеда, биволи, свине, овце и кози/ в България за периода от 2000 г. до 2014 г. При обработката на данните е извършен йерархичен клъстерен анализ и са построени математически модели, отразяващи връзките между изследваните обекти. При всички животни има тенденция на чувствителен спад в техния брой. Изключение прави секторът, свързан с отглеждане на биволи, където се наблюдава тенденция на слабо повишаване на интереса на фермерите.*

Ключови думи: *йерархичен клъстер анализ, математически модели, селскостопански животни*

DATA MODELING IN THE AGRICULTURAL SECTOR IN BULGARIA, RELATED TO THE BREEDING OF SOME FARM ANIMALS FOR THE PERIOD 2000-2014

NELI KERANOVA

Abstract: *The main objective of this work is to assess and analyze statistical data in the stock-breeding sector. They refer to the number of farmed livestock /cattle, buffaloes, pigs, sheep and goats/ in Bulgaria for the period 2000 to 2014. During the data processing a hierarchical cluster analysis is made and mathematical models are built, reflecting the link between the researched objects. There is a tendency to a substantial fall in the number of all animals. The sector related to the breeding of buffalos is an exception, with a tendency towards slightly increased interest of farmers.*

Key words: *hierarchical cluster analysis, mathematical models, livestoc*

1. Въведение

България е страна с дългогодишни традиции и опит в развитието на животновъдството. В настоящата работа са установени връзките между брой отглеждани селскостопански животни (говеда, биволи, свине, овце и кози) в България и годините на изследване (2000-2014 г.). Направен е йерархичен клъстерен анализ по метода на междугруповото свързване. Построени са регресионни модели, отразяващи връзките между разглежданите обекти. В резултат на извършените анализи се установи, че съществуват силни връзки между годините на проведеното изследване и броя на разглежданите селскостопански животни. При говедата, свинете, овцете и козите се очертава тенденция на намаляване ръста на отглеждане на тези животни. Само при биволите интересът на фермерите се засилва във времето.

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2. Материали методи

Настоящото изследване е разработено с данни за брой отглеждани селскостопански животни (говеда, биволи, свине, овце и кози) в България за периода 2000-2014 г. Статистическите данни в изследването са взети от базата данни FAOSTAT.

Построени са математически модели върху получените данни. За целта са използвани подходящи регресионни уравнения. Определени са коефициентите на корелация и детерминация. Чрез тях са направени изводи за степента на влияние на годината върху брой отглеждани селскостопански животни. Дадена е графика, представяща изменението на количеството на всеки вид животни във времето.

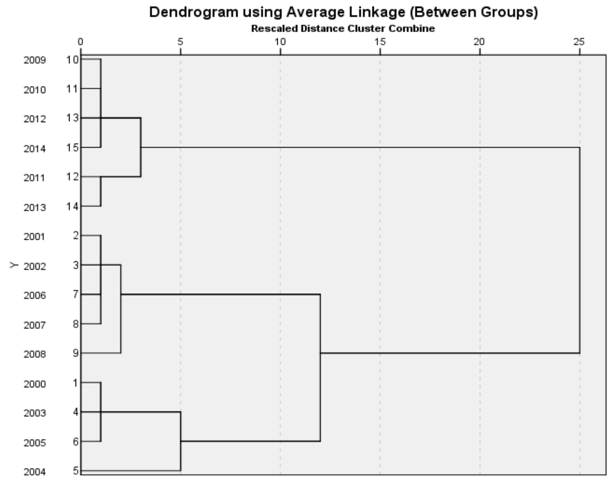
Обработката е извършена чрез статистическата програма IBM Statistics SPSS 23 [1].

3. Резултати и обсъждане

В настоящата работа се моделират и анализират данни, свързани с брой отглеждани селскостопански животни в България от 2000 г. до 2014 г. За оценка на статистическите данни е използван йерархичен клъстерен анализ. Направено е групиране на годините в зависимост от броя на съответните животни, като се използва методът на междугруповото свързване и за мярка е използвано евклидовото разстояние. На Фигури 1-5 са поместени дендрограмите, представящи графично организирането на данните в клъстери.

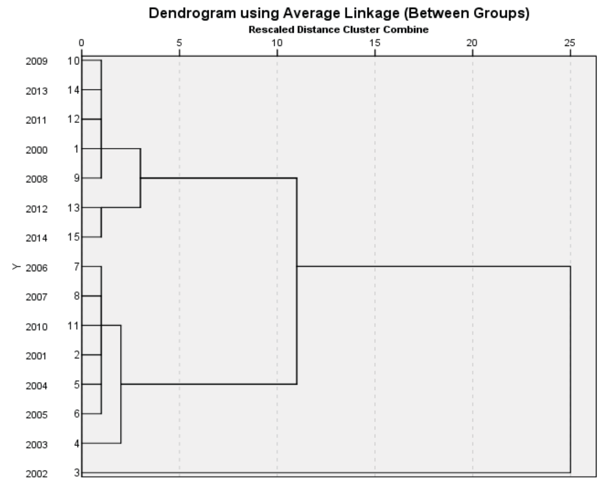
Според резултата за брой говеда в България се открояват три основни клъстера (Фигура 1). Първият се разделя на два подклъстера: единият включва 2009, 2010, 2012 и 2014 г., а вторият – 2011 и 2013 г. Те се обединяват на евклидово разстояние 3 единици. Вторият основен клъстер включва 2001, 2002, 2006 и 2007 г., като към тях на разстояние 2 евклидови единици се присъединява 2008 г. Третият клъстер се състои от два подклъстера: първият се образува от 2000, 2003 и 2005 г, а в самостоятелен подклъстер е 2004 г. Тези два подклъстера формират един обобщен клъстер на разстояние 5 евклидови единици.

На Фигура 2 се откроят три основни клъстера. Първият включва два подклъстера: единият се състои от 2000, 2009, 2011 и 2013 г.,



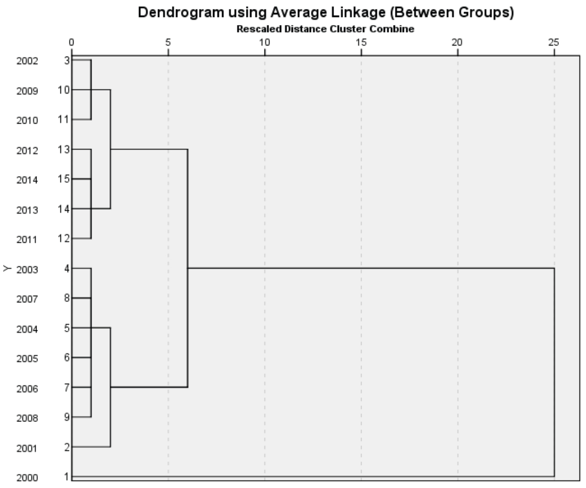
Фиг. 1. *Йерархичен клъстерен анализ по брой отглеждани говеда в България*

а вторият – 2012 и 2014 г. Те се обединяват на разстояние 3 евклидови единици. Вторият основен клъстер също се състои от два подклъстера: 2001, 2004, 2005, 2006 и 2007 г. от една страна и като самостоятелен подклъстер – 2003 г. Третият клъстер съдържа само 2002 г. и той е най-отдалечен от останалите два клъстера – на разстояние 25 евклидови единици.

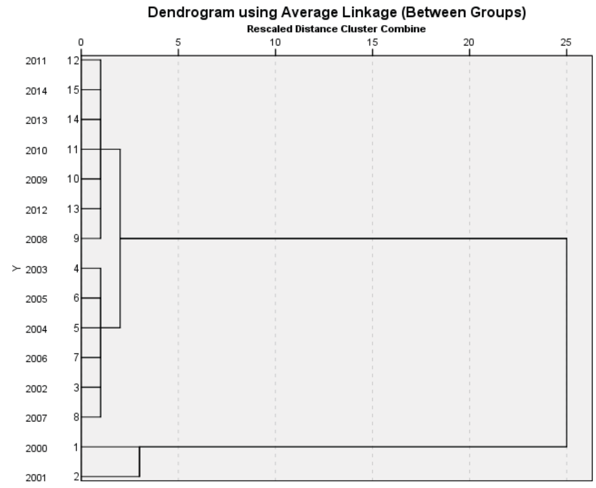


Фиг. 2. *Йерархичен клъстерен анализ по брой отглеждани биволи в България*

Резултатът от йерархичния клъстер анализ за брой отглеждани овце е даден на Фигура 3. Очертават се четири клъстера: първият включва 2002, 2009 и 2010 г., вторият – 2011, 2012, 2013 и 2014 г., които се присъединяват към първия клъстер на разстояние 2,5 евклидови единици.



Фиг. 3. *Йерархичен клъстерен анализ по брой отглеждани свине в България*



Фиг. 4. *Йерархичен клъстерен анализ по брой отглеждани овце в България*

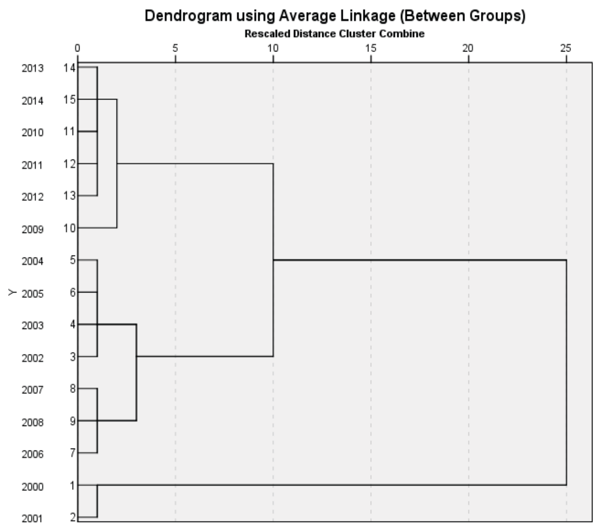
Третият клъстер включва два подклъстера: първият се състои от периода 2003-2007 г., а вторият – 2001 г. Присъединяват се на разстояние 2,5 евклидови единици. Последният и най-отдалечен клъстер обхваща периода през 2000 г.

В резултат на йерархичен клъстерен анализ става ясно, че при отглеждането на свине имаме един клъстер, включващ 2002 и периода от 2009 до 2014 г.. Втори клъстер обхваща 2001, 2003-2008 г. Двата клъстера се обединяват на разстояние от 6 евклидови единици. Последният клъстер се състои само от 2000 г. и той е най-отдалечен от всички останали.

На дендрограмата, представяща групирането по брой отглеждани овце, се оформят два обобщени клъстера. Първият се състои от два подкрътера: от 2008 до 2014 г. и от 2002 до 2007 г.Вторият клъстер включва 2000 и 2001 г., които се присъединяват към горния клъстер на разстояние 25 евклидови единици.

От Фигура 5 става ясно, че групирането на годините според брой отглеждани кози е подобно на това според брой овце.

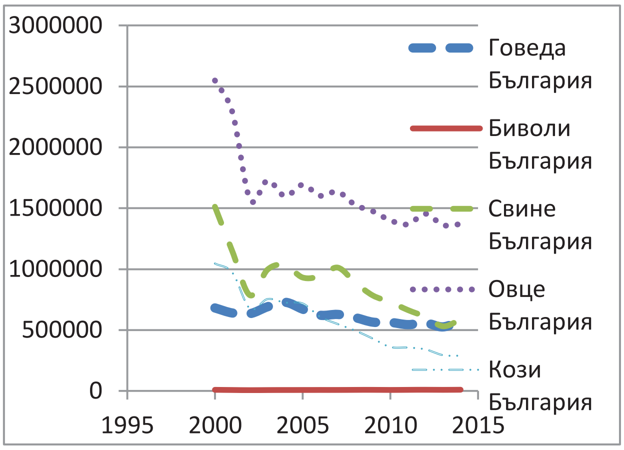
Получените резултати за групирането на данните по години се обясняват с резултатите, представени на Фигура 6. При йерархичния клъстерен анализ за всички животни бе установено, че 2000 г. - 2001 г. формират самостоятелни клъстери и причина за това е по-големият брой отглеждани животни през този период. Голямата отдалеченост от останалите клъстери се обяснява с факта, че в следващите години рязко спада броят на селскостопанските животни в България. На графиката са посочени измененията в количеството на отглежданите



Фиг. 5. *Йерархичен клъстерен анализ по брой отглеждани кози в България*

селскостопански животни в периода 2000-2014 г. При всички от 2000 г. до 2003 г. се наблюдава спад, като най-силен той е в овцете, а най-слаб – при говедата и биволите. Следващият период, който може да се разграничи, е от 2003 г. до 2004 г., когато има увеличение в броя на животните от всеки сектор. От 2004 г. до 2006 г. е период с плавни пикове и спадове, а от 2007 г. до края на 2014 г. има спад. Изключение прави секторът, ориентиран към биволите, където според статистическите данни се наблюдава известен ръст. Като цяло за разглеждания период от време се наблюдава намаляване на интереса на фермерите към отглеждане на селскостопански животни.

Статистическите данни в тази работа са моделирани чрез различни регресионни модели, описани в таблица 1. При всички модели регресионните коефициенти са статистически значими, тъй като степента им на значимост (Sig.) е по-малка от грешката (0.05).



Фиг. 6. *Графично представяне на брой (в хил.) отглеждани селскостопански животни в България за периода 2000 г. – 2014 г.*

Селскост. животни	***Регресионен модел***
Говеда	$y = 5.10^{126} x^{-36,61}$
Биволи	$y = 17{,}411x^2 - 69738x + 7.10^7$
Свине	$y = 3.10^{54} e^{-0{,}056x}$
Овце	$y = 7697{,}7x^2 - 3.10^7 x + 3.10^3$
Кози	$y = 2.10^{86} e^{-0{,}093x}$

Таблица 1. *Регресионни модели на изменение на брой отглеждани животни*

Селскостоп. животни	***Коеф. на корелация (R)***	***Коеф. на determ. (R^2) (%)***
Говеда	-0,84	71
Биволи	0,77	59
Свине	-0,88	78
Овце	-0,88	78
Кози	-0,98	96

Таблица 2. *Коефициент на корелация и коефициент на детерминация*

Данните за брой говеда се моделират със степенен регресионен модел, биволи – с полиномен регресионен модел от втора степен, свине и кози – показателен регресионен модел, овце – полиномен регресионен модел от втора степен.

Коефициентите на корелация за всички животни показват висока степен на зависимост между брой отглеждани селскостопански животни от времето. Коефициентите на детерминация също показват висок процент на влияние на годината върху броя на животните.

4. Заключение

На базата на проведените регресионни анализи и построените математически модели можем да направим заключение, че за различните сектори на животновъдството се установяват различни тенденции – на нарастване или намаляване количеството отглеждани селскостопански животни в България през периода 2001-2014 г. Буди оптимизъм нарастващият брой биволи, отглеждани у нас, имайки предвид както по-високите хранителни качества на биволските продукти, така и по-високата им себестойност.

Факторите, оказващи влияние върху спада в отглежданите количества селскостопански животни, най-общо могат да се обобщят в следните няколко направления: недостатъчни държавни субсидии, подпомагащи фермерите, морално остаряло техническо оборудване на фермите, недостатъчно количество инвестиции от страна на производителите, незадоволителна степен на образование и квалификация на хората, заети в този сектор и др.

ЛИТЕРАТУРА

1. Ganeva, Z., (2016). To rediscover the statistics with SPSS, Elestra, Sofia

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RECTANGULAR PLATES – SINGLE TRIGONOMETRIC SERIES, EXPONENTIAL FUNCTION

LILIYA PETROVA

Abstract: *A method of single trigonometric series is applied for investigation of a plate, simply supported at two of their opposite ends and arbitrary at two others. In the investigation instead a hyperbolic functions are used an exponential function. In a general case the load of the plate is with arbitrary distribution. The investigation rends an account asymmetrical location of the load acting of the plate. A rectangular plate, simply supported at two of their opposite ends and clamped at two others, is investigated automated with asymmetrical distributed load. It is determines automated the normal displacement and of the forces in a plate. It is made a verification of the results obtained.*

Key words: *rectangular plates, single trigonometric series, exponential function*

1. THE REATIONSHIPS OF THE PLATE IN CARTESIAN COORDINATES

A differential equation for equilibrium of the plate

For a plate with constant thickness it has a kind

$$\frac{\partial^4 w}{\partial x^4}+2\frac{\partial^4 w}{\partial x^2\partial y^2}+\frac{\partial^4 w}{\partial y^4}=\frac{q(x,y)}{D} \qquad D=\frac{Et^3}{12(1-\nu^2)}, \quad (1)$$

where $q(x,y)$ is a function of the external load; D is the cylindrical rigidity of the plate; $w(x,y)$ is a function of the normal displacements of the points of the plate's middle surface; t is a thickness of the plate; ν is a Poisson's coefficient.

The forces in the plate with a positive directions

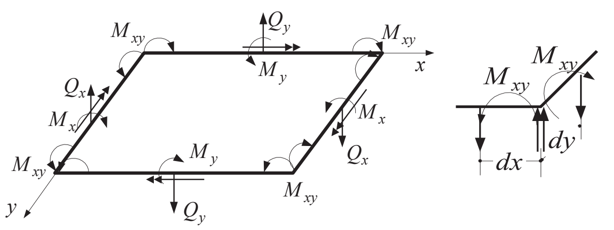

Fig.1

$$M_x=-D\left[\frac{\partial^2 w}{\partial x^2}+\nu\frac{\partial^2 w}{\partial y^2}\right] \qquad M_y=-D\left[\frac{\partial^2 w}{\partial y^2}+\nu\frac{\partial^2 w}{\partial x^2}\right]$$

$$M_{xy}=-D(1-\nu)\frac{\partial^2 w}{\partial x\partial y},$$

$$Q_x=\frac{\partial M_x}{\partial x}+\frac{\partial M_{xy}}{\partial y} \qquad Q_y=\frac{\partial M_y}{\partial y}+\frac{\partial M_{xy}}{\partial x},$$

$$Q_x^*=-D\left[\frac{\partial^3 w}{\partial x^3}+(2-\nu)\frac{\partial^3 w}{\partial x\partial y^2}\right] \quad Q_y^*=-D\left[\frac{\partial^3 w}{\partial y^3}+(2-\nu)\frac{\partial^3 w}{\partial x^2\partial y}\right], \quad (2)$$

$$r_x=\pm\left(Q_x+\frac{\partial M_{xy}}{\partial y}\right)_{\substack{x=0\\x=a}} \qquad r_y=\pm\left(Q_y+\frac{\partial M_{xy}}{\partial x}\right)_{\substack{y=0\\y=b}},$$

$$r_x=\mp\left(\frac{\partial^3 w}{\partial y^3}+(2-\nu)\frac{\partial^3 w}{\partial x\partial y^2}\right)_{\substack{x=0\\x=a}} \quad r_y=\mp\left(\frac{\partial^3 w}{\partial y^3}+(2-\nu)\frac{\partial^3 w}{\partial x^2\partial y}\right)_{\substack{y=0\\y=b}}.$$

A boundaries conditions at ends with external normal y.

Depending on a way of supporting they have a kind

fixed end

$$w(x,y)=0 \quad Y_m(y)=0$$

$$\frac{\partial w(x,y)}{\partial y}=0 \quad Y_m^I(y)=0$$

simply supported end

$$w(x,y)=0 \quad Y_m(y)=0$$

$$M_y(x,y)=0 \quad Y_m^{II}(y)=0$$

free end

$$M_y(x,y)=0 \quad Y_m^{II}(y)-\nu\alpha_m^2 Y_m(y)=0 \qquad (3)$$

$$Q_y^*(x,y)=0 \quad Y_m^{III}(y)-(2-\nu)\alpha_m^2 Y_m^I(y)=0$$

2. A SINGLE TRIGONOMETRIC SERIES

A single trigonometric series is applies at rectangular plates simply supported in two opposite ends. At the two other ends the plate, in a case $y=0$

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$y=b$, the supporting in a general case is arbitrary (fig. 2).

An introduced coordinate system xOy is according with the supporting and the loading of the plate.

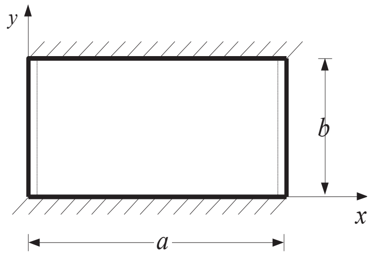

Fig.2

Analytical expression for a function of external load

$$q(x,y)=q\,f(x)f(y),$$

where q is an intesity of external load;

$f(x), f(y)$ are a functions of load in directions of axes x и y at $q=1$;

A function of the normal displacement of the points of the plate's middle surface

$$w(x,y)=\sum_m Y_m(y)\sin(\alpha_m x)\,,\ \alpha_m=\frac{m\pi}{a}\,,\ (m=1,2,..\infty) \quad (4)$$

The choice of the function of elastic surface of the plate must be to satisfy the boundaries conditions into his simply supported ends in this case parallels of the axi's y.

A development of the external load in the single trigonometric series at sin into axi's x, m-Furrier's coefficient

$$q(x,y)=\sum_m q_m(y)\sin(\alpha_m x) \quad q_m(y)=\frac{2}{a}\int_0^a q(x,y)\sin(\alpha_m x)dx \quad (5)$$

A function $Y_m(y)$ from elastic surface of the plate

From condition $Y_m(y)$ to satisfy the differential equation from equilibrium of the plate, after substituing (4) and (5) in (1), is receives the following *unhomogeneous* arbitrary differential equation about function $Y_m(y)$

$$Y_m^{IV}(y)-2\alpha_m^2 Y_m^{II}(y)+\alpha_m^4 Y_m(y)=B_m(y),\ \text{where}\ B_m(y)=\frac{q_m(y)}{D}. \quad (6)$$

The characteristic equation, corresponding to (6) and its roots has a kind

$$r^4-2\alpha_m^2 r^2+\alpha_m^4=0 \quad (7)$$

$$r_{1,2}=\pm\alpha_m\,,\quad r_{3,4}=\pm\alpha_m \quad (8)$$

General integral of arbitrary unhomogeneous differential equation about function $Y_m(y)$ accepts a kind

$$Y_m(y)=C_{1_m}e^{\alpha_m y}+C_{2_m}e^{-\alpha_m y}+C_{3_m}ye^{\alpha_m y}+C_{4_m}ye^{-\alpha_m y}+\overline{Y}_m(y) \quad (9)$$

where $\overline{Y}_m(y)$ is a partial integral of *unhomogeneous differential equation* about *function* $Y_m(y)$;

C_{1_m}, C_{2_m}, C_{3_m} *u* C_{4_m} *are an integration constants* in an expressions for $Y_m(y)$.

A determination of an *integration constants* C_{1_m}, C_{2_m}, C_{3_m} *u* C_{4_m} are make from the boundaries conditions at arbitrary supported ends of the plate – in this case parallel of axi's x.

A derivations of functions $Y_m(y)$

$$Y_m^I(y)=C_{1_m}\alpha_m e^{\alpha_m y}-C_{2_m}\alpha_m e^{-\alpha_m y}+C_{3_m}(1+\alpha_m y)e^{\alpha_m y}+C_{4_m}(1-\alpha_m y)e^{-\alpha_m y}+\overline{Y}_m^I$$

$$Y_m^{II}(y)=C_{1_m}\alpha_m^2 e^{\alpha_m y}+C_{2_m}\alpha_m^2 e^{-\alpha_m y}+C_{3_m}\alpha_m(2+\alpha_m y)e^{\alpha_m y}-C_{4_m}\alpha_m(2-\alpha_m y)e^{-\alpha_m y}+\overline{Y}_m^{II} \quad (10)$$

$$Y_m^{III}(y)=C_{1_m}\alpha_m^3 e^{\alpha_m y}-C_{2_m}\alpha_m^3 e^{-\alpha_m y}+C_{3_m}\alpha_m^2(3+\alpha_m y)e^{\alpha_m y}+C_{4_m}\alpha_m^2 e^{-\alpha_m y}(3-\alpha_m y)+\overline{Y}_m^{III}$$

$$Y_m^{IV}(y)=C_{1_m}\alpha_m^4 e^{\alpha_m y}+C_{2_m}\alpha_m^4 e^{-\alpha_m y}+C_{3_m}\alpha_m^3(4+\alpha_m y)e^{\alpha_m y}-C_{4_m}\alpha_m^3 e^{-\alpha_m y}(4-\alpha_m y)+\overline{Y}_m^{IV}$$

Displacements and forces in the plate, presented in single trigonometric series

The coefficients of the trigonometric series

$$M_{x_m}(y)=\alpha_m^2 Y_m(y)+\nu Y_m^{II}(y),\ M_{y_m}(y)=Y_m^{Ii}(y)-\nu\alpha_m^2 Y_m(y)$$

$$M_{xy_m}(y)=\alpha_m^2 Y_m^I(y) \quad (11)$$

$$Q_{x_m}(y)=\alpha_m^2\left(Y_m^{II}(y)-\alpha_m^2 Y_m(y)\right),\ Q_{y_m}(y)=\left(Y_m^{III}(y)-\alpha_m^2 Y_m^2(y)\right)$$

$$Q_{x_m}^*(y)=\alpha_m\left((2-\nu)Y_m^{II}(y)-\alpha_m^2 Y_m(y)\right),\ Q_{y_m}^*(y)=\alpha_m\left(Y_m^{III}(y)-(2-\nu)\alpha_m^2 Y_m^I(y)\right)$$

$$r_{x_m}(y)_{\substack{x=0\\x=a}}=\mp\left[\alpha_m\left(-\alpha_m^2 Y_m(y)+(2-\nu)Y_m^{II}\right)\right]_{\substack{x=0\\x=a}}$$

$$r_{y_m}(y)_{\substack{y=0\\y=a}}=\mp\left[\alpha_m\left(-\alpha_m^2 Y_m(y)+(2-\nu)Y_m^{II}\right)\right]_{\substack{y=0\\y=a}}.$$

A final normal displacements, forces and reactions in the plate accept a kind

$$w(x,y)=\sum_m Y_m(y)\sin(\alpha_m x)\,,$$

$$S(x,y)=\sum_m S_m(y)\left|\begin{matrix}\sin(\alpha_m x)\\ \cos(\alpha_m x)\end{matrix}\right.,\ r(x,y)=\sum_m r_m(y)\left|\begin{matrix}\sin(\alpha_m x)\\ \cos(\alpha_m x)\end{matrix}\right.. \quad (12)$$

In the expressions (12) $S(x,y)$, $r(x,y)$ is a general significations for a forces, reactions in a plate, $S_m(y)$, $r_m(y)$ are the coefficients of trigonometric series for the same forces and reactions. The multiplication with $\sin(\alpha_m x)$,

$\cos(\alpha_m x)$ is accords with the differential relationships of the forces in the plate.

3. An investigation of the bilateral fixed plate

An integration constant in a general integral $Y_m(y)$

A boundary conditions at the ends of the plate $y=0$ $y=b$ - clamped has a kind

$$w(x,0)=0 \quad Y_m(0)=0 \quad w(x,b)=0 \quad Y_m(b)=0$$
$$\frac{\partial w}{\partial y}(x,0)=0 \quad Y_m^I(0)=0 \quad \frac{\partial w}{\partial y}(x,b)=0 \quad Y_m^I(b)=0 \qquad (13)$$

It is introduses the signification $\eta_m=\alpha_m b$.

The matrix of coefficients and the vector of free terms of equations boundarie's conditions are present in a kind

$$[M]=\begin{bmatrix} 1 & 1 & 0 & 0 \\ \alpha_m & -\alpha_m & 1 & 1 \\ e^{\eta_m} & e^{-\eta_m} & \frac{\eta_m}{\alpha_m}e^{\eta_m} & \frac{\eta_m}{\alpha_m}e^{-\eta_m} \\ \alpha_m e^{\eta_m} & -\alpha_m e^{-\eta_m} & e^{\eta_m}(1+\eta_m) & e^{-\eta_m}(1-\eta_m) \end{bmatrix} \quad \{V_m\}=-\begin{Bmatrix} \overline{Y}_m(0) \\ \overline{Y}_m^I(0) \\ \overline{Y}_m(b) \\ \overline{Y}_m^I(b) \end{Bmatrix} \qquad (14)$$

After a solution of the received system equations for a plate, clamped at their two opposite ends, for an integration constants are receive the following expressions

$$[M]^{-1}=\frac{1}{\left[-4\eta_m^2+\frac{1}{e^{\eta_m^2}}-2+e^{\eta_m^2}\right]}\begin{bmatrix} -2\eta_m^2+\frac{1}{e^{\eta_m^2}}-1-2\eta_m & -2\frac{\eta_m^2}{\alpha_m} & (1+\eta_m)e^{\eta_m}+\frac{(-1+\eta_m)}{e^{\eta_m}} & \frac{\eta_m}{\alpha_m}\left(\frac{1}{e^{\eta_m}}-e^{\eta_m}\right) \\ -2\eta_m^2+e^{\eta_m^2}-1+2\eta_m & 2\frac{\eta_m^2}{\alpha_m} & (-1-\eta_m)e^{\eta_m}+\frac{(1-\eta_m)}{e^{\eta_m}} & \frac{\eta_m}{\alpha_m}\left(-\frac{1}{e^{\eta_m}}+e^{\eta_m}\right) \\ \left(-\frac{1}{e^{\eta_m^2}}+2\eta_m+1\right)\alpha_m & 2\eta_m+\frac{1}{e^{\eta_m^2}}-1 & \left(-e^{\eta_m}+\frac{1-2\eta_m}{e^{\eta_m}}\right)\alpha_m & \left(e^{\eta_m}-\frac{1+2\eta_m}{e^{\eta_m}}\right) \\ \left(-1+2\eta_m+e^{\eta_m^2}\right)\alpha_m & -2\eta_m+e^{\eta_m^2}-1 & \left((-2\eta_m-1)e^{\eta_m}+1\right)\alpha_m & \left((2\eta_m-1)e^{\eta_m}+\frac{1}{e^{\eta_m}}\right) \end{bmatrix} \qquad (15)$$

$$\{C_m\}=[M]^{-1}\{V_m\}. \qquad (16)$$

It follows a determination the coefficients of trigonometric series and the functions of displacement, forces and reactions in the plate.

4. Numerical examples

The load is nonsimmetyrical distributed into axi's y.

The geometry, the supporting and the loading of the plate are shown in fig. 3.

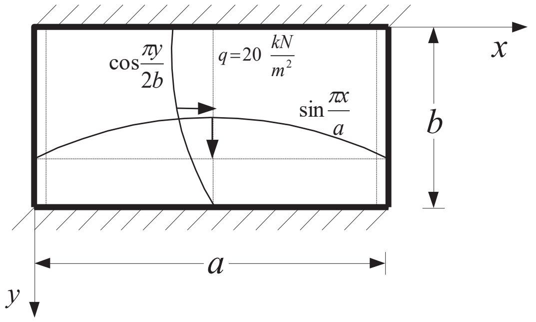

Fig. 3

A characteristics of a plate

A lengths of the side of the plate $a=6m$; $b=6m$;

A thicknes of the plate $t=0{,}12\,m$.

Module of elasticity $E=2.10^7\ \frac{kN}{m^2}$;

A Poisson's coefficient $\nu=0{,}17$.

A function of external load has a kind,

$$q(x,y)=q\cos\frac{\pi y}{2b}\sin\frac{\pi x}{a} \quad \text{for } 0\le x\le a \text{ and } 0\le y\le b, \qquad (17)$$

$\left(q=20\ \frac{kN}{m^2}\right)$.

m - *Furrier's coefficient in development of external load in sin series on the axi's* x

$$q_m(y)=\frac{2}{a}\int_0^a q(x,y)\sin(\alpha_m x)dx \qquad (18)$$

or
$$q_m(y)=\begin{vmatrix} q\cos\frac{\pi y}{2b} & npu\ m=1 \\ 0 & npu\ m\neq 1 \end{vmatrix} \qquad (19)$$

A right part of unhomogenous differential equation accepts a kind

$$B_m(y)=\frac{q}{D}\cos\frac{\pi y}{2b} \qquad (20)$$

A partial integral $\overline{Y}_m(y)$ of unhomogeneous differential equation

$$\overline{Y}_m(y)=K_m\cos(\beta y) \qquad (21)$$

After substitution in (8)

$$K_m\left(\beta^4+2\alpha_m^2\beta^2+\alpha_m^4\right)\cos\beta y=\frac{q}{D}\cos\frac{\pi y}{2b}, \qquad (22)$$

from where on the method of undetermined coefficients, at

$$K_m=\frac{q}{D}\frac{1}{\beta^4+2\alpha_m^2\beta^2+\alpha_m^4} \quad \beta=\frac{\pi}{2b}, \qquad (23)$$

It follows

$$\overline{Y}_m(y)=\begin{vmatrix}K_m\cos(\beta y) & npu\ \ m=1\\ 0 & npu\ \ m\neq 1\end{vmatrix}. \qquad (24)$$

A derivations of $\overline{Y}_m(y)$

$$\overline{Y}_m^{I}(y)=-K_m\beta\sin(\beta y),\ \overline{Y}_m^{II}(y)=-K_m\beta^2\cos(\beta y),$$

$$\overline{Y}_m^{III}(y)=K_m\beta^3\sin(\beta y),\ \overline{Y}_m^{IV}(y)=K_m\beta^4\cos(\beta y). \quad (25)$$

A results from the solutions with $m=1$ terms are shown in a tables 1.1-1.5.

Table 1.1.

m	$\alpha_m=\dfrac{m\pi}{a}$	$\eta_m=\alpha_m b$	e^{η_m}	C_{1_m}	C_{2_m}	C_{3_m}	C_{4_m}
1	0.5236	3.1416	23.1407	-3.1925	-167.1078	0.7458	-86.5716

m	$D\overline{Y}_m,\ D\overline{Y}_m^{I},\ D\overline{Y}_m^{II},\ D\overline{Y}_m^{III}$											
	$y=0$				$y=0{,}5b$				$y=b$			
1	170.3003	0	-11.6722	0	120.4205	-31.5260	-8.2535	2.1608	1.0428e-14	-44.5845	0	3.0558

Table 1.2.

m	$DY_m(y),\ DY_m^{I}(y),\ DY_m^{II}(y),\ DY_m^{III}(y)$											
	$y=0$				$y=0{,}5b$				$y=b$			
1	0	0	33.0776	-47.0593	27.0978	-1.8832	-11.2358	2.3869	-5.0116e-13	7.1054e-14	21.9896	22.6900

Table 1.3.

m	$Dw(x,y)$											
	$x=0$			$x=0.1675a$			$x=0.333a$			$x=0.5a$		
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$
1	0	0	0	0	13.5489	-2.5058E-13	0	23.4674	-4.3402e-13	0	27.0978	3.3184E-1
	$x=0{,}667a$			$x=0.833a$			$x=a$					
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$			
1	0	23.4674	3.3184E-15	0	13.5489	-2.5058E-1	0	3.3184E-15	0			

Table 1.4.

m	$M_x(x,y)$											
	$x=0$			$x=0.1675a$			$x=0.333a$			$x=0.5a$		
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$
1	0	0	0	-2.8116	4.6695	-1.8691	-4.8698	8.0879	-3.2374	-5.6232	9.3391	-3.7382
	$x=0{,}667a$			$x=0.833a$			$x=a$					
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$			
1	-4.8698	8.0879	-3.2374	-2.8116	4.6695	-1.8691	0	1.1437E-15	0			

m	$M_y(x,y)$											
	$x=0$			$x=0.1675a$			$x=0.333a$			$x=0.5a$		
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$
1	0	0	0	-16.5388	6.2494	-10.9948	-28.6460	10.8242	-19.0435	-33.0776	12.4987	-21.9896
	$x=0{,}667a$			$x=0.833a$			$x=a$					
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$			
1	-28.6460	10.8242	-19.0435	-16.5388	6.2494	-10.9948	-4.0507e-15	1.5306e-15	2.6929e-15			

m	$M_{xy}(x,y)$											
	$x=0$			$x=0.1675a$			$x=0.333a$			$x=0.5a$		
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$
1	0	0.8184	-3.0879e-14	0	0.7088	-2.6742e-14	0	0.4092	-1.5440e-13	0	0	0
	$x=0{,}667a$			$x=0.833a$			$x=a$					
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$			
1	0	-0.4092	1.5440e-14	0	-0.7088	2.6742e-14	0	-0.8184	.0879e-14			

m	$Q_x(x,y)$											
	$x=0$			$x=0.1675a$			$x=0.333a$			$x=0.5a$		
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$

1	-17.3194	9.7729	-11.5137	-14.9990	8.4636	-9.9712	-8.6597	4.8864	-5.7569	1.0605e-15	0	0
	x=0,667a			x=0.833a			$x=a$					
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$			
1	8.6597	-4.8864	5.7569	14.9990	-8.4636	9.9712	17.3194	-9.7729	11.5137			

m	$Q_y(x,y)$											
	$x=0$			x=0.1675a			x=0.333a			x=0.5a		
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$
1	0	0	0	23.5297	-1.4516	-11.3450	40.7546	-2.5142	-19.6501	47.0593	-2.9032	-22.6900
	x=0,667a			x=0.833a			$x=a$					
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$			
1	40.7546	-2.51420	-19.6501	23.5297	-1.4516	-11.3450	5.7629e-15	0	-2.7786e-15			

m	$Q_x^*(x,y)$											
	$x=0$			x=0.1675a			x=0.333a			x=0.5a		
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$
1	-31.6945	14.6558	-21.0701	-27.4482	12.6923	-18.2472	-15.8472	7.3279	-10.5350	-1.9407e-15	0	1.2901e-15
	x=0,667a			x=0.833a			$x=a$					
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$			
1	15.8472	-7.3279	10.5350	27.4482	-12.6923	18.2472	31.6945	-14.6558	21.0701			

m	$Q_y^*(x,y)$											
	$x=0$			x=0.1675a			x=0.333a			x=0.5a		
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$
1	0	0	0	23.5297	-1.6658	-11.345(	40.7546	-2.8853	-19.6501	47.0593	-3.3317	-22.6900
	x=0,667a			x=0.833a			$x=a$					
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$			
1	40.7546	-2.8853	-19.6501	23.5297	-1.6658	-11.3450	5.7629e-15	0	-2.7786e-15			

Table 1.5.

m	$r_x(x,y)$						
	$x=0$			$x=a$			
	$y=0$	$y=0.5b$	$y=b$	$y=0$	$y=0.5b$	$y=b$	
	-31.6945	14.6558	-21.0701	-31.6945	14.6558	-21.0701	
1	$r_y(x,y)$						
	$x=0$	x=0.167a	x=0.333a	$x=0.5a$	x=0.667a	x=0.833a	$x=a$
y=0	0	-23.5297	-40.7546	-47.0593	-40.7546	-23.5297	-5.7629E-15
$y=b$	0	11.345	19.6501	22.69	19.6501	11.345	2.7786E-15

A cause a symmetry of the supporting and loading the results of displacements and forces are writed only for a part of the plate.

For verification are write an equations for equilibrium of the plate or for the part of the plate.

4. Conclusions

The presented investigation uses only one function – the exponential. The replacement of hyperbolic trigonometric functions by exponential simplifies the expressions used in the solution and in the some cases improve the conjuences at $(m=1,...,\infty)$ terms of series.

The solutions are conduct with a compoused PC program. The results obtained are compared.

The method is applies analogical at arbitrary distributed loads on the plate.

References

1. Varbanov Chr., A. Tepavicharov, T. Ganev, Theory of elasticity and plasticity, *Thechnika*, Sofia, 1992.
2. Tc. Krustev, T. Karamanski and oth., Guidance for a solution of a problem of theory of elasticity, stability and dynamics of elastic's systems, *Thechnika*, Sofia, 1974.
3. Timoshenko S. P., S. Voinovski-Kriger, Plates and Shells, Moscow, 1966.

4. Szilard R, *Theory and Analysis of Plates*, Classical and Numerical Method, Prentice-Hall, New Jersry, 1976
5. Vainberg D.B., E.D. Vainberg, A solution of a plates, Budivelnik, Kiev, 1970.

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