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Simulation modeling of RTM with parallel structure

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Abstract. This article discusses some aspects related to simulation modelling of robotic technology modules (RTMs). A model of RTM with parallel-structure, consisting of 8 machines with different working hours, which are served by 1 robot, is presented. The results of the operation of the simulation model are confirmed by an analytical model under the same operating conditions.

1. Introduction

A major role for the construction of flexible automation systems has mainly CNC technological equipment, industrial robots, automated systems and means of inter-operational transport. Robotic Technology Modules (RTMs) are commonly used manufacturing systems, including one or several technology machines, a service industrial robot (PR), peripherals required, combined with a common management system, and implementing a single process. Each module, thanks to its interaction with an automated control system, can operate as a standalone production unit or be part of a unified manufacturing system.

Therefore, the tasks of designing a new type of module or exploiting an existing one are of particular practical significance.

2. Explanation

Simulating the work of a flexible production system (APS) built from several machines served by a single robot is a process of bringing the real system into a simulation model that serves as the basis for its time study to uncover the impact of random factors on the basic parameters of the APS [5].

Interaction between the different components of the production system and its impact on overall performance can be analyzed by simulation modeling.

In a parallel structure RTM with more than 2 machines served by 1 robot, the description of the analytical models is difficult due to the large number of possible system states. To ease the practical work of analyzing and predicting the performance of such systems, it is appropriate to use simulation modeling. Analytical and simulation models of two robotic machine systems have been developed.

2.1. Simulation model of RTM for the production of foundry hearts

The existing production area for foundry hearts is located in a company producing automotive products in Bulgaria. The equipment is a parallel-structure RTM and includes 5 machines (Figure 1) serviced by 1 robot at a yield of 265 units / hour. The machines produce different hearts for the products on the production sheet of the company.

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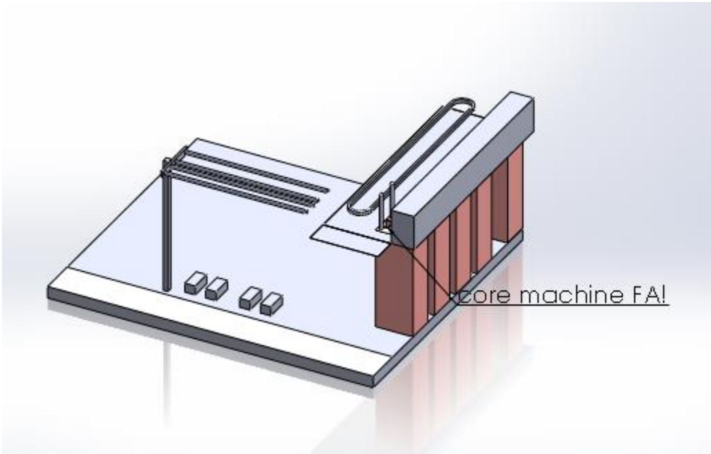


Fig. 1 Manufacturing section

To analyze the work of the robotized module and to reveal possibilities for increasing the productivity simulation modeling was performed in a General Purpose Simulation System (GPSS) [3]. A simulation model of the RTM with 5 parallel machines (type FAl), loaded by a service robot operating in a rectangular coordinate system, was made. Machines produce casting hearts of varying mass and productivity. The industrial robot charges machines with the same amount of sand. There are 10 simulations of the module work and the result is averaged. The yield value obtained is 241.31 pcs/hour.

The analysis of the results of the simulations shows that the simulation modeling gives very close performance values to that of the real system, which confirms its credibility. Analytical probability modeling has been performed, using three known methods and the results for the yields obtained are shown graphically in Fig. 2 [1]. The similarity of the obtained values confirms the reliability of the proposed analytical probability models, taking into account the specificities in them. The smallest estimated value for RTM performance is obtained with a linear graph analysis model in a decomposition decision method because of the multiple averaging of the processing times. This makes its use inappropriate for RTMs with a large difference in machine operating times [4].

Table 1 Parameters of the parts and machines in RTM 8m 1r

Machine	1	2	3	4	5	6	7	8
Performance, kg/h	2400	1300	1160	855,5	800	613,5	600	553
Mass in 1 pcs, kg	48	26	23,2	17,11	16	12,27	12	11,06

The performance results of the system under consideration in simulation and analytical modeling do not indicate the possibility of increasing productivity under the set operating conditions. In order to expand the production it is necessary to increase the productivity of the module to 400 pcs / hour. According to the company's preliminary estimates it is possible to complete the module with another 3 machines, which necessitates the modeling of a new production system in order to obtain estimates of the productivity under certain operating conditions.

It considers the RTM of 8 foundry heart machines that are served by 1 available robot that operates in a Cartesian coordinate system. Machines produce different hearts at different times of work, with material consumption for each item being manufactured different (Table 1). The dimensions of all the machines are the same and this allows to structure different variations of the RTM, as shown in Fig. 3.

The sanding position is at the left of the chart, the fill time is 3 cc, and the emptying time is 2 s. For a single charge, the robot needs to load sand, move to the machine, empty the sand, and to return to the starting position. The differences in compression variants determine the different service times of the machines.

2.2. Simulation model of RTM in GPSS/W

A simulation model in GPSS/W environment was developed for selecting a suitable variant of the 8-core machine-building and 1 servo robot, providing an estimated performance value corresponding to the assignment as well as for determining the appropriate service times, the production system [6]. It is built on the basis of the developed model of the existing real system and takes into consideration the proposed variants of the structure-layout scheme available to the equipment.

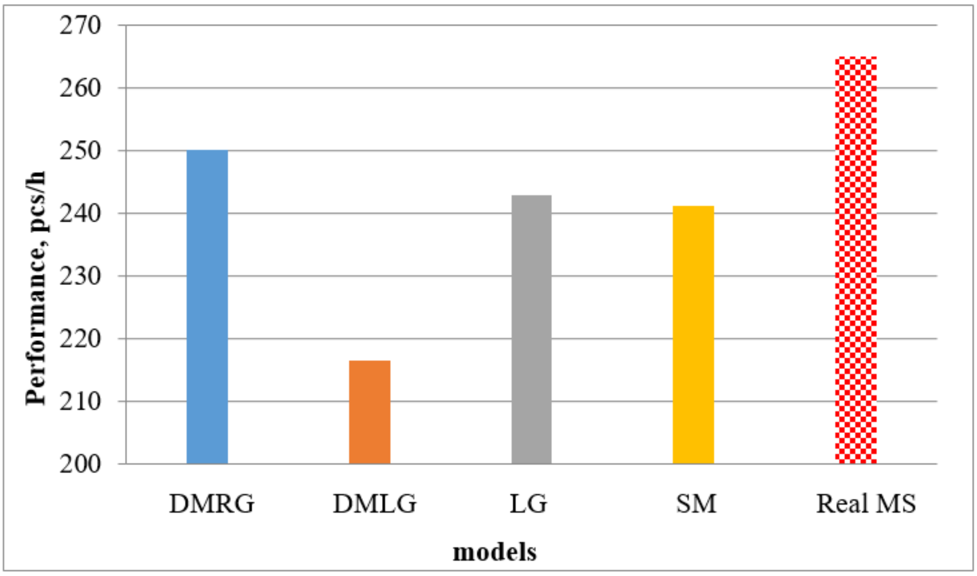


Fig. 2 Results of RTM (5m 1r) modeling

A number of simulations of operation of the module have been carried out and the results are shown graphically in Fig. 4.

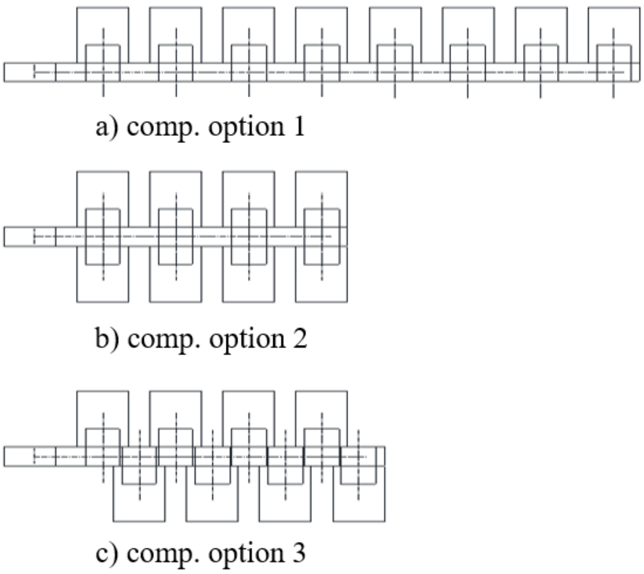


Fig. 3 Structure-compiling schemes of RTM (8m 1r)

The simulation has been given an exponential law of distribution of processing and service times. Analytical probability models, described and solved with linear average graph, decomposition method with branched graph and decomposition method with linear graph, were developed under the same conditions. Comparing the results obtained in analytical and simulation modeling shows close values, confirming the reliability of the models.

With such an organization of the RTM, it is obvious that the factors on which the productivity depends are: the component of the module, the speed of the robot movement and the mass of the manipulated object (the loaded sand). In the module's compilation, two scenarios of service sequence are considered: from the machine with the highest consumption of sand to the one with the smallest; and from the machine with the smallest sand consumption to the largest one.

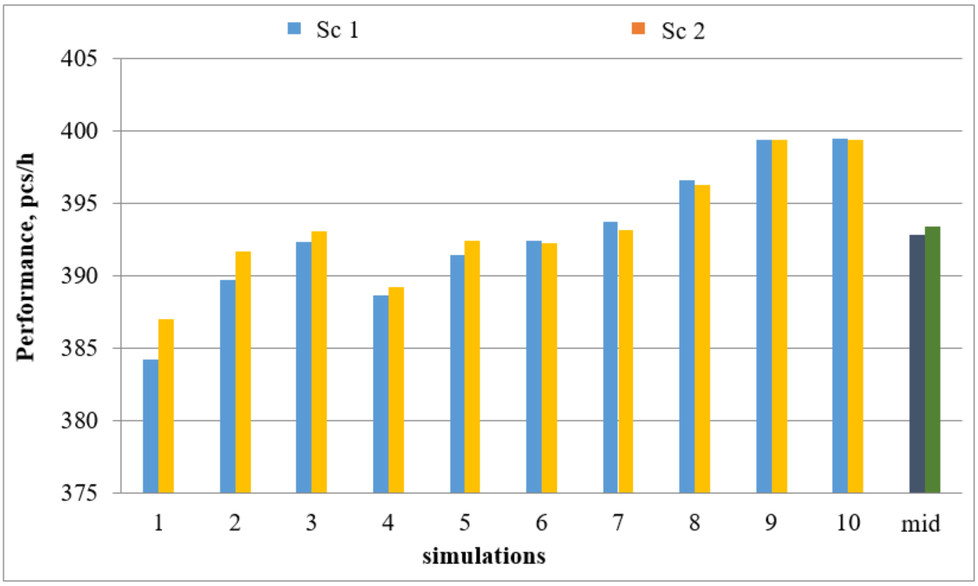
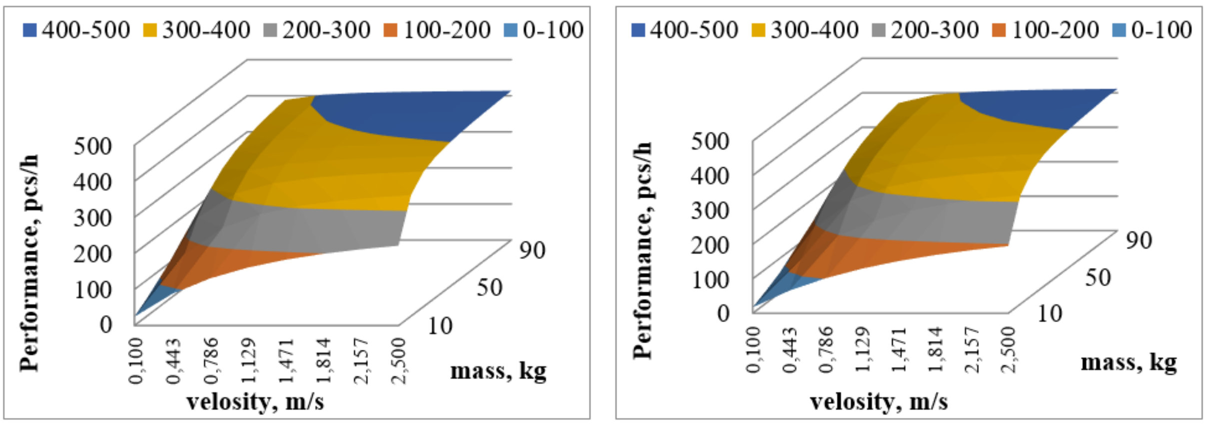


Fig. 4 Performance of RTM (8m 1r) determined in 10 simulations

The mass of the manipulated object can vary between 10 and 100 kg. This means that for the purposes of the study, the mass of sand borne by a robot on a course changes within the specified range.

The possible range for varying the speed of the robot has been investigated, with values of 0.1 to 2.0 m/s being obtained. These speed limits are a consequence of the limitation imposed by the condition of positioning accuracy when driving at a set speed [2].



a) b)

Fig. 5 Performance of RTM at linear graph and
a) 1 scenario of comp. option 2; b) 2 scenario of comp. option 2

In Fig. 5 shows the dependence of the RTM performance calculated with a linear graph in the component 2 (figure 3.b) of the machine composition and a) the first scenario of servicing the machines - from the machine with the highest consumption of sand to that with the smallest b) a second scenario of servicing the machines - from the least sandy machine to the largest one.

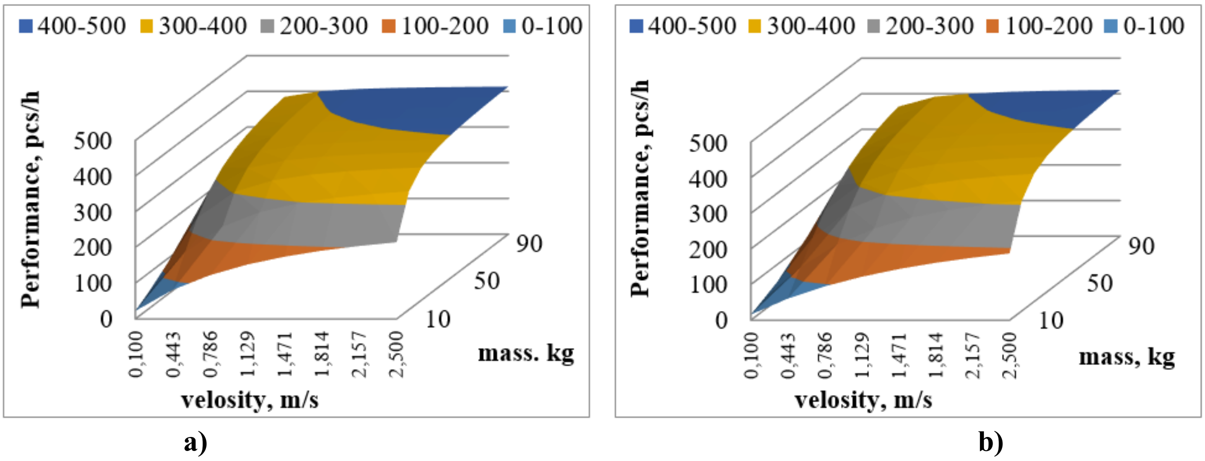


Fig. 6 Performance of RTM at linear graph and a) 1 scenario of comp. option 3; b) 2 scenario of comp. option 3

In Fig. 6 shows the dependence of the RTM productivity calculated with a linear graph in the machine component 3 and the two service scenarios described. From the results presented, it can be concluded that in the second and third variant of the module composition and in the first and second scenarios of servicing the machines the desired performance of RTM for foundry hearts can be achieved.

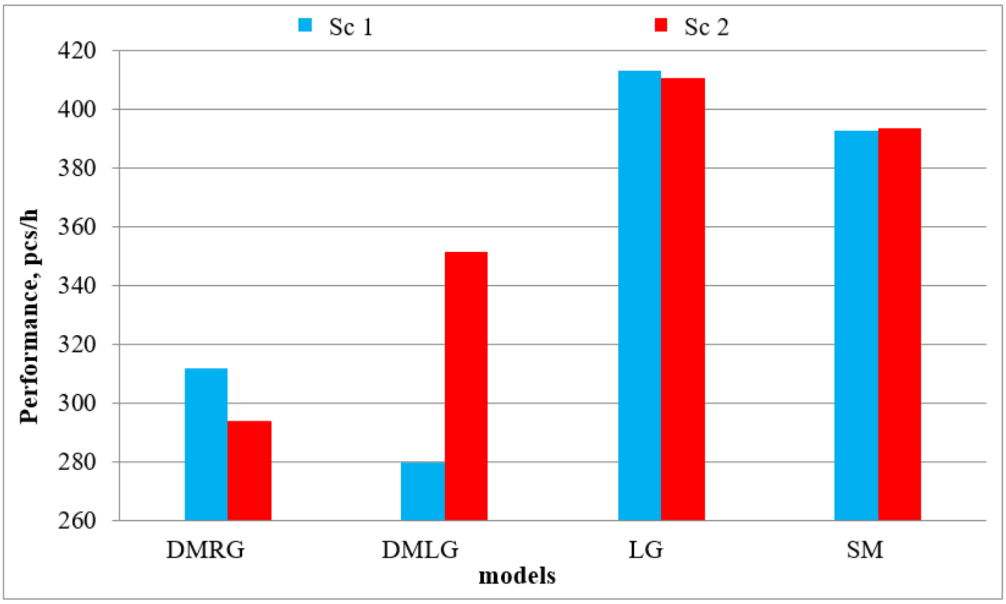


Fig. 7 Performance of RTM (8m 1r) in analytical and simulation modeling

In order to verify the operation of the RTM in real conditions, a comparison of the results of the analytical and simulation model made for 8 machines operating in parallel, serviced by 1 robot was made. For simulation of the operation of 8 machines, which are serviced by 1 robot, 123 units were used (Component Option 1). The results of the simulation modeling are given in fig. 7. It has been found that in the second and third variant of the module assembly and the first or second service scenario, the desired performance of the RTM for the production of foundry hearts can be achieved but with different parameters of the servicing robot for load carrying capacity and speed, allows variation under specific production conditions.

An analytical probability modeling of the RTM was performed in the three compression variants and the two service scenarios adopted for each of them.

In Fig. 7 presents performance results for analytical and simulation modeling of RTM for a second compression variant. The graph shows the role of the Machine Serving Scenario on the estimated productivity value with accepted model and method of solution. The results are obtained by loading the machines with the same amount of sand (100 kg).

The difference in the predicted values for the performance of the RTM obtained in the simulation model and the linear counting analytical model is less than 4.5%. For both types of models, exponential laws are established to divide the times between the events described. The use of simulation models makes it possible to lay down other laws of distribution of times when information is available about them.

3. Conclusions

As a result of the analysis we can draw the following conclusions:

1. The performance of a parallel structure RTM depends on the order of service of the machines, under the same conditions. For a given ratio of the operating and servicing times of each machine, an appropriate service scenario can be defined to provide the desired predictive value of the performance of the RTM modeled for specific operating conditions;

2. The method chosen to solve analytical probability models influences the obtained predictive values of the performance of the RTM because of the different way of accounting for losses which, under certain production conditions and a large number of machines in the module, makes use of simulation modeling appropriate;

3. In the presence of a priority setting the order of servicing of the machines in the RTM, based on simulation modeling, recommendations can be formulated regarding the service time under given operating conditions, which influences the choice of a specific industrial robot for incorporation into the module.

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