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The effects of applying different levels of printing pressure on quality in offset printing

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Abstract. In offset printing technique, a sufficiently high contact pressure between blanket and impression cylinders needs to be applied for the proper ink transfer onto printing substrate. The aim of this research is to investigate dependence of various print quality parameters on three printing pressure levels applied, in printing units, during four color heat set web offset printing process on LWC paper. This was examined by measuring various control elements of the prints, in order to obtain quantitative information about standard print quality parameters. Through the evaluation of this important printing factor and relating it to the print quality, it will be possible to find out in which ways and to what extents different printing pressue levels affect offset print quality.

The printing pressure between the offset blanket cylinder and the pressure cylinder is a very important factor for ink transfer in offset printing, respectively, it has a great influence on the quality of the prints. For the purpose of transferring ink and wetting solution from one surface to another, the application of optimum pressure intensity as well as its uniform distribution between the offset blankets and the pressure cylinders are decisive factors, however, here this pressure is considered in the context of HSWO printing which is realized through a rubber-to-rubber printing apparatus. The quality is complexly dependent on various factors such as: printing form, offset blankets, printing substrate, ink, printing speed, dampening solution, ink-water balance, printing machine condition and personnel qualification. Printing papers also have a significant impact on print quality with their characteristics – surface roughness, surface shrinkability and surface viscoelasticity. The fiber component in it changes the roughness profile, resulting in uneven ink transfer. Higher values of printing pressure provoke a larger contact area of the paper with the printed one in contact with the ink, thus guaranteeing a better and denser ink film. The transfer of ink in the printing section depends on the printing pressure in the section, the rheology of the ink and the amount of ink on the offset blankets. By increasing the roughness (Sk – surface roughness parameter) of the paper, with exponential development missing points in the image after printing. The surface deformability of the paper is a more important parameter for a good printing result than the overall compressibility of the paper. If solid tone areas are printed with enough available ink, the effect of surface texture on print quality can be compensated for. There is a strong relationship between the surface structure and the deformable behavior of certain papers under load, as well as the offset blankets with its print quality characteristics. The contact formed in the printed section is dependent on the time of pressure applications, i.e. the time during which the sheet of paper spends in the contact zone between the cylinders, under pressure. Ink film and uniformity of solid tone areas can be improved by increasing printing pressure, as surface compression increases the surface area of the contact area and reduces paper surface roughness. There are different methods for evaluating print pressure in the offset printing process. One of them is based upon Prescale film, which is a double layer pressure sensitive film, it is installed in the contact area between the two cylinders. Under pressure, the microcapsules on the first sheet rupture and the color-forming material reacts to form color on the second sheet of film. The pressure in the deformable printing area of the counter-rotating cylinders can also be determined by a force measuring device, a piezoelectric transducer, mounted on the surface of the carrier cylinder, but the method is applicable to a printing apparatus with a printing cylinder. The purpose of this study is to determine how different pressure levels affect four-color print quality in offset printing technology, and this analysis includes the investigation of six print quality parameters in offset printing conditions measured on paper with applying three different levels of print pressure. The following quality control parameters were selected:

1. Tone Value Increment (TVI),
2. Gray balance,

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3. Deviation of the optical density of a dense field,
4. Relative print contrast,
5. Color range,
6. Color differences (ΔE).

Vulkan Alto ND2 offset blanket with the following characteristics were used in the experiment - thickness d=1.7 mm; compressibility of the canvas during installation - 0.05mm; thickness of the pad before installation of the offset blanket - 0.25mm; recommended average height above the cylinder rings after installation of the pad and offset blanket - +0.10mm in the range (0.09mm-0.11mm); average load value - 250 N/cm2; deformation at medium load – 0.23mm; surface microgeometry (roughness) – 0.8 µm; elongation (linear deformations) – <0.9%; tensile strength - >60N/mm.

Three measurements were taken at three different positions on each print section, two in the end areas of the cylinders and one in the center of each print section, for each print pressure level (total of 108 measurements). Three different printing pressures between the offset blanket webs are applied in each printing section: low printing pressure level, normal printing pressure level and high printing pressure level. All applied printing pressure levels correspond to gaps between the two offset cylinders, their numerical values for the three pressure levels are respectively:

0.12 – 0.16 mm (low level of printing pressure),
0.08 – 0.12 mm (normal level of printing pressure)
0.04 – 0.06 mm (high level of printing pressure), Table 1.

Although it is a very important parameter in print production, the settings of the inking machines have not been taken into account. A total run of 5,000 sheets was printed using a GOSS M600 web offset press, Kodak Electra XD positive printing forms (dot shape - round square, FM modulation) and Flint HSWO process inks on LWC type paper, under ideal atmospheric conditions for printing (relative air humidity 49% and air temperature of 22°C), printing speed of 20000 sheets/h. The ink sequence is black, cyan, magenta and yellow (KCMY). Before the actual job is printed, the press is optimized by printing approximately 1000 sheets to set and fill the zone inking ink profile. After printing, prints were randomly selected from the print run, and three sheets of the printed print run were measured for each applied pressure (total of nine samples). The determination of quality parameters was performed using an EXACT ADVANCED X-RITE spectrophotometer.

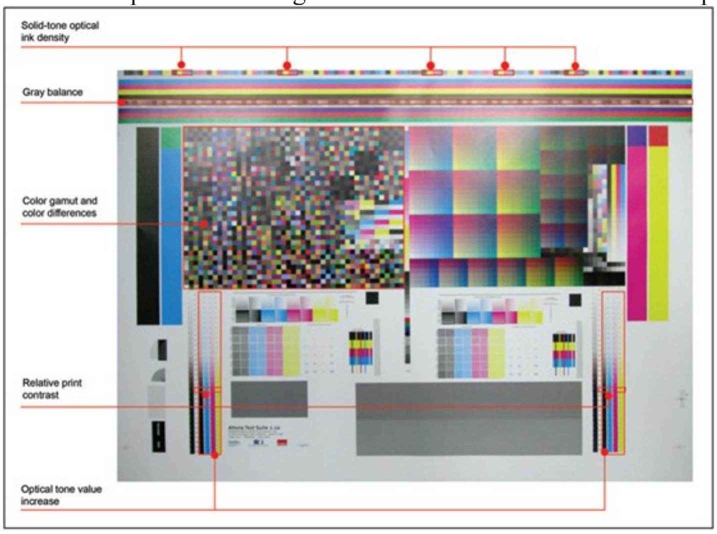

FIGURE 1. Control elements for measurement in quality control

Tone Value Enhancement. TVI Tone Value Enhancement measurements were measured on scales of prints on LWC paper (vertical control strips on both sides of printed sheets containing fields of values from 0% - 12% in 1% increments, 20% – 80% with 10% steps and margins of 88% – 100% with 1% steps) and mechanical dot growth with the same scale of the printing form respectively Figure 1. EXACT ADVANCED X-RITE meter was used, a SpectroPlate digital device for obtaining mechanical dot gain with settings adjusted to match the printed forms under consideration, and an X-Rite i1 basic Pro spectrodensitometer for TVI measurements, with the following settings: polarization filter – auto, white standard - auto, ISO density filter, source D50, observer angle 2°). A total of 432 TVI values were measured (9 control scales x 4 colors x 2 sheet sides x 3 printing pressure levels x 2 test sheets for each printing pressure level) and mechanical growth of 72 points measured on the printing forms (9 control scales x 2 sides of the plate x 4 printing forms) then the resulting results are averaged and analyzed.

Gray Balance. To evaluate gray balance parameters, ECI/bvdm Gray is used control strip (S), Figure 1. The results of this measurement were obtained by densitometric measurements of the relative optical density values of the ink for different gray balance half-fields (30%, 50% and 70%) using a meter EXACT ADVANCED X-RITE (applied settings: source D50, standard observer angle 2°). Total 81 measurements, 3 different scales x 3 positions on each scale per sheet x 3 print pressure levels x 3 samples for each print pressure level. Then, to verify the obtained results, spectrophotometric measurements were carried out using the X-Rite i1 Profiler. Here the measurements are a total of 360 measurements: 3 different halftone values (70%, 50% and 30%) x 2 types of color synthesis (CMY and black) x 20 measurements on three paper samples x 3 prints with different pressure levels. Then the color differences from ΔE values were calculated between the chromatic balance of gray (CMY) and achromatic (K) fields of the corresponding tone values on the samples printed with the same level of printing pressure.

Solid (100%) Field Optical Density Deviations. This parameter was obtained using an X-Rite i1 Profiler measuring device (same settings as mentioned above) on the solid tones of the horizontal control, Figure 1. There are a total of 120 measurements (10 fields per color x 4 colors x 3 levels of print pressure).

Relative print contrast. A key parameter for calculating relative print contrast is optical density values. These values were obtained from control elements in Figure 1 on LWC paper by measuring control fields of 100% and 80% using an X-Rite i1 Profiler device (applied settings: source D50, standard viewing angle 2°). A total of 72 measurements were performed; 2 measurements for each color x 4 colors x 3 print pressure levels x 3 sheet samples for each print pressure level.

Color difference (ΔE) and color gamut. For the purpose of color gamut and color difference measurements, an ECI2002V CMYK PM 5.0.5 test chart was used. An EXACT ADVANCED X-RITE spectrophotometer was used as a measuring instrument, for color sampling (applied settings: source D50, standard observer 2°). There are a total of 4455 measurements (1485 control fields on each test chart x 3 print pressure levels). After the measurements, a comparative analysis was done with the reference range to determine color gamut differences and color deviations with the software, as well as to generate 2D images of extracted profiles. Color difference values were calculated using the ΔE94 formula as prescribed by the given software. In the following points, the analysis of all listed quality parameters should be indicated, presenting results and determining the dependence of each one on the change in the level of printing pressure, giving the level of this pressure that generates the highest quality of print.

ANALYSIS OF PRINT PRESSURE VALUES

Three different levels of printing pressure were applied between the offset blanket webs by varying the distances between them: low printing pressure, normal printing pressure and high printing pressure. Measured print pressure values for each printing unit (left values) and values after adjustment between cylinders (right values) are shown in Table 1. An attempt was made to apply as uniform a pressure as possible to each printing unit, but deviations were observed between them (8.89%–13.85%). The maximum values of the printing pressure are on a printing section that prints magenta, respectively, the lowest printing pressure is registered on a printing section of yellow color.

TABLE 1. Pressure values during printing [N/cm2] - left columns and gaps between cylinders [mm] - right columns, for each printing section (low-low, normal-medium (normal), high-high pressure printing)

Ink	Low Printing Pressure		Normal Printing Pressure		High Printing Pressure	
Cyan	381,1	0,15	565,21	0,11	698,73	0,07
Magenta	425,32	0,17	596,15	0,14	712,32	0,08
Yellow	369,76	0,13	550,81	0,10	675,65	0,05
Black	404,21	0,14	541,32	0,09	655,15	0,05

ANALYSIS OF CHANGES IN TONAL DENSITY VALUES

The mechanical dot gain values measured on the print are presented in Table 2. They show that all values are output correctly, with no major increase or decrease in tone value. The maximum positive gain is a deviation of 1.35% measured at 20% tonal density in yellow, and the maximum negative deviation is 1.65% measured at 50% tonal density in cyan. The lowest total TVI values were measured for cyan, while the highest values were measured for yellow, although they analyzed approximately the same values on all control fields for the four colors.

TABLE 2. Mechanical dot growth and average TVI values [%] measured on Kodak Electra XD offset printing forms

	10%	20%	30%	40%	50%	60%	70%	80%	90%	Avg. TVI %
Cyan	10,05	20,30	29,65	38,80	48,35	59,60	68,90	79,30	89,10	-0,75
Magenta	10,65	20,95	31,15	40,00	48,50	59,90	69,70	79,90	89,60	-0,06
Yelow	10,55	21,35	30,70	40,30	49,05	60,30	70,00	80,35	89,70	0,16
Black	10,80	20,95	30,95	39,70	48,95	60,45	69,60	79,70	89,55	-0,03

TONE VALUE INCREMENT (TVI)

The resulting TVI values as well as the normalized ISO TVI values (purple lines and dashed purple line for dividing black ink) that correspond to certain printing conditions (printing process, ruler, paper and printing form)) according to the ISO 12647-2:2004 standard are presented in Figure 2. As a result of applying a higher level of printing pressure (red curves), generally higher reproduced TVI values. An exception is observed for cyan, where reproduced at a normal printing pressure level (green curves) generate the highest TVI values for all halftone field values considered, similarly at 90% TV field for magenta, 70%, 80% and 90% margins of yellow ink and 90% TV margin of black ink. The lowest TVI values were generated using low print pressure (yellow curves), except for the 60% and 70% black ink fields, which TVI values were higher than those produced with normal pressure level at print. All mentioned TVI differences are quite small and do not exceed the TVI value of 0.60%. The highest TVI values were recorded in black ink (which is a common case due to the fact that it is printed in the first printing section and often with a greater thickness of the ink film) Figure 2. d), although black (K) is printed using the smallest print pressure value considering normal and high print pressure levels. The smallest TVI values were obtained for cyan prints, which were printed from the second highest value of printing pressure and the lowest mechanical gain of raster dots. A similar TVI was recorded with the magenta and yellow ink measurements. The shapes of the generated TVI curves for different printed pressure levels are also very similar, indicating constant ink transfer during the printing process. In terms of set target ISO values for chromatic inks (purple curve) and for black ink (dotted purple curves), it can be observed that each level of printing pressure produces higher TVI values in the light dots (C 10% and 20%; M 10% – 30%; Y 10% – 30%) of chromatic colors, while within black ink the TVI values are higher in midtones as well (K 10% – 60% halftone fields). On the other hand, each different level print pressure produced generally lower TVI values in the dark areas (70% and 80%). TVI values measured at 40%, 50% and 80% TV fields are recorded in the tolerance values, respectively, given in Table 3.

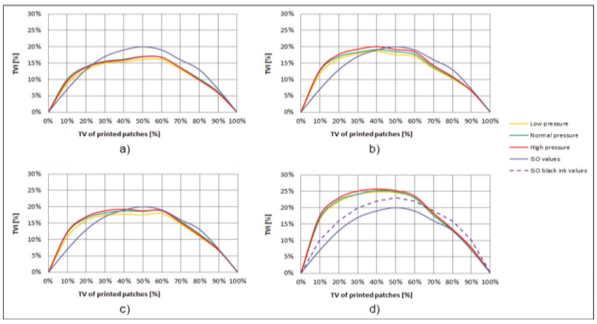

FIGURE 2. Increase the tone value: a) cyan, b) magenta, c) yellow and d) black

TABLE 3. Tolerances of tonal value increase [%] according to ISO 12647-2

Tone value of patch (control element)	Variator tolerance
40 – 50	4
75 - 80	3

The TVI results analyzed show that there is not one specific level of print pressure that can be applied to each of the print units to reproduce the desired TVI results, rather it is found that different print units need different level of pressure applied when printing.

GRAY BALANCE ANALYSIS

The gray balance values obtained are presented as a function of three process inks (C, M, Y) optical density values measured at three control fields (30%, 50% and 70%), Table 4 as and by their CIE L*a*b* coordinates, table 5. To determine the gray balance ECI/ a gray control strip (S) bvdm is used, which consists of three pairs of fields. Each pair consists of a gray balance box printed with three process inks (C, M, Y) and one printed with black ink only. The aim is to match chromatic gray tones to true gray by adjusting the pressure levels when printing, ie between the offset blanket webs. To achieve an ideal gray balance with respect to the first measurement, a method was used whereby all three color density values for each control field (30%, 50% and 70%) should be as equal as possible. This is confirmed by calculating standard deviation values between three averaged optical ink density values for appropriate halftone percentage and print pressure level, Table 4. A dominant color of prints, that is, its optical density is yellow, for each measured TV patch gray balance and applied pressure level, which indicates an imbalance of the density values of the three process colors. By increasing the printing pressure, the optical density of the ink of all three inks generally also increases, the density differences between the dominant ink (Y) and the other two inks (C, M) are not characterized by a predictable pattern. Namely, the smallest deviation between the optical density values are recorded in gray at a balance of 50% halftone field printed with a normal level of print pressure, but also very similar results were obtained using low and high print pressures for this semitone value. On the second control field (50%), printed with low print pressure produced the most balanced optical density values, which showed an s value of 0.0568. 70%, the gray balance correction revealed that the best result was produced at a high level of print pressure (s=0.0703). Each level of print pressure produces a similar result, but each produces the best gray balance for different halftone fields. It can be noted that there is no predictable trend of gray balance values changing with changes in pressure level, and the differences between the calculated standard deviations are very small, changing the printing pressure level did not affect the gray, it appears balanced parameter of prints to a great extent. The spectrophotometric method was used to check the obtained gray balance data, the measurements are listed in tabular form. Table 5 presents L*a*b* and color difference (ΔE94) values calculated between measured L*a*b* values of the same chromatic (CMY) gray balance for margins (30%, 50% and 70%) and achromatic margins printed with the same level of print pressure. These results do not support those previously obtained based on densitometric evaluation. According to the ΔE94 values presented, the low level of printing pressure produces the smallest color differences on each gray halftone field; generated high print pressure gives the second best result for color differences at 30% and 50% margin; and last is the normal print pressure, which produced the best result for a 70% gray balance field. If the spectrophotometric results are an accurate and reliable analyzer of the study it can be concluded that a low level of printing pressure should be the most suitable in terms of gray balance.

TABLE 4. Optical density of the ink and values of the standard deviation of prints on paper with a matte finish

TV	Printing pressure level	Cyan	Magenta	Yellow	σ
30%	Low	0,339	0,328	0,388	0,0315
	Normal	0,333	0,329	0,385	0,0308
	High	0,355	0,342	0,404	0,0323
50%	Low	0,542	0,540	0,640	0,0568
	Normal	0,548	0,550	0,654	0,0605
	High	0,577	0,568	0,678	0,0603
70%	Low	0,853	0,814	0,954	0,0720
	Normal	0,871	0,831	0,975	0,0736
	High	0,884	0,869	0,980	0,0703

ANALYSIS OF DEVIATION IN DENSE FIELD DENSITY

For the calculations of the deviations are used at 100% field for each color, indicating the reference values corresponding to the conditions of the printing process in the relevant standard. Using formula from figure 3, the deviations from the standard normalized optical densities for each color were calculated as such for the three different levels of printing pressure (low, medium-normal and high), the calculated values are presented in table 7.

TABLE 5. Calculated values of ΔE94 between chromatic gray balance (CMY) and achromatic (K)

TV	Printing pressure level	Gray balance patch			Black patch			ΔE94
		L^*	a^*	b^*	L^*	a^*	b^*	
30%	Low	40.07	-1.56	-0.40	39.76	-0.11	-1.00	2.32
	Normal	39.77	-2.08	-0.35	38.33	-0.23	-0.81	2.53
	High	39.03	-2.26	-0.90	37.43	-0.18	-0.67	2.50
50%	Low	54.03	0.87	-0.17	51.59	0.05	-1.53	2.91
	Normal	53.98	0.31	0.08	50.63	-0.07	-1.46	3.71
	High	52.94	0.53	-0.28	49.82	-0.03	-1.18	3.30
70%	Low	68.04	1.82	-1.28	66.78	0.30	-2.49	1.59
	Normal	68.05	1.25	-1.16	66.20	0.14	-2.45	2.38
	High	67.17	1.57	-1.13	65.32	0.20	-2.10	2.64

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(x_i - \mu\right)^2}$$

Where:
σ- standard deviation
N- total number of measurements (10 for each ink x 3 for each printing pressure level)
Xi – optical density value of the ink at the ith measurement
µ - reference value for the corresponding ink (table 6)

FIGURE 3. Formula for calculating the deviations from standard optical standards

TABLE 6. Dense field optical density values

Printing pressure	Cyan	σ_c	Magenta	σ_m	Yellow	σ_y	Black	σ_k
Low	1.480	0.0508	1.392	0.0597	1.423	0.1750	1.721	0.0746
Normal	1.498	0.0500	1.411	0.0493	1.417	0.1679	1.709	0.0577
High	1.554	0.1117	1.459	0.0967	1.436	0.1883	1.759	0.0448

Observations show that increasing the pressure between the offset blanket webs also increases the density of the ink print on the sheet, resulting in higher optical density values. The only exception is the yellow and black (Y,K) solid fields when changing natix from low to normal level. The next change from normal to high printing pressure reproduces higher density values for all inks. This is confirmed by analysis for all observed fields, except for 30% halftone in cyan and yellow (C,Y), reproduced with normal print pressure level and the values obtained for them are shown in Table 4. The standard deviation values show a downward trend after first change of printing pressure level from low to normal, table 6 and figure 4. The normal printing pressure level generates the smallest deviations in dense field density for three process inks (CMY). After a second print and increasing the pressure level, the standard deviation values increased, except for black ink, where the smallest standard deviation value was recorded. Increasing the print pressure from low to normal does not prove the theoretical assumptions and results in increasing ink optical density values increase, instead producing less optical density for yellow and black inks and overall generating the lowest standard deviations from reference values. Further increasing the print pressure level, from normal to high generates the highest solid tone high ink optical density values that support the theory, but generally also produce the highest standard deviation values.

PRINT CONTRAST ANALYSIS

Table 7 presents relative print contrast values for each process ink and applied print pressure level. This print quality parameter is obtained by measuring the optical density values of the ink at solid field and 80% halftone, and then the contrast values are calculated. The relative printing contrast values obtained were lower than the reference: by 43%, M 38%, Y 38%, K 33% [55] for each printed process ink and printing pressure level applied in the study, except the black ink producing higher relative print contrast values for all print samples at different pressure levels. The lowest relative print contrast value was obtained using a normal print pressure level. The high level of print pressure generated the highest relative contrast values for all four process inks, as well as the smallest differences from the given reference, suggesting that for best relative contrast reproduced on matte-coated papers, uses a high level of printing pressure. Explanations for obtaining this relative contrast of the print can be found in the assumption that the surface structure of the considered type of paper, as well as the thickness of the applied ink layer are variable. In the parts of paper where there is an uneven thickness of the layer, an uneven lateral scattering of light occurs, which leads to a change in the tone value, correspondingly, the optical density of the ink increases. Variable side scattering of light on different areas of the same sheet of paper can be observed microscopically as well as by printing a sequence of parallel lines of the appropriate thicknesses and gaps between them on the paper, then measuring the optical density of the gaps using a microdensitometer and a microdensity profile is generated. It will show a greater optical density of the paper in areas with a thinner coating layer compared to those areas that are coated with a greater thickness of the ink layer.

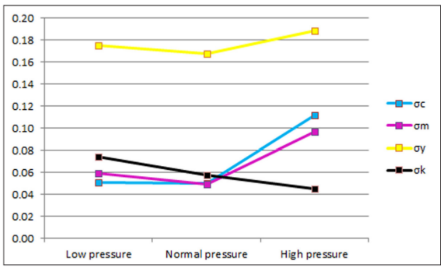

FIGURE 4. Optical density deviation values at different print pressure levels

TABLE 8. Values of relative contrast at different levels of printing pressure

Printing pressure	Cyan	Magenta	Yellow	Black
Low	38.37%	35.37%	34.53%	39.20%
Normal	37.20%	35.70%	33.53%	38.03%
High	39.70%	36.37%	34.70%	39.87%

ANALYSIS OF COLOR GAMUT AND COLOR DIFFERENCES (ΔE94)

Different levels of printing pressure generate different color gamut volumes, which is related to the different thicknesses of ink transferred to the substrate, resulting in different optical densities of ink prints. Applying a high level of printing pressure in the process reproduces the largest volume of the color gamut; the normal print pressure level generates a lower gamut volume, while the lowest gamut volume reproduced is when using a low print pressure level, Table 8. Comparisons of gamut volumes between the values obtained when applying different levels of printing pressure are also presented in Figure 5. From the figure, it can be seen that the generated gamut volumes using three levels of printing pressure are almost identical, although the volume of the color gamut may be slightly wider, which is noticeable when using a high level of printing pressure (red line) compared to the other two data sets (green line - normal level of printing pressure and yellow line – low level of printing pressure). Color difference values were calculated using the CIE 94 (ΔE94) formula, Table 8. The test results showed that generally the smallest color difference (ΔE94) values were achieved using a high print pressure level (except yellow ink printed with low print pressure). Regarding color difference tolerances accepted in the printing industry, calculated color differences for cyan and yellow ink fall into the category of normal-invisible differences (ΔE94<1) for all three applied printing pressure levels; the calculated color differences for magenta are in the third group of average differences that are apparent to the untrained eye (2<ΔE94<3.5), and the color differences for black ink belong to the obvious difference group (3.5<ΔE94<5). The calculated color differences between different print pressure levels for each printed ink do not differ by more than 0.63 (black ink), which is a virtually invisible color difference to human perception. So even if it is difficult to distinguish the resulting variations of these two parameters in terms of print quality reproduced by three different print pressure levels visually, the data suggests that the high print pressure level provides a slightly better performance.

TABLE 8. Color gamut volumes, color differences (ΔE94) between measured samples and test reference target data

Printing pressure	Color gamut volumes	ΔE94			
		Cyan	Magenta	Yellow	Black
Low	370.832	0.65	3.26	0.71	4.45
Normal	372.737	0.52	3.29	0.84	4.44
High	379.188	0.44	3.14	0.79	3.82

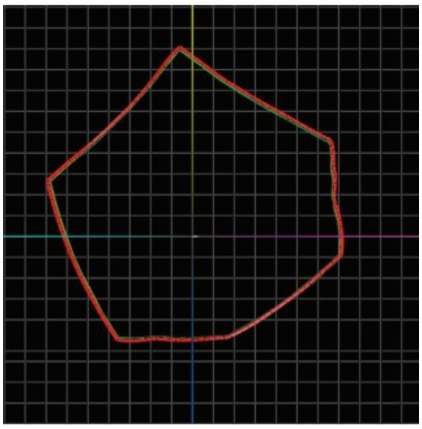

FIGURE 5. Comparison of color gamut profile for three different printing pressure levels

CONCLUSION

After research and analysis on how different printing pressures affect on the quality of offset printing and the prediction that a change in its level will have a large impact on various print reproduction parameters, the following conclusions are described. The applied print pressure levels affect some print quality parameters to a lesser extent, while others to a greater extent, and there are no clear trends for print quality to deteriorate or to improve with the same change in the level of pressure when printing. Obtained mechanical point gain values on the shapes show that all tonal values are reproduced correctly, with no large increases or decreases in tonal value. Taking into account ISO 12647-2:2004 and the reference TVI values for the paper type considered, the most suitable TVI values are achieved by using different print pressure levels for different separations: a high print pressure level gives the best TVI values for magenta printing, a normal print pressure level is shown to be the best option for cyan and yellow, while when generating a low level of printing pressure, the best results are for black ink. If one relies on spectrophotometric results, as more accurate, and calculated values of color differences (ΔE94) for gray as a balance parameter (table 5.), one can conclude that a low level of print pressure gave the best result for gray balance, even when changing print pressure the level did not cause massive variations in gray balance between individual samples printed at different print pressures. Regarding dense optical field density, it has been confirmed that normal print pressure level produces the best print quality result for three out of four separations (CMY) while high print pressure generates the best result for black (K) as calculated values of the standard deviation in table 6. The best relative print contrast and color gamut volume are produced by using a high level of print pressure for each color (CMYK). The same print pressure produces the smallest color difference values for three separations (CMK), at low print pressure the level produces the smallest color difference for yellow only (Y). Even if it was observed that for example a normal level of printing pressure never achieved the best printing result within black ink printing for each of the considered quality parameters printing, as well as from the presented results, from the analyzed parameters of the quality of offset printing, it is very difficult to determine which level of printing pressure is the most effective, because, as can be seen, different levels of printing pressure have different effects on different parameters for print quality. To complement this feature of print quality, further research directions should focus on the study of additional print quality parameters (point deformation, line reproduction, visual evaluation, etc.).

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