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INFLUENCE OF DIFFERENT PRINTING PRESSURE LEVELS ON SHEET-FED OFFSET PRINT QUALITY

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ABSTRACT

In the sheet-fed offset printing technique, an adequate high contact pressure between the blanket and the impression cylinders has to be applied for the proper ink transfer onto the printing substrate. The aim of this research is to investigate the influence of three printing pressure levels between blanket and impression cylinders, on various print quality parameters, during a four color sheet-fed offset printing process on gloss-coated paper. This was examined by measuring different control elements of both the printing plates and prints, in order to obtain quantitative information about the standard print quality parameters. Through the evaluation of this important printing factor and relating it to print quality, it would be possible to find out in what ways and to what extent different printing pressue levels affect sheet-fed offset print quality, and if the necessary normal printing pressue level produces the best print reproduction for all print quality parameters.

Keywords: *printing pressure levels, sheet-fed offset, print quality parameters.*

INTRODUCTION

The printing pressure between blanket and impression cylinders is a very important factor for ink transfer during a sheet-fed offset printing process, and therefore has a huge impact on the final print quality. For ink and dampening solution transfer from one surface onto another, the application of optimal printing pressure intensity, as well as the even pressure distribution between the blanket and the impression cylinders are the crucial factors. Print quality depends on various factors such as: printing plate, blanket of the blanket cylinder, printing substrate, ink, printing speed, dampening solution, ink-water balance, printing press condition and operator actions [1]. Printing pressure in the offset printing technique includes different contact zones: between ink rollers; between dampening rollers; between ink form and dampening form rollers on one side and plate cylinder on the other; between plate and blanket cylinders, and in the end - between blanket and impression cylinders [2]. The ink transfer within the printing nip is dependent on the nip's dwell time, i.e. time that a sheet of paper spends in a contact zone between the cylinders, the nip pressure amount and geometry, ink rheology and the ink amount on the blankets [3, 4]. Concerning printing substrates, there are several paper properties that mostly affect offset print quality. These are: surface roughness, surface compressibility and viscoelasticity of the paper surface. The higher the printing pressure applied, the larger the area of the paper surface which comes into contact with the ink on the printing surface, thus improving ink coverage. If solid-tone areas are printed with enough available ink and increased nip pressure, ink coverage and uniformity of solid-tone areas can be improved, because the surface compression increases the surface contact area and decreases the surface roughness volume of the paper, which compensate the effects of the surface structure [5 - 7].

There are various methods for printing pressure estimation in an offset printing process. One of them is based upon the Prescale film, which is a two-sheet film sensitive to pressure, that has to be mounted in the contact zone between an impression and a blanket cylinder. When pressure is applied, the micro capsules on the first sheet crack and the color-forming material reacts with the color-developing material on the other sheet of the film. The level of ink density will depend on the intensity of the applied pressure. After the color is generated, printing pressure as well as pressure distribution can be estimated by ink deepness readings [2]. Pressure in a deformable nip zone of counter-rotating rolls can also be determined by means of a piezoelectric transducer installed in one of the rolls; force sensors which measure the pressure in a rolling nip by means of a small hole drilled in the rod, connected to a measuring chamber which, however, fails to provide reliable data at the exit of the metering nip [8].

The aim of this research is to determine how the application of different printing pressure levels between blanket and impression cylinders affects four color sheet-fed offset print quality, which will be accomplished through examination of various print quality parameters, measured both on the printing plates and the gloss-coated paper prints.

EXPERIMENTAL

In this study examination of six different print quality parameters for the sheet-fed offset lithographic printing technique, measured on gloss-coated paper prints under the aplication of three different printing pressure levels between blanket and impression cylinders were included. These print quality parameters are: tone value increase - TVI, gray balance, solid - tone optical ink density, relative print contrast, color gamut and color differences (ΔE).

The hardness of all four blankets (Flint Group dayGraphica 3610) was measured using Shore durometer PCE-DX-A, which amounted to 82 Shore A, after which the printing pressure measurements between the blanket and the impression cylinders took place using a Nip Control Pressure Indicator [9, 10]. Three measurements were taken, on three different positions of each printing unit, for each pressure level (108 measurements). Three different printing pressures between blanket and impression cylinders were applied on each printing unit: a low printing pressure level, a normal printing pressure level, and a high printing pressure level. All applied printing pressure levels correspond to appropriate distances between blanket and impression cylinders as following: 0.12 mm - 0.10 mm (low printing pressure level), 0.08 mm - 0.06 mm (normal printing pressure level), and 0.07 mm - 0.04 mm (high printing pressure level). As can be noticed, it was impossible to adjust always the same distance between the blankets and impressions cylinders on each printing unit in order to achieve the same printing pressure level, which resulted in certain distance overlaps. A total circulation of 200 sheets was printed by a sheet-fed offset KBA Rapida 75 printing machine using FUJIFILM Brillia LP-NV negative acting printing plates and TOYO (TK HU NEO ERP) process inks on gloss-coated paper (115 g/m^2), under printing speed of 7.000 sheets/h and ink sequence of black, cyan, magenta and yellow (KCMY). Afterwards, a random sampling of the prints took place and three sheets were taken for each pressure level applied (total of 9 sheet samples). When the printing pressure measurements and printing process were done, six standard print quality parameters were estimated, by measuring different print quality control elements (Fig. 1).

Tone value increase values were measured on nine TV patches of gloss-coated prints from 10 % to 90 % (TECHKON SpectroDens, 432 measurements), while mechanical TVI (dot gain) was measured on the same TV patches, but only on the plates (TECHKON SpectroPlate, 72 measurements), (Fig. 1). Before the generation of optical TVI curves, for 0 % and 100 % TV patches were assigned for those exact tone values and as such were included in the TVI curves generation.

ECI/bvdm Gray Control Strip (S) was used for gray balance parameter estimation (81 measurement), (Fig. 1), and VIPTRONIC VIPDENS 2000 densitometer - to determine the relative optical ink density values on different TV gray balance patches (30 %, 50 %, and 70 %).

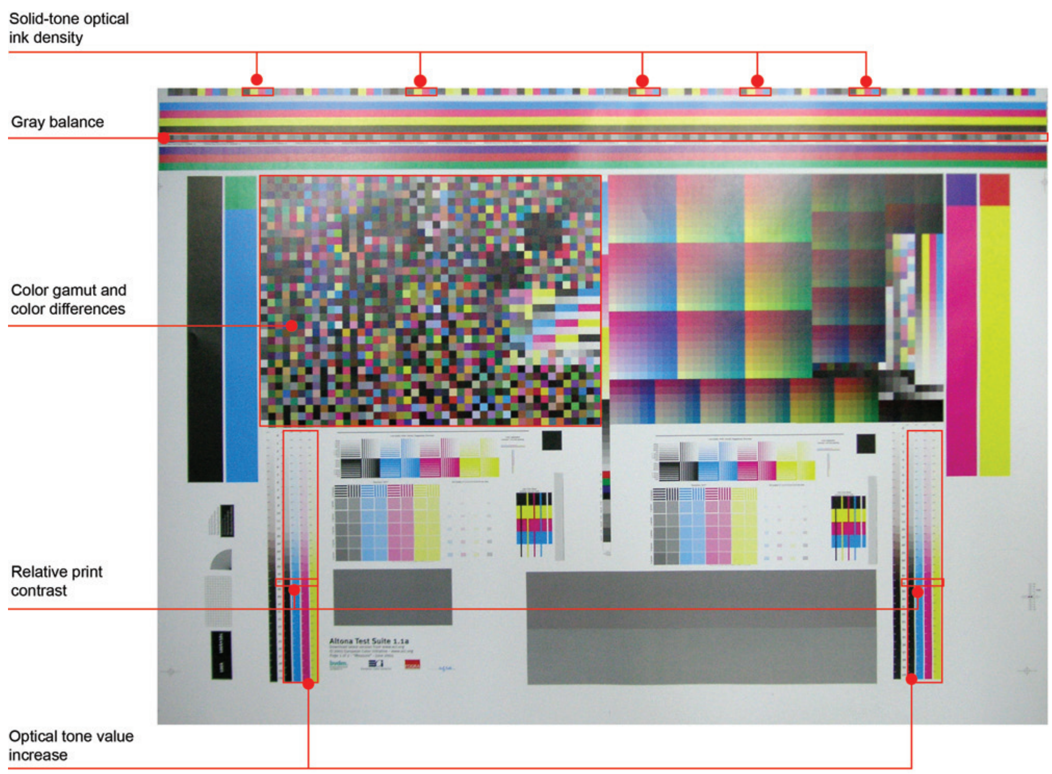

Fig. 1. Measured control elements of the gloss-coated paper print.

Solid-tone optical ink density was obtained using the TECHKON SpectroDens measuring device on the solid-tone patches of horizontal control bar (120 measurements), (Fig. 1).

A key parameter for calculating relative print contrast values is the optical density. Its values were obtained by measuring TV patches of 100 % and 80 % using VIPTRONIC VIPDENS 2000 device (72 measurements).

ECI2002V CMYK PM 5.0.5 testchart and a Gretag Macbeth spectrophotometer, Spectrolino were used for color gamut volume and color differences measurements (1,485 patches on each test chart, printed using three different printing pressure levels; 4,455 measurements in total). The GretagMacbeth ProfileMaker Pro 5.0.5 software, Measure Tool and Profile Maker was used for the subsequent color profiles generation and obtaining information about color differences. Subsequently, the profiles were compared to the reference one, in order to determine color gamut differences and color deviations with the Chromix Color Think Pro 3.0 software, as well as to generate 2D representations of extracted profiles. Color difference values were calculated using ΔE_{94} formula.

RESULTS AND DISCUSSION

In this section of the paper, analysis of variable factor values (printing pressure levels), as well as analysis of six print quality parameters data, will be presented and discussed, after which determination of their dependance on printing pressure levels, as well as optimal printing pressure level selection for a specified print quality parameter will be possible.

Printing pressure values analysis

Three different printing pressure levels were applied between the blanket and the impression cylinders during printing process: a low, a normal and a high printing pressure level. The measured printing pressure values for each printing unit are presented in Table 1. It was endeavoured to apply printing pressure as uniform as possible on each printing unit, but there were certain deviations between them (8.25 % - 12.32 %). The maximum printing pressure values were recorded on the printing unit that prints magenta ink. Generally, the lowest printing pressure was recorded on the cyan printing unit.

Table 1. Printing pressure values [N/cm^2] for each printing unit and applied printing pressure level.

Ink	Printing pressure level		
	Low	Normal	High
C	365.56	530.00	653.33
M	415.56	604.44	700.00
Y	366.67	543.33	674.44
K	391.11	548.89	642.22

Tone value increase analysis

Mechanical dot gain

Mechanical dot gain (TVI) values measured on the printing plates are presented in Table 2. They show that all TV are reproduced correctly, without significant increases or tone value drops. The maximum positive TV deviation is 1.25 %, recorded on the 20 % TV patch of yellow separation, and the maximum negative TV deviation is 1.75 % (a smaller TV than aimed), measured on the 50 % TV patch of cyan separation. The lowest overall mechanical dot gain values were recorded on cyan separation, while the highest values were recorded on yellow separation, though the TV of all four separations are quite uniform.

TVI of the prints

The TVI parameter includes both mechanical dot gain (growth of the physical half-tone dot) and optical dot gain. Higher printing pressure level application should lead to greater dot spread of the prints (higher mechanical dot gain) which will result in higher overall TVI of the prints. In Fig. 2 the TVI values measured on gloss-coated paper prints are presented in the form of TVI curves, printed by four process inks (cyan, magenta, yellow and black). Analysing the TVI curves presented in Fig. 2, it can be noticed that as a result of higher printing pressure level application, the TVI values rise on three separations (magenta, yellow and black), but there is also present a very small distinction between TVI values under different printing pressure level applications. The highest TVI values were recorded within the black separation prints, Fig. 2-d), even though this separation (K) was printed using the smallest printing pressure level for high, and the second largest amount for low and normal printing pressure levels. In addition, the TVI of this plate separation were the second highest. The maximum registered TVI value was 36.08 %, produced under high printing pressure on the 30 % black separation TV patch. The smalest TVI values were obtained on cyan separation prints, Fig. 2-a), which were printed using the lowest amount of low and normal printing pressure, and the second lowest high printing pressure amount, as well as the lowest mechanical dot gain of the plate (drop of TV values, avg. m. dot gain = - 0.75 %).

The analysis of TVI data generated using different printing pressure applications and their comparison, shows that the lowest TVI values were produced using low printing pressure, while the highest TVI values were obtained using high printing pressure level, Table 3. TVI values almost match over a wide TV range, and a distinctive borderline between the curves cannot be easy recognized. There are TV patches printed by the normal printing pressure level showing high TVI values than TV patches, printed by high printing pressure level (10 % - 90 % TV patches of cyan ink separation, 10 % TV patch of magenta ink separation; 70 % and 90 % TV patches of yellow ink separation). There are also two TV patches printed using low printing pressure level where the highest TVI values were recorded (yellow ink TV patches of 70 % and 80 %, by 0.10 % and 0.30 % higher than the same TV patches printed using high printing pressure level, respectively). The biggest TVI difference

Table 2. Mechanical tone values and average mechanical dot gain [%] of the offset FUJIFILM Brillia LP-NV printing plates.

Ink	10%	20%	30%	40%	50%	60%	70%	80%	90%	avg. m. dot gain
Cyan	9.95	20.20	29.65	38.70	48.25	59.50	68.80	79.20	89.00	- 0.75
Magenta	10.55	20.85	31.05	39.90	48.40	59.80	69.60	79.80	89.50	- 0.06
Yellow	10.45	21.25	30.60	40.20	48.95	60.20	69.90	80.25	89.60	0.16
Black	10.70	20.85	30.85	39.60	48.85	60.35	69.50	79.60	89.45	- 0.03

Table 3. Average TVI values.

Ink	Printing pressure level		
	Low	Normal	High
Cyan	19.91 %	21.34 %	20.94 %
Magenta	22.07 %	22.52 %	23.09 %
Yellow	19.62 %	19.58 %	19.82 %
Black	26.37 %	26.92 %	27.23 %
CMYK	21.99 %	22.59 %	22.77 %

Table 4. Average TVI values of the 50 % TV patch for different separations and printing pressures applied.

Ink	Printing pressure level			TVI for 50 % TV control
	Low	Normal	High	
Cyan	23.48 %	25.55 %	24.88 %	20 %
Magenta	25.45 %	26.43 %	26.88 %	20 %
Yellow	22.95 %	23.05 %	23.48 %	20 %
Black	31.20 %	32.13 %	32.23 %	20 %

between two TV patches amounts to 2.07 %, recorded on the 50 % TV patch of cyan ink separation, and produced using low and normal printing pressure levels.

Table 4 presents the standard TVI values for 50 % TV patches, according to ISO 12647-2:2004 standard [11], and the obtained TVI values on the prints. The smallest deviations from the reference value were recorded applying low printing pressure level for all four process inks used. Normal printing pressure level generated the second smallest TVI values for all printing inks used, except for the cyan, while a high printing pressure level produced the highest TVI values for magenta, yellow and black ink.

The low printing pressure level is considered to be the most appropriate for this print quality parameter according to the specified standard TVI value of the 50 % TV control patch. However, TVI distinctions presented here are quite small and will not produce significant reproduction variations.

Gray balance analysis

Table 5 shows measured optical ink density values of the three process inks (C, M, Y), measured on three different gray balance TV patches of the gloss-coated paper prints (30 %, 50 % and 70 %). The dominant color of the prints is yellow for each pressure level applied and measured gray balance TV patch. By increasing pressure during the printing process, the optical ink density also rises. High printing pressure produced the biggest optical ink density differences, greater than for printing using a low printing pressure condition. The smallest overall optical ink density differences between the dominant color (Y) and the other two colors (C, M) were obtained using normal printing pressure level for each measured TV patch, which proved to be the best option for accomplishing optimal gray balance reproduction.

Solid-tone optical ink density analysis

Solid-tone optical ink density values measured on the prints are presented in the Table 6. By increasing the printing pressure level during the printing process, generally higher solid-tone optical ink density values are produced. An exception is the printing pressure level shift from low to normal, on magenta, yellow and black (M, Y, K) solid-tone patches, where lower optical ink density values than when using low printing pressure level are produced. The next printing pressure level shift, from normal to high, produced as expected, higher solid-tone optical ink density values for all process inks.

It is clear that when the contact pressure between the impression and the blanket cylinder increases, ink deposition on the substrate will also rise, resulting in higher optical ink density values. This was also confirmed for all measured TV patches of 30 %, 50 %, 70 % except for 30 % yellow ink separation TV patch using normal printing pressure level (Table 5).

Table 5. Optical ink density values of the prints.

Printing pressure level	30 %			50 %			70 %		
	C	M	Y	C	M	Y	C	M	Y
Low	0.347	0.346	0.391	0.580	0.572	0.667	0.925	0.862	0.983
Normal	0.354	0.353	0.389	0.594	0.580	0.677	0.934	0.863	0.987
High	0.355	0.366	0.407	0.599	0.604	0.698	0.942	0.896	1.019

Table 6. Solid-tone optical ink density values.

Printing pressure level	C	M	Y	K
Low	1.576	1.517	1.465	1.792
Normal	1.578	1.468	1.447	1.761
High	1.596	1.582	1.487	1.844

Relative print contrast analysis

The relative print contrast values, as well as their standard deviations (calculated from the given reference relative print contrast values for each process ink) are presented in Table 7. This parameter was measured on the solid-tone and TV patches of 80 %. The obtained relative print contrast values are smaller than the reference ones (C 43 %, M 38 %, Y 38 %, K 33 %) [12] for each printed process ink and printing pressure level applied, with the exception of black ink, which produces higher relative print contrast values for all printing pressure levels.

The highest overall relative print contrast (the smallest σ value) was produced applying low printing pressure level, and the lowest was gained by printing with normal printing pressure (highest σ value).

Explanations for gaining these values of relative print contrast parametar may be found in the surface structure investigation of this paper type, as well as in its coating layers, because optical density depends on the lateral light scattering of the printing substrate. An unevenly applied coating layer can lead to a large TVI and ink density increase, in the areas with evenly applied coating layer, the tone-value increase is small and the optical ink density is not so high [13].

Color gamut and color differences (ΔE) analysis

Different printing pressures generate different color gamut volumes, which is related to various ink thicknesses transfered onto the substrate material, resulting in different optical ink density of the prints. Higher printing pressure application during the print process produce bigger color gamut volume and vice versa, which means that the smallest color gamut volume values are produced using a low printing pressure level, while the biggest ones, use a high printing pressure level (Table 8). Color gamut comparisons between values obtained using different printing pressure levels application are also presented in Fig. 3. It is evident that the generated color gamuts, using three different printing pressure levels, are almost matching, though a slightly wider color gamut can be noticed by applying high printing pressure (red line) comparing to other two data sets (green line - normal printing pressure level, and yellow line – low printing pressure level). CIE L*a*b* color difference values were calculated using CIE 94 (ΔE^*_{94}) formula (Table 8). The test results show that the smallest average color difference (avg. ΔE) was achieved using a low printing pressure level, while normal printing pressure generated maximum color differences.

Table 7. Relative print contrast values and their standard deviation values.

Printing pressure level	C	M	Y	K	σ
Low	38.17 %	35.50 %	32.33 %	37.50 %	4.23 %
Normal	34.83 %	33.50 %	32.17 %	34.67 %	5.56 %
High	37.00 %	33.83 %	32.83 %	36.83 %	4.87 %

Table 8. Color gamut volumes, color differences (ΔE_{94}) between measured samples, reference test target data, and average color differences (avg. ΔE).

Printing pressure level	Color gamut volumes	ΔE_{94}				
		Cyan	Magenta	Yellow	Black	avg. ΔE
Low	393,510	1.05	2.56	0.99	2.18	1.695
Normal	394,099	0.64	3.04	1.11	2.79	1.895
High	404,062	1.04	2.55	0.99	2.25	1.708

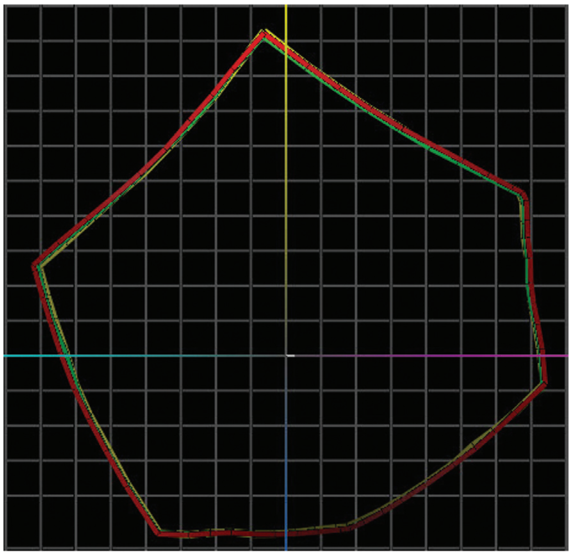

Fig. 3. Comparison of color gamuts obtained using three different printing pressure levels.

CONCLUSIONS

After analysis of the different printing pressure levels effects on the presented print quality parameters, the following conclusions can be made.

The use of normal pressure level generated optimal gray balance reproduction, while in case of TVI values, relative print contrast and color difference parameters, it was confirmed that the low printing pressure level gives the best print quality results. The high printing pressure level application during the offset printing process produced the highest color gamut volume and the highest solid-tone optical ink density.

The presented results of the investigation suggest optimal printing pressure levels for reaching best print reproduction for each analysed print quality parameter. A general conclusion can be drawn that a low printing pressure level enables a better overall print quality result comparing to the other two printing pressure settings.

In order to complement the print quality characterization, further directions of research should be focused on the investigation of additional print quality parameters (dot deformation, line reproduction, visual assessment, etc.), as well as on inclusion of more variable factors (printing speed, different fountain solution effects and ink zones effects on print quality, etc.).

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