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THE INFLUENCE OF IMPURITIES IN PRINTING SUBSTRATE ON THE DEFORMATION OF SCREEN ELEMENT AND DOT GAIN IN COLDSET PRINT

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Original scientific paper
Newspaper print (coldset), because of the most economic production, became quantitatively the most used print technology for the daily, weekly and monthly printed media on the market. A variety of different factors affect the appearance and quality of printed product, some of which are of crucial importance and should be monitored during the whole print run - print density and dot gain of screen elements. Newspaper print can be considered of satisfactory quality if all of the screen elements were reproduced correctly. In this research the influence of geometrical and optical deformation of hybrid screen elements on the printing quality was analysed, results of the valorised deformation of halftone values that are in a direct connection to gained quality were compared. Also, the printing densities in the print run were analysed by densitometric and spectrofotometric methods. The emphasis in this research is on the cyan colour component, since these screen elements clearly show the influence of impurities in printing substrate on deformation of screen element and dot gain. The observed characteristics were valorised by scientific methods and presented by graphic overviews. The impact of prevailing, recycled printing substrate on printing quality was determined.

Keywords: *dot gain, newspaper print, recycled printing substrate, reproduction quality*

Utjecaj nečistoća u tiskovnoj podlozi na deformaciju rasterskog elementa i prirast rastertonske vrijednosti u novinskom tisku

Izvorni znanstveni članak
Novinski ofset tisak, zbog najekonomičnije proizvodnje, postao je brojem otisaka na tržištu najzastupljenija tiskarska tehnika za dnevne, tjedne i mjesečne tiskane medije. Na izgled i kvalitetu otisnutog proizvoda u novinskom tisku utječe niz faktora od kojih su neki od presudne važnosti i morali bi biti kontrolirani tijekom proizvodnje cijele naklade - gustoća obojenja i prirast rastertonskih vrijednosti. Kako bi se novinska reprodukcija smatrala kvalitetno otisnutom, glavni uvjet je pravilno reproduciranje svih rasterskih elemenata. Istraživanjem se ispitao utjecaj geometrijske i optičke deformacije rasterskih elemenata hibridnog rasteriranja na kvalitetu tiska, komparirani su rezultati mjerenja deformacije rastertonskih vrijednosti koji su u izravnoj vezi s dobivenom kvalitetom. Također su denzitometrijskim i spektrofotometrijskim metodama analizirane gustoće obojenja otisaka kroz cijelu nakladu. Naglasak u ovom istraživanju je na cijan komponenti, jer se na tim rasterskim elementima najjasnije vidi utjecaj nečistoća u tiskovnoj podlozi na deformaciju rasterskog elementa i prirast rastertonske vrijednosti. Promatrana svojstva su valorizirana znanstvenim metodama i prezentirana grafičkim prikazima. Ustanovljen je utjecaj prevladavajuće, reciklirane tiskovne podloge na kvalitetu reprodukcije.

Ključne riječi: *kvaliteta reprodukcije, novinski tisak, prirast rasterskog elementa, reciklirana tiskovna podloga*

1 Introduction

Newspaper print (coldset) has become, by quantity, the most common printing technique on the market due to its low unit price of prints. This type of printing is used for production of daily, weekly and monthly print media. It is a type of the offset at which the print, after printing process, is not subject to the process of drying, as opposed to magazine print (heatset). For this reason, printing speed reaches quantity of 38 500 prints per hour. The most widely used way of reproduction of multi tone images in print is screening, where different tones simulate raster elements of the highest printing densities (2), but different area coverage. However, the manner in which screen elements are going to be reproduced depends on how screening process is done, as it is important to take advantage of different types of screen elements whether it is the frequency modulated or amplitude modulated. Printing quality is the most affected by print density and dot gain that occur due to the printing ink characteristics, machine temperature, pressure between cylinders, printing blankets, printing substrate, technical condition of the machine, fountain solution, printing plates and the process of making printing plates. When the area of the screen element increases in relation to its initial shape before exposition of printing plates or film, this phenomenon is called the dot gain. Dot gain (Z) [1, 2] is the difference between the measured tone value on the print (F_D) and known tone values in the prepress (F_P). Dot gain can be geometrical and optical.

$$Z(\%) = F_D - F_P. \tag{1}$$

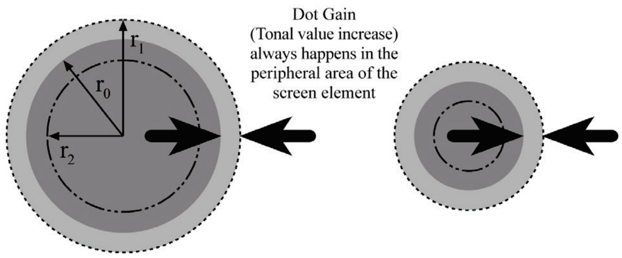


Figure 1 Dot gain

Geometrical dot gain is the result of physical application of colour to the printing substrate and is influenced by the ink performance, viscosity, pressure in printing process and properties of printing substrate. Optical dot gain occurs as that light enters the ink layer and reaches the printing substrate, a certain part scatters. Scattered light can come from the edge of the ink in a way that it reflects part of the light outside the physical dimensions of the screen element or remain trapped beneath the element. Screen element therefore appears to be larger, although physically it is not, and consequently the edges of the screen element are perceived with shadow.

Because of the growing awareness of ecology nowadays grows the use of recycled printing substrate. Recycled printing substrate undoubtedly affects the quality of the print, mainly on the deformation of the screen element and dot gain. The development of screen element technology constantly keeps pace with the development of new printing materials for it to give the best possible reproduction in all tonal values [3]. The transition modulated - hybrid screen element is a new screening technology, which allows the use of advantages of both AM and FM technology and therefore achieves a high quality reproduction of the whole range of tonal values. Special emphasis is placed on high-quality reproduction in low and high tonal values. Hybrid screen uses patented technology for smooth transitions from one screening technology to another, mathematically determining the tonal value at which reproduction no longer benefits from AM screening. For example, the size of AM screen elements is reduced in low tonal values until the minimum size of the elements in the printing process is achieved, after that it removes some of the elements, so it is possible to get a lower tonal value without further reduction of screen element size. In higher screen values, screen smoothly transits from AM to FM so shadow areas on the images may appear stochastic, although this is not true stochastic screening. Reproduction areas that use FM screening use smaller elements in FM mode, they are still aligned by AM grid from high tonal values. In this way a transition modulated screening technology is gained that does not show any noticeable transition between technologies, because of the equal screen element alignment. Solids are also reproduced exclusively by AM angles regardless of screen values [4, 5, 6].

In this study, by image analysis of screen elements on printed samples, the influence of impurities in the printing substrate on reproduction of screen elements and dot gain will be valorised. The impact of the printing substrate on reflectance and absorption of light will be analysed in a way to eliminate its effect, and then compare the spectral curves for selected tonal values of cyan colour component. As a result of the research it is expected to gain knowledge of the impact of recycled printing substrate on the overall reproduction quality in the newspaper offset, and the effect of using hybrid screen element.

2 Experimental part

This study focuses on image analysis of screen elements on samples and changes they go through from the exposition of plates to the print process on the printing substrate. Cyan colour component was analysed, because the preparations for the study showed that this component is the most notable in relation to the spectral reflectance of printing substrate and impurities that are found in the composition of recycled printing substrate. Image analysis will be done by photographing screen patches using digital microscope Dinolite Pro AM413T with enlargement 200×. Digitalized patches will then be analysed with image analysis software, ImageJ.

2.1 Methodology

Samples for analysis were printed in real graphic production on one printing unit on coldset machine in the uncalibrated, but linearized printing process with print run of 10 000 prints. Process colours, in the recommended conditions by ISO standard 12647-3: 2004 [7, 8], which define production conditions for coldset offset printing, will be used. Printing reproduction quality control will be monitored by visual analysis and integral print density (D_i). The minimum value of the integral print density in printing process was the recommended value set by the international ISO standard. Samples were printed on paper 42,5 g/m^2 weight with a high percentage of recycled secondary raw materials.

Table 1 Colorimetric and surface characteristics of printing substrate

Characteristic	Value
Weight ISO 536	42,5 g/m^2
Humidity ISO 287	7,4 %
Whiteness ISO 2470, D65	58,7 %
Colour a* DIN 6174	-0,16
Colour b* DIN 6174	2,94
Opacity ISO 2471	95,1 %
Breaking ISO 1924-1	4588 m
Voluminosity ISO 534	1,45 cm^3/g
Straining ISO 1924-1	1,12 mm
Roughness OS DIN 53108	137 ml/min
Harshness US DIN 53108	136 ml/min

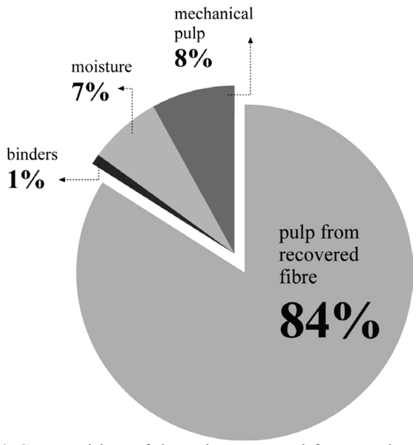


Figure 2 Composition of the substrate used for samples printing

Densitometric and spectrophotometric measurements were carried out by X-Rite SpectroEye device. The print density by Murray-Davies formula enabled obtaining real tonal values [9, 10]:

$$F_D = (1-10-D_t)/(1-10-D_s), \quad (2)$$

(F_D − dot area, D_t − density of inking on halftone area, and D_s – density of inking on solid area)

Then dot gain was calculated on the observed screen samples. Spectrophotometric measurements obtained data on optical characteristics of the sample which were then presented by the relative reflectance curve. Relative reflectance is observed in the wavelength range from 380 nm to 730 nm [11, 12]. Measurement conditions were set as standard D65 illumination with viewing angle 2°.

In the end with the help of imaging analysis the percentage of dot gain values which can be attributed to the impurities in the news media were calculated.

2.2 Test image

Test sample used for the research is shown in Figure 3. It consists of multitone reproductions and halftone fields of 2 %, 3 %, 5 %, 7 %, 9 %, 10 %, 20 %, 30 %, 40 %, 50 %, 60 %, 70 %, 80 %, 90 %, 91 %, 93 %, 95 %, 97 % and 99 % screen value, dimensions 4,75 × 4,75 mm. By measurement of integrated printing density the calculation of dot gain will be also gained. Printing plate contains elements for the image analysis of sample quality by the observer, grey balance, and gradients.

Figure 3 Test image

3 Results and discussion

3.1 The curves of relative reflectance and absorption

By spectrophotometric measurement of screen patches Cyan 5 %, Cyan 50 % and Cyan 95 %, were obtained spectral values for wavelength range from 380 nm to 730 nm. From the obtained data the curves were made for relative reflectance and absorption.

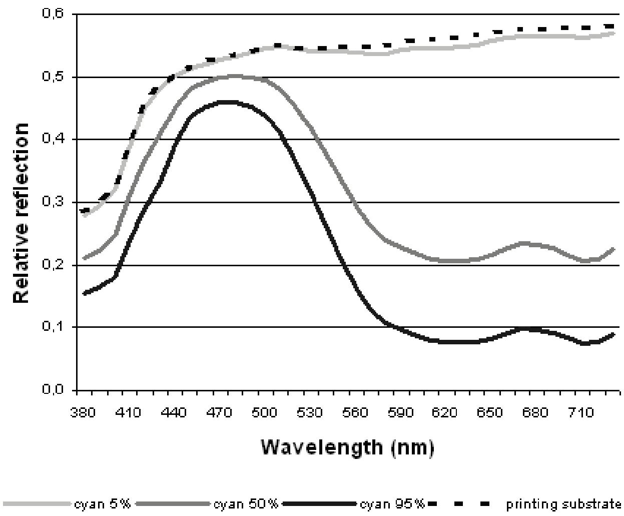


Figure 4 Relative reflectance curves of cyan screen patches with halftone value 5 %, 50 % and 95 % with shown relative reflectance of printing substrate

The relative absorption curve shows the absorption measured on the samples after the influence of substrate on the obtained spectral values was neutralized. Principle by which colorimetric instruments work, such as spectrophotometer, is based on the way one sees and perceives colour. [13] Light shines from the source and illuminates the colour sample. Part of the light is absorbed by the sample, and the rest is reflected. The sensor measures the information for each colour and the information is then forwarded to the computer where the values are determined using algorithms that simulate the behaviour of the three types of cones found in the human eye. These algorithms are defined by the CIE organization for the standard observer, and produce three standardized colour values X, Y and Z, which are then converted into coordinates for CIE chromatic diagram or some other system for displaying colours. Because these functions do not have to be formed by filters, the absolute accuracy of spectrophotometers is very high.

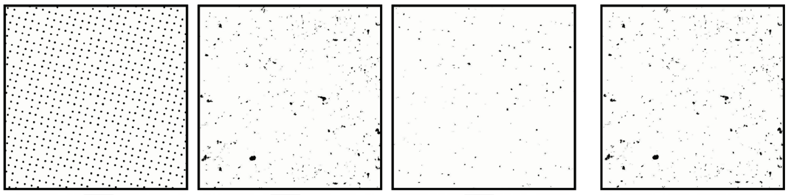
Relative reflectance curves in Fig. 4 confirm the conclusions derived from the curve of the relative absorption. On the graph the relative reflectance curve of printing substrate can also be seen.

The graph shows that the relative reflectance of printing substrate is less intense in the blue part of the spectrum, and increases towards the red part of the spectrum. Relative reflectance measured on screen patch Cyan 5 % is very similar to the relative reflectance curve of printing substrate, although its intensity is smaller in the red part of the spectrum. Curves for patches Cyan 50 % and 95 % are similar in shape but show different intensity. The curve for Cyan 50 % has the highest intensity in the blue part of the spectrum around 470 nm, up to 0,5, and the lowest in the red part of the spectrum, around 630 nm, up to 0,07.

3.2 Image analysis of prints

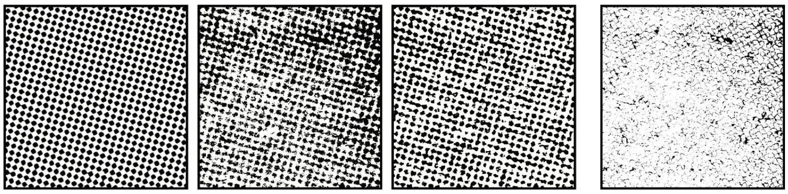
Screen patches for cyan component of tonal value 5 %, 50 % and 95 % were analysed using an image analysis program ImageJ. Printed samples were first photographed by digital microscope, and then the analysis of screen patches was conducted for gaining total number of particles, the total particles area, the average particle size and coverage of the observed patch. The obtained data was compared with the prepress on RIP (Raster Image Processing) server before exposition of printing plates on the CTP device (Computer to Plate). Prints were separated into CMYK components. Special emphasis was placed on isolated cyan component. The end result of the analysis was the valuable data on the effect of impurities in the printing substrate on increment of tonal values.

In a sample with Cyan component screen patch dot area 5 % it was determined by the analysis that the prepress patch (on the RIP), before exposition of printing plates, contained 648 particles, with total covered area 1,193 mm^2 or 5,3 % area fraction of the observed patch, while average size of particles was 0,0018 mm^2. On the printed screen patch the total number of particles was reduced to 564, with a total area of 0,312 mm^2, 1,4 % fraction of the patch, with an average particle size of 0,0006 mm^2. Analysis of isolated cyan component printed on the same patch revealed 196 particles, the total particle area of 0,083 mm^2 – 0,4 % fraction of the observed patch and with average particle size 0,0004 mm^2. Calculated percentage of impurities in the printing substrate was 1 %.



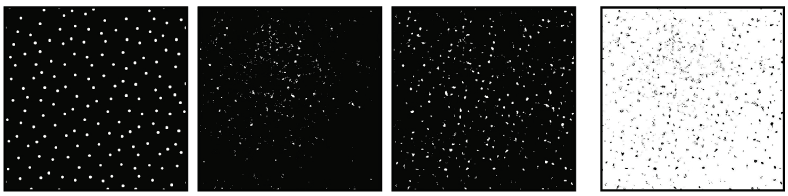
Cyan Dot Area 5%	RIP	Print	Isolated color component	Impurities in the printing substrate
Particle count	648	564	196	1%
Total area (mm²)	1,193	0,312	0,083	
Average size (mm²)	0,0018	0,0006	0,0004	
Area fraction (%)	5,3	1,4	0,4	

Figure 5 Image analysis of Cyan halftone patch 5 %



Cyan Dot Area 50%	RIP	Print	Isolated color component	Impurities in the printing substrate
Particle count	734	1212	659	4%
Total area (mm²)	11,197	15,974	8,257	
Average size (mm²)	0,3188	0,2974	0,0125	
Area fraction (%)	49,8	70,8	36,8	

Figure 6 Image analysis of Cyan halftone patch 50 %



Cyan Dot Area 50%	RIP	Print	Isolated color component	Impurities in the printing substrate
Particle count	176	713	591	1,5%
Total area (mm²)	21,349	21,996	21,770	
Average size (mm²)	0,0065	0,0316	0,0382	
Area fraction (%)	94,9	97,5	96,5	

Figure 7 Image analysis of Cyan halftone patch 95 %

In a sample containing screen patch with Cyan component tonal value 50 % the analysis determined that on the patch from RIP server, before exposition of printing plates, there were 734 particles (not much higher than on the halftone patch 5 %), but significantly higher total particle area of 11,197 mm^2 than on halftone patch 5 %, with an average particle size of 0,3188 mm^2. On the printed screen patch the total number of particles has increased to 1212, with total particle area of 15,974 mm^2, with an average particle size of 0,2974 mm^2.

Analysis of isolated Cyan colour component printed on the same sample revealed 659 particles, with a total covered area of 8,257 mm^2 and an average particle size 0,0125 mm^2. Calculated percentage of impurities in the printing substrate was 4 %.

In a sample with Cyan component screen patch dot area 95 % the analysis revealed that in the patch from the RIP server, before exposition of printing plates, there were 176 particles, less than on 5 % and 50 % patch, the total covered area of the observed patch was 21,349 mm^2 and the average particle size 0,0065 mm^2. On the printed screen patch the total number of particles was increased to 713, the total covered area on 21,996 mm^2, with an average particle size of 0,0316 mm^2. Analysis of isolated Cyan component printed on the same patch gave the result of 591 particles, with a total covered area of 21,770 mm^2, and the average particle size 0,0382 mm^2. Calculated percentage of impurities in printing substrate was 1,5 %.

4 Dot gain

Densitometric analysis showed integral print density from which, with the use of Murray-Davies equation, the real screen values and dot gain values were calculated.

The analysis showed that dot gain on patch with Cyan component of tonal value 5 %, declined –4 %. In the patch halftone 50 % showed dot gain 16 % and on halftone 95 %, dot gain was 2 %.

Table 2 Dot gain gained by densitometer

	Cyan 5 %	Cyan 50 %	Cyan 95 %
Dot Gain	–4 %	16 %	2 %

5 Conclusion

In this study, an analysis of the spectral reflectance or absorption of the samples confirmed the measured results of dot gain and image analysis. It is interesting to determine the increase of the reflectance measured in both patches Cyan 50 % and Cyan 95 % in the spectral range of about 670 nm. This effect can be attributed to the influence of printing surface.

For image analysis, the number of particles in cyan screen patches tonal value 5 % (dot gain 1,4 % on the print), although not significantly lower than the number of particles in the RIP (dot gain 5,3 %) due to the small average particle size, compared to the one that is measured on RIP and the effect of impurities in the printing substrate on dot gain, creates a negative value in raster image analysis (was –3,9 %). This is also confirmed by densitometric measurements. The intensity of the light reflectance from the analysed patch is nearly equal to reflectance of printing substrate, the average difference was only 0,01 in favour of the substrate, although the intensity of the reflectance is lower in the red part of the spectrum. Number of particles on the screen patch - Cyan tonal value 50 % on the RIP showed a significantly lower value than those measured on the print patch. Dot gain values on the print are 70,8 %, and on the RIP 49,8 %, giving a difference of 21 %. For the impact of impurities in the printing substrate, measured value goes as high as 4 %. On the patch Cyan tonal value 95 % the number of particles found in the print (dot gain 97,5 %) was significantly higher than on RIP patch (dot gain 94,9 %), but their average size was again lower, indicating a very large coverage of the observed patches on the print. It can be estimated that the dot gain is 0,6 %, and the impact of the printing substrate 1,5 %.

Taking into account that hybrid screen in the lower screen values behaves like FM screen, reasons can be found for the small particle size on samples with lower and higher screen values. However, the dot gain does not only mean trouble in the print. Lower dot gains can give good contrast and high print densities with less printing ink used. FM screen technology has a stable appearance, despite ink density fluctuations during the printing process. FM screen gives reproduction with more detail than AM due to smaller screen elements and greater frequency.

The reasons for results obtained by image analysis lies in the fact that the image analyses assessed only geometrical, and not optical dot gain that affects the overall dot gain measured by densitometer.

The middle values (tonal values 50 %) recommended dot gain values, according to ISO 12647-3:2004, of 26 % for AM screen. On the basis of conducted research it can be concluded that programmed dot gain of 26 % is not necessary for gaining results in average values in accordance with the ISO standard, because dot gain in uncalibrated printing process already at 16 % gave satisfactory results.

Analysis of samples in this study showed that the influence of impurities in modern materials with a significant proportion of pulp from recovered fibre, has a great effect on dot gain on screen elements and reproduction quality in the printing process. Based on this analysis, it is possible to define the impact of impurities in printing substrate on dot gain from 1 % to 4 %.

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