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ACTA GRAPHICA 230

Determining the Quality of a Reproduction Obtained with Digital Thermal Printing Plates

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Abstract:

TNowadays, flexographic printing process is the most cost-effective printing technique. Due to its capacity to produce very good print quality it is predominantly used for labelling and packaging applications. Additionally, flexography has become a very strong competition to the gravure printing process in performing more demanding printing tasks. In order to improve reproduction quality obtained by flexographic printing technique, some modifications in producing printing plates have been developed in the recent years. In this paper, two new technologies, DigiCap and SquareSpot, are presented. The aim of the research was to analyse and define the quality of reproduction obtained with DigiCap and SquareSpot technologies in the production of printing plates. The definition of the overall reproduction quality was determined using objective and subjective analysis. Three image quality attributes were observed: line reproduction quality, circularity of dots and dot gain in objective analysis.

Keywords:

Reproduction Quality, Printing Plate, Flexographic Printing Technique

1. Introduction

The flexographic printing is a versatile technique, which is a worthy adversary of the offset and gravure printing techniques due to its quality of printing. This technique is also the fastest growing printing technique nowadays (Mesic, 2006). The flexographic printing is a method of direct rotary printing that uses very resistant photopolymer relief printing plates, which are mounted on the plate cylinders. Using these flexible printing plates, it is possible to print on a wide range of absorbent and non-absorbent printing substrates. In flexographic printing process, the printing ink is transferred to printing plates by using the anilox roller, which receives printing ink from the chambered doctor blade system (Cusdin, 1991).

There are a few factors that affect the quality of the flexographic prints: the production technology for printing plates, type of printing inks, printing substrates, anilox roller, doctor blades, plate mounting etc. (Flexographic Technical Association, 2003).

Printing plates are primarily produced using digital thermal technology, the most important element of which is the thermal imaging layer (TIL). Thermal layer on the surface contains a layer which is, with the help of a digitally navigated thermal laser (l= 830 nm), removed from the parts where the future printing elements will be. The resulting copy template is then laminated to a photopolymer plate. After the laminating has been done, the illumination of photopolymer plates with a thermal layer is performed by removing the thermal layer with a laminator and rinsing the photopolymer plate. The process of producing a printing plate is not fully digitalized and therefore it is equated at times with the method of "computer to film". Raster elements created by this method include flatter peaks of raster elements, which create a smaller dot gain in a reproduction (Novaković, 2010).

In the recent years, digital thermal technology has been improved by two new technologies for producing printing plates: DigiCap and SquareSpot.

DigiCap is an advanced screening technology which produces a micro-structure on the surface of the raster element. This technology reduces halo edges on the dots and increases the density on solid patterns (***, 2013a). SquareSpot is an advanced imaging technology that uses focused laser energy to produce raster elements with highly aligned peaks but without microstructure generated on their surface. This technology, with highresolution laser imaging system (of 10,000 dpi), produces higher level of dot stability and tonal uniformity (***, 2013b). The use of both technologies contributed to the improved transfer of ink from the printing plate to the printing substrate (***, 2012).

The aim of this research was to analyse the overall quality of prints made by using these two modern technologies for producing printing plates. The printing process was done with two types of printing inks applied on two different printing substrates. The definition of the overall reproduction quality was determined by measuring attributes (line reproduction quality, circularity of dots and dot gain) and performing visual analysis.

2. Methods and Materials

The observed samples were obtained by using printing plates made by DigiCap (hereinafter: DigiCap samples) and SquareSpot technology (hereinafter: SquareSpot samples). The printing plate made with DigiCap technology had a microstructure of 5 x 10 mm2.

Both used photopolymer printing plates were produced by a digital thermal technology based on thermal imaging layer using Kodak Flexcel NX system. All plates were produced in two screen rulings: 133 lpi and 150 lpi. Printed plates were mounted to the flexographic printing machine Focus CentraFlex.

The process of printing was performed by using medium hard mounting tape. The screen ruling of anilox rollers for water based ink was 1016 lpi (400 lpcm) and for UV curable inks 1270 lpi (500 lpcm).

Two different printing substrates that were used in the process were coated paper (MC Primecoat, produced by Fasson, Avery Dennison) and top-coated polypropylene (PP Top White, produced by Fasson, Avery Dennison).

All printing substrates were printed with two types of cyan inks: water based inks (Aquabase

+, produced by Van Son Liquids) and UV curable inks (produced by Flexocure Gemini FlintGroup).

During the process of printing, the conditions were constant (25°C and 50% RH). A single operator managed the printing process at a speed of 50 m/min.

Device PIAS-II (Personal Image Analysis System) was used in the process to enable defining of the quality of printed lines and raster elements. The device was created by using a high performance digital microscope with an image analysis software produced based on international print quality standards ISO-13660.

Densitometric measurements were performed using a device SpectroEye for calculating the dot gain values.

3. Results and Discussion

In defining the overall quality of reproductions, the analysis was performed in four successive steps: observing line reproduction quality, observing circularity of dots and dot gain and performing visual analysis.

Experimental results obtained after an an objective analysis are presented as mean values of 10 measurements in various positions.

3.1 LINE REPRODUCTION QUALITY

The line reproduction quality of the ideal line with a width of 0.01 mm was assessed in two ways: using the analysis of the printed line width and using a model for objective assessment of the line quality.

The printed *line width* was analysed using PIAS-II device. The average line width was defined by measuring the reflectance value of the substrate (R_{max}) and the line reflectance value (Rmin). According to ISO 13660, the edge contours of the line are defined as the point of 60% (dynamic threshold) transition between R_{max} and R_{min} (1) *(Briggs, 1999).*

$$R_{60} = R_{max} - 0.6(R_{max} - R_{min}) \qquad (1)$$

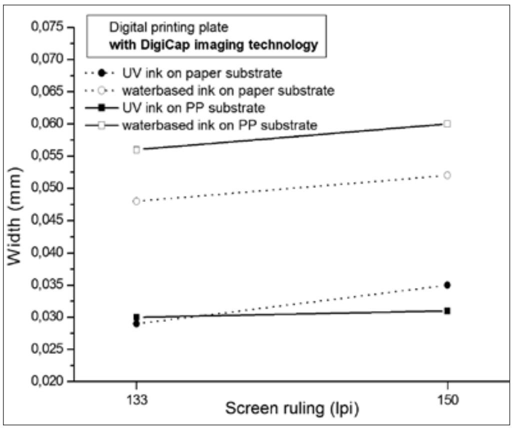

Figure 1. Line width of DigiCap samples

Line width values printed by plate made with DigiCap technology are presented in Figure 1. The obtained results indicated that all samples had greater width increment when printed with screen ruling of 150 lpi, except for samples printed with UV ink on a PP substrate where differences were not visible. The highest increment was recorded in samples obtained with water based inks, especially when printed on a PP substrate (Δw = 0.046 mm for 133 lpi and Δw = 0.50 mm for 150 lpi).

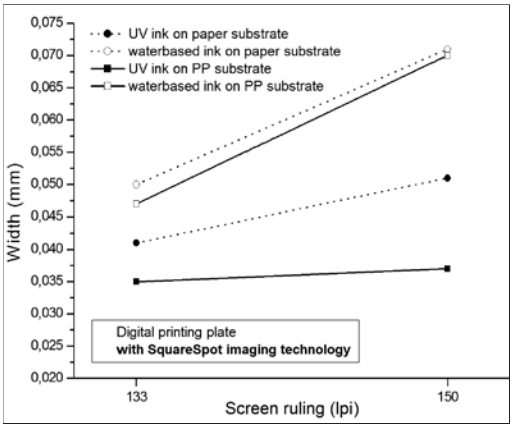

Figure 2. Line width of SquareSpot samples

All samples with a higher screen ruling had major changes in the width, whereby the biggest increment was visible in samples printed with water based inks (Figure 2). Samples produced on a paper substrate contain larger deviations than samples printed on PP substrates when compared to the ideal line width in respect to both screen ruling (Δw = 0.040 mm for 133 lpi and Δw = 0.061 for 150 lpi). The smallest increment of the line width is obtained in samples printed with UV inks on the PP substrate (Δw = 0.025mm for 133 lpi and Δw = 0.027 for 150 lpi).

In order to improve the analysis of the line reproduction a *model for an objective assessment of the printed text and lines quality* was used. Based on the linear regression analysis, Tse M. K. proposed a model for an objective assessment of the printed text and lines quality (2). In his research he established a strong correlation among line quality attributes: line width, blurriness and contrast. All observed attributes were defined as independent variables. This empirical model enables the prediction of subjective score of the prints.

$$S = -\frac{1}{37{,}7} \times B + 5{,}38 \times C + \frac{1}{16{,}4} \times W \qquad (2)$$

In this equation, *S* represents *score* predicted by the model, *B* is *line blurriness* [mm], *C* is *contrast* and *W* is *line width* [mm] (Tse, 2007).

Line blurriness parameter describes the blurriness of the line edge or a lack of sharpness. The line blurriness measures the transition from the substrate reflectance to the line. It is defined as the distance between the dynamic thresholds of 10% and 90% for each line edge (ISO 13660, 2001).

Contrast of the line is measured as the relationship between the darkness of the line and its field. It is calculated according to the following equation:

$$Contrast = (R_{\max} - R_{\min}) / R_{\max} \qquad (3)$$

where R_{max} is the reflectance of the substrate and R_{min} the reflectance of the line (ISO 13660, 2001).

The results of the model for an objective assessment of the line quality are shown in Figures 3 and 4.

Figure 3 shows that samples printed with UV inks had extremely high score values in comparison to samples printed with water based inks.

The calculated score values in samples that were printed by the same type of ink with the screen ruling of 133 lpi, were equal or very similar. In samples produced by ink with screen ruling of 150lpi, differences were obtained depending on the substrate; samples printed on paper had higher score values (up to 3.6%).

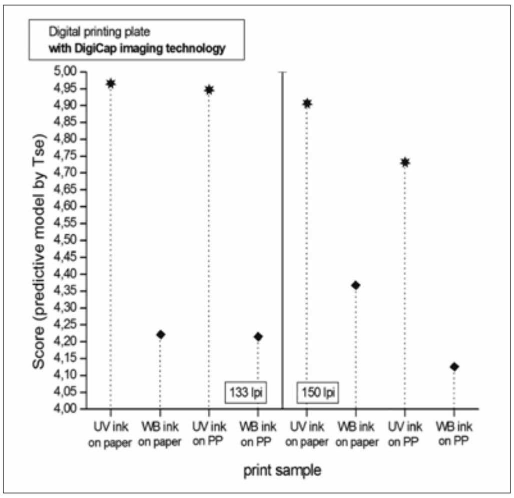

Figure 3. Score results of DigiCap sample analysis with model for an objective assessment of the line quality

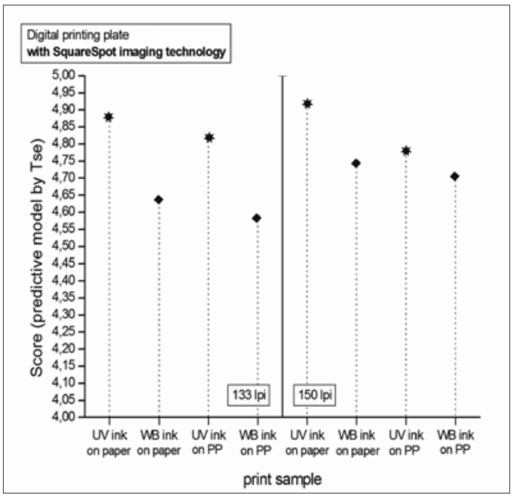

Figure 4. Score results of SquareSpot sample analysis with model for an objective assessment of the line quality

Observing the score results of SquareSpot sample, higher values were noticed in samples printed with UV ink compared to the samples printed with water based ink, (differences vary from 1.5% to 4.88%). Based on the substrate type, samples which were printed on polypropylene substrate had lower score values compared to samples printed on paper. Samples, which were printed by ink with screen ruling of 150lpi and UV inks, contained differences depending on the type of substrate they were printed on ($\Delta S_{paper\text{-}PP}$ = 2.85%).

3.2 CIRCULARITY OF DOTS

The shape of a printed dot on the substrate depends on several factors: surface and geometry of a raster element on the printing plate, the volume of cells on the anilox roller, the pressure between the rollers and the printing speed (Hamblyn, 2004). Deviation of the dot shape is examined based on the degree of circularity. Dot circularity is a very important parameter, since it presents the shape of the dot in comparison to a perfect circle. Circularity of dots was calculated according to the following equation:

$$C = \frac{p^2}{4\pi A} \qquad (4)$$

where *p* is the length of the outside boundary of the dot and *A* is the area of the raster element.

The *circularity of a dot* is equal to one for a circle and greater than one for any other closed shape.

When printing was performed on paper and polypropylene substrates with a plate made by DigiCap technology, it was observed that the results of circularity of dots were identical. The perfect circularity of dots was recorded at low and middle halftone values (0.4 and 20%), while dot deformations occurred at higher halftone values (70%). At 70% halftone value with screen ruling of 133 lpi, the degree of dot circularity, in samples printed with UV inks, was lower compared to samples printed with water based inks (Figures 5 and 6).

It was evident from the results given in Figures 7 and 8 that dot deviations from the original were more noticeable at highest halftone values in samples printed with UV inks, except in the sample printed on the polypropylene substrate with screen ruling of 133 lpi. The samples printed with water-based inks had equal dot circularity at low and middle halftone values, regardless of whether the substrate was paper or polypropylene (0.4 and 20%). In all SquareSpot samples, the perfect circularity was achieved at halftone values of 0.4 and 20%.

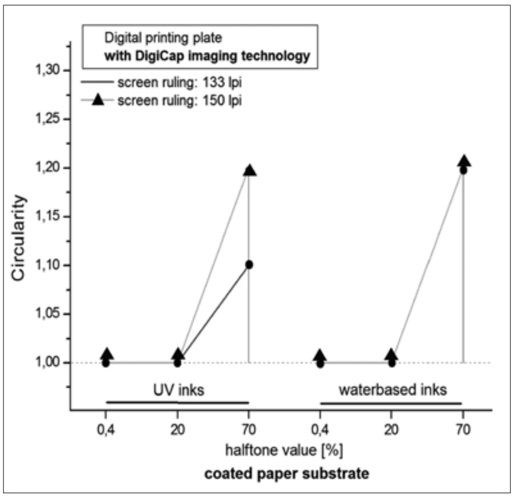

Figure 5. Degree of dot circularity in DigiCap samples printed on paper

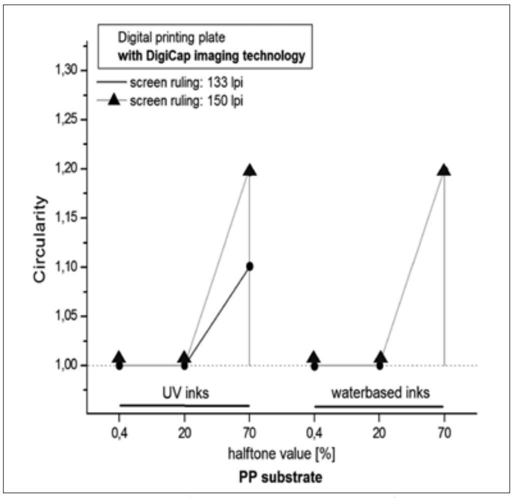

Figure 6. Degree of dot circularity in DigiCap samples printed on polypropylene

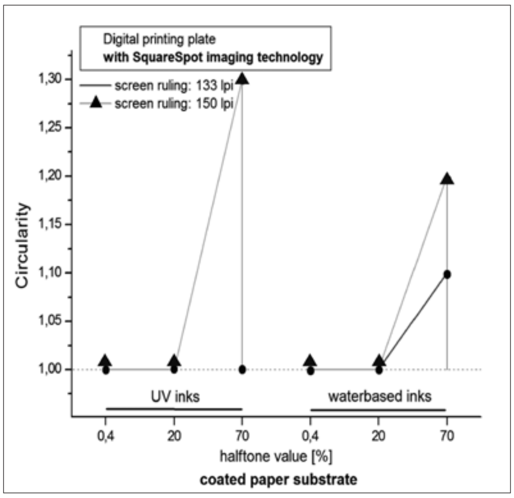

Figure 7. Degree of dot circularity in SquareSpot samples printed on paper

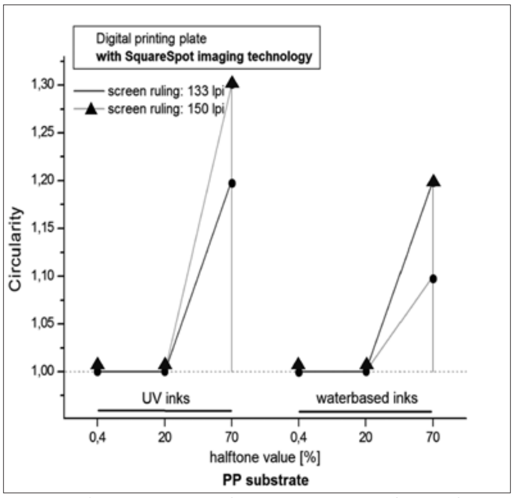

Figure 8. The degree of dot circularity in SquareSpot samplea printed on polypropylene

3.3 DOT GAIN

Dot gain is another very important parameter that characterizes the quality of reproduction. The increment of the halftone values in relation to its nominal values, before the exposition of printing plates or film, is called dot gain.

The dot gain are defined as a difference between the nominal percentage of halftone values (F_F) and the calculated percentage of halftone values (F_D) (Kipphan, 2001):

$$DG(\%) = F_D - F_F \qquad (5)$$

The percentage of halftone values F_D is determined using the Murray - Davies Equation *(Murray, 1936)*:

$$F_D(\%) = \frac{1-10^{-(D_R-D_0)}}{1-10^{-(D_V-D_0)}} \times 100 \qquad (6)$$

in which D_R is the optical density of the halftone patch, and D_V is optical density of the solid tone patch and D_o is the optical density of printing substrate (paper).

The results of dot gain values of halftone values: 0.4, 20, 50, 70% are shown through the dot gain curves in Figures 9-12. By observing dot gain curves in Figure 9, it can be concluded that higher dot gain values in all halftone values

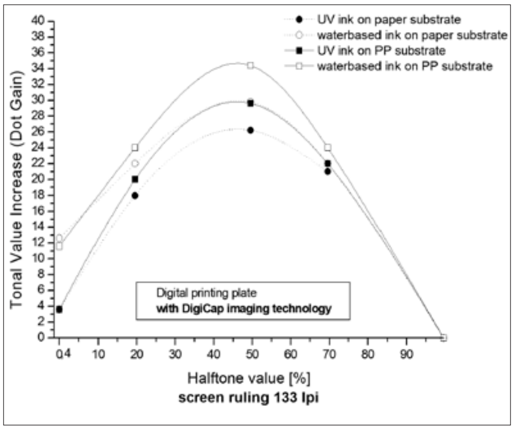

Figure 9. Dot gain curves of DigiCap samples with 133 lpi

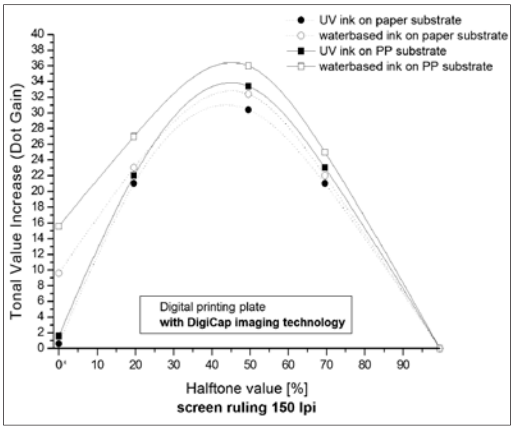

Figure 10. Dot gain curves of DigiCap samples with 150 lpi

were characteristic for samples printed with water based inks, while the lowest dot gain values were obtained in samples printed with UV inks.

Dot gain values for smallest halftone values (0.4%) were higher in samples printed with water based inks ($DG_{0.4}$= 12.6 on paper and $DG_{0.4}$= 11.6 on PP) in comparison to samples made with UV inks ($DG_{0.4}$= 3.6, both, on paper and on PP).

Figure 10 shows that the highest dot gain values were obtained in samples printed with water-based inks on the PP printed substrate. Matching in the increase of dot gain was visible in 20% of samples printed with water-based inks on paper and samples printed with UV inks.

Halftone value of 0.4% had the lowest value increment in samples printed with UV inks ($DG_{0.4}$= 0.6% on paper and $DG_{0.4}$= 1.6% on PP), while higher discrepancies were observed in samples printed with water based inks on paper ($DG_{0.4}$ = 9.6%). Extremely large discrepancies were recorded in samples printed with the same inks on the PP printing substrate ($DG_{0.4}$ = 15.6%).

For halftone values of 50%, the dot gain values were increased depending on the printing substrate. Higher increment was recorded in samples printed on the PP printing substrate, compared to the samples printed on paper.

The dot gain values in samples printed with SquareSpot technology coincided in almost all halftones values when they were printed with the same type of ink (Figure 11). The sample printed with water-based ink on the PP substrate had the highest values of dot gain in all observed halftones. The dot gain values in samples printed with UV inks were low, especially in samples printed on the PP substrate. In case of the halftone value of 70%, the lowest increment was obtained in samples printed with UV inks on paper.

In relation to halftone values of 0.4%, the maximum dot gain was $DG_{0.4}$= 13.6% in samples printed with water based inks, and minimum dot gain was $DG_{0.4}$= 6.6% in samples printed with UV inks on the PP printing substrates.

Extremely high values of dot gain were obtained in samples printed with water-based inks (Figure 12). The differences were very small or almost none, taking into account the used substrate. Defined dot gain curves of the samples printed with UV inks had same trend as in samples printed by ink with 133lpi screen ruling. The lowest dot gain values of 21% at a halftone value of 70% were present in samples printed with UV inks on paper.

The highest dot gain values were obtained in samples printed with water-based inks on the PP printing substrate ($DG_{0.4}$ = 13.6%; DG_{20} = 35%; DG_{50} = 37.2%), while the lowest values were measured in samples printed with UV inks on the same substrate ($DG_{0.4}$ = 6.6%, DG_{20} = 29%, DG_{50} = 31.2%).

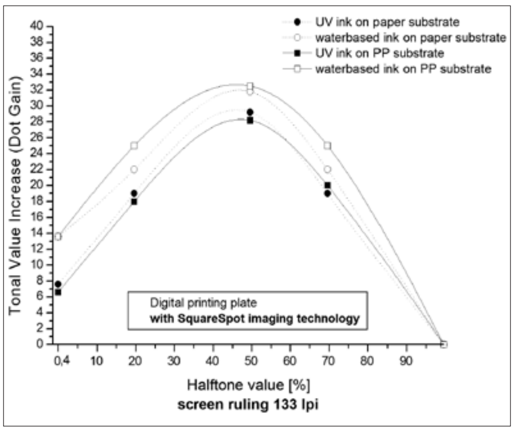

Figure 11. Dot gain curves of SquareSpot samples with 133 lpi

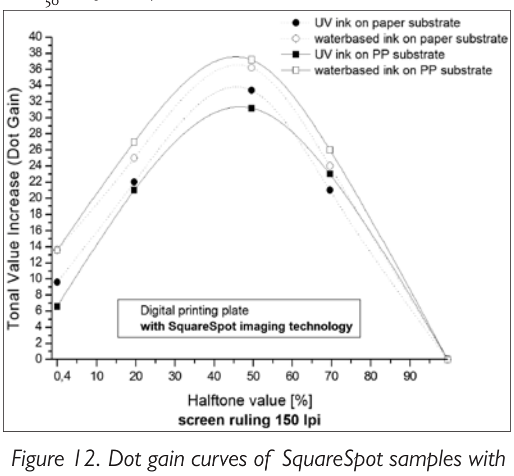

Figure 12. Dot gain curves of SquareSpot samples with 150 lpi

3.4 VISUAL ANALYSIS

the visual analysis of print quality was conducted under the standard viewing conditions for graphic arts (ISO 3664:2009) at D50 illumination (ISO 3664, 2009). Every sample was analyzed by 30 respondents.

Visual assessment of reproduction quality was performed using the following criteria: dot reproduction quality and line reproduction quality.

The total score obtained was the arithmetic value of all assigned score values given by all respondents.

After assessing results of visual analysis, the higher score values were obtained for samples printed with UV inks with both screen rulings. Samples printed with inks on paper as a printing substrate, had better scores in comparison to samples that were printed on the PP substrate (Figure 13). In case of screen ruling 133lpi, samples printed with water-based inks have higher scores values comparison to samples printed with the screen ruling of 150lp

In visual analysis, the samples printed with UV inks by plate made with SquareSpot technology were assessed with higher score values (Figure 14). In reference to these samples, in case of both screen rulings, there were very small differences in respect to the printing substrate. Samples that were printed with water-based inks scored lower results in case of screen ruling 150 lpi in comparison to screen ruling133 lpi.

4. Conclusion

Based on the conducted research, it can be concluded that samples, which were printed by using printing plate made by DigiCup technology, have better results in all the researched qualitative parameters.

Printing with UV inks in both, DigiCup samples and SquareSpot samples, offers high quality reproduction.

The right selection of the printing substrate also plays a very important role in producing highquality reproductions. Samples printed with water-based inks on the PP printing substrate, in respect to the observed qualitative parameters, have lower reproduction quality. Samples that are printed with UV inks, according to the results of the research, contain no significant discrepancies.

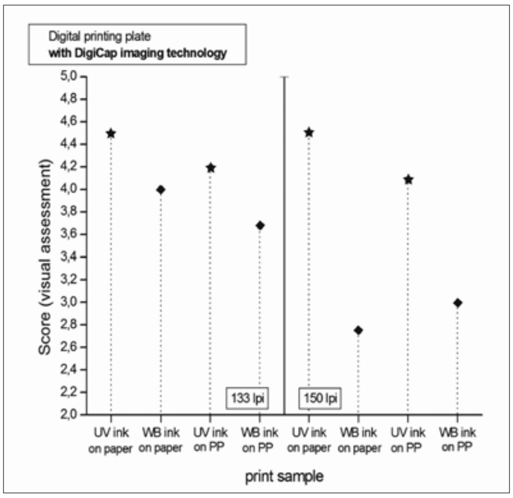

Figure 13. Visual assessment of quality for DigiCap samples

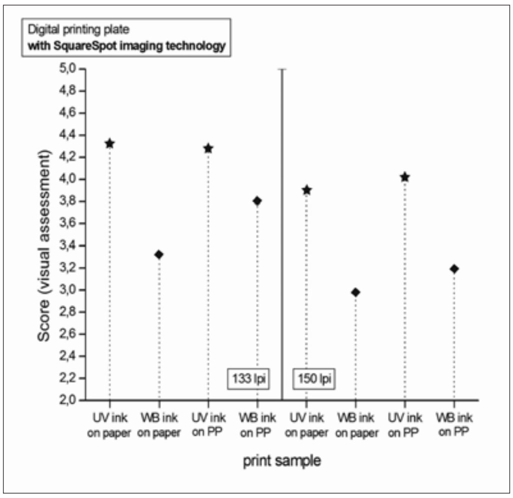

Figure 14. Visual assessment of quality for SquareSpot samples

Very good reproduction quality was achived in samples printed with water-based inks with both screen rulings when printed by DigiCap technology. When these inks are printed by SqureSpot technology, in respect to ink with screen ruling of 150 lpi only a poor reproduction quality had been obtained.

Visual analysis confirmed the measured results and disclosed that in case of a small screen ruling of 133 lpi, all DigiCup samples have been assessed similarly. In case of a higher screen ruling (150 lpi), the difference was increased depending on the ink and printing substrate. In SquareSpot samples, differences were recorded in case of both screen rulings, depending again on the ink and printing substrate, with that being especially visible at screen ruling 150 lpi. The conducted research produced basis for a continued research on other printing substrates printed with different screen rulings that are used nowadays in the flexographic production.

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