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INFLUENCE OF THE ELECTROPHOTOGRAPHIC PRINTING UNITS ARRANGEMENT ON BACK-TRAP MOTTLING

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Abstract: *This work the analysis has been performed how different arrangement of applying the liquid EP toner can influence the formation of secondary and tertiary inking. Specially developed software enabled the exchange of the printing arrangement of the process inks. Twelfth different Indigo variations were obtained which were compared with the offset prints. The analysis was made by two devices: X-rite DTP 41, Personal IAS. The back-trap mottling is feature for multicolour overprint and the densitometry as the method, is suitable for the analysis of such appearances. The results are also presented in CIE colour space (CIELabΔE_{2000}). EP prints will be achieved if the lightest process colour (Y) will be printed first and the darkest colour (C) as the last one.*

Key words: *Digital Color Offset,, Personal IAS, CIE Lab ΔE_{2000}, Back-trap Mottling*

1. INTRODUCTION

Electrophotography (EP) is a very complicated printing process, in which the unique virtual printing form is generated on photoconductor drum, which changes after each impression is made. To obtain one impression it is necessary to make 6 basic phases: charging, imaging, developing, transfer, fusing and cleaning (Yamana, S.,2004). With the development of EP toner the machine constructions change. There are basically two main types of EP machines (with one pass and with several passes). They can both be used in direct and the indirect printing process (Kiphan, H.,1997).

For achieving the multicolour reproduction, the transparent inks are generally used. After applying them, they act as filters, which partly let the reflected light from the printed substrate and partly absorb it. In printing process 4 process inks (CMYK) are used which are based on the colours of subtractive synthesis with the addition of achromatic black (Young, T., 2002).

To create the secondary inks (red, green, blue) it is necessary to apply two different process inks on the printing substrate (as thick as possible). One of these two inks adheres directly to the printing susbstrate while the other is applied to already adhered one. Such principle is applied in realization the majority of the printed products and it is used in EP printing process as well (Larson, J. R., et al. 2002).

The uniformity of such prints is possible to observe optically by mottling which appears on imperfectly adherence of toner on the printing substrate, i.e. on already made print. In this work the influence of order of the process inks application on mottling is analysed.

2. THEORETICAL PART

2.1. Mottling

Mottling is the undesired change in optical properties of the printed and unprinted substrate. It is used in the analysis of the printing substrate as well as in the analysis of prints formed with greater ink layers (especially with complex EP inks and with the lithographic offset ink). Theoretically, the optical changes can be the consequence of different factors activity during the printing process (such as the wetting solutions, thickness of the printing substrate, composition of ink, printing speed). Generally, there are three types of mottling: optical mottling, mottling caused by the paper wetting and back-trap mottling (Marttila, J.,2007).

Optical mottling is so called continuous tone mottling, i.e. the mottling of one tone. It is usually visible on printing substrates with high gloss and on the printing substrate with high grade of lightness. Optical mottling is not visually dominant on the impression and there are the smallest complaints regarding it.

Optical mottling is important for paper selling because it is visible in comparing different paper kinds. Papers with expressed optical mottling look dirty. Absorption of the wetting solution into paper is inevitable in lithographic printing technique. It is possible to avoid the mottling caused by paper wetting with the introduction of line IR dryers which decrease the humidity in paper with its temperature. In spite of that, such mottling is possible by the application of very liquid inks. The results of such mottling are either the watertightness (the remained humidity value is monitored on the printing substrate) or wetting (the humidity absorbed in the printing substrate is monitored).

Back-trap mottling can be seen only in multicolour printing. It is caused by the imperfect construction of the printing unit which creates the defined technical deformations in the printing zone. The uninform porous structure in the printed top layer is characteristic for the mechanism of back-trap mottling, in which the thickness of the layer is uneven in relation to the paper surface.

The lines of the ink splitting follow the profile of the previously formed layer, which creates the difference in the final coating on the print (back-trap mottlig). Contemporary printing techniques control well the back-trap mottling which is necessary for the development of the new types of paper, ink and very quick printing units.

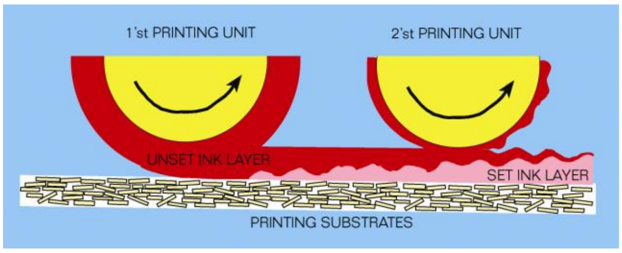

Figure 1. Schematic presentation of the back-trap mottling appearance

Particularly the ununiformly absorbance of ink into the printing substrate apears on the four colour printing unit, so called "tandem" construction of the printing units. In this connection, the back-trap mottling is formed, which is mostly expressed after the printing of 1st and 2nd separation (printing unit). On the 3rd and 4th printing unit it is hardly visible. The reason for that is the existence of the shorter time interval between the last two printing units, where the ink absorbance into the printing substrate is very low. Only on characteristic constructions the back-trap mottling can be noticed on 3rd printing unit, but never on 4th one (Niesner, G.,1993).

Because of that, the EP machines use the standard order of printing YMCK (i.e. printing from the chromatically lightest tone towards the achromatic ink). The order of ink applying in lithographic offset is KCMY (i.e. from the achromatic black towards the chromatically lightest ink).

Penetration of the lithographic ink into the printing substrate and the penetration of the melted EP toner are completely different. In printing wet on wet (the ink is applied on the wet printing substrate) the physical state of the previouisly printed ink is important.

Quicker penetration of ink into the printing substrate will create better acceptability of the following ink. Uneven absorbance in wet on wet printing process will result in the ununiform acceptance of ink and in the increased back-trap mottling.

The drying process of the top layer influences the back-trap mottling. During the drying time there is the migration of the liquid oil binders from the ink. On the places with greater quantity of the liquid carrier component in the surface layer, the absorbance is slowlier, which is the cause of the back-trap mottling. Although the printing substrate is the main cause of mottling, the characteristics of the printing inks (percentage of absorbance, colour tone and the pigment concentration) also influence the mottling effect.

The devices which measure refectancy are used for the determination of mottling. The value of mottling (M) is obtained by measuring the reflectancy through the complementar colour filter. The measured mottling is dependent on the measured reflectance values and only the samples with similar reflectance values can be compared. In the mottling determination on the lighter tones the reflectance value of 60% is taken, while the reflectance value of 20% is taken for the direct mottling value of the darker samples.

3.EXPERIMENTAL PART

The special printing form was constructed for investigations. It contains the visual and measuring colour stripes for the reproduction of red, blue, green and brown tones, which appeared by the overprint of the process inks. The fine art paper (Symbol gloss) with the grammage of 135 g/m^2 was used as the printing substrate. Experimental prints were made on 4 colour digital printing machine HP Indigo TurboStream, where the printing order of the primary colours varied for 6 times (MCYK, CMYK, CYMK, YCMK, MYCK, YMCK).

With the device for image analysis Personal IAS the optical back-trap mottling was measured, which directly speaks about the uniformity of the applied inks. Prints made on the EP machine (HP Indigo TurboStream) were compared with the prints of the standard lithographic offset (Heidelberg Speedmaster 74) while the comparison of two very qualitative printing systems was performed.

The printed patches were measured spectrophotpo-metrically and presented in CIE Lab colour space. The inking difference CIE LAB ΔE_{2000} was calculated. Formula for the calculation of the inking difference (ΔE_{2000}) is standardized by CIE (International Commisino on Illuminatiom). All the results were obtained by measuring 10 printed samples, on which base the medium value was calculated (Luo M. R., et al. 2001).

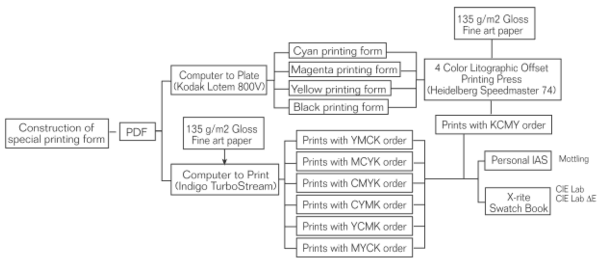

Figure 2. Schematic presentation of experiments

4. RESULTS AND DISCUSSION

The quality of the ink bonding onto the printing substrate can be analysed by back-trap mottling which is based on reflectance measurements. The values of the back-trap mottling for the secondary tone values (from 10 % halftone value to 100% halftone value in steps of 10% halftone value) are presented in figure 2.

On all three secondary colours the mottling oscillates mostly in the area of low and medium tone value (from 10% halftone value to 70% halftone value). The offset printing technique gives more uniform tones (lower mottling value) in regard to the EP printing with liquid toners.

The maximal value of the measured mottling is visible in the area between 20 and 40 % in which the screen dots are completely reproduced. There is no uniformity in the measured results for this area and because of that greater number of measurements is necessary in order to get the reference value.

The reason for that is a very small measuring area of the instrument Personal IAS (2,5 x 2,5 mm), which cannot select precisely the measuring area (number of the selected elements is always different). The areas with the printed elements lesser than 250 μm are not suitable for mottling measurements in spite of that mottling has the greatest value.

Measuring of the back-trap mottling can be used for the quality analysis of printing the darker tones which are formed by applying greater quantity of ink on the printing substrate (from 80% halftone value to 100% halftone value). The measured values of the full tone will have the lowest mottling value, which gives the most uniformly printed surface (M=0).

In offset printing technique, cyan is usually placed on the first printing unit. The printed cyan colour penetrates mostly in the printing substrate and it firmly adheres to the cellulose fibers of the printing substrate. In the further process the printed layers dry by oxipolimerization. In printing the blue colour, the layer of the magenta colour is applied very quickly, i.e. on the fresh impression, forming the back-trap mottling M_{sred}=0,36.

If cyan is applied in EP first, it will totally adhere to the printing substrate, forming the thin surface layer. The coating of the next ink is not so successful, which is visible in back-trap mottling. In relation to the classical offset, the EP blue iumpressions obtained by identical printing order have the increase of the average values of mottling for ΔM=0,41.

By the software change of the order application of ElectroInk (M+C) the average back-trap mottling will be decreased for ΔM=0,05. The lowest value of back-trap mottling is measured on the red offset impression ($M_{100\%}$=0,37; $M_{90\%}$=0,06; $M_{80\%}$=0,23).

It is characteristic for it that the patch with 90% and 80% screen has lower mottling value than the full tone patch.

The reason for that is much thicker layer of magenta which closes the free surfaces in the screen area, while in the full patch it generates one relief surplus. Identical printing order on EP impression will form the double value of mottling M_{sred}=0,40.

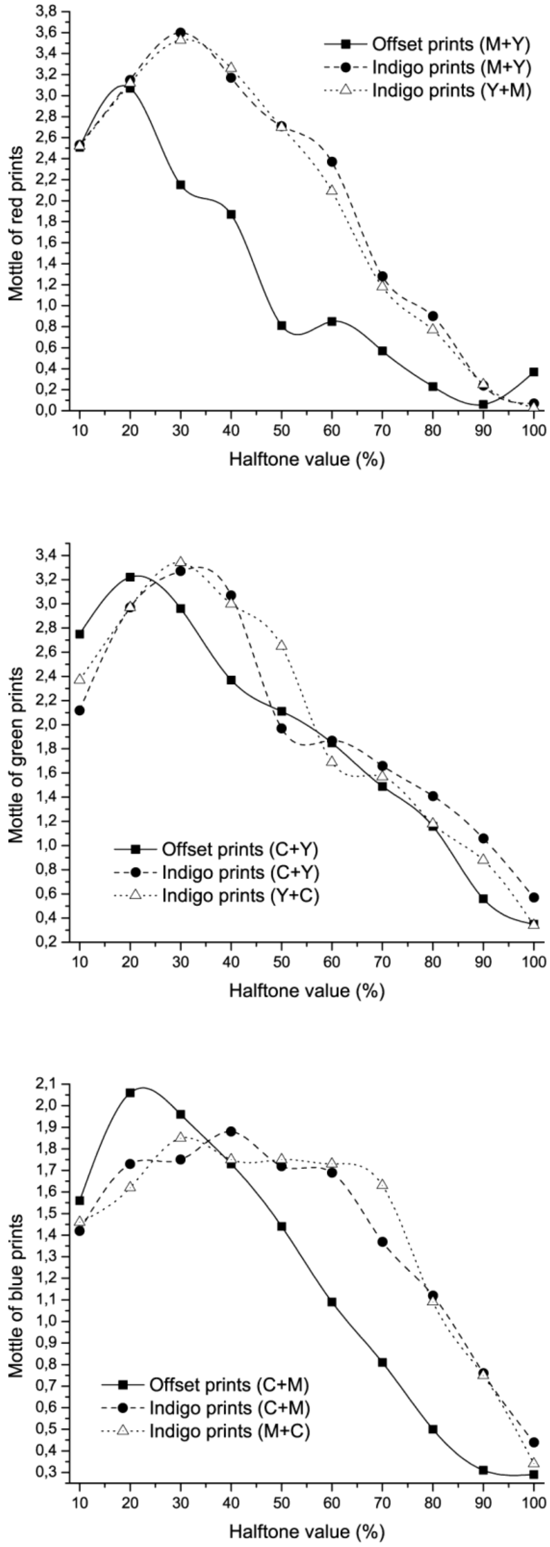

Figure 3. Back- trap mottling of the printed red, green and blue

In connection with this the mottling of the full red tone is $M_{100\%}$=0,07.The change of the EP order of ink application (Y+M) will result in the increase of the average mottling for 0,13. Green is printed with the most ununiformity. In classical offset, the printing of cyan on yellow will form the average mottling M_{sred}=0,69. Identical printing substrate printed in EP printing technique (identical order of ink application) will form the average mottling M_{sred}=1,01. Varying of order of the ink application on the printing substrate (Y+C) will result in the decrease for ΔM=0,21.

The influence of the order of the liquid EP ink application (ElectroInk) is best visible on the printed tertial inks (brown one). The brown ink is formed from 100% overprint of cyan, magenta and yellow. With their mutual permutation it is possible to get 6 different brown tones. The smallest mottling value was obtained by the combination of YMC (M_{YMC}=0,36). After that the combinations: M_{CMY}=0,38; M_{MCY}=0,39; M_{CYM}=0,39; M_{MYC}=0,42 and M_{YMC}=0,56 follow.

The technique of the standard offset recommends the printing order CMY, whose mottling is M_{CMY}=0,43. Such a high mottling value is generated by the wetting solution which, by its absorbing into the printing substrate, causes the increase of ununiformity of the printing substrate. If we want to get the brown impression true to the offset impression by the EP, the combination of MYC application has to be used.

Colorimetry as the measuring method enables more precise analysis of the produced impressions. It can also be used in the analysis of how the change of the ink application order can influence the inking, and what is the difference in regard to the standard offset printing.

The inking value of the full tones in colour CIE Lab space as well as their deviation in brightness (ΔL) and colours (ΔC), is presented in figures 3 and 4.

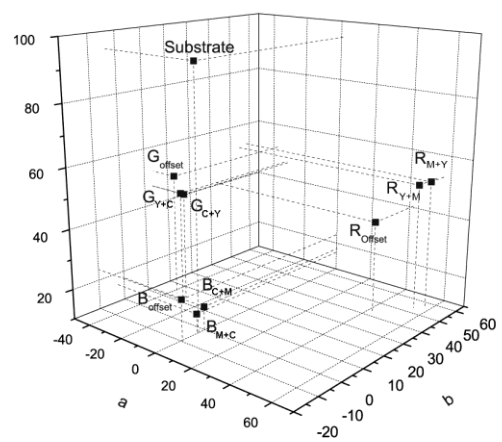

Figure 4. Colour difference in inking of the secondary inks made by the double printing on HP Indigo and Heidelberg Speedmaster 74.

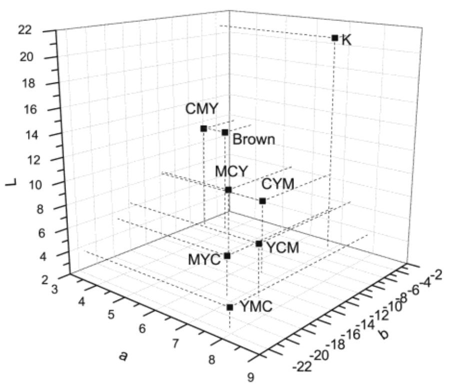

Figure 5. Inking difference in brown colours obtained by triple printing of HP Indigo and Heidelberg Speedmaster 74.

The comparison of the lithographic offset impression (KMCY) with the EP impressions (MCYK, CMYK, CYMK, YCMK, MYCK and YMCK), shows the greatest variations in blue. With the application of MK + C will the inking difference be realized ΔE_{2000}= 8,5020, while the layer of C+M will create the inking difference ΔE_{2000}= 7,2753. In this way two blue ElectroInks mutually vary for 1,2267. Such variation is more expressed along the chromaticity axes (a,b). Offset red impressions are obtained by applying the yellow ink on previously printed magenta (M+Y). In relation to the red obtained in offset, EP variation of order in applying yellow and magenta will give lower difference if yellow is printed first (ΔE_{Y+M}= 2,0259). With the identical application order (offset = EP) greater inking difference will be formed (ΔE_{M+Y}= 2,3035), which is more expressed in brightness (L).

Green offset impressions were obtained by printing C+Y. With the identical order of ink application (C+Y), in offset and EP the inking difference ΔE_{C+Y} = 5,8205 will be realized. In the case of changing the inking order on HP Indigo TurboStream (Y+C), the inking difference will be decreased (ΔE_{Y+C}= 5,3142). Although both types have relatively similar pigment concentration, the inking difference is influenced by the construction of the printing unit and by the principle of impression drying. In reality, the offset impressions were obtained by printing wet on wet while the EP prints were obtained by printing dry on dry.

Chromatic variations of the tertiar brown colours are presented in figure 4. By comparing the offset impression (CMY) with the EP impressions (6 variations) the smallest inking difference (ΔE_{C+M+Y}=1,0245) was noticed. It is achieved by the identical order of ink applying (CMY). The greatest difference was obtained by the printing order YMC (ΔE_{Y+M+C}=10,7588), i.e. when yellow was printed first. Another variations in EP printing give the following inking differences: ΔE_{M+Y+C}= 8,3905, ΔE_{Y+C+M}= 7, 5824, ΔE_{C+Y+M}= 5,2349 and ΔE_{M+C+Y} = 4,5292.

In relation to the offset, EP printing based on the starting application of the chromatically darker inks (cyan, magenta) will influence the inking decrease during the process. Ink bonding to the clear printing substrate (unprinted one) is much better than the bonding to the previously printed substrate. In secondary and tertiary tones, the first printed layer is somewhat more abundant (greater inking density) in comparison to the other layers.

The reason for that is the structure of ink which is adapted by its composition so that it is better bonded to the surface of the printing substrate (coating) in regard to the previously formed impression (already applied ink). Finally, it influences the total colour intensity of the printed layers, i.e. the reproduction of the secondary and the tertiary tones.

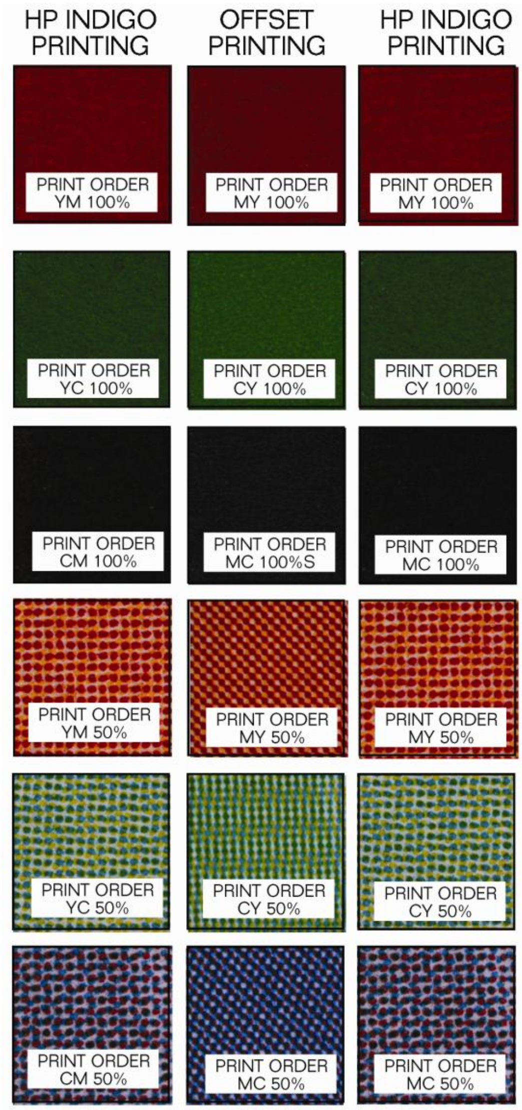

Figure 6. Indigo and Offset prints measured with IAS

5. CONCLUSION

Measuring of the back-trap mottling is recommended for monitoring the dark tones (especially of thicker layers). In this way the usage of the mottling method for monitoring the reproduction quality of the secondary (200% application) and tertiary (300% application) inks is suggested. On lighter and medium tones (the printing elements are lesser than 250 μm) the mottling measurement by means of image analysis is pointless. This is because of the impossibility of selecting always the same surface, so that in the analyzed samples there is not the same number of the printing elements.

For achieving the more uniform EP impressions (the smallest mottling value) the printing order is recommended which is based on printing the lightest process ink (yellow) to the darkest process ink (cyan). By changing the EP order of toner application, the greatest change in tones will be achieved in which cyan (green M_G=0,23; brown M_{BR}=0,20; blue M_B=0,10; red M_R=0,04) is contained. Red, green and blue EP impressions (HP Indigo) will be more similar to the offset impreasions in the inking if they are printed in the order: M+C (blue), Y+C (green) and Y+M (red).

In EP printing with the liquid ElectroInk, with the first application of chromatically lighter ink, the inking difference will be decreased in relation to the classical offset, by which the varying of the colour separation will enable the following inking deviations: blue (ΔE_{2000}= 1,2267), green (ΔE_{2000}= 0,5063) and red (ΔE_{2000}= 0,2776). The varying of the inking layer application will considerably influence the final impression in brown. Between HP Indigo impression and the offset impression, the smallest inking difference (ΔE=1, 0245) will appear at identical printing order (C+M+Y). The greatest difference in brown impressions is achieved by the reverse printing order (Y+M+C). In this connection the inking variation was 9,7343. Equations left justified and numbered consecutively.

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