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Printability of Synthetic Papers by Electrophotography

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Abstract:

This paper deals with the printability of synthetic papers by the electrophotography technique. Prints of CMYK colour fields from 20% to 100% raster tone values were printed on three types of synthetic papers (one film synthetic paper and two fiber synthetic papers). The investigation of the appearance included densitometric measurement of the CMYK prints. The results have shown differences in the optical density and optical tone value between CMYK prints made on various synthetic papers. The highest optical density and the increase of the optical tone value were observed on the film synthetic paper, where CMYK prints were more saturated. The highest abrasion resistance of CMYK prints was obtained from the fibre synthetic paper.

Keywords:

Printability, Electrophotography, Synthetic Paper, Abrasion Resistance

1. Introduction

Electrophotography is one of the leading digital printing techniques. In electrophotographic printing the optical print quality is formed by a combination of three factors: process, toner and paper *(Sipi, 2003)*. The toner particles are charged electrostatically in the developing unit and are attracted to the drum by the oppositely charged image portions of the photoconductor. The transfer from the photoconductor onto the substrate takes place by means of electrostatic forces *(Kipphan, 2001)*.

The printing characteristics of paper are differentiated according to the printability and pressroom runnability *(Kipphan, 2001)*. When used to describe paper, the term *printability* refers to the quality of the image expected when applied to the particular paper *(All about paper, 2004)*. Printability, which comprises both physicochemical and technological properties of paper, is a particularly important feature of paper containing synthetic fibres. In terms of technological properties, most attention is focused on the interrelation between ink and paper base, which is very important for obtaining high quality prints *(Paszkowska et al., 2005).* The printing process always involves interaction between the printing ink and the printing material, i.e. the paper *(Muck, Hladnik, 2003).* The ink has to satisfy many important requirements before its colour is considered. It has to stay on the paper, it has to dry quickly, and it has to be printable. The same ink applied to different paper may differ significantly in appearance. Paper type, particularly its surface properties, is fundamental to the appearance of the finished printed properties *(Mortimer, 1998), (Renmei et. al., 2005).*

In the past, several studies investigating electrophotographic prints on various papers have been conducted. Salesin et. al. studied the abrasion of digital reflection prints. Damage to prints can occur when they are accidentally subjected to rubbing action by other materials. The study was concerned with the suitability of various testing procedures and methods to quantify the abrasive damage *(Salesin et. al, 2008).* Bhattacharyya et. al studied the ink-substrate adhesion in LEP (liquid electrophotographic) printing. They have established that the relationship between macroscopic time dependent work of adhesion measurement, polar content of paper and ink surfaces, and interfacial acid-base interaction is revealed *(Bhattacharyya et. al, 2009).* Kuo et al. studied the modelling of tone deviation during switch-on transient for colour electrophotography. Tone values reproduced during the switch-on transient are statistically different from the tone values reproduced during continuous printing after the switch-on transient has ended. Analyses of experimental data showed that a number of pages printed after switch-on and halftone levels are a statistically significant factor in modelling tone deviation *(Kuo et. al, 2009).* Sipi studied the role of coated paper properties in adhesion. The sample set included electrophotographic prints on coated papers, where the ratio of different coating pigments was varied *(Sipi, 2001).*

The aim of our research study was to estimate the suitability of various synthetic papers for printing by means of the electrophotography technique. Densitometric measurements determined the optical density and optical tone value increase of CMYK prints of different tone values, and solid CMYK prints defined the abrasion resistance.

2. Experimental

2.1 Printing materials

In this study three types of synthetic papers were used: one film synthetic paper (Yupo as a *Paper 1*) and two types of fibre synthetic papers (Pretex as a *Paper 2* and Neobond as a *Paper 3*). Paper 1 is a biaxially-oriented film synthetic paper. It consists of three extruded polypropylene - PP layers with inorganic filler (Calcium Carbonate – $CaCO_3$). It does not contain wood pulp or other bio materials and has a penetration layer on both sides. Paper 2 is a high-quality, impregnated and double-side coated special paper made from selected pulp and synthetic fibres (polyamide – PA and polyester - PES) in the combination with a special binder system. Paper 3 is a durable and hardwearing synthetic fibre paper. This double-side coated paper comprises a mixture of selected pulp and synthetic fibres (polyamide - PA, polyester – PES and viscose), reinforced with special impregnation.

All three types of synthetic papers can be processed in all classic printing processes and in various digital printing processes. Synthetic papers were printed by means of electrophotography technique using a Canon imagePRESS C1. A printing test form was prepared with CMYK colour fields of 20 %, 40 %, 60 %, 80 %, and 100 % raster tone values.

2.2 Methodology

Optical density, optical tone value increase and abrasion resistance of CMYK prints were measured using a reflection densitometer D19C (Gretag-Macbeth, Canada) under the following conditions: 0°/45°measurement geometry, 0.00

– 2.50 D measurement range, 3.6 mm measurement aperture, and 2x linear polarization filter, calibrated on the unprinted paper. Abrasion resistance test of solid CMYK prints was performed with a Prüfbau Quartant abrasion resistance tester (200 rubbing cycles).

3. Results and Discussion

3.1 Properties of synthetic papers

In the first part of the investigation the surface properties of synthetic papers were analyzed. Measured properties of synthetic papers are presented in Table 1.

Synthetic papers are defined as products composed of at least 20% synthetic substances. These papers have a well-developed surface capable of absorbing printing inks, a coefficient of maximum ink absorption of at least 50%, and the capability of fixing the printing inks, even those with low adhesiveness to the base paper. Synthetic papers can be divided into papers manufactured from synthetic materials in the form of spunbonded fibres with an effectively infinite length or short fibres that are added to pulp and into products made from granulated materials formed by extrusion in the form of a biaxially oriented multilayer paper. The greatest benefit of synthetic paper is its durability under almost any conditions. Consequently, these papers can be used in many applications where traditional cotton or pulp-based paper lacks sufficient strength, such as ID documents, luggage tags, entry tickets, high quality catalogues, labels, geological and leisure maps, and educational and visual charts *(Debeljak et. al, 2010)*. From the Table 1 it is evident that there is a difference in gloss, roughness, porosity, absorbency and surface energy between the tested synthetic papers. All three papers are hydrophobic, especially the film synthetic paper (Paper 1). Paper 1 is also smoother and has higher gloss compared to the other two tested synthetic papers.

3.2 Optical density of CMYK prints

Optical density D is defined in the form of logarithmic ratio:

$$D = \log\frac{1}{\beta} = \log\frac{I_0}{I} \qquad (1)$$

Reflectance factor β is the ratio of the light intensity I of the light remitted by the ink film in relation to the intensity of light I_0 remitted by the blank paper. Reflectance factor β decreases as the film thickness increases *(Kipphan, 2001)*.

The optical density (D) of the CMYK prints was measured on the fields of 20%, 40%, 60%, 80% and 100% raster tone values. The results of the optical density measurements on prints for individual colours are presented in Figures 1-3.

Table 1: Properties of synthetic papers.

Properties	Paper 1	Paper 2	Paper 3
Grammage [g/m²]	100	100	100
Thickness [μm]	133	95	112
Gloss [75⁰]	53	7	27
Roughness, PPS [μm]	1.2	3.8	8.1
Air permeance [ml/min]	/	/	7
$Cobb_{60}$ [g/m²]	0.2	4.7	5.2
Surface energy [mJ/m²]	24.3	22.4	26.5
- dispersion part	17.9	12.8	10.6
- polar part	6.4	9.6	15.9

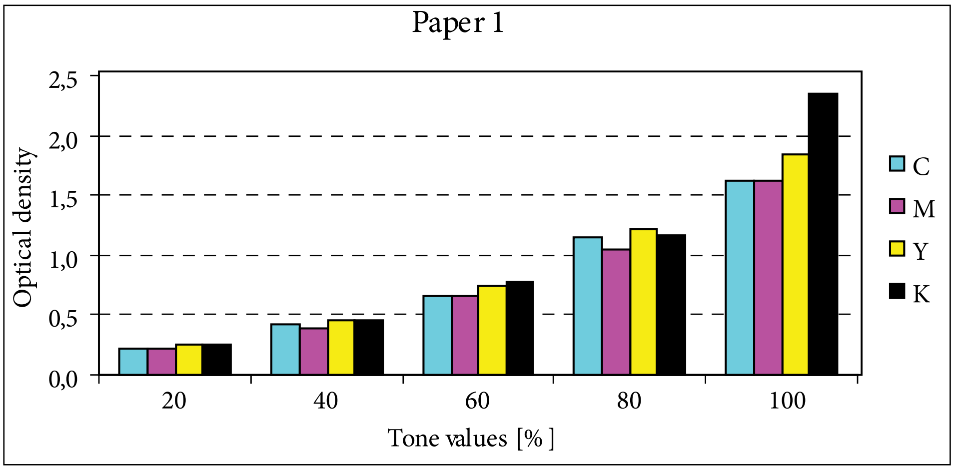

Figure 1: Optical density of CMYK prints at Paper 1.

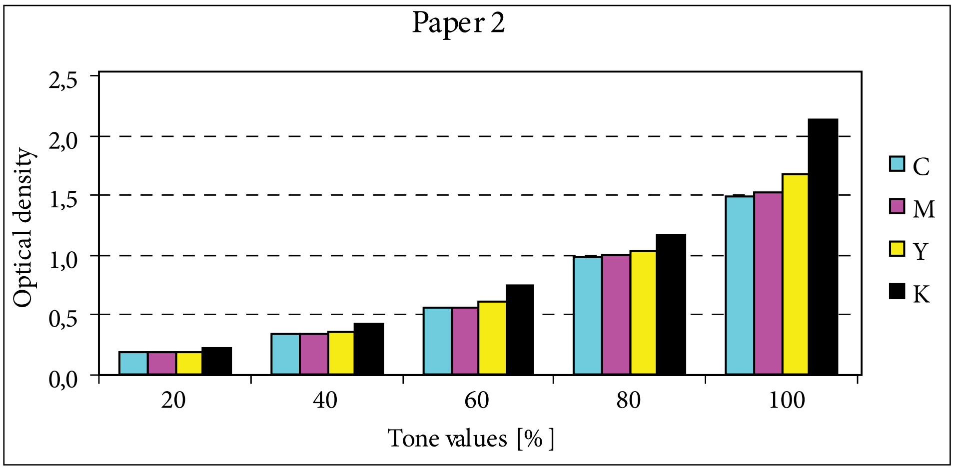

Figure 2: Optical density of CMYK prints at Paper 2.

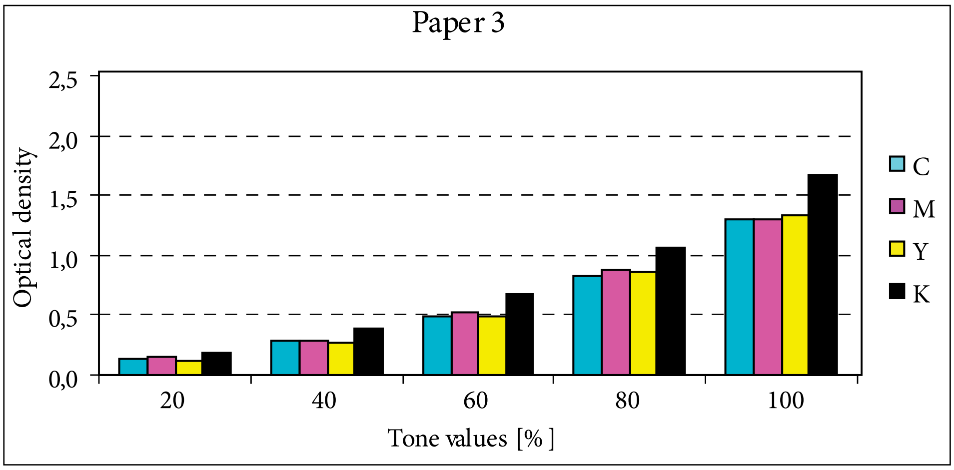

Figure 3: Optical density of CMYK prints at Paper 3.

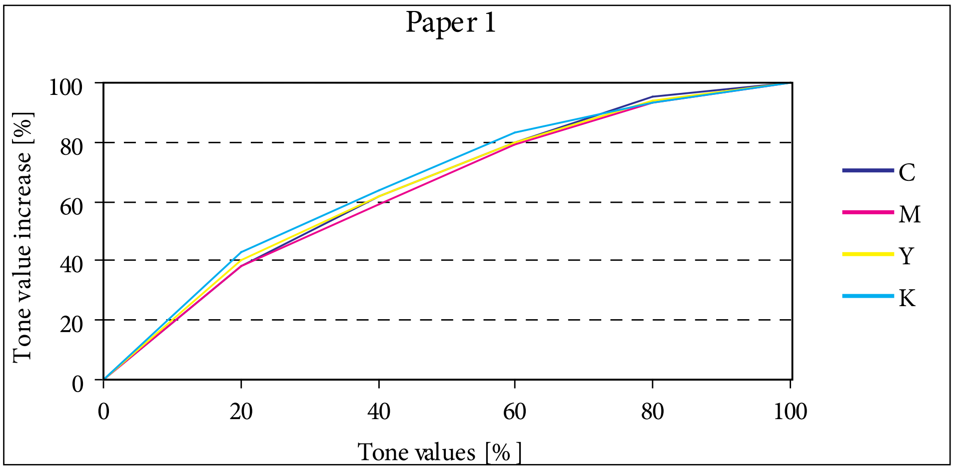

Figure 4: Optical tone value increase of CMYK prints at Paper 1.

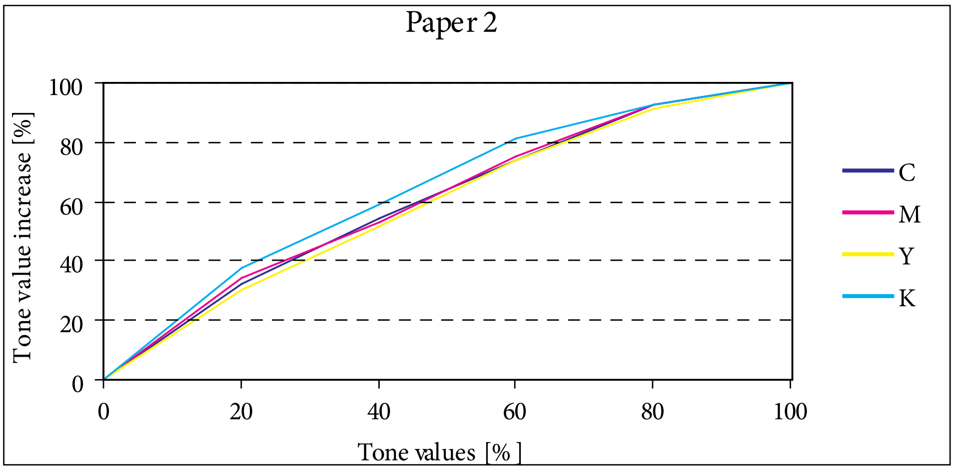

Figure 5: Optical tone value increase of CMYK prints at Paper 2.

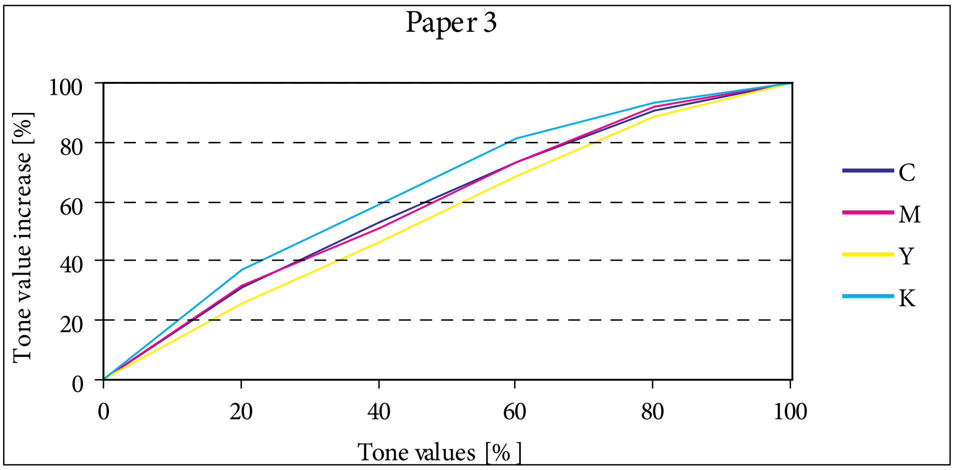

Figure 6: Optical tone value increase of CMYK prints at Paper 3.

The results of the optical density measurements on the 20% to 100% raster tone values indicate that different types of synthetic papers have impact on it. The most obvious deviation was observed at CMYK prints made on Paper 1, where at all raster tone values the optical density was the highest. On the other hand, optical density of CMYK prints made on Paper 3 reached the lowest values. By increasing the amount of ink, the differences between CMYK prints were higher. On average, black prints on all papers obtained the highest values (Paper 1: $D_{K,100\%}$= 2.35, Paper 2: $D_{K,100\%}$ = 2.12, Paper 3: $D_{K,100\%}$ = 1.67). Cyan, magenta and yellow prints were found to behave differently from black prints. The optical densities for cyan, and magenta prints were almost the same at Paper 2, except at solid tone value. Cyan print obtained the lowest optical density on all papers (Paper 1: $D_{C,100\%}$= 1.62, Paper 2: $D_{C,100\%}$ = 1.49, Paper 3: $D_{C,100\%}$ = 1.30). In electrophotography the toner adhesion to paper is an important quality parameter. Toner adhesion to paper is believed to occur both mechanically and chemically. In mechanical adhesion, as the toner penetrates to the voids in paper structure, the polymeric molecules interlock within themselves and with the surface. Mechanical forces are relatively weak but with small polymer molecules the bond strengths can be enhanced. Mechanical bonding is believed to be the strongest with porous and rough structures because of a better chance of intermingling between the polymer particles and greater potential bonding area. There are several theories of the original chemical adhesion: chemical reaction, adsorption, electrostatic and diffuse theory. The best accepted theory is that of adsorption where wettability and surface energy of the substrate and viscosity of the colorant are important. Among physical properties of the paper, porosity and roughness have the most pronounced influence on mechanical adhesion *(Vikman et al., 2000).* The surface of Paper 3 is rougher (see *Table 1*) and more porous than the surfaces of other two papers. Moreover, Paper 3 had the highest surface energy with high polar contribution, resulting in better wetting and penetration of inks into the paper. This explains the lower optical density of CMYK prints on Paper 3 compared to CMYK prints on Paper 1 and on Paper 2.

3.3 Tone value increase of CMYK prints

The optical tone value increase refers to the fact that a printed dot appears bigger than it geometrically is. This is so because the light that enters the substrate under the dot can exit from the substrate between dots due to light scattering in substrate *(Yang et al., 2001).* The optical tone value increase essentially depends on paper's surface and its absorption/ink setting behaviour. Figures 3-6 present the data concerning the optical tone value increase measured on the CMYK prints from 20% to 100% raster tone values.

From the Figure 6 it can be observed that the highest tone value increase (TVI) is in the mid values, from 40% to 60%. The increase of tone values ranges from 13-24%, with the largest values for the black print ($TVI_{K,20\%}$ = 23%, $TVI_{K,40\%}$ = 24%, $TVI_{K,60\%}$ = 23%, $TVI_{K,80\%}$ = 13%) and the smallest at magenta prints. The highest tone value increase was obtained on Paper 1. The reason behind could be in the absorbency of paper, because Paper 1 is most hydrophobic of all papers tested (*see Table 1*). Also the optical density of CMYK prints was the highest in the case of Paper 1 (see Figure 1). Figure 5 shows that black prints once again experienced the highest increase of tone value. The increase in the tone values results in the higher saturation and darker appearance. In Figure 6, where results for Paper 2 are shown, an increase in the total tone values ranging from 5-21% is seen. Once again the largest values were obtained at the black raster tone values ($TVI_{K,20\%}$ = 16%, $TVI_{K,40\%}$ = 19%, $TVI_{K,60\%}$ = 21%, $TVI_{K,80\%}$ = 13%). In the case of both samples (Paper 2, Paper 3) the yellow print experienced the smallest increase of the optical tone value. In the case of all CMYK prints on Paper 3 the smallest values compared to prints were obtained on Paper 1 and Paper 2.

3.4 Abrasion resistance of CMYK prints

Abrasion resistance is the ability of a material to withstand some mechanical rigours such as rubbing, scraping or erosion that tends progressively to remove the material from its surface. Such ability helps to maintain material's original appearance and structure. However, there has been a paucity of information concerning physical changes in digital prints due to the application of physical forces such as flexing and rubbing with abrading materials. Physical abuse of print can undoubtedly be deleterious just as a change in colour characteristics. The ink should adhere strongly, and the print needs to be resistant to mechanical stresses. The abrasion resistance of prints is determined by the characteristics of print carriers, printing technology, as well as the type and the composition of the printing ink. Abrasion resistance is therefore an important surface property of prints *(Prokai et al., 2010), (Salesin et al., 2008)*. Figure 7 displays the optical density of solid CMYK prints measured after 200 rubbing cycles.

From the Figure 7 it is evident that on average CMYK prints have the best abrasion resistance on Paper 2. The optical density after 200 rubbing was D_C=0.018, D_M=0.014, D_Y=0.026 and D_B=0.016. It is interesting that the optical density value for the cyan print on Paper 1 was over 0.03, for magenta over 0.025, while on yellow and black prints the values lay under 0.01. In general, if optical density values exceeded 0.02, the prints have weak abrasion resistance. If density values are lower than 0.01, the prints have good abrasion resistance. It was noticed that on both fibre synthetic papers (Paper 2 and Paper 3), the yellow and black prints have slightly lower abrasion resistance, while resistance is very high on Paper 1.

4. Conclusions

This study focuses on the printability of different grades of synthetic papers using the electrophotography technique. The results witness to the fact that there is a difference in the optical density and optical tone value, and thus in the perceived appearance of the CMYK prints. The highest optical density and optical tone value increase were observed in the context of the film synthetic paper (Paper 1), where CMYK prints were more saturated. Paper 1 has very hydrophobic and smooth surface so it cannot absorb the ink, while fibre synthetic papers have slightly higher absorption values and higher roughness, especially Paper 3. Paper 3 also has the highest surface energy with high polar contributions, resulting in better wetting and penetration of inks into the paper. This explains the lower optical density of CMYK prints on Paper 3 compared to prints on Paper 1 and Paper 2. On average the highest abrasion resistance of CMYK prints was obtained from Paper 2.

These preliminary results can be used for further optimization of interactions between different synthetic papers and inks, for end print reproduction.

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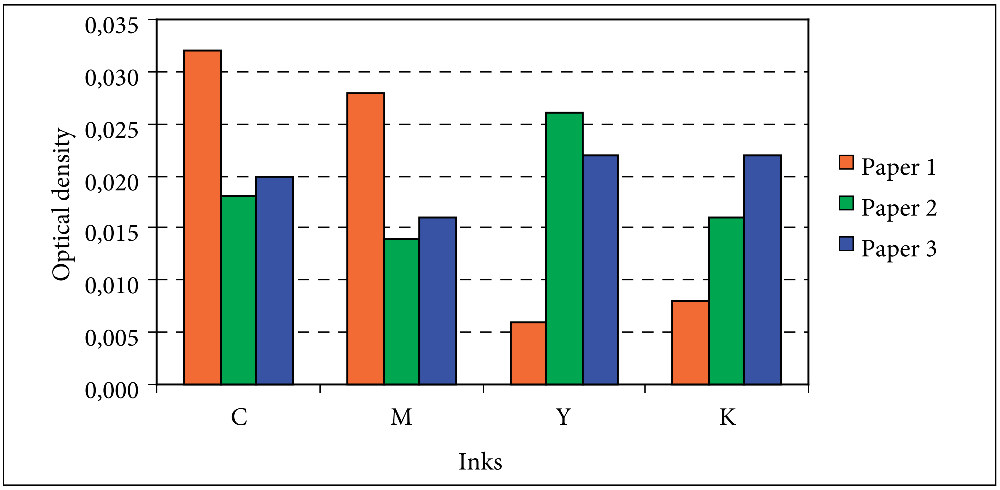

Figure 7: Optical density of solid CMYK prints measured after 200 rubbing cycles.

References

BHATTACHARYYA M. K., NG H. T., HANSON E. G., JACKSON B. J., MORSE S. D., ARONHIME M. (2009) Investigation of Ink-Substrate Adhesion in LEP Printing. *NIP 25: 25th International Conference on Digital Printing Technologies*, Louisville, USA, pp. 561-564.

DEBELJAK M., BRAČKO S., HLADNIK A., GREGOR-SVETEC D. (2010) Comparison of ultraviolet inkjet printing on different synthetic fibrous papers. *Tappi Journal,* pp. 17-25.

KIPPHAN H. (2001) *Handbook of print media: Technologies and Production Methods*. Springer, pp. 103, 127, 140-141.

KUO Y. F., YANG C. L., YIH Y., ALLEBACH J. P., GELEYNSE C. D. (2009) Modeling of Tone Deviation during Switch-on Transient for Color Electrophotography. *NIP 25: 25th International Conference on Digital Printing Technologies*, Louisville, USA, pp. 703-706.

MORTIMER A. (1998) *Colour Reproduction in a Digital Age*. Pira International, Leatherhead, pp. 260-261.

MUCK T., HLADNIK A. (2003) Evaluation of the quality of ink-jet printed paper by planar chromatography. *Journal of planar chromatography*, Vol. 16, Nu. 2, pp. 154-159.

PASZKOWSKA K., PODSIADLO H., AMBROZIEWICH A. (2005) Influence of the fibre composition of paper containing synthetic fibers on printing properties. *Paper Technology*, Vol. 46, Nu. 1. p. 21.

RENMEI X., FLEMING P., PEKAROVICOVA A. (2005) The Effect of Ink Jet paper Roughness on Print Gloss. *Journal of Imaging sciences and Technologies*, Vol. 49, Nu. 6., pp. 660-666.

PROKAI P., SZENTGYÖRGYVÖLGYI R., BORBÉLY Á., GREGOR-SVETEC D. (2010) Abrasion resistance of prints produced by electrophotographic printing technology. *Proceedings of International Joint Conference in Environmental and Light Industry Technologies*, Óbuda University, Budapest, pp. 229-233.

SALESIN E., SCOTT J., NISHIMURA D., ADELSTEIN P., REILLY J., BURGE D. (2008) Abrasion of Digital Reflection *NIP 24: 24th International Conference on Digital Printing Technologies*, Pittsburgh, Pennsylvania, USA, pp. 228-230.

SIPI K. M. (2001) Toner Layer Structure and Toner Adhesion on Coated Paper. *NIP 17: 17th International Conference on Digital Printing Technologies*, Springfiled, USA, pp. 145-150.

YANG L., GOORAN S., KRUSE B. (2001) Simulation of Optical Dot Gain in Multichromatic Tone Production. *Journal of Imaging sciences and Technologies*, Vol. 45, Nu. 2, pp. 198-204.

VIKMAN K., SIPI K. M., OTTINEN P. (2000) Applicability of FTIR and Raman Spectroscopic Methods to the Study of Ink Jet and Electrophotographic Prints. *NIP 16: 16th International Conference on Digital Printing Technologies*, Springfiled, USA, pp. 408-413.

***ALL ABOUT PAPER (2004) [online]. http://www.pinc.org/vault/all_about_paper_04.pdf

***SIPI K. M. (2003) Tone paper interactions induced by the fixing process in electrophotographic printing [online]. http://owww.media.hut.fi/~julkaisut/lisensiaattityot/LI_Sipi.pdf