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INFLUENCE OF UV CURING VARNISH COATING ON SURFACE PROPERTIES OF PAPER

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Original scientific paper

In order to achieve better properties of the printing substrates their improving is possible in various ways. In this article the possibility of the substrate improving is analyzed with different surface coverage of varnishes cured by UV radiation, where three characteristic kinds of paper were used (fine art glossy paper, offset paper and calendered paper). The applied methods are based on measuring the optical properties with the varnish impregnated surface (colouring, gloss, smoothness), as well as determining the physical property of absorbency. Double properties of the printing substrates are obtained by the layer of UV varnish which is cured by LED light. The investigation results show that the absorbency decreases on gloss coated paper by the application of UV varnish coating, while it increases on uncoated paper (offset and calendered paper). The varnish coating with smaller coverage (33 % UV varnish) is not relevant for the absorbency and for optical properties of the natural paper. Important changes in roughness and optical properties are achieved with 66 % coating which is especially visible on fine art paper.

Keywords: *UV varnishing of paper, gloss, absorbency, smoothness*

Utjecaj nanosa laka koji se suši UV zračenjem na površinska svojstva papira

Izvorni znanstveni članak

U svrhu postizanja boljih svojstava tiskovne je podloge moguće oplemenjivati na različite načine. U ovom radu analizira se mogućnost oplemenjivanja s različitom površinskom pokrivenošću lakova koji se suše UV zračenjem, pri čemu su korištena tri karakteristična papira (papir za umjetnički tisak gloss, offsetni papir i kalandriran papir). Primijenjene metode su bazirane na mjerenju optičkih svojstava lakom impregnirane površine (obojenje, sjaj i glatkoća), kao i na određivanju fizikalnog svojstva upojnosti. Dvojne osobine papirnih podloga dobivaju se nanosom UV laka koji suši LED svjetlošću. Rezultati istraživanja pokazuju da se kod gloss premazanog papira upojnost smanjuje nanosom UV laka, dok se kod nepremazanih papira (offsetni, kalandrirani) upojnost povećava. Nanos laka s manjom površinskom pokrivenošću (33 % UV laka) nije relevantntna za upojnost i optička svojstva naravnih papira. Značajne promjene u hrapavosti i optičkim svojstava postižu se 66 % nanosom, što je posebice vidljivo kod papira za umjetnički tisak.

Ključne riječi: *UV lakiranje papira, sjaj, upojnost, glatkoća*

1 Introduction

The coating process is an important phase in the paper production process. Smoother printing substrates with improved appearances are formed by coating and better adhesion of the printing inks is enabled as well. Paper is a porous material in which liquids (moisture, fat) and gasses (water vapor, oxygen, flavor etc.) penetrate well. To protect the graphic products from different outdoor factors, it is necessary to apply the protective layer on paper. It is mainly made by wax impregnation and by laminating different materials in layers (PE polyethylene, aluminum foil, or melted polymer) [1]. In recent time one of the methods for applying the impregnated layers has been the UV InkJet printing technology. In this technology the liquid is directly applied on the printing substrate and it is cured by LED UV light. In this way of printing, the printing inks are applied, but the transparent UV dried varnishes can be also applied in this printing technique. In this way a new surface of changed properties is obtained. It is analyzed in this article how different surface coverage of the UV varnish influences the printing substrates which are used in printing industry. They are natural paper (offset paper), mat calendered papers and glossy coated paper for fine art printing. The characteristic properties of the paper surface are analyzed: absorbency, smoothness, gloss and tone [2].

2 Theoretical part

Paper is a thin flat material which is made from interwoven cellulose fibers, formed after water elimination from the mashed fibrous product [3]. Cellulose fibers are the basic but not the only component in paper. For the satisfactory printing and optical properties, fillers, sizing agents and colorants are added to paper.

In order to get the good adhesiveness of inks and the high quality of printing the paper must be qualitatively coated. The coating of the paper can be done on one side (more often on board) and on both sides (mostly on colour printed paper). During the coating process it is necessary that the coating fulfils all the cracks in paper and that it covers the peak cellulose fibres on the paper surface. Three coating methods are applied: by means of the blade, by nozzles and the combination of coating and pressing (Fig. 1). The coating can be done in several layers, in which the trend to decrease the paper base and the trend to increase the paper fillers can be noticed (Fig. 2).

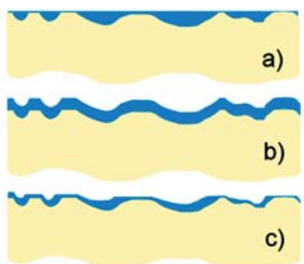

Figure 1 Methods of paper coating: a) by the blade b) by spraying with the nozzles c) by the combination of coating and pressing

Paper coating is often done with the opaque printing inks. The coatings based on inks contain two basic components: white pigment (clay, calcium carbonate, talcum, titan dioxide) and sizing agents (starch, latex). Because of better sheet formation it is necessary to add some additives which can be: sprays, co-binders, thickeners. The coexistence of the content is ensured, the rheological properties are determined, the share of water is defined which prevents the changes in the final coating application. There are other additives which influence the physical and optical properties of the finally formed coating (the added thickeners, lubricants, hardening agents, fluorescent agents for whitening, agents for preventing froth formation, agents for preventing gas releasing [4-5].

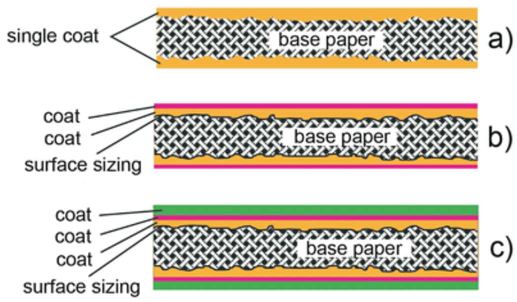

Figure 2 Schematic presentation of the types of coated paper: a) fine art paper with 1 coating; b) fine art paper with 2 coatings; c) fine art paper with 3 coatings

The pigment particles used for coating are difficult to separate mutually and it is impossible to mix them in their natural state. Because of that, water is an essential component, without which it is impossible to mix the components and consequently to make the uniform coating. When the water evaporates from the finally formed layer, the applied layer consolidates so that the binders bind pigment particles with the paper base. For the satisfying free flow and energy savings for drying, the pigment coating contains a minimal quantity of water. The share of pigment in the finally dried coating ranges from 85 to 95 %. [6].

In pigment coatings the ideal binder must satisfy many properties. They are: a good binding force, good water retaining, easy mixing, solubility in water, compatibility with other coating components, unchanging the coating viscosity, good mechanical and chemical stability, good optical and mechanical properties, without odour, resistance to frothing, resistance to microorganisms, low price and easy accessibility. In terms of their origin and binders solubility they can be classified to compounds which can be soluble or insoluble in water. The soluble ones are: starch, proteins, carboxyl methyl cellulose, polyvinyl alcohols (PVA, PVOH), while the insoluble ones are carboxyl styrene / butadiene latex (XSB Latex), styrene acrylat latex (SA Latex) polyvinyl acetate latex (PV Ac Latex). Water soluble binders better retain moisture. It directly influences the rheological coating properties making them more viscous, more pseudo-plastic and more thixotropic. Synthetic additives in binders (co-binders) have similar effect. By carboxylation of SB-latex small quantities of unsaturated carboxyl acids will be activated (acrylic acids, met-acrylic acids, melamine acids) which considerably improve the compatibility of these highly hydrophobic polymers with other coating components. Latex (synthetical product which contains the dispersed polymers in water) often needs co-binder or thickener in order to adjust the rheological properties and retain the water in desired quantity [7-9].

Finally formed coating layer must satisfy many printing properties. It must be big enough to resist the strain during the printing process. In this way the surface tension of the coating will define the minimum of the allowed binder quantity in coating. The increase of binder part will have negative influence on opacity, gloss and tackiness. The binder surplus can cause problems with applying the printing ink, i.e. with the print quality.

2.1 Improving the printing substrate with the UV varnish coating by the InkJet technique

One of the possibilities of printing substrate improving is the coating of UV varnishes by spraying through tiny nozzles. The liquid varnish is used in this case, which is distributed directly on paper and then fixed by means of UV light. The formed varnish drops have small size (6 pL) and they stiffen under the influence of LED light source (curing). So it is adjusted to printing on non absorbent printing substrates (the curing process is immediate without possibility to blur).

UV varnishes do not evaporate while curing and they do not demand great quantity of easily volatile solvents, by which a good light resistance and the resistance to high temperatures is achieved. InkJet varnish must have defined viscosity (adjusted to the work of the printing head). The non compatible varnish can cause blocking of nozzles (the droplets are formed by spraying through the nozzles with the diameter smaller than 20 µm) [10].

Because of that the basic compound of UV varnish which is cured by LED light is complex and it contains: 25–35 % solvent (hexamethylene diacrylate hexane diol diacrylate), 10–20 % binders (synergistic acrylate amine), 30–40 % acrylic esters, 10–20 % photo sensitive monomers, 5–15 % phosphine oxide derivate and 0–1 % additives [11].

3 Experimental part

For the needs of experiment three types of digitalized printing forms were constructed whose coverage ranged from 0 to 100 % screen value in a step of 33 % of screen value. For experimental printing the UV InkJet printer Cutter Roland Versa LEC 300 was used which apart from the standard CMYK uses UV varnish and UV white ink. In Versa Work RIP the following parameters were defined: varnishing mode (gloss), resolution (740 × 740 dpi), head moving (un-indirection) and screening method (dither). Three standard printing substrates were used in the experiment: offset paper (Masterprint 140 g/m^2) mat calendered paper (Splendogel EW 115 g/m^2), fine art paper (Chorus lux gloss 130 g/m^2).

By UV printing of wire side (WS) and felt side (FS) three characteristic samples were made: prints with the surface coverage of 33 % (mark a), prints with the surface coverage of 66 % (mark b) and the prints with the surface coverage of 100 % /(mark c).

The optical properties of the varnished and not varnished paper were measured with two devices: with spectrophotometer X-rite DTP 20 (measuring geometry 0/45° and standard observer 10°) and the device for gloss measuring Elcometer 407 (measuring geometry 60°). CIE Lab and GU (gloss unit) results were obtained from which the colour differences (CIE ΔE_{00}) and gloss difference ΔGU were calculated. Regarding the physical properties, only those connected with the optical properties of paper were examined. They were measurements of paper roughness after Bendtsen, and determination of adsorption of the UV varnished printing substrate after Cobb.

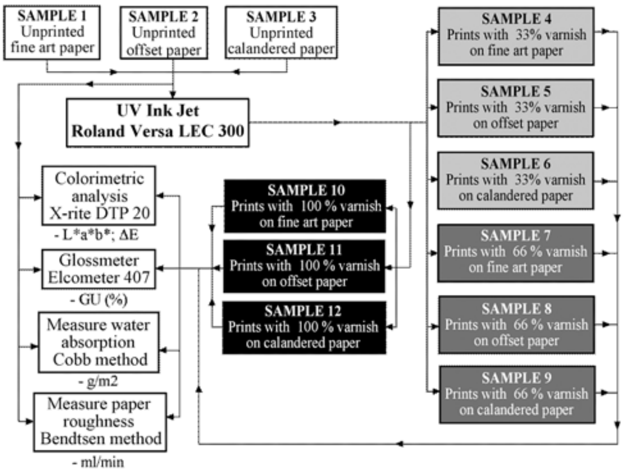

Figure 3 Schematic presentation of the performed experiment

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Results and discussion

In the work of Arney J. S. & Alber M. L. the optical properties of the halftone reproduction were examined where the surface was improved with the ink by means of InkJet technology [12]. In this work the analysis is directed to UV InkJet printing technique which enables the coating of transparent varnishes which modify the properties of the printing substrates. On 3D graphs (Fig. 4) the colour difference of three characteristic printing substrates (WS and FS) is presented which is the result of 3 ways of varnishing (33 %, 66 % and 100 % screen value). All the differences are compared with the samples which were not varnished (samples 1, 2 and 3).

On WS fine art paper, partly coating of UV varnish (sample 4 and sample 7) gives small colour changes. ($\Delta E_{0\text{-}33\,\%}$ = 0,50; $\Delta E_{0\text{-}66\,\%}$= 0,54). Solid (100 %) with the coating (sample 10) gives visible change in colouring ($\Delta E_{0\text{-}100\,\%}$ =2,44), where the change is the result of the loss of the original paper lightness and colour change of the tone in direction of –b coordinate (yellow). Varnishing of FS paper gives continuous optical changes ($\Delta E_{0\text{-}33\,\%}$ = 0,48; $\Delta E_{0\text{-}66\,\%}$ = 1,51; $\Delta E_{0\text{-}100\,\%}$ = 2,32), which enables better noticing of the screen treated paper. The difference in tone between WS and FS is obvious. The coating of varnish with the coverage of 66 % screen value gives the biggest difference in colouring (ΔE_{samp9} = 1,09). The reason for that is the reflection from the uneven printed surface which results in great UV varnish dispersion.

In regard to the fine art paper, the natural offset paper has greater tone deviation. The wire side of the offset paper (samples 4, 8 and 11) gives the following colour changes obtained by varnishing process: $\Delta E_{0\text{-}33\,\%}$ =0,84; $\Delta E_{0\text{-}66\,\%}$ = 1,77; $\Delta E_{0\text{-}100\,\%}$ = 2,75. By varnishing the FS smaller colour changes appear ($\Delta E_{0\text{-}33\,\%}$ = 0,80; $\Delta E_{0\text{-}66\,\%}$ = 1,44 and $\Delta E_{0\text{-}100\,\%}$ = 2,61). The difference between the WS and FS is possible to be detected only by spectrophotometric devices ($\Delta E_{WS\text{-}FS}$ = 0,08). By the application of UV varnish the colour differences between two sides of paper increase. They are the most noticeable in the sample 8 (ΔE_{samp10} = 0,34), where the change in chromaticity appears (ΔC = 0,24).

Mat calendered paper has the smallest colour changes in the process of UV varnishing. On WS (samples 6, 9 and 12) they are: $\Delta E_{0\text{-}33\,\%}$ = 0,47; $\Delta E_{0\text{-}66\,\%}$ = 0,70; $\Delta E_{0\text{-}100\,\%}$ = 1,62; so they are almost identical to colour differences in FS ($\Delta E_{0\text{-}33\,\%}$ =0,46; $\Delta E_{0\text{-}66\,\%}$ = 0,76; $\Delta E_{0\text{-}100\,\%}$ = 1,55). On the calendered paper the greatest difference can be found among the uncoated WS and uncoated FS sides FS (ΔE = 0,40). By means of the UV varnishing process, the difference in tone is slightly decreased (33 % and 100 % UV varnish).

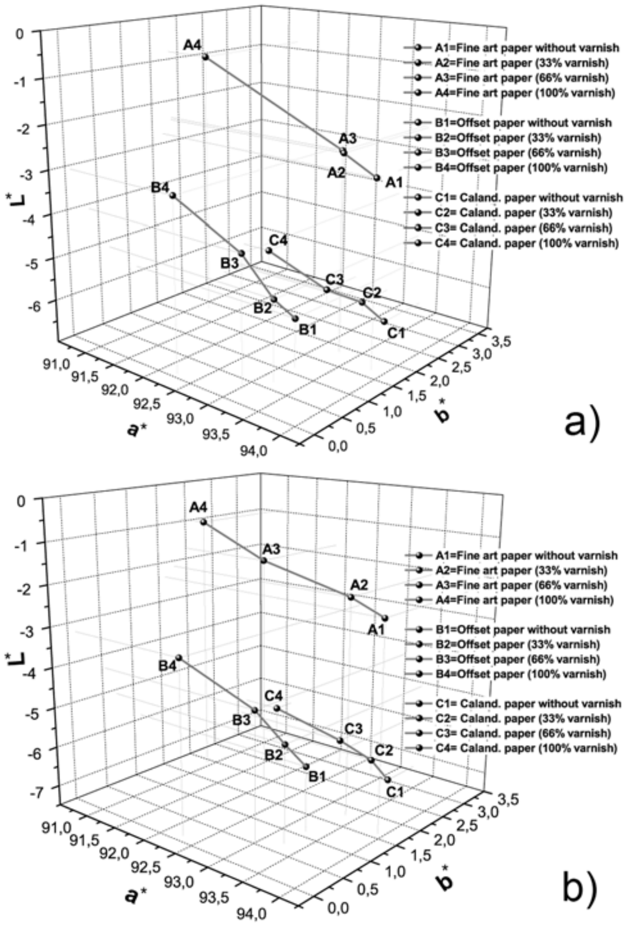

Figure 4 Changes in colouring of the offset, calendered and coated paper caused by the different coating of UV varnish: a) WS b) FS

The exception is the surface with 66 % varnish on which the decrease in colour difference is noticeable (ΔE = 0,15). A suitable method which can determine the effect of UV varnishing is based on optical gloss measurements (Fig. 5). In this case the gloss meters are used whose geometry can be 20°, 60° and 85°. For measuring the UV varnished paper surface the angle of 60° is used.

Because of the coating on both sides, the fine art paper has very high starting gloss value (G_{WS} = 35,30 %, G_{FS} = 35,30 %). By UV varnishing the surface gloss is increased where a considerable gloss difference is obtained: $\Delta G_{0\,\%\text{-}100\,\%}$ = 56,78 % (WS), $\Delta G_{33\,\%\text{-}100\,\%}$ = 60,04 % (FS). The felt side of paper has more constant gloss. By greater number of measurements (before and after varnishing) the average deviation of gloss is ΔG_{Mean} = 2,02 %. The WS deviations of the original paper are greater ($\Delta G_{0\,\%}$ = 5,12 %), in relation to the surface which was coated with 100 % UV varnish ($\Delta G_{100\,\%}$ = 1,47 %).

On offset and mat calendered paper there are no considerable changes in gloss when applying UV varnish. On the contrary the gloss is insignificantly decreased. On the offset paper this fall is maximal: $\Delta G_{33\,\%\text{-}100\,\%}$ = 0,11 (WS), $\Delta G_{0\,\%\text{-}100\,\%}$ = 0,08 (FS). The deviations which appeared during measurements oscillate a little on both paper sides: ΔG_{Mean} = 0,15 % (WS); ΔG_{Mean} = 0,10 % (FS).

On the mat calendered paper the UV varnishing gives different gloss values on the felt and wire side of paper.

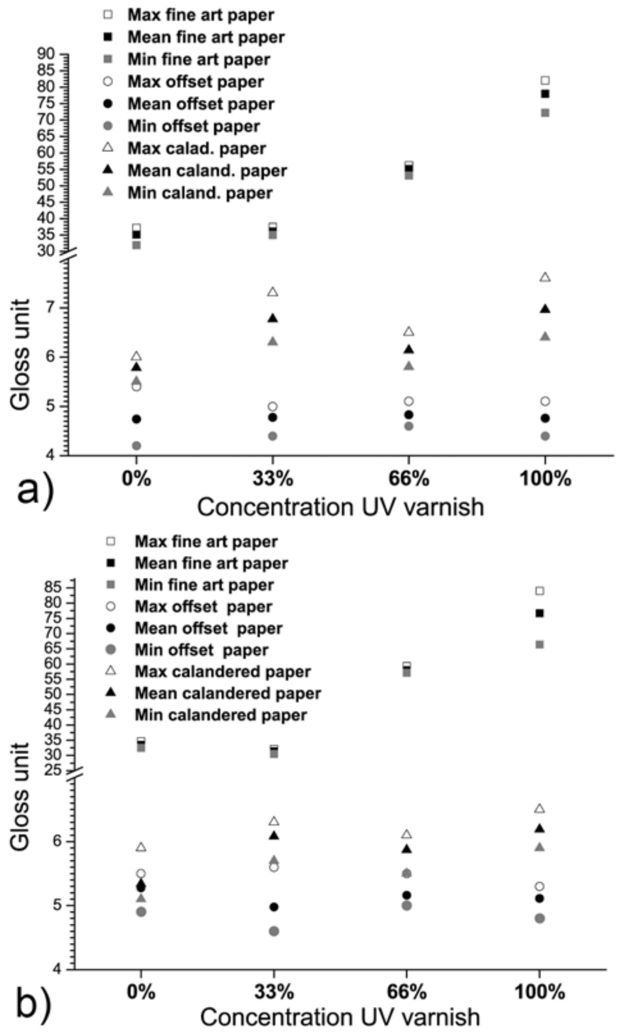

Figure 5 The gloss of the offset, calendered and gloss coated paper appeared because of the different coverage of UV varnish: a) WS; b) FS

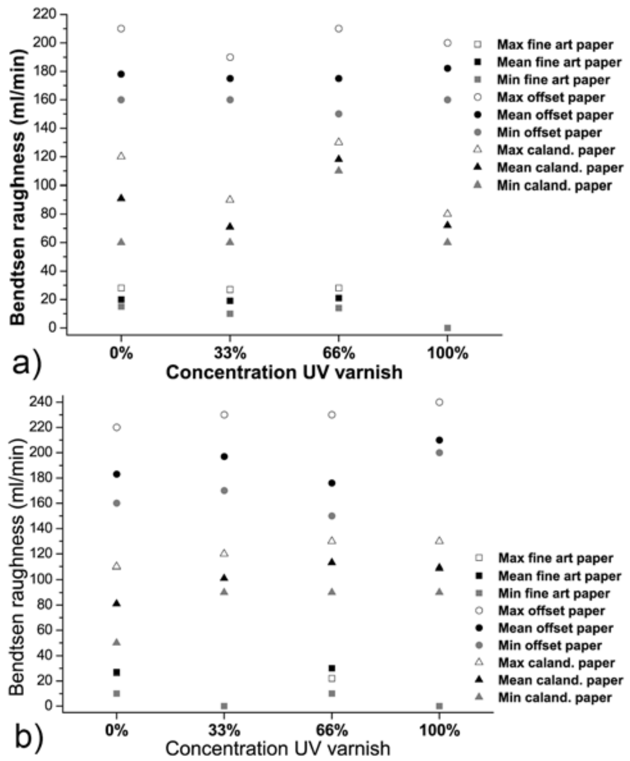

Figure 6 Roughness of the offset, calendered and gloss coated paper which appeared because of different coating of UV varnish: a) WS; b) FS

The increase of coverage with varnish results in gloss fall: $\Delta G_{33\,\%\text{-}100\,\%} = 0{,}06$ % (FS); $\Delta G_{33\,\%\text{-}100\,\%} = 0{,}17$ % (WS). The deviations within the measurements are minimal ($\Delta G_{\text{Med}} = 0{,}05$ % WS; $\Delta G_{\text{Med}} = 0{,}09$ % FS).

The method which indirectly brings the optical and mechanical paper properties in correlation is based on roughness (smoothness) measurements of paper. The surface roughness after Berndtsen is performed by measuring the air flow through the paper, where a small permeability defines the greater smoothness (Fig. 6).

Fine art paper has small original roughness ($Rg_{0\,\%} = 20$ ml/min WS; $Rg_{0\,\%} = 26$ ml/min FS). By adding the varnish, the roughness value on both sides decreases, and the sample with the maximal coating (100 % varnish) could not be measured ($Rg_{100\,\%} = 0$ ml/min). Maximum in resulting deviations is made by partly varnish coverage: $\Delta Rg_{33\,\%} = 17$ ml/min (WS) and $\Delta Rg_{66\,\%} = 20$ ml/min (FS). Original offset paper has the greatest surface roughness ($Rg_{0\,\%} = 178$ ml/min WS; $Rg_{0\,\%} = 183$ ml/min FS). By screen varnishing the roughness decreases ($\Delta Rg_{0\,\%\text{-}66\,\%} = -3$ ml/min), while with 100 % screen value the roughness increases ($\Delta Rg_{0\,\%\text{-}100\,\%} = 4$ ml/min). The greatest deviations are in measurements which appeared on the surface varnished with 66% UV varnish ($\Delta Rg_{66\,\%} = 60$ ml/min). The roughness results on FS vary more than the results on WS if varnishing is done with UV varnish. The value of roughness increases with the coverage of 33 % and 100 % and decreases with 66 %. The reason for that is a great deviation in measurements which appear during the UV varnish ($\Delta Rg_{66\,\%} = 80$ ml/min) which is a direct result of the imperfect moving of InkJet printing head.

Original mat calendered paper has different roughness on WS and FS ($\Delta Rg_{\text{WS-FS}} = 10$ ml/min). The wire side has more roughness ($Rg_{0\,\%} = 91$ ml/min) than the felt side ($Rg_{0\,\%} = 81$ ml/min). The surface coverage with 33 % and 100% UV varnish results in roughness decrease ($\Delta Rg_{0\,\%\text{-}100\,\%} = 21$ ml/min), while the sample with 66 % varnish creates the additional noise which results in greater roughness ($\Delta Rg_{0\,\%\text{-}66\,\%} = 27$ ml/min). As the felt side is smoother, the surface is made rougher by the UV varnishing process. From all three experimental layers 66 % UV varnish causes the greatest roughness ($\Delta Rg_{66\,\%} = 28$ ml/min). With the comparison of the varnished sides it can be seen that the starting smoother side FS becomes rougher than the wire side ($\Delta Rg_{\max} = 10$ ml/min).

The liquid absorbency is the important physical property for paper printing substrates. Because in the printing process different liquids (inks) are applied, the distilled water is used as the standard for measuring absorbency. The penetration of water is observed in the period of 2 min [13].

The FS of the original fine art paper has greater absorbency than the wire side ($\Delta Ab = 2{,}19$ g/m^2). In the varnishing process the fine art paper has decreased absorbency $\Delta Ab_{0\text{-}100\,\%} = 70{,}19$ g/m^2 (WS); $\Delta Ab_{0\text{-}100\,\%} = 72{,}38$ g/m^2 (FS). During the absorbency measurements greater deviation results on FS of the original paper were noticed ($\Delta Ab_{0\,\%} = 5{,}96$ g/m^2), which decreased during the UV varnish application ($\Delta Ab_{100\,\%} = 0{,}8$ g/m^2). The absorbency results on WS are more uniform (deviations of the original surface are $\Delta Ab_{0\,\%} = 4{,}93$ g/m^2, and of solid tone they are $\Delta \text{Ab}_{100\,\%} = 0{,}17$ g/m^2). The results of screened UV varnishing are completely in accordance with the absorbency results. It

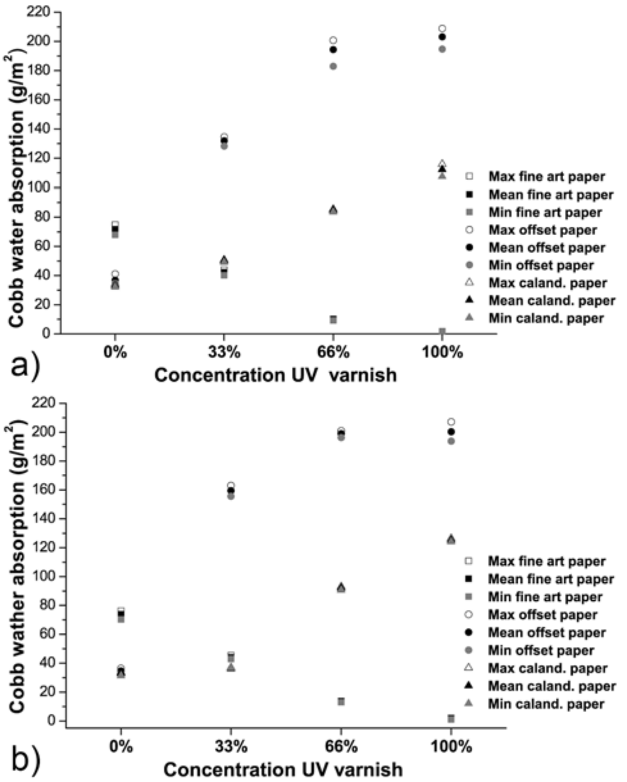

Figure 7 The absorbency of the offset calendered and coated paper because of different coating of UV varnish: a) WS; b) FS

means that the coverage of 33 % and 66 % of UV varnish decreases the absorbency values approximately by 33 % i.e. by 66 %. It is not the case with higher tonal values because greater coating layer fulfils the paper surface.

On the uncoated paper the absorbency is increased by application of UV varnish. On WS of the offset paper the maximal change is $\Delta Ab_{0\text{-}100\,\%}$ = 166,17 g/m^2 while on FS it is $\Delta Ab_{0\text{-}100\,\%}$ = 165,6 g/m^2. The majority of changes are the result of minimal coating of UV varnish (33 %). In relation to the original paper, greater absorbency on WS results from the application of varnish. The formed greater absorbency results in greater deviation within the measured results (WS from $\Delta Ab_{0\,\%}$ = 6,32 g/m^2 to $\Delta Ab_{100\,\%}$ = 14,17 g/m^2, and from $\Delta Ab_{0\,\%}$ = 3,48 g/m^2 to $\Delta Ab_{100\,\%}$ = 13,27 g/m^2 FS).

Mat calendered paper has the starting absorbency very similar to offset paper ($\Delta Ab_{\text{off-calend}}$ = 0,56 g/m^2). There is the difference between the calendered wire side and the felt side ($\Delta Ab_{\text{off-calend}}$ = 2,81 g/m^2). After varnishing, the value change of the maximal absorbency is considerably smaller ($\Delta Ab_{0\,\%\text{-}100\,\%}$ = 79,21 g/m^2 WS; $\Delta Ab_{0\text{-}100\,\%}$ = 92,36 g/m^2 FS). The calendaring process of paper influences the deviation of the measured results. The absorbency deviations are minimal on the FS after the varnishing process (max deviation is on untreated paper $\Delta Ab_{0\,\%}$ = 2,44 g/m^2). Minimal deviations in relation to the original paper are obtained by the screened coating of UV varnish (the difference is smaller than 2 g/m^2). By increasing the surface tension greater deviations in measurements appear ($\Delta Ab_{100\,\%}$ = 8,33 g/m^2).

Photos of samples made by experimental varnishing (magnification 50×) are presented in Figs. 8, 9 and 10. On fine art paper the uneven areas of UV varnish are visible under microscope (33 % and 66 % of UV varnish).

The method based on roughness measurements by means of the air permeability is not the most suitable one for measurements. The surface roughness is the results of non absorbent pigment coating which did not allow deeper penetration of UV varnish. The majority of the applied photo initiators is activated which results in uneven surface. The coating of UV varnish on the uncoated papers does not have the expressed effect of the surface unevenness. The reason for that is the great hygroscopicity of the cellulose fibres which absorb almost all the quantity of the applied UV varnish. LED light did not activate the photo initiators and the networking process did not start. This appearance is much more expressed on factory rougher offset paper which

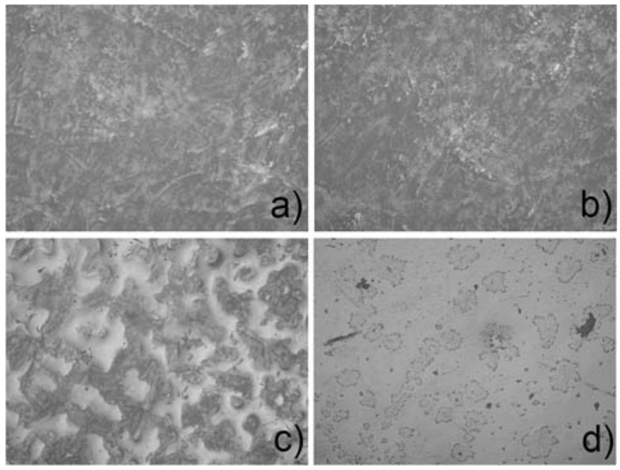

Figure 8 FS of the gloss fine art paper: a) unvarnished, b) 33 % varnish, c) 66 % varnish, d) 100 % varnish

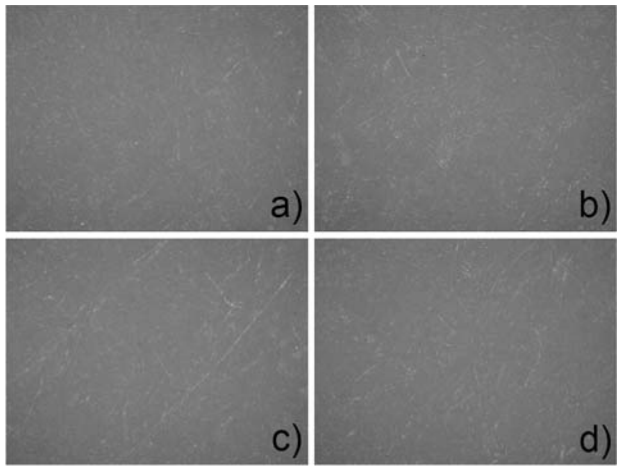

Figure 9 Felt side of the offset paper: a) unvarnished surface, b) 33 % varnish, c) 66 % varnish, d) 100 % varnish

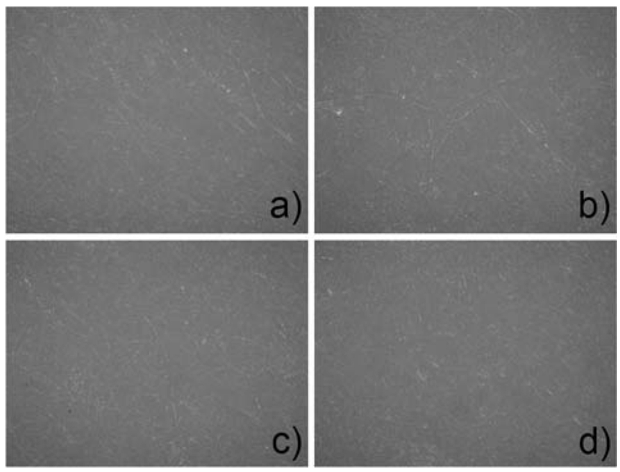

Figure 10 FS of the mat calendered paper: a) unvarnished surface, b) 33 % varnish, c) 66 % varnish, d) 100 % varnish

has greater absorbency. This is shown by the results made with WS (rougher) and FS (smoother).

5 Conclusion

The investigation results show that by UV varnishing of smoother substrates great chromatic changes appear which are visible with the naked eye $\Delta E > 1,5$. The native paper whiteness decreases and the varnished paper surface slightly begins to yellow. The most intense yellowness appears at maximal UV varnish coating. If the tone change on the natural paper is not desirable, the felt side has to be varnished. The varnish application with smaller surface coverage (33 % UV varnish) is not relevant for the tested optical and mechanical properties of natural paper. Maximal varnish coverage (100 %) does not give the expected economical effect. Considerable changes of the optical properties are achieved by 66 % coating which is especially visible from the measured roughness.

On fine art paper, the increase of UV varnish coating results in proportional gloss increase, which can be applied for stressing definite areas on printed products. At that the roughness and absorbency lightly decrease. By UV varnishing of offset and calendered paper the additional gloss is not achieved, and it is not recommended as the printing substrate for obtaining the additional visual effects on the print. By screened varnishing the roughness is additionally increased which causes greater absorbency. The marked surface differences are noticeable in measuring the wire side of natural paper.

Dual properties of the paper substrates appear by UV varnish application which is cured by LED light. On gloss coated paper the absorbency decreases by the application of UV varnish and on uncoated paper (offset paper, calendered paper) the absorbency increases. The process of UV varnishing enables the application of fine art paper as possible protection from moisture (water resistant layer). It is not the case for natural paper which becomes more absorbent by UV processing. Such paper can be used as roll-blotter.

6 References

[1] Walenski, W. Das Papier das Buch. Verlag Beruf + Schule, 1994.
[2] Tracton A. A. Coatings Technology handbook, CRC Press, 2006, Boca Raton, USA (FL), pp. 25-1.
[3] The Invention of Paper. // Congress Book 10. // Tschudin, P. F., IPH, 1994. pp. 17–22.
[4] Altemeier, M. Size Press Filling Boosts Ash Content Enhances Uncoated Free-sheet Quality. // Pulp and Paper, (1)2004, pp. 52–54.
[5] Willenbacher, N. TAPPI 1997, Advanced Coating Fundamentals. // Symposium notes, TAPPI Press, Atalanta 1997.
[6] Holik, H. Handbook of Paper and Board, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2006.
[7] Gill, R. A. The Effect of PCC Filler Characteristics on the Optical and Permeability Aspects of Paper. // Tappi International Paper Physics Conference Proceedings, 1991, pp. 211–218.
[8] Etzel, R. OptiSpray-the new improved coating technology and first production results, // Das Papier, 2004, T-53pp.
[9] Scholkopf, J; The moment ink contact the surface: a fresh look at the absorption dynamic into coated paper. // Das Papier, 2004, T-26 pp.
[10] Majnaric, I. Analysis of Colour Reproduction Created by Applying Multiple Layers of White Ink on PVC Foil. // Proc. MATRIB 2010/Croatian Society for Materials and Tribology, 2010, pp. 268.
[11] Madhusoodhanan, S. Image Quality and Surface Tension of Digital UV Curable Ink. // Proccedings of IS&T NIP 24th International Conference on Digital Printing Technologies / Pittsburgh Pannsylvania, 2008, pp. 363-366.
[12] Optical Effects of Ink Spread and Penetration on Halftones Printed by Thermal Ink Jet. // Recent Progress in Ink Jet Technologies II, Eric Hanson (Ed), Springfield 1996, pp. 503-507.
[13] Wetting and Liquid Absorption Characteristics of Ink Jet Paper. // Recent Progress in Ink Jet Technologies II, Eric Hanson(Ed), Springfield 1996, pp. 486-490.

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