

# Control of the offset printing image quality indices

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**Abstract.** The problem of assessing printing quality is urgent nowadays and requires informative adaptation and development methods. The study of "printing ink – substrate" boundary, taking into account a great variety of printing ink, is of high scientific and applied interest. The paper presents research results of the printouts made on the coated paper by the offset printing method. Visualization of the components distribution of offset ink in substrate surface and volumetric layers of the substrate is presented. Based on the scanning electron microscopy and energy dispersive spectra analysis of the printouts cross-sections, colorimetric parameters and the character of ink layers distribution in pores of the paper, coated layers of two coloured inks at different applications during printing, are compared. The tendency of bigger distortion of the required colour at higher depth of the ink penetration is observed. The obtained data can be used for the values of pre-distortions, predefined in the pre-press, so that the printing ink can be chosen depending on the required reproduction accuracy.

## 1. Introduction

The quality indicators of the offset printout significantly depend on the stage of the ink fixation on the printing substrate during printing, a complicated processes, which depends on the physicochemical characteristics of the interacting systems.

The analysis of the printing main elements allowed to identify the following factors influencing the product quality: printing material and ink, dampening solution and equipment configuration options. The problem of printing quality assessment is quite complicated and urgent, requiring informative methods of adaptation and development.

In references [1, 2], computers are utilized for assessing offset printing quality, including dots deviation control and imitation of ink film thickness distribution for various images. Printability of functional inks on multilayer curtain coated substrates was investigated in reference [3], where pore size was the determining factor for penetration of the nano-sized ink.

Electron microscopy can be used for both printing material analysis [4, 5], particularly, the form and the pores location in the paper volume, and for monitoring ink distribution in the printing substrate structure [6, 7]. Besides, it can be used for analyzing image quality and for assessing other factors, which characterize interactions between printing ink and substrate surface [8].



The ink components were visualized in reference [9] by focused ion beam to determine which of the ink components entered the coating layer. This work agrees with other published findings, which show that the pigments and hard resins remain on the surface of the coating, whereas mineral and vegetable oils are mobile and penetrate into the coating layer. Ester solvent and dissolved wax also penetrate into the coating layer. Liquid spreading on solid surfaces and penetration into porous matrices (powders and coated papers) are also investigated in reference [10] both experimentally and theoretically.

## 2. Problem statement

Investigating the “printing ink–substrate” boundary, taking into account a great variety of printing inks, is of high scientific and applied interest. In papers [5, 6, 11] there is some data showing electron microscopy images of the “printing ink–board” boundary. However, the factors influencing the printout process and curing on the substrate surface, have not been considered.

The aim of the research is the study and monitor the influence of the offset printing ink emulsifying efficiency on the process of its absorption and curing on the substrate surface. Besides, it is practically important to control the degree of ink emulsification under printing conditions, taking into account simple reliability indices of the printout quality.

## 3. Experiment methodology

Printouts printed with two offset inks by leading manufacturers were studied: Litoflora FTX FlintGroup (**I1**) and Toyo (**I2**) in a standard manner of 100% covering black (**K**)–Cyan (**C**)–Magenta (**M**). Coated TitanGloss paper was used as a substrate. The printouts were printed under comparable conditions on the four-color ManRoland704 printing machine without thermal control of the printing apparatus with alcohol damping.

To obtain and keep the acidity within the pH=4.8-5.3 range, the dampening solution concentrate Hydrofast 307 GS was used. Chemically pure isopropyl alcohol was used as an additive, while acetone content was 0.03vol.%. Feed rate of the dampening by the duct roller was 23%. The degree of the printing ink emulsifying efficiency ( $D_e$ ) at the interaction with dampening solution was defined according to the reference [12].

Quantitative assessment of the depth of ink absorption into the substrate structure was defined by the “printing ink–substrate” boundary, according to the cross-section images obtained with high-resolution field emission scanning electron microscope JSM7500F (JEOL). Spatial resolution was better than 1 nm. To decrease charging and prevent destruction of the non-conductive samples under the electron beam, the sample surface was coated with platinum layer (about 10 nm thick) in argon atmosphere using the AutoFineCoater JFC-1600 magnetron sputtering system.

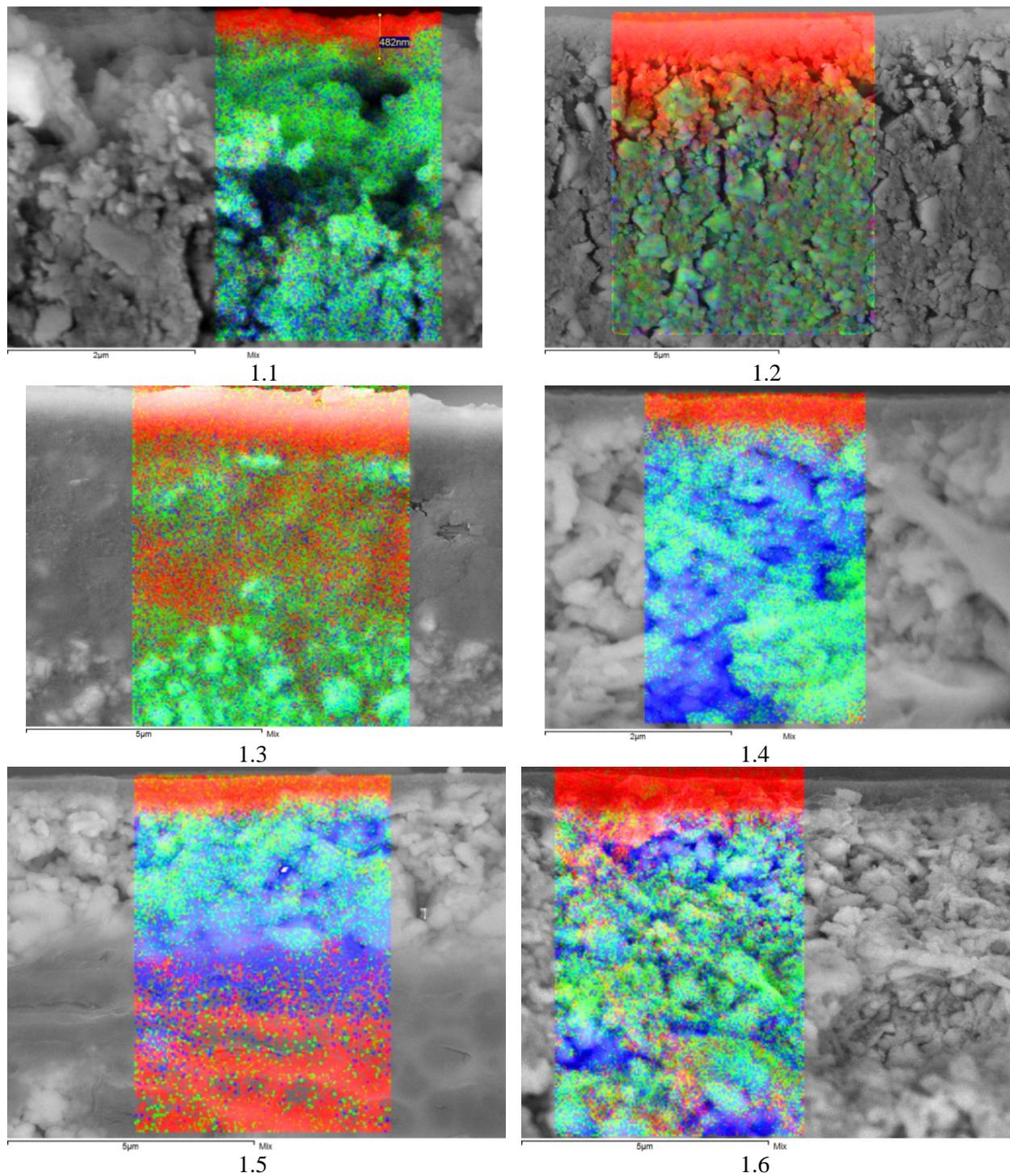
For element composition and distribution on the surface and in the volume of paper layers, energy dispersive spectrometer (EDS, Oxford X-Max80) was used with the SATW window at 10 kV accelerating voltage,  $2 \cdot 10^{-10}$  A probe current, 40 s acquisition time and minimal counting rate. Si was used as the optimization element.

For the printout quality indices, optical density and colour difference  $\Delta E$  in the system of Lab colour space with regard to the colour coordinates were considered, given in the file. Optical density was defined by the conventional method using the GretagMacbeth SpectroEye spectrophotometer.

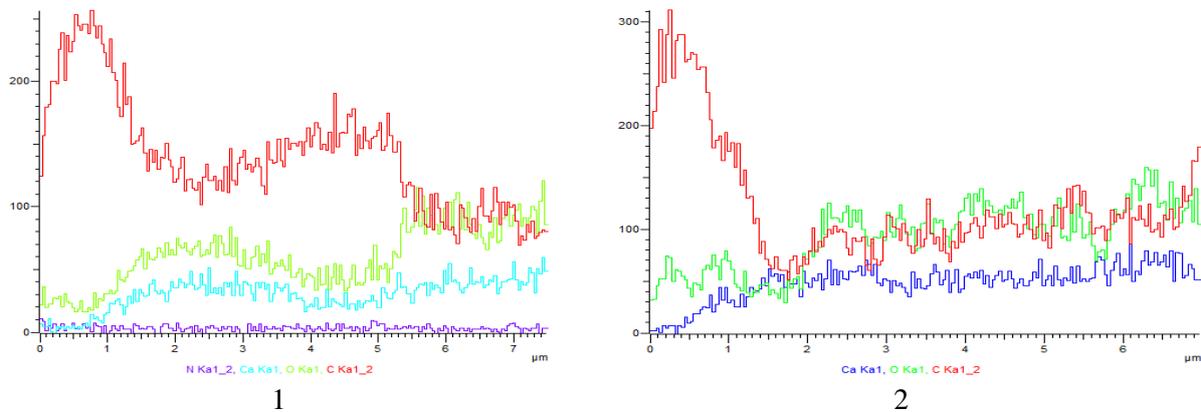
## 4. Experimental results

Experimental results are presented in Table 1 and in Figure 1–2 in the form of SEM images of the printout cross sections, printed by the following offset printing ink: Litoflora FTX FlintGroup (**I1**) and Toyo (**I2**) in a standard manner of 100% covering black (**K**)–Cyan (**C**)–Magenta (**M**), with superimposed EDS mapping of the ink layers elements distribution, along with the X-ray signal intensity at different adsorption depth into the paper pores.

Based on the obtained SEM images and EDS analysis of the printouts cross-sections, colorimetric values and the character of the ink layer distribution on the surface and in the pores of the paper coated layer, two colored ink series are compared during the printing process, specifically: **K / KC / KCM**.



**Figure 1.** Beginning. SEM images of printouts cross-section: 1.1 – **I1 K** (20000x); 1.2 – **I1 K/C** (10000x); 1.3 – **I1 K/C/M** (10000x); 1.4 – **I2 K** (20000x); 1.5 – **I2 K/C** (10000x); 1.6 – **I2 K/C/M** (10000x).



**Figure 2.** EDS mapping of elements distribution and X-ray signal intensity as a function of penetration depth: 1 – **I1** K/C/M (10000x); 2 - **I2** K/C/M (10000x).

## 5. Results and discussion

The thickness of the ink layer varies according to the zones, depending on the total area of the printing elements in the given zone and is defined at the “printing ink–substrate” boundary. The thickness and the optical density of black (**K**) ink layers are equal in both cases, while the values of the colour difference are moderate, and the ink layer penetration into the coated layer surface is almost invisible (Table 1, Figure 1, positions 1.1 and 1.4).

**Table 1.** Ink layers parameters.

Ink	D <sub>e</sub> %	Optical density	ΔE	The layer thickness on the surface, μm			Adsorption depth, μm		
		K / KC / KCM	K / KC / KCM	K	/ KC	/ KCM	K	/ KC	/ KCM
<i>I1</i>	65	1.7 / 1.4 / 1.5 ± 0.1	2.2 / 1.7 / 4.0 ± 0.2	0.4 ± 0.1	0.8 ± 0.3	0.9 ± 0.2	0.3 ± 0.1	1.5 ± 0.2	4.5 ± 0.3
<i>I2</i>	54	1.7 / 1.4 / 1.4 ± 0.1	1.8 / 1.0 / 0.7 ± 0.1	0.4 ± 0.1	0.5 ± 0.1	0.6 ± 0.1	0.4 ± 0.1	0.4 ± 0.1	0.6 ± 0.2

After the application of the second ink (**C**, wet printing), the difference becomes more essential (Table 1, Fig. 1, positions 1.2 and 1.5) and obtains significant values after the application of the third ink (**M**, Table 1, Figure 1, positions 1.3 and 1.6). It can be seen in elements distribution curves (Figure 2, positions 1 and 2) that the **I1** depth of penetration into the pores of the coated layer is about 4.5 μm, and the thickness of the ink layer directly on the paper surface is approximately 1 μm (determined by the boundary of increasing Ca signal, which constitutes the coated paper layer basis). For the **I2** these values are approximately 0.6 μm. It should be noted that the thickness of the ink layers in all **I2** applications and the depth of penetration into the paper have approximately equal values.

Such ink behavior can be explained by varying degree of emulsification while printing. On the one hand, the printing elements contact the dampening form roller during each plate cylinder rotation cycle and bear a layer of dampening solution on their surface, which migrates into the inking unit during subsequent contacts. On the other hand, form printing roller transfers the dampening solution into the inking unit, while in contact with the dampened whitespace areas of the printing plate. Higher emulsifying value of the **I1** ink (Table 1) means that there is possibly more dampening solution in the transferable ink layer. Herewith, optical density of the ink layers both for **I1**, and for **I2** have comparable values, and are within the tolerance limits permitted by the ISO 13655 standard.

The values of the colour differences are significant: for **I1** ΔE=4±0.2 is the boundary and the maximum possible value when printing with the so-called psychological fidelity (differences are visible to the naked eye); ΔE=0.7±0.1 for **I2** is an exact reproduction of the specified object colour.

## 6. Conclusions

In conclusion, precision of the given colour reproduction on the printout and the character of different ink adsorption in surface pores and volumetric paper structure layers were reasonably compared.

The tendency of the larger distortion of the required colour can be observed at all versions of ink application for the case of the maximum penetration of the printing ink components into the structure of the coated material.

Based on the collected pre-distortion data values defined in the pre-press process, the choice of ink for the specified printing system can be made with regard to the required accuracy of the multicolored image reproduction.

## References

- [1] Lundström J and Verikas A 2010 Detecting halftone dots for offset print quality assessment using soft computing *Fuzzy Systems (FUZZ)*, IEEE Conf. Publications pp 1–7
- [2] Yu J and Wei P 2011 Modeling the axial oil distribution of offset printing *Electrical and Control Engineering (ICECE)*, IEEE Conf. Publications pp 4968–4971
- [3] Bollström R, Tobjörk D, Dolietis P, Salminen P, Preston J, Österbacka R and Toivakka M 2013 Printability of functional inks on multilayer curtain coated paper *Chemical Engineering and Processing: Process Intensification, Advances in Coating and Drying of Thin Films* vol 68 pp 13–20
- [4] Kugge Ch, Craig V S J and Daicic J 2004 A scanning electron microscope study of the surface structure of mineral pigments, lattices and thickeners used for paper coating on non-absorbent substrates *Colloids and Surfaces A: Physicochemical and Engineering Aspects* **238(1-3)** 1-114
- [5] Ozaki Y and Kimura M 2000 Visualization of printing of ink vehicle on paper surfaces by a SEM technique *Appita J.* **3** 216-219
- [6] Preston J S, Elton N J, Husband J C, Dalton J S, Heard P J and Allen G C 2002 Investigation into the distribution of ink components on printed coated paper *Colloids and Surfaces A: Physicochemical and Engineering Aspects* **205(3)** 183–198
- [7] Verikas A, Lundström J and Gelzinis A 2011 Advances in computational intelligence-based print quality assessment and control in offset colour printing *Expert Systems with Applications* **38(10)** 13441–13447
- [8] Pietrov D, Gereige I and Gourgon C 2013 Automatic detection of NIL defects using microscopy and image processing *Microelectronic Engineering* **112** 163–167
- [9] Koivula H, Preston J S, Heard P J and Toivakka M 2008 Visualisation of the distribution of offset ink components printed onto coated paper *Colloids and Surfaces A: Physicochemical and Engineering Aspects* **317(1-3)** 557–567
- [10] Rosenholm J 2015 Liquid spreading on solid surfaces and penetration into porous matrices: coated and uncoated papers *Advances in Colloid and Interface Science* **220** 8–53
- [11] Varepo L G, Nagornova I V, and Trapeznikova O V 2015 Application of electron microscopy to quality control of surface ink layers *Procedia Engineering* **113** 357–361
- [12] Surland A 1983 Factors determining the efficiency of lithographic inks *TAGA Proc.* pp 191–233