Influence of surface properties of ink jet papers on print sharpness

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Abstract: *In printing the final print quality depends on the quality of the digital image as well as the properties of the printing system and the paper used. One of the most widely used digital printing technology is ink jet where the ink is ejected directly onto a substrate from a jet device driven by an electronic signal. Most ink jet inks have a low viscosity and a low surface tension, which put high demands on the surface properties of papers. The aim of this study was to investigate the influence of surface properties of commercially available papers suitable for ink jet printing on print sharpness. We used two high glossy, one glossy, one semi-gloss and two matte papers. For the assessment of the surface properties, we measured surface roughness with the portable Roughness Tester TR 200. We also measured surface gloss with QIP Glossmaster. For the characterization of print sharpness we used image analysis method. Print sharpness was estimated according to the modulation transfer function (MTF). Results obtained in this paper showed that the surface properties of paper are in direct relation with print sharpness.*

Keywords: *print sharpness, modulation transfer function, paper properties, ink jet printing*

Introduction

Today, ink jet printing has become the dominant digital printing method for commercial large format and desktop small format printing. Ink jet printing provides unique advantages of high colour gamut, high print quality and print on demand at affordable prices. This printing technology can be described physically as deposition of a finite amount of liquid (ink) onto a porous media (paper) [1]. The ink consists of colourants (dyes or pigments) carried by vehicles. During printing, the colourants should stay close to the paper surface to yield a large colour gamut, whereas the carrier should rapidly evaporate or absorb into the paper to prevent slow drying, paper deformation and inter-colour bleeding. Therefore, it is very important to take care during selection of paper for ink jet printing. Improved print quality is achieved by covering the paper surface with pigments [2] or a light-weight coating during paper manufacturing. The interaction between paper and ink, paper porosity, roughness, together with optical properties such as whiteness, opacity, light scattering and gloss must be considered during ink jet printing [3, 4].

Many researches have studied influence of paper properties on final ink jet prints. They have taken into account different parameters of paper, and their conclusions about the print quality were based on different print attributes, but mostly it was the colour reproduction (colour gamut, colourimetric values, optical density, print contrast, etc). Wu et al. [3] investigated some of the paper properties such as roughness, porosity, brightness, whiteness and gloss. They found that paper with low roughness, low porosity or air permeability, high brightness or whiteness and high paper gloss exhibited a high gamut volume. Perales et al. [5] studied the effect of the colourimetric properties of different types of paper, having different finishing and grammage, on the colour gamut in ink jet printing. It was shown that the greatest colour gamut volume corresponds to the glossy papers. Unlike the works mentioned so far, in addition to the colour gamut, Lundberg et al. [6] also studied the print quality in terms of line quality. They showed that paper composition variations in hardwood content, filler content and type of pulp did not have a major impact on line quality or colour gamut. However, an increased amount of filler decreases the colour gamut volume. In order to improve the quality of printing, papers are submitted to a process of coating. Lee et al. [7] found that the highly-absorbent, porous nature of silica pigments are excellent pigment for coated ink jet printing papers. This is because most ink jet inks consist of 90% water and therefore, the paper must absorb water quickly to avoid wicking and maintain sharp edge acuity (high print sharpness). Eric and Aslund [8] used eight commercially available paper grades suitable for ink jet printing to indentify the most critical parameters. The results showed that it is possible to design a lightly coated paper suitable for high-speed ink jet printing which gives an acceptable colour gamut volume. They also found that hydrophilic surface minimizes mottling effect but can, on the other hand, decrease print sharpness. Jing-lei et al. claimed that the uniformity of coating layer structure has great effect on print quality of dot and line. But, by increasing printing resolution they obtained higher quality of printed lines. And under high printing resolution, to some extent, the quality of ink jet paper have little effect on printing sharpness [9].

Most of these studies are based on examining the influence of paper properties on colour reproduction (gamut volume). Some of them have introduced new secondary print quality attributes, such as print sharpness and print mottling.

The aim of our study was to investigate the effect of surface roughness and gloss of different coated papers on the print sharpness. The print sharpness can be analyzed by different methods. For determining print sharpness we measured Spatial Frequency Response (SFR) using slanted edge test form. This test form is defined by ISO 12233:2000 standard. Device or system sharpness is measured as a Spatial Frequency Response (SFR), also called Modulation Transfer Function (MTF). MTF is a measure of device or system sharpness, only indirectly related to the sharpness perceived by an average observer. To get metrics more related with human perception information about viewing distance and the human visual system must be included. The Subjective Quality Factor (SQF) factor takes into account both system sharpness (defined by MTF) and human visual system (defined by Contrast Sensitivity Function - CSF), calculating the degree of perceived sharpness for selected viewing distance [10].

Materials and Methods

The investigation was performed using six different coated papers specially designed for ink jet printing: 1 – *Premium high glossy paper*, 2 – *Photo matte paper*, 3 – *Glossy paper*, 4 – *Matte paper*, 5 – *Semi-gloss paper* and 6 – *Glossy paper*. Samples were marked with numbers, to facilitate presentation of results.

The chosen printer was Epson StylusPro 7800 which uses eight high-density pigments based ink system. Printed test form contains two slanted edges (5°); one placed vertically, one horizontally. After printing, samples were scanned by scanner Canon CanoScan5600F at 1200spi. This resolution is recommended by standard ISO 24790:2012 [11].

Surface roughness was evaluated by contact stylus roughness meter Roughness Tester TR 200 and surface roughness parameter (Ra) of samples was obtained. For all samples cut-off length was adjusted at 0.25 mm and evaluation length was set up at 5. Gloss was obtained using QIS Glossmaster glossmeter. Measurements were made with 85° geometry.

Slanted edge, which could reflect the sharpness of print, was analyzed by image analysis method with program Imatest 3.1 (SFR module). Print sharpness was evaluated according to MTF and SQF values. The MTF curve generating algorithm is explained in [10]. Region of interest (ROI) was defined as 150 × 300 pixels and was manually adjusted for each image in order to enclose the detected edge more precise. ROI of all samples is presented in Figure 1 and Figure 1. Figure 1 shows vertically oriented slanted edge, and Figure 2 shows horizontally oriented slanted edge. We choose to measure both orientations, because position of edge influence on results.

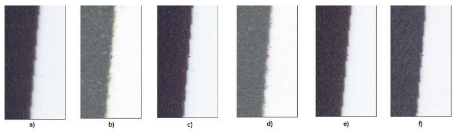

Figure 1: ROI areas for all samples (vertically)

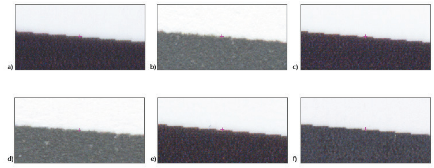

Figure 2: ROI areas for all samples (horizontally)

Results and Discussion

Paper properties of selected papers are presented in Table 1. Papers with glossy coating have smallest surface roughness (0.033-0.242µm) and largest gloss (79.6-90.6), while the results on matte papers are completely opposite. The largest surface roughness has sample 2 (2.623µm), but this samples does not have the smallest gloss. Slightly smaller surface roughness has sample 4 (2.102 µm), and that sample has the smallest gloss (3.6).

Table 1. Paper properties

Samples	1	2	3	4	5	6
Surface roughness Ra [µm]	0,033	2,623	0,061	2,102	0,572	0,242
Gloss	90,6	5,6	79,6	3,6	51,7	87,8

Correlation between paper properties is presented in Figure 3. On the basis of correlation coefficient (R^2=0.929) it can be concluded that paper properties (surface roughness and gloss) are directly related to each other. When gloss increases, the surface roughness decreases. Gloss is associated with high surface smoothness (low surface roughness).

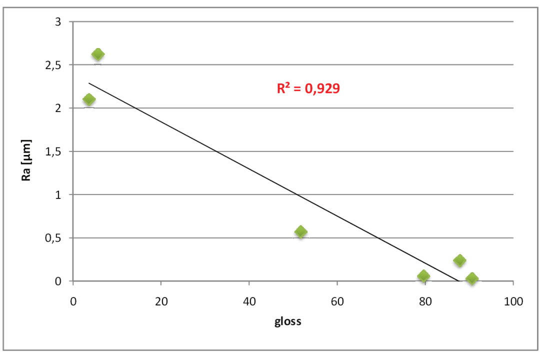

Figure 3: Correlation between surface roughness (Ra) and surface gloss

In Figure 4 are summarized MTF and SQF values for all printed samples. As noted, there were some differences in values, dependent on the slanted edge orientation. Generally, MTF and SQF values are smaller for horizontal slanted edge. This is probably due to the fiber distribution of papers. Sample 6 (glossy paper) has the largest print sharpness, although it does not have the largest gloss and smallest surface roughness. The smallest sharpness was obtained for different papers, depending on the position of edge.

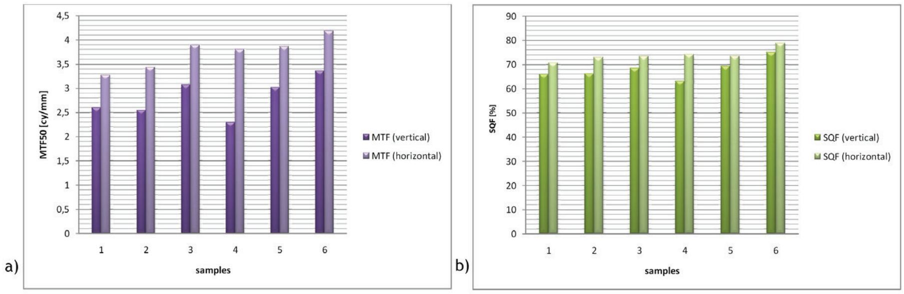

Figure 4: a) MTF values and b) SQF values for all samples

In order to see how paper properties influence print sharpness all obtained results were compared. In Figure 5 are presented correlations between print sharpness (MTF) and paper properties (surface roughness and gloss). We did not found strong correlation between print sharpness and paper properties. Correlation between paper properties and print sharpness for vertical directionof edge is R^2=0.489 and 0.466. And even lower correlation was obtained for the horizontal direction of the edge (R^2=0.039 and 0.073). This was also concluded for comparison between SQF values and paper properties, shown in Figure 6.

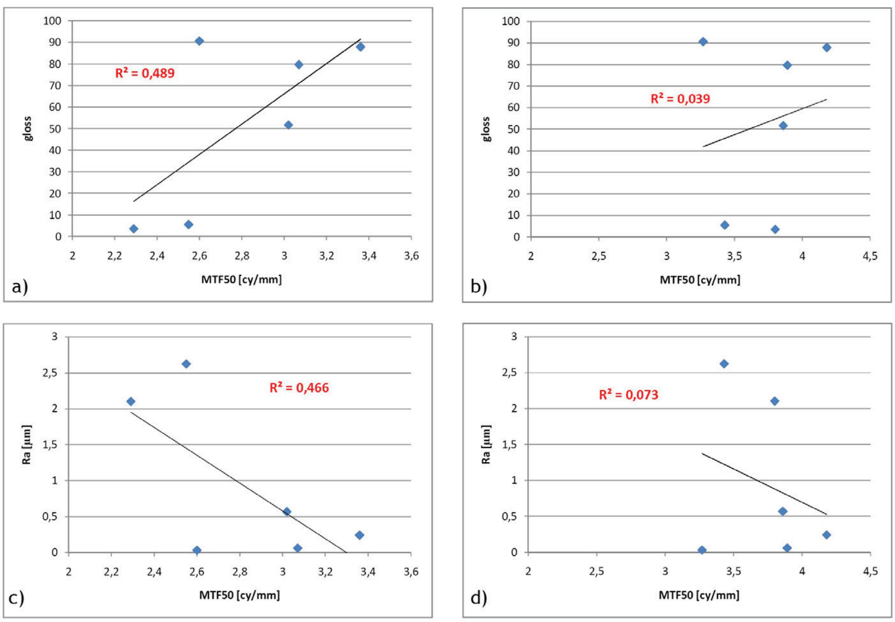

Figure 5: Correlation coefficient between print sharpness (MTF) and a) gloss , b) surface roughness for vertical slanted edge; c) gloss, d) surface roughness for horizontal slanted edge

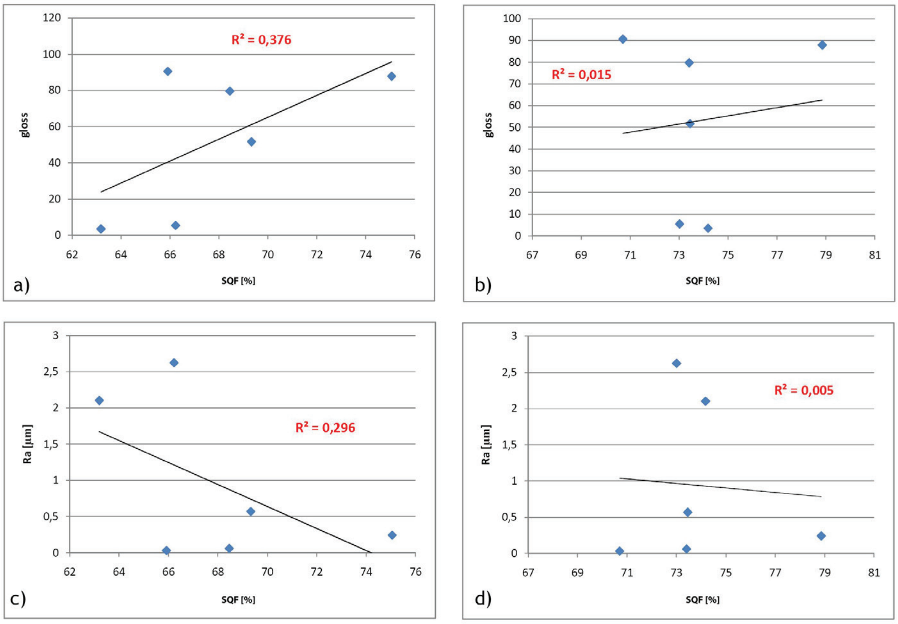

Figure 6: Correlation coefficient between print sharpness (SQF) and a) gloss , b) surface roughness for vertical slanted edge; c) gloss, d) surface roughness for horizontal slanted edge

Conclusions

In this study, the effect of gloss and surface roughness of coated papers on the print quality was evaluated in terms of print sharpness. The study was conducted on six different types of paper with different coating, using one ink jet printer.

According to the obtained results we can conclude that these paper properties (surface roughness and gloss) have strong correlation (R^2=0.929). Paper gloss is directly associated high surface smoothness (low surface roughness). Evaluating print sharpness we found that there was large difference between results obtained for vertical and horizontal edge. This is due to the structure of paper (fiber distribution).

We also found that gloss and surface roughness affect print sharpness to some extent. As might be expected, larger print sharpness was achieved on glossy papers. However, it is impossible to model this effect accurately, because correlation between paper properties and print sharpness (MTF and SQF values) are not strong enough. Such effect could perhaps be modeled if more samples are taken into account and for only one edge direction, because structure of paper largely affects the print sharpness.

Acknowledgements

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