Improved Print quality by Surface fixation of Pigments

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Abstract

Inkjet printing is a non impact printing method that deposits a limited amount of ink onto the paper surface. To improve runnabillity and printability the demands on papers ability to rapidly absorb the fluid and make the colorants stay on the surface increase. These demands get more pronounced as the technology develops and the print speed significantly increases.

The quality of a printed image is strongly influenced by the physical and the chemical interactions between the ink and the paper. Some print quality parameters can be measured objectively by physical measurements using instruments. Subjective print quality evaluation involves human judgments of the final print.

In this article, the print quality on commercial papers as well as on trial papers with different amounts of salt for surface fixation has been studied. The printouts have been made with a desktop printer that uses pigmented inks. The print quality measurements have been both objective measurements such as print density and line quality and subjective image evaluation using a test panel in a perceptual study. The perceptual study focused on detail reproduction, and efforts were made to separate the influence of the print density from the edge definition on the detail reproduction. The study confirms the influence of ink and paper interaction on print quality and the relation to different levels of surface fixation.

Introduction

The impression of a printed image is a combination of many different attributes such as color reproduction, detail reproduction, gloss, etc. The print quality is a result of the physical and chemical properties of the ink and the paper but also of the dynamic interactions between paper and ink during the imbibition process.

The inkjet printing process can be described as the deposition of a limited amount of liquid onto a paper surface. By thermal and physical interaction at the air/ink and ink/paper interfaces, the carrier fluid evaporates or absorbs into the porous substrate by capillary flow and diffusion [1; 2]. If the surface energy of the substrate is sufficiently low, the droplet spreading is reduced, resulting in smaller, more distinct printed dots [3]. During the imbibition process, the carrier fluid should penetrate fast into the substrate or evaporate to avoid color to color bleeding that will impair the detail reproduction [4]. Furthermore, the colorants should stay close to the surface to reproduce a large color gamut and saturated colors [5]. Absorption speed and surface energy can be reduced by adding hydrophobic sizing agents into the paper [3]. Salt can be used as surface treatment to increase print density as described in the patent literature [6].

The main purpose of this work was to determine the influence of surface fixation treatment of the paper on detail reproduction in a final printout.

Detail reproduction in terms of edge sharpness and dot gain can be measured objectively, but the impression of a printed image can only be measured subjectively. There are several existing methods for subjective print quality evaluation [7]. As the difference in print quality was relatively small the pair wise comparison method was chosen in this study.

Materials and Methods

The desktop printer HP Officejet Pro 8000 printer using pigmented, water-based ink was used for printouts. Four non-commercial trial, uncoated surface sized paper with varying level of surface fixation, together with six different uncoated surface sized commercial papers with and without surface fixation were used in this study. The paper samples containing different levels of surface fixation (paper G-J) were produced in a full scale paper machine in the same production run. In the production of paper H-J only the level of surface fixation was varied for each trial point compared to paper G. The paper samples can be found in *table 1*.

Table 1. Papers with and without surface fixation.

Paper	Code	Surface fixation	Grammage [g/m^2]
Commercial paper 1	*A*	*Y*	81
Commercial paper 1	*B*	*N*	81
Commercial paper 2	*C*	*Y*	80
Commercial paper 3	*D*	*Y*	82
Commercial paper 4	*E*	*N*	79
Commercial paper 5	*F*	*N*	80
Ref – No fixation	*G*	*N*	78
Low fixation	*H*	*Y*	79
Medium fixation	*I*	*Y*	79
High fixation	*J*	*Y*	*79*

Test charts for print quality evaluation were created in Photoshop/ Adobe in design CS3 and all colors were defined in RGB coordinates. The test chart for line quality evaluation contains 1.5 mm horizontal and vertical black printed lines on an unprinted background and on a yellow printed background. Lines were scanned by using a flatbed scanner: Epson expression 10000XL. Image analysis was used to evaluate the line quality in terms of raggedness, defined as the standard deviation between 70% of the intensity in the image and an ideal smooth line.

The test chart for evaluating the color reproduction contains 11x7 color patches of cyan, magenta, yellow, black, red, green and blue color in steps of tone values from 0 to 100%. Test chart for evaluating the color reproduction is depicted in *figure 1*.

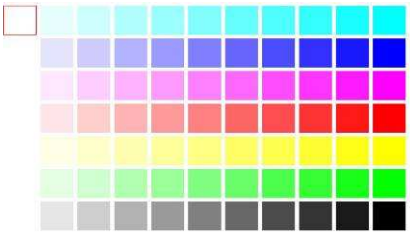

Figure 1. *Test chart for evaluating color reproduction.*

Spectral reflectance was measured in a spectrophotometer with an optical geometry of 45°/0° and 2 degrees of observing angle. Measurements were made with settings for D50 illumination and with a neutral filter.

Subjective print quality evaluation: An RGB GATF 7125 image with a resolution of 1808 x 2280 pixels was used as test image for subjective evaluating the print quality. This test image mainly contains bright colors and a lot of fine details. The left part of the image contains more colors than the right part. The test image, divided into two parts is depicted in *figure 2-3*. An initial perception study was made on the two images, (left image and right image) to determine if the judgment of the detail reproduction in the image got distorted by variations in color reproduction between the samples.

Figure 2. *Left part of the test Image*

Figure 3. *Right part of the test image.*

The test panel consisted of 15 persons and they were asked to judge the images by detail reproduction by pair wise comparison. The participants in the perception study were students from Graphical Arts and technology program at the Mid Sweden University. The participants were of 20 to 40 years of age and 30% men and 70% women. The printed images were presented in a neutral grey painted room with well defined illumination.

To reduce the influence of print density on perceived detail reproduction a second study was performed on the same image in gray scale. The gray scale image is depicted in *figure 4*.

Figure 4*. Test image for subjective print quality evaluation*

The gray scale image was printed with composite black ink on paper A-J (*table 1).*

Two additional samples were added to this perception study. One sample was created to resemble the print density and the other to resemble the detail reproduction of an untreated paper. By a look up table (LUT) the amount of color in the grayscale image could be reduced to create an image with a print density similar to paper G. The final image was printed on a paper with a high level of surface fixation (paper J) and is listed as "sample K" in *table 2*. The other additional sample was created by applying a 2x2 Gaussian-blur filter on the original grayscale image. The filtered image was printed out on paper J and is listed as "L" in *table 2*.

Table 2. Paper samples used in the second perception study

Paper	Code	Surface fixation	Grammage [g/m^2]
Commercial paper 1	*A*	*Y*	81
Commercial paper 1	*B*	*N*	81
Commercial paper 2	*C*	*Y*	80
Commercial paper 3	*D*	*Y*	82
Commercial paper 4	*E*	*N*	79
Commercial paper 5	*F*	*N*	80
Ref –No fixation	*G*	*N*	78
Low fixation	*H*	*Y*	79
Medium fixation	*I*	*Y*	79
High fixation	*J*	*Y*	*79*
High fix+ low dens	*K*	*Y*	*79*
High fix + blurr	*L*	*Y*	*79*

The perception study with the grayscale images was performed in 3 different laboratories, all neutral grey painted room with controlled illumination. The test panel consisted of 40 participants of 20 to 60 years of age and 50% men and 50% women. Most of the participants were experienced in evaluating print samples. The test panels were asked to look at the detail reproduction in the images and judge the images in a pair wise comparison.

Light microscopy: Images of half tone dots were taken with a light microscopy and 210 x magnification (top view). A MATLAB routine was used for calculating the printed area covered by ink representing the final spreading of the droplets. The pixels covered by ink were calculated by

using a threshold value of 33 percent of the maximum intensity of the printed dots.

Result

Small variations in surface fixation did not significantly affect the line quality as determined by objective measurements. An example is shown in *figure 5*, where almost no difference in line sharpness can be observed between paper B and A.

Figure 5. *A horizontal printed line on a yellow background printed on paper B (left image) and paper A(right image)*

However, in *figure 6* it can be seen that a high level of surface fixation improves the line quality in terms of color to color bleeding.

Figure 6. *A horizontal printed line on a yellow background printed on the paper sample without surface fixation, sample G (left image) and paper with a high level of surface fixation, paper J (right image)*

A high level of surface fixation reduces the raggedness of a horizontal black printed line on yellow background. The result of raggedness and its standard deviation in brackets is presented in *table 3*.

Table 3. Raggedness measured on paper with varying levels of surface fixation.

Sample	K-W hor [um]	K-Y hor [um]	K-W vert [um]	K-Y vert [um]
Ref-No	3.9(0.4)	10.0(0.2)	4.4(1.5)	6.7(1.9)
Low	3.7(0.1)	8.8(1)	3.4(0.7)	6.8(0.2)
Medium	3.9(0.3)	8.4(2)	3.8(0.4)	6.0(0.1)
High	3.3(0.2)	6.3(0.2)	4.4(1)	6.3(0.2)

The CIE L*a*b* Chroma was calculated for all papers. It was observed that an increased level of surface fixation increases the Chroma for higher tone values. The result for red color printed out on paper G-J is depicted in *figure 7*. The result is representative for all colors tested. It can be noticed that for lower tone values (<40%), an increased amount of surface fixation slightly reduces the Chroma.

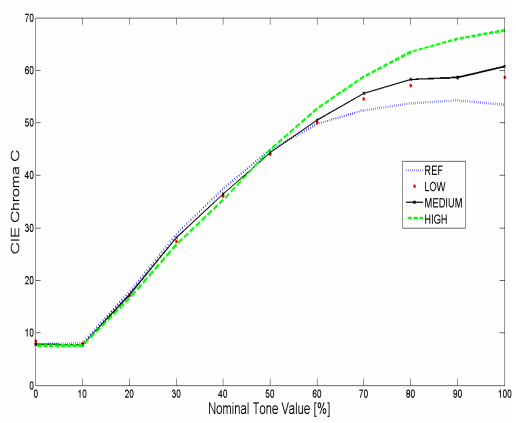

Figure 7. *CIE L*a*b* Chroma for paper G- J. The dotted blue curve represents paper G, the dotted red curve represents paper H, the solid black curve represents paper I and the dashed green curve represents paper J.*

Perception study: The result from the initial perception study is presented in *figure 8-9*. The data in *figure 8* (the image containing more colors), correlate well with the data in *figure 9* (less colors). This indicates that it was possible to judge the detail reproduction in the images, neglecting differences in print density between the samples. The error bars displays the standard deviation for each sample.

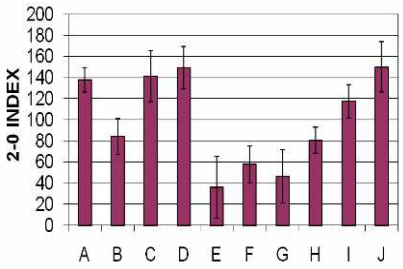

Figure 8*. Results from the initial perception study on the left part of the image*

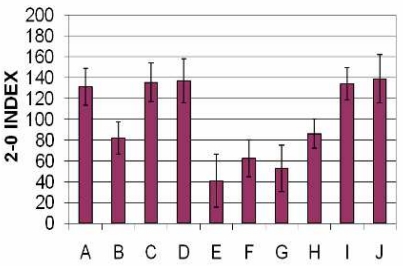

Figure 9*. Results from the initial perception study on the right part of the image.*

Grayscale image: The results from the perception study at three different labs were correlated and were therefore added together. The result is presented in *figure 10*. It can be observed that an increased level of surface fixation improves the detail reproduction (samples G-J).

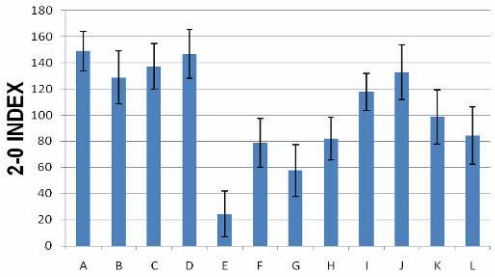

Figure 10. *Results from the perception study on the grayscale Image.*

By comparing sample K and G in *figure 10* it can be seen that the image with a lower print density printed on a paper with a high level of surface fixation (sample K) resulted in a better detail reproduction than for the untreated paper (sample G). This indicates that an increased level of surface fixation not only improves the colour reproduction but also improve detail reproduction in a printed image. Comparing paper L (high level of surface fixation and blurred image) and G (without surface fixation and original image) an improved detail reproduction for paper L compared to paper G can be observed. It shall also be noticed that paper G exhibited a lower Chroma than paper J (*figure 7).*

An example from the light microscopy images of a 10% red printed surface on samples with varying amount of surface fixation is depicted in *figure 11.* The printed dots appeared to be smaller and more distinct for the paper with higher amount of surface fixation (right image).

Figure 11. *Microscopy images of a 10% red surface printed out on paper with a low (left) and high (right) amount of surface fixation.*

The number of pixels in the printed area was calculated for 10% half tone values of cyan, magenta and yellow printed on paper G-J. The result shows that an increased level of surface fixation decreases the ink spreading of the droplets. The result for cyan printed on paper G-J is depicted in *figure 12.* The result is representative for 10% surfaces of cyan and magenta.

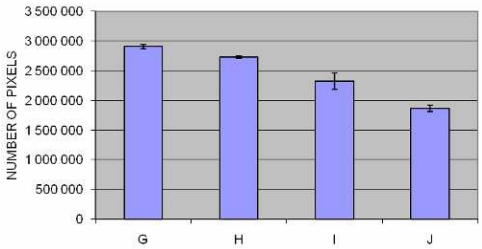

Figure 12*. Droplet spreading for a 10% surface printed out on paper G-J.*

Discussion

An earlier study on the effect of variations in paper composition on print quality indicates that, within a certain parameter window, paper content such as different levels of filler, beating of the fibers, sizing and type of pulp has a minor effect on the print quality [8]. This leaves the opportunity to vary the surface treatment to improve the print quality.

It might be speculated that applying salt on a surface would increase the surface energy, and increase the droplet spreading. This can worsen the detail reproduction in the final print, especially for hydrophobic, slow absorbing surface sized papers. This has not been shown in this work for printouts made with pigmented inks. The result in this work might be explained by changes in electrostatic interactions between the pigments at the paper-ink interface [9] possibly yielding a faster aggregation of the color pigments on papers having a high level of surface fixation.

For lower tone values it was found that a high level of surface fixation slightly reduces the Chroma. Microscopy images show that a high level of surface fixation decreases the droplet spreading, reproducing a more distinct printed dot. The contribution from the white background is included in the spectral measurement, resulting in a lower Chroma.

Among the commercial papers, no observable difference in edge sharpness was found for a paper with surface fixation treatment. For papers J and G, with a high and low level of surface fixation, respectively, the edge sharpness measurements and the results from the perceptual study indicate that the surface fixation treatment improves the line quality and the detail reproduction.

Conclusion

The detail reproduction in a printed image is an interplay between the print density and the edge definition originating from surface spreading of the droplets.

In this study, these two mechanisms have been separated. It was shown by both objective and subjective measurements that the detail reproduction in a printed image can be improved by using paper surface fixation for printouts with pigmented inks. This study furthermore indicates that both the print density and the edge definition are improved by the surface fixation treatment.

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References

[1] G. Desie, C. Van Roost C," Validation of ink Media Interaction Mechanisms for Dye and pigment-based Aqueous and solvent Inks", J. Imaging Sci. Technol., Vol. 50, p. 294-303, (2006).

[2] P. Salminen, Studies of water transport in paper during short contact times, PhD Thesis, Åbo Akademi University, (1988)

[3] A. Lundberg, J. Örtegren. G. Ström, E. Alfthan, Microscale droplet absorption into paper as porous medium, submitted to Nordic Pulp Paper Res., (2010).

[4] S. Bandyopadhyay, Effect of Paper Properties on Print Quality of Inkjet Printer, Proc. IS&Ts NIP17, Int. conf. on Digital Printing Technol., p. 141-144. (2001)

[5] L. Yang, B. Kruse, "Evaluation of the Effects of Ink Penetration in Ink Jet Printing: Experiments and Simulation", Jour. Imaging. Sci. and Technol., 48, p 260-264, (2004).

[6] D.F. Varnell, Composition and method for improved inkjet printing performance, US Patent 6207258, (2001)

[7] P.G.Engeldrum, Psychometric scaling, ISBN 0-9678706-0-7, (2000)

[8] A. Lundberg, J. Örtegren, E. Alfthan, On the effect of variation in paper composition on print quality, Proc. IS&Ts NIP25, Int. conf. on Digital Printing Technol., pp 316-319. (2009)

[9] S. Magdassi, The Chemistry of inkjet inks, ISBN_13 978 981-281-821-8, (2010)

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