On the Effect of Variations in Paper Composition on Inkjet Print Quality

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Abstract

During the last few years, digital printing technology has begun to play a significant role in the printing industry due to the quest for short runs and variable data printing. Digital printing using inkjet technology makes heavy demands on the paper's ability to rapidly absorb liquid and thereby increases the need to understand what parameters that affect the dynamics and interactions between paper and ink and how print quality is affected by these parameters. In this paper, the print quality for nine pilot papers with varying composition and eight different commercial papers has been studied. The printouts have been made with two small office/Home office printers; the print quality measurements for this study have been line quality-measurements and color -gamut volume measurements. The line quality and the color gamut volume for the commercial papers and the pilot papers are discussed.

Introduction

Inkjet printing on paper can be described physically as deposition of a finite amount of liquid (ink) onto a porous media (paper) [1]. The ink consists of colorants (dyes or pigments) carried by vehicles typically based on water for the case of home and office (SoHo) inkjet printers. [2] During printing, the colorants should stay close to the paper surface to yield a large color gamut [3], whereas the carrier should rapidly evaporate or absorb into the paper to prevent slow drying, paper deformation and inter-color bleeding [4]. At the high-volume end, the paper for H&O printing should be cost-effective and compatible with several printing technologies. Paper, surface treated with starch in the paper production process, fulfills these prerequisites. Improved print quality is achieved by covering the paper surface with pigments [5] or a light-weight coating during paper manufacturing. At the high-quality end, glossy photo-quality papers can be produced at a relatively high cost. Brighter and more vivid colors can be achieved by coating the papers off-line with a coating formulation typically containing silica particles and poly-vinyl alcohol [6; 7]. Improved print quality at reduced or maintained cost is a continuous strive for the paper manufacturing industry. The key elements of a paper is pulp (type of fibers, shares and beating), fillers (typically calcium carbonate from chalk or marble, ground or precipitated), starch, glue, chemicals for water retention, and fluorescent whitening agent (FWA). The paper properties are affected by both the composition of the paper and the manufacturing process, and the paper structure can be described as a network of fibers, which is more or less porous. More about the paper and paper production can be found in the literature [8]. The dynamics and interaction between ink and paper is a complicated process. To be able to understand what happens, when an inkjet droplet hits a paper surface and absorbs into the paper, it is therefore important to be familiar with the physical properties of both the papers and the inks. It is well known that the paper properties and the ink properties affect the print quality [9; 10; 11]. An interesting question at issue is how the print quality is correlated to the dynamics and interactions between inkjet ink and paper. In this study, it was investigated how the paper composition such as different levels of grinding, filler, fibers and sizing affect the print quality when printing with water-based pigmented ink and dye-based ink in SoHo printers. The main purpose of the work was to improve the physical paper-properties such as cockle and waviness without reducing the print quality. This introduction study deals with the effects of paper properties on print quality.

Materials and Methods

Paper: High-speed inkjet papers, uncoated copy papers with and without ColorLok®, and coated inkjet paper together with nine pilot papers with known composition were used in this study. The pilot papers were produced in a pilot paper machine at MoRe Research (Figure 1). The composition of paper 1 is similar to the composition of a regular copy paper. In the production of papers 2-9, only one parameter was varied for each trial point compared to paper 1. All pilot papers contained short fibers (hardwood, HW) and long fibers (softwood, SW). The pilot papers all contained the same starch, filler and retention agent. Paper 2 was internally sized, paper 3-5 had various amounts of HW/SW/filler content, paper 6 contained eucalyptus fiber as HW fiber. Paper 7 and 8 contained HW, SW exposed to varying degrees of beating. Paper 9 contained pulp that had not been dried before paper production.

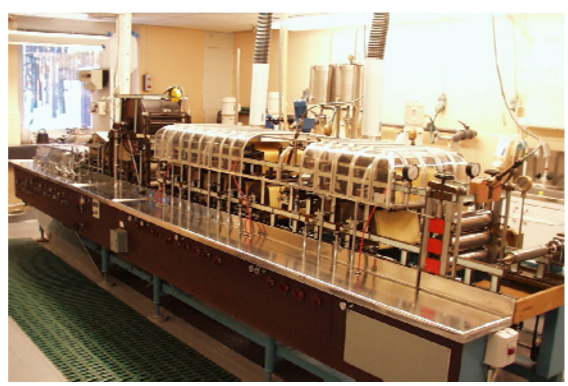

Figure 1. Pilot paper machine.

It should be noted that one major difference between the paper production processes used when producing the pilot papers is the lower production speed, as compared to commercial paper making. The pilot papers were not surface treated, and not calendared. A list of papers is shown in table 1.

Table 1.Nine pilot papers and eight commercial papers

No.	Paper	Production	Grammage [g/m²]	Thickness [µm]
1	Reference	Pilot	93.6	135
2	Internally sized	Pilot	92.9	129
3	Low HW content	Pilot	94.0	133
4	High HW content	Pilot	93.9	132
5	High filler content	Pilot	91.9	129
6	Eucalyptus pulp	Pilot	92.2	142
7	Low beating SW, low beating HW	Pilot	91.3	141
8	Low beating HW, high beating SW	Pilot	91.9	146
9	Wet pulp	Pilot	94.7	130
10	High Speed	Ziegler	90.3	107
11	High Speed	Int. paper	91.9	120
12	Copy	Int. paper	93.1	120
13	Inkjet coated	Kanzan	98.6	117
14	Inkjet coated	Kanzaki	107	137
15	High Speed	M-real	90.4	132
16	High Speed	M-real	90.4	120
17	ColorLok®	Int. Paper	80.9	108

Printers: Two SoHo printers were used for printouts: HP Photo Smart ProB9180 printer using pigmented, water-based ink, with a drop size of 3pl, and an Epson Stylus RX685 printer, using dyes in water-based ink with a drop size of 1.5 pl. Test charts for line quality evaluation and color gamut volume measurements were created in Photoshop and RGB as color mode. The line quality test chart contains a 1.5 mm wide black line on unprinted background and a 1.5 mm wide black line on yellow printed background, both horizontal and vertical printed. The test chart for color gamut volume measurements was build up by 950 different combinations of process colors, intended to be located at the outer border of the color gamut. The printouts were made with color management and plain paper as printer settings.

Line quality evaluation: Images were scanned using an EPSON Expression 10000XL and the line width, the raggedness and blurriness were analyzed by using Matlab and a custom made routine. To evaluate the raggedness the program calculates the standard deviation of the distance between the line, defined as the threshold value 60% of the maximal intensity in the image, and the ideal smooth edge of the line. The blurriness was defined as the width corresponding to 30% to 70% of the total intensity range of the printed line and the line width was calculated by using the threshold value of 50%.

Color Gamut Volume: The printed papers were measured using a spectrophotometer with D50 illumination and 2° observer viewing angle. The CIE L*a*b* values were calculated from the spectral reflection data [13]. Spectrochart was used for calculations of L*a*b* values and Matlab was used for visualizing the color gamut volume and for calculations of the color gamut volume.

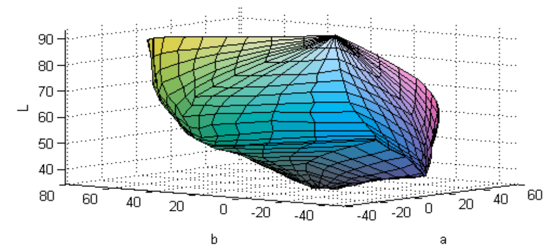

*Figure 2. The figure illustrates an example of a color gamut volume visualized in L*a*b* space.*

Results

It can be seen that paper compositions in terms of hardwood content (10% variation), filler content (6% variation), and type of pulp (Eucalyptus, wet pulp) did not affect the line quality and color gamut of the pilot papers in important ways. Low beating of the fibers of the pilot papers worsened the line quality. This has been illustrated in figure 3 where the raggedness has been calculated for all pilot papers 1-9. Paper 7 is the paper with low beating of the fibers and paper 1 is the reference paper.

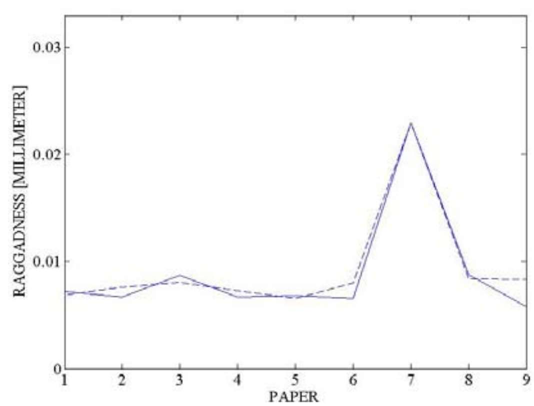

Figure 3. Raggedness for a black line printed on a yellow printed background, printed in HP B9180 for pilot papers 1-9.The dashed line represents raggedness for a horizontally printed line and the solid line represents a vertically printed line.

Among the uncoated papers, the high speed inkjet papers exhibited larger color gamut than the pilot papers and the copy paper for pigmented inks, whereas only small differences in color gamut could be measured for the high speed inkjet papers, the copy paper and the pilot papers in the case of dye-based ink. The coated paper 13 (Kanzan) yielded relatively poor line quality when printed with pigmented ink. The coated paper 14 (Kanzaki) yielded relatively high line quality (low raggedness) for both dye-based and pigmented inks. This can be seen in *figure 4* where the calculated raggedness has been plotted for each commercial paper.

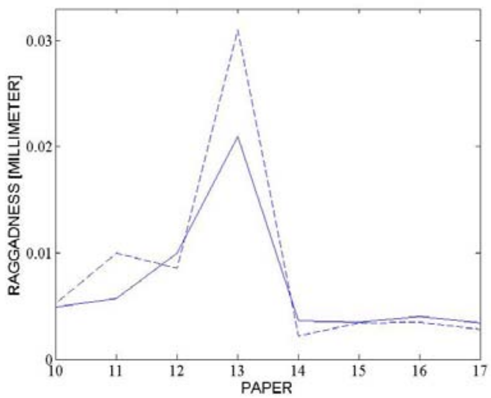

Figure 4, Raggedness for a black line printed on a yellow printed background, printed in HP B9180 for commercial papers 10-17. The dashed line represents the raggedness for a horizontally printed line and the solid line represents a vertically printed line.

Table 2. Color gamut volume for nine pilot papers and eight commercial papers.

No.	Paper	Volume (kΔE) RX685	Volume (kΔE) B9180
1	Reference	204	230
2	Internally sized	199	214
3	Low HW content	204	227
4	High HW content	203	232
5	High filler content	193	220
6	Eucalyptus pulp	205	231
7	Low beating SW, low beating HW	201	234
8	Low beating HW, high beating SW	199	231
9	Wet pulp	203	227
10	High Speed	215	287
11	High Speed	192	232
12	Copy	194	175
13	Inkjet Coated	478	343
14	Inkjet Coated	448	387
15	High Speed	220	313
16	High Speed	236	333
17	ColorLok®	185	361

ColorLok® reproduces approximately the same color gamut volume as coated paper when printed with pigmented water-based ink (table 2). When printed with dye-based ink on ColorLok®, the color gamut is relatively small. This has been illustrated in figure 5. The upper image represents printouts made with HPB9180 on copy paper with and without ColorLok®. The lower image represents printouts made with EPSON RX685 on copy paper with and without ColorLok®. The shaded volume represents the color gamut of print-outs on copypaper with ColorLok®.

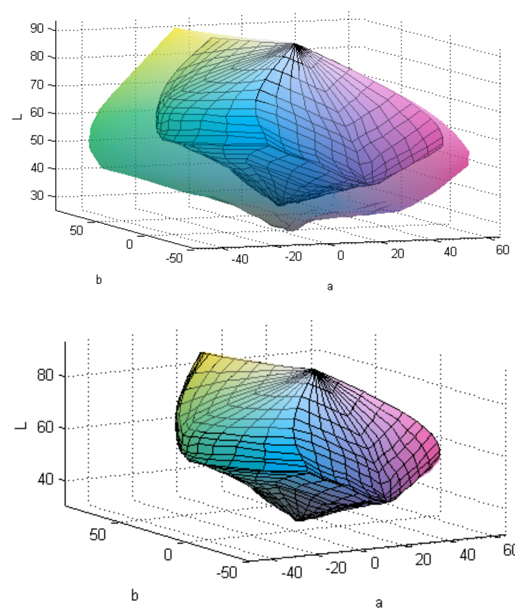

Figure 5. Upper part: Color gamut volume for printouts made with pigmented ink on copy paper without ColorLok® (smaller volume) and copy paper with ColorLok® (the shaded,-larger volume). Lower part: Same as above for printouts made with dye-based ink.

Discussion

The main purpose of this study was to investigate how the different paper compositions such as sizing, filler content, different levels of beating affect the print quality. The idea was that these variations of parameters should give an increased understanding about how different parameters can affect the print quality, in terms of color gamut volume and line quality measurements**.** Only relatively small differences in color gamut volume were found between the nine pilot papers. Hydrophobic internal sizing agents are expected to reduce the ink penetration and thereby increase the optical density [12] and the color gamut volume. Unexpectedly, the color gamut volume of the printed paper 2 did not exceed the color gamut volume of the printed paper 1. An increased amount of filler in the papers reduces cost and introduces light scattering centers in the paper, which is beneficial for the reflectivity, brightness and the opacity of the paper. Data from the print-outs presented in this study show that an increased amount of filler in the paper gives a smaller color gamut volume (paper 5). It has been speculated that the ink penetrates further into the paper due to the hydrophilic nature of the filler [14] resulting in a smaller color gamut volume. It can also be speculated that the amount of small pores increases with a high amount of filler which can give higher ink penetration into small pores and also affect the light scattering.

As expected, low beating of the fibers in one of the pilot papers worsened the line quality, but an increased level of filler should generally improve the line quality. In this study, the amount of filler was increased with 6% and it did not significantly affect the line quality. One explanation to this can be the small drop size giving low lateral spreading. In general, data from print-outs on the pilot papers shows that the paper content in the papers studied here has some, however minor, effects on the color gamut and the line quality. This gives some freedom to tune the paper content in order to decrease other types of problem during printing, such as cockling and curl of the paper. It has furthermore been shown that a commercial paper with ColorLok® produced a large color gamut when printed with pigmented ink but not with dyes.

Conclusion

- Paper composition variations in hardwood content, filler content and type of pulp did not have a major impact on line quality or color gamut. However an increased amount of filler decreases the color gamut volume.

- Most of the high speed inkjet papers exhibited a larger color gamut than the pilot papers and the copy paper in the case of pigmented inks.

- ColorLok® yielded high color gamut for pigmented ink and low color gamut for dye-based ink.

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References

[1] A. Marmur, Liquid penetration into porous Media, Proc. IS&Ts NIP16, Int. conf. on Digital Printing Technol., p. 236-238. (2000).

[2] B. Zhmud, Dynamic Aspects of Ink-Paper Interaction in relation to Inkjet Printing, Proc. Pira int.conf. Ink on Paper, (2003).

[3] 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).

[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] M. Dohnal, Pigment Particles and Their Effect on the Colour Gamut of Printing, Proc. CGIV, p. 608-612. (2002).

[6] H. Nilsson, A. Fogden, ”Inkjet print quality on model paper coatings”, Appita Jour., 61, (2008).

[7] H.K .Lee, M.K. Joyce, P.D. Fleming, et al., Influence of silica and alumina oxide on coating structure and print quality of ink-jet papers, Proc. Tapi Jour., p. 1-16. (2005).

[8] Christer Fellers, Bo Norman, Pappersteknik, (KTH Stockholm, 1998)

[9] J. Heilman, U. Lindqvist, Significance of Paper on Print Quality in CIJ Printing, Proc. IS&Ts NIP14, Int. conf. on Digital Printing Technol., p. 577-581. (1998)

[10] G. Baudin, E. Rousset, Inkjet Printing: Effect of Paper Properties on Print Quality, Proc. IS&Ts NIP17, Int. conf. on Digital Printing Technol., p. 234-238. (2001)

[11] D.F Varnell, “Paper properties that influence ink-jet printing”, Pulp and paper Canada, 99,p 4, (1998).

[12] L.Yang, A. Fogden, N. Pauler, Ö. Sävborg, B. Kruse, “Studying Ink Penetration with Microscopic and spectroscopic Techniques”, Jour. of Imaging Sci. and Technol., 50,327-332,(2006).

[13] Abhay, Sharma. ”Understanding color Management, (Thomson Delmar Learning 2004)

[14] L. Pal, S. Agate, P.D. Fleming, Effects of Paper Manufacturing Factors on Inkjet Print Quality and light fastness, Proc. IS&Ts NIP23, Int. conf. on Digital Printing Technol., p. 749-754. (2007)

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