Finishing of Digital Prints – A Failure Mapping

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Abstract

The new possibilities with personalized and on-demand printing are strongly dependent on successful finishing. Today, however, the finishing is often seen as the week link in digital printing. The area is in great need of improvements to attain higher quality and cost effectiveness. A research study, based on a market analysis, was performed in close co-operation with the graphical industry. The study includes tests of different folding techniques and its function in a Print-on-Demand production process. The objective is to analyze the printed papers fold quality and functionality in the finishing process.

Three different digital printing units, using the xerographic technique, were tested. Uncoated and coated paper qualities of stock weights above and below 150g/m^2, developed for digital printing, were used in the study. The folding tests were performed 1-2 hours after printing. A single fold was applied to each printed test image, using two different folding machines and several folding strategies. The tests were performed in a climate–controlled laboratory, where the settings 20ºC and 30%, 50% and 70%RH were used.

Results show substantial differences between different folding techniques. The use of creasing was of vital importance in all cases. The results also indicate a diverse function of the tested digital printing units, most probably explained by dehydration of the papers in the printing process.

Introduction

Digital printing has introduced new possibilities to printed products. Today, print shops can offer high quality prints in limited editions and to a relatively low cost. The field of personalized prints is rapidly growing. Also, the time from order to delivery may decrease drastically due to a more effective production process. All these benefits are desirable, but they also introduce new demands.

- Limited editions require *effectiveness* to attain profitable production.
- Personalized prints require *precision* due to product uniqueness.
- Short-term delivery times require *flexibility* in the working organization.

The work presented in this article is part of a major technical mapping, driven in close cooperation with the graphical industry, of possibilities and lacks in the area of digital print finishing. Systematic tests are performed in order to highlight the interplay between paper, digital printing and finishing. Results will include technical aspects of quality and functionality in the finishing process, as well as theoretical models for understanding the results. Finishing of digitals prints is a field in great need of new knowledge.

The aim of this study is to investigate the folding properties of papers printed in 4-color xerographic presses and printers.

Material and Methods

Advantages with digital printing compared to traditional techniques are partly explained by the short time needed for delivering the printed product, nowadays found under the conception Print-on-Demand (PoD). The objective of this study is to investigate PoD from the perspective of finishing performance, and then especially folding. The study is based on a market analysis, where 55 digital printing professionals have given their view on problems related to the finishing process.

The basic idea is to apply a single fold, 1-2 hours after printing, to a digitally printed 4-color test image and analyze the results. Interesting features are fold quality and functionality in the finishing process. Digital printing is often connected to dry papers, leading to problems with static electricity and fold cracks.

A test image was developed for the study. It includes regions for analyzing folding properties, as well as images and areas for print quality evaluation, see Figure 1. The regions used for folding tests, basically consist of five different color areas. These are plain paper and, using the CMYK notation, 100%C, 100%K, 100%K + 70%C, 80%C + 80%M + 80%Y + 80%K. Folding on plain paper gives possibility to analyze paper influence, while the different colors are used for analyzing color influence on the result and visual judgment. The five color areas are distributed asymmetrically over the fold. For complementary tests it is also possible to fold over a single color area. The test image is designed for A3 or A3+ format and includes folding regions for testing opposite fiber orientation (A4 format).

In order to systematically analyze the folding properties of digital printing several interesting factors are included and varied. These regard paper, printing unit, climate and folding strategy. In the following text each varied factor is explained in separate sections.

Figure 1.The test image used during the study.

Paper

Papers were chosen according to the recommendation from Swedish paper suppliers that stock weights above 150 g/m^2 should be scored before folding. The papers used in this study are above and below this limit. Uncoated papers (4CC) of stock weight 130 and 160 g/m^2, and coated papers (4CC Silk and 4CC Art) of stock weight 130 and 170 g/m^2 are included. All papers are bought from a paper retailer.

During the study paper humidity was measured before and after the printing (using a Rotronic S1 Hygromer). All papers were stored in the print room and stay in the package until the printing starts.

Printing

The printing units used in this study cover different production capacities of the xerographic technique. A roll-fed (50cm) digital press with Xeikon engine (DICO-press) represents the large-scale digital production. A large printer, Xerox DC2060, is also tested. The smallest printing unit included in this study is the copier/printer Xerox DC12. All paper qualities were printed in the digital press, while uncoated and glossy papers were printed in the two printers.

After printing the papers were cut into A3 (or A4) format and stacked in heaps of 250 samples for conditioning.

Climate

The digital press is positioned in a climate-controlled laboratory, giving possibility to vary both humidity and temperature. Three climate settings were used in this study, a room temperature of 20ºC and air humidity 30%, 50% and 70%RH. All operations, including printing and finishing, in each test combination were performed under the same climate settings. Tests on prints from the two printers were performed in a room temperature of 20ºC and air humidity 30%RH.

Finishing

A single fold was applied to the test region with different color areas on each test image, 1-2 hours after printing. The folding strategy was varied in several aspects. Both knife (Horizon spf-11) and buckle (Eurofold) folder was used. The knife-folding process starts in a collator (Horizon MC-80). An automatic creaser (Morgana) was used to test the effect of pre-scoring before folding. Three variations were applied. These were, folding without pre-scoring, folding with pre-scoring *around* the spine and folding with pre-scoring *into* the spine. Test prints from DICO-press and DC2060 were folded in both fiber orientations of the papers. On the DC2060 folds *against* the papers fiber orientations were done on A4 format. To cut the prints into suitable format a hydraulic cutter (Ideal 7228) was used. The same finishing equipments were used for all paper qualities.

This test plan results in 288 unique test combinations, which are summarized in Table 1. Each combination was repeated for about 30 samples, giving more than 8000 samples to analyze.

Table 1. The table below shows a schematic view of the study. Each cell represents a test with one printing unit and paper quality, folded *with* (w) or *against* (a) the paper fiber orientation. The notation Dxx% means DICO-press in xx%RH, DC means Xerox DocuColor.

Print unit	130g/m^2			170(160)g/m^2		
	Uncoat	Silk	Art	Uncoat	Silk	Art
D30%	w&a	w&a	w&a	w&a	w&a	w&a
D50%	w&a	w&a	w&a	w&a	w&a	w&a
D70%	w&a	w&a	w&a	w&a	w&a	w&a
DC2060	w&a	-	w&a	w&a	-	w&a
DC12	w	-	w	w	-	w

Results

A common result for all paper qualities, climates and printing techniques is that acceptable fold quality is possible to achieve, using correct folding strategy. The use of pre-scoring before folding was of vital importance in all cases. Besides this, the results are more related to specific factors, as reported in the following text.

A major difference in both fold quality and functionality in the finishing process were found between samples from the digital press and the two printers. The digital press showed the advantage of better color reproduction, but gave worse folding results. The digital press and the two printers diverse in the technique used for fixing color. The digital press uses a heated oven, combined with heated cylinders, giving complete dehydration of the papers. The printed papers are then more brittle and sensitive to static electricity. The relative humidity in the paper rolls before printing was 27-46%RH. The two printers use heated cylinders with silicone for fixing color. Here, the coated papers lost 5-9%RH in the printing process, and the uncoated 9-15%RH, as seen in Figure 2. The silicone used in the printers gives a slippery surface on the prints, which prevent papers from sticking together.

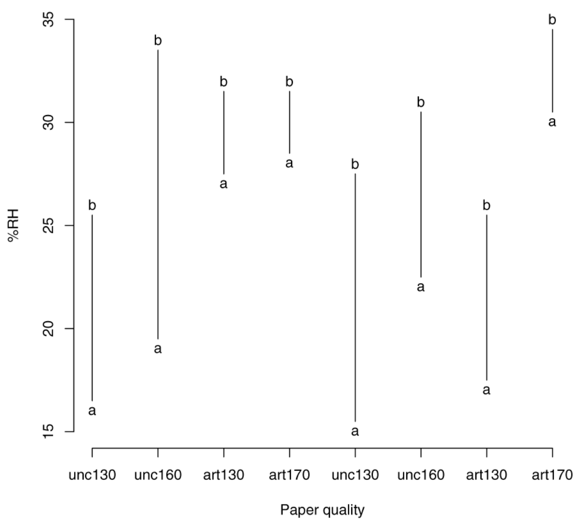

Figure 2. The plot shows the difference in relative humidity in the papers before (b) and after (a) the printing. The displayed values are the mean of three measurements. The four lines to the left are prints from the DC2060 and the other from the DC12.

The three different climates tested with the digital press (30%, 50% and 70%RH) show most differences regarding functionality in the finishing process. The finishing was most free of troubles in the lowest humidity setting of 30%RH. The following setting with 50%RH presented almost equal results, but with 70%RH, the functionality was changed to the worse. The most common difficulties were experienced with papers sticking together by moist, as well as failure in the feeding line of the finishing equipments. Wavy papers caused the latter. Static electricity was experienced in the same amount for all tested climate settings. The finishing equipments having air-separating mechanism almost solved this problem.

Interesting results regarding papers and pre-scoring before folding were found. All prints folded without pre-scoring showed cracking in the fold, see an example in Figure 3.

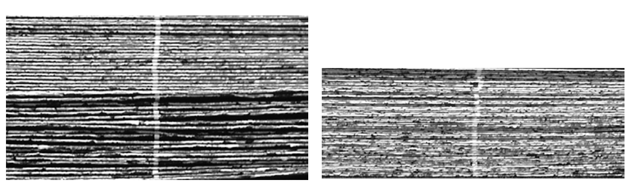

Figure 3a,b. Samples of 130g/m^2 papers printed in the DICO-press, folded without pre-scoring. Image (a) shows uncoated papers and image (b) glossy coated papers. The left half of image (a) and (b) is covered with 320% toner layer and the right half by a 170% toner layer. The upper half of image (a) and (b) show samples folded with the paper fiber orientation, and the lower half against the fiber orientation.

In this case, folding *against* the papers fiber orientation presented more sharp cracks compared to folding *with* the papers fiber orientation. The uncoated papers were less damaged then the coated papers. This was best seen when using the printers.

When using pre-scoring, the situation was more complex. In general, the uncoated papers showed best fold quality when the pre-scoring was done *around* the spine and *with* the papers fiber orientation, see Figure 4. The uncoated papers were also more damaged on the heavier toner layer (320%).

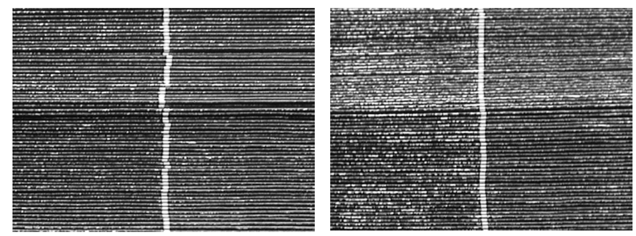

Figure 4a,b. Samples of uncoated 130g/m^2 papers, printed in the DICO-press. Image (a) show samples folded with the paper fiber orientation, image (b) against the fiber orientation. The left half of image (a) and (b) is covered with 320% toner layer and the right half by a 170% toner layer. The upper half of image (a) and (b) show samples folded with pre-scoring around the spine, and the lower half into the spine.

A quite opposite result was experienced with the coated papers. Here, the best fold quality was achieved when pre-scoring *into* the spine and *against* the papers fiber orientation, see Figure 5.

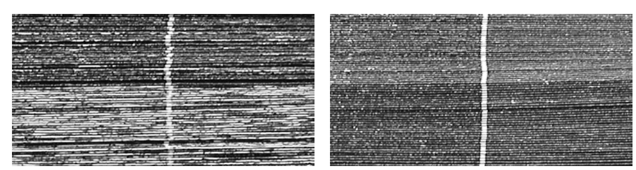

Figure 5a,b. Samples of glossy coated 130g/m^2 papers, printed in the DICO-press. Image (a) show samples folded with the paper fiber orientation, and image (b) against the fiber orientation. The left half of image (a) and (b) is covered with 320% toner layer and the left half by a 170% toner layer. The upper half of image (a) and (b) shows samples folded with pre-scoring around the spine, and the lower half into the spine.

Cracking on the coated papers was less sensitive to heavy toner layers; often the cracks appeared over the entire fold. This result agrees with results presented by Barbier et. al. (2001), showing that coated papers cracks simultaneously over the fold. A common result for all three types of papers (uncoated, silk and gloss) was that pre-scored heavier stock weight paper presented better fold quality then papers with less weight.

The two folding techniques (knife and buckle) differed in function. The knife folder had to be run in low production speed, 500-1000 sets/hour (maximum 3500). At higher speeds the feeding was stopped by paper jam. In the buckle folder the feeding of papers into the first pair of folding cylinders was a major failing. This failing was more apparent on the higher stock weight papers, as well as on the slippery printer prints. Overall the buckle folder gave slightly better fold quality, despite the worse function.

Discussion

The development and commercial use of digital printing is strongly dependent on the printed papers finishing performance. So far, lots of attention in the area of digital printing has been concentrated to the print quality. In this ongoing research project the objective is to provide new knowledge on finishing of digital prints. This will be achieved by combining professional experience with well-planned systematic tests and development of sophisticated routines for analyzing the results.

The results from this study indicate a diverse function of the tested digital xerographic printing units. It seems that the two printers are well suited for fast Print-on-Demand production, while the larger digital press competes with print quality and production capacity. The dehydration of the papers in the digital press caused trouble in the finishing process, which were not solved by increasing air humidity. A different production scope, with more time for the prints to recondition, and high quality personalized printing might be better suited for the digital press.

It was expected that the higher humidity would show better functionality in the finishing process, following the recommendations in for example Modo Digital Papers (1999). The result of this study partly points at the opposite recommendation, probably explained by the contrast between dry papers and humid air which ended with wavy papers and papers sticking together by moist. If a Print-on-Demand recommendation should be made, based on this study, it would be to keep the climate settings at room temperature and about 30-50%RH.

All paper qualities tested in this study needed pre-scoring to get acceptable fold quality. The fact that 130 g/m^2 papers presented worse fold quality then the heavier papers indicate that a more suited creasing rule is needed. There are special creasing rules meant for lower paperweights available, but these are not yet tested in this study.

The rich collection of samples generated in this study will be used for further analyses. In an ongoing work the objective is to develop routines for classifying damages caused by folding digital prints. The results will hopefully lead to an understanding of the digital printed papers folding performance. This will be achieved by modeling results from imitated production cases in terms of print specific factors and paper qualities. The area of paper physics will be of great importance for understanding folding properties. Results on relevant paper properties were presented in Barbier (1999), Koubaa and Koran (1995), Schaffrath and Göttsching (1991), Stenberg (1999) and Van Liew (1974).

The applied tests with folding digital prints will continue in the project. During the summer of 2002 new tests are performed with the same papers in an Indigo digital press. Future tests include other paper qualities, printers and finishing solutions.

Growth in the digital printing market is probably most dependent on developments in the areas of software solutions and finishing. Hopefully the research within this project will help to answer some of the questions about possibilities and limitations with digitally printed products.

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Biography

Johan Eklund received his M.Sc. degree in 1997 and his Ph.lic. degree in 2000 in Mathematical Statistics, after undergraduate and graduate studies at the University of Umeå, Sweden. He joined the research group at the Digital Printing Center in Örnsköldsvik, Sweden in April 2001. His main research activities regard finishing of digital prints. A long-term goal is to provide classification routines for damage caused during folding.