Print Quality of Dry-Toner Color Electrophotography for Production Printing and Comparison to Offset Printing

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Abstract

One of the major digital printing technologies used for production printing is dry-toner electrophotography. The main technical challenge is print quality and many researches have been done to improve it in the recent years. In our study, dry-toner color electrophotography was compared to conventional offset printing. A Xerox iGen3 press and a Heidelberg Speedmaster press were used. The substrates used were different uncoated and coated paper stocks. The GATF 11x17 Four-Color Test Form was printed on the papers by both printing presses. Print quality, such as color gamut, dot gain, print contrast, and trapping, were evaluated and compared. Higher dot gains were found on Speedmaster than on iGen3 except for black color. Higher print contrast values were found for iGen3 than for Speedmaster except for black color. Wider color gamuts were achieved on iGen3 than on Speedmaster, especially on uncoated papers. With high print quality, it is expected that more production printing will be done by dry-toner color electrophotography.

Introduction

The printing industry has seen rapid growth of applications of digital printing presses due to higher demands of short-run or print-on-demand and variable data printing jobs [1]. One of the major digital printing technologies used for production printing is dry-toner electrophotography [2]. The main technical challenge is print quality and many researches have been done to improve it in the recent years, such as the image-on-image (IOI) architecture introduced by Xerox [3, 4]. The print quality of color electrophotography is catching up with that of offset printing; therefore, it is very interesting to compare their print quality and find out the differences.

Experimental

Substrates

Four commercial paper substrates were selected: uncoated 28# Envelop grade and 90# Index grade, coated 80# Text Gloss grade and 80# Cover grade.

The surface roughness was measured using a Mitutoyo Surface Roughness Tester Model 211. The arithmetic mean deviation of the roughness file, R_a, was measured with evaluation length of 2.5 mm.

Brightness and cast values were measured using X-Rite SpectroDensitometer 528.

Printing Processes

The GATF 11x17 in. Four-Color Test Form was printed on the paper substrates by a dry-toner color electrophotographic press and an offset printing press.

The dry-toner color electrophotographic press used was a Xerox iGen3™ 110, with EFI Fiery® Color Server as its RIP. Dry Inks from Xerox were used. The printing sequence was magenta, yellow, cyan, and black. The line screen was set at 175 lpi. The printing was done at a speed of 240 sheets/hour.

The offset printing press used was a sheetfed Heidelberg Speedmaster™ SM 74. Digital Thermal Plate Pro-T from Fujifilm was used and processed by a Fujifilm 4300E Platesetter with Trueflow® system from Screen Media Technology as its RIP. The line screen was set at 150 lpi. The inks were K&E Inks from ESI Manufacturing. The printing sequence was black, cyan, magenta, and yellow. The printing was done at a speed of 13,500 sheets/hour. The ink feeding amounts were kept the same for all the papers.

Print Quality Evaluation

The reflective density of CMYK solids, print contrast of CMYK, and ink trapping were measured using X-Rite SpectroDensitometer 528. The test form included tone scales for each color, which were used to measure the dot areas and calculate the dot gain values.

The test form included a standard color field, the IT8.7/3 Basic Data Set. The L*a*b* values of the patches were measured with a GretagMacbeth Eye-One iO, which were then processed by GretagMacbeth ProfileMaker® Pro 5.0.8 to create a profile. Using CHROMiX ColorThink® Pro 3.0, the profile gamuts were plotted and compared.

Results and Discussion

Paper Properties

The results of measured paper properties are listed in Table 1. Coated text gloss and cover papers are much smoother than uncoated envelop and index papers. Envelop paper has lower brightness than the other three.

Table 1 Paper Properties

Paper	R_a (μm)	Brightness (%)	Cast (%)
Envelop	1.42	77	3
Index	1.38	91	4
Text Gloss	0.38	91	5
Cover	0.19	94	5

The reflection densities of CMYK solids of different substrates are compared in Table 2. It is very clear that reflection density was affected by paper surface roughness in both printing methods. Uncoated papers have very rough surface, which results in uneven ink film thickness, thus very low reflection density.

Table 2 Reflection Density Values

Speedmaster				
	Black	Cyan	Magenta	Yellow
Envelop	0.88	0.72	0.81	0.72
Index	0.91	0.74	0.87	0.70
Text Gloss	1.45	1.16	1.30	0.98
Cover	1.40	1.26	1.30	0.96
iGen3				
	Black	Cyan	Magenta	Yellow
Envelop	1.55	1.31	1.21	0.98
Index	1.60	1.38	1.23	0.94
Text Gloss	1.90	1.76	1.62	1.06
Cover	1.86	1.76	1.64	1.08

The dot gain curves were obtained by plotting dot gain values against the original tone values. The dot gain curves for envelop paper are shown in Figure 1. In offset printing, the dot gain curves of four colors are similar in shape, and slightly different in magnitude. The highest values were found at 40% or 50% tint level. The curves are skewed towards the lower values with the 25% tint level showing more gain than the 75% tint. In electrographic printing, the dot gain curves of four colors do not have similar shape and the magnitudes are very different. The dot gain curve of black color has a peak of 40% at 40% tint level. The dot gain curves of the other three colors are kind of flat, sometimes have two peaks.

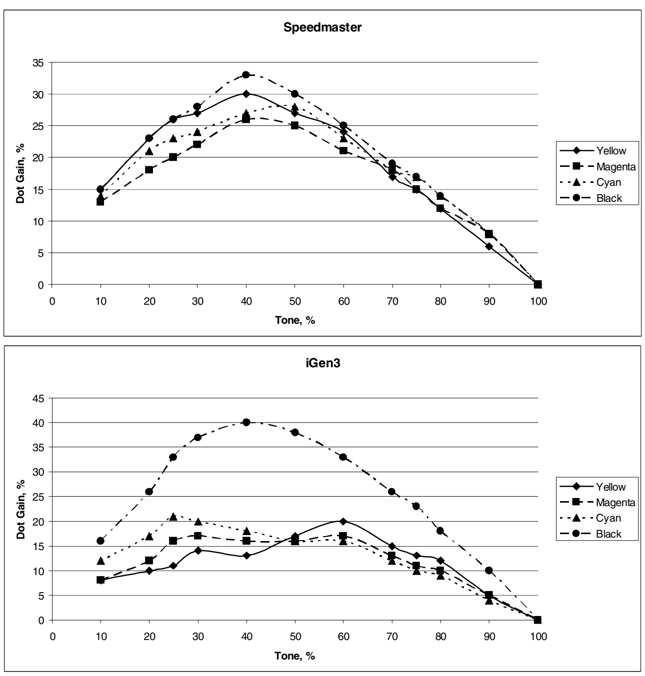

Figure 1. *Dot gain curves of CMYK colors on envelop paper.*

The dot gain curves of Speedmaster and iGen3 are compared in Figure 2. Higher dot gains were found on Speedmaster than on iGen3 except for black color. Dot gain is made up of two components: optical gain and mechanical gain. Mechanical gain, or physical dot gain, is the dot spreading that occurs during photomechanical operations, like platemaking, or during the printing process as the ink is transferred from plate to blanket to paper in offset printing or from photoreceptor to paper in electrophotography.

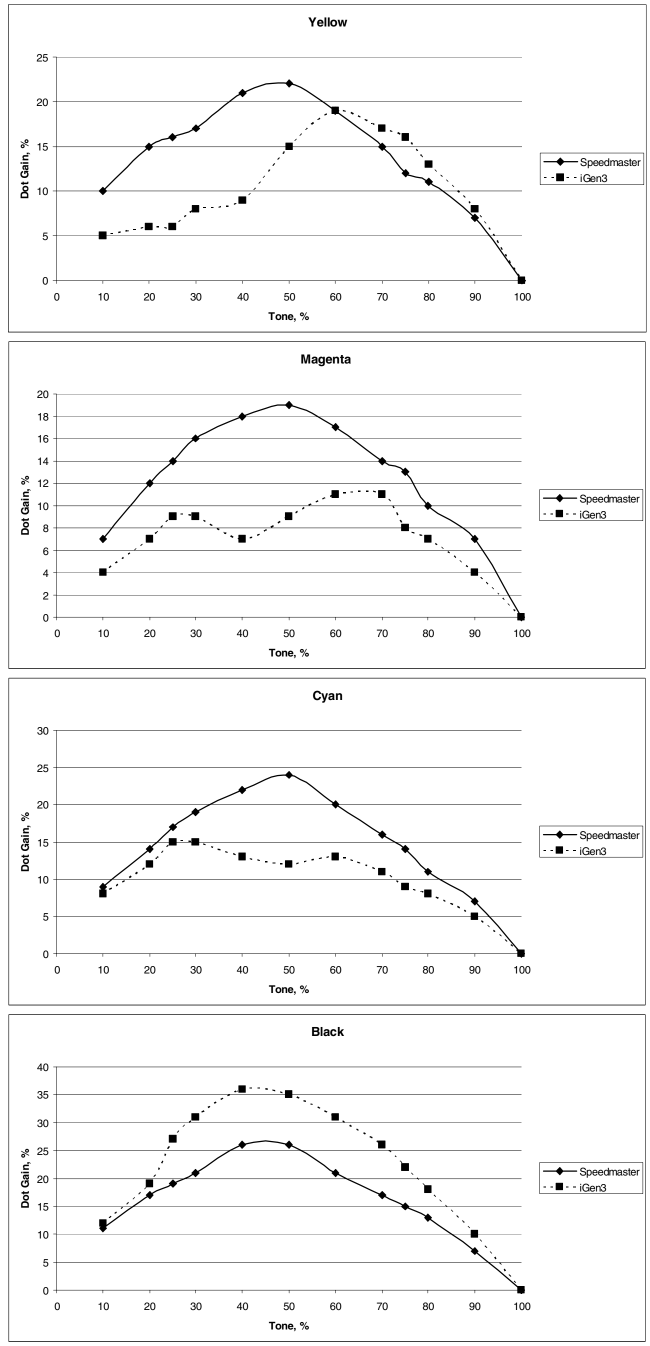

Figure 2. *Dot gain curves of Speedmaster and iGen3 on cover paper.*

Optical gain is strongly influenced by the surface characteristics of the paper. Uncoated paper, for instance, has more optical gain than coated paper. Figure 3 shows that uncoated envelop and index papers have more dot gains than coated text gloss and cover papers for both printing methods, however, the differences in electrophotography are smaller than in offset printing.

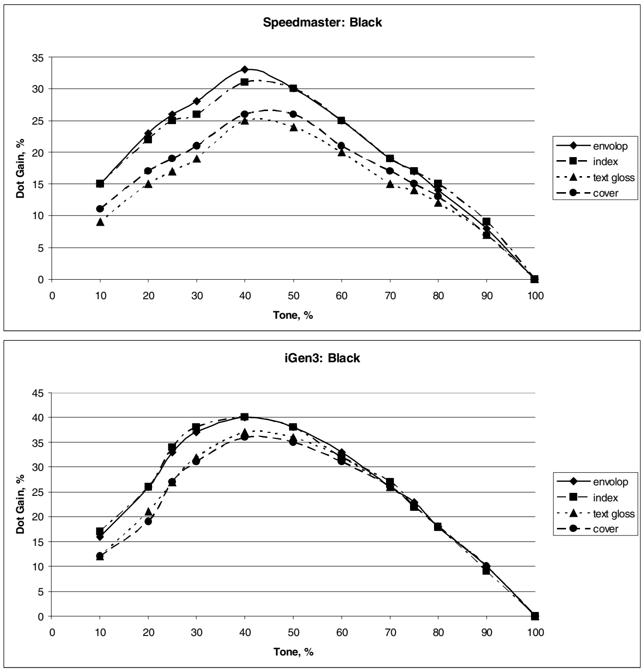

Figure 3. Dot gain curves of four papers for black color on both presses.

The print contrast values are listed in Table 3. Higher print contrast values were found for iGen3 than for Speedmaster except for black color. Print contrast is influenced by dot gain. Excess dot gain of black color on iGen3 contributes to the low print contrast values.

Table 3 Print Contrast Values

Speedmaster				
	Black	Cyan	Magenta	Yellow
Envelop	16%	13%	19%	16%
Index	19%	21%	23%	18%
Text Gloss	39%	32%	37%	29%
Cover	36%	34%	37%	29%
iGen3				
	Black	Cyan	Magenta	Yellow
Envelop	12%	39%	35%	24%
Index	17%	46%	39%	26%
Text Gloss	23%	52%	52%	25%
Cover	25%	55%	55%	28%

The ink trapping values are listed in Table 4. Opposite phenomena were observed for Speedmaster and iGen3. For Speedmaster, higher trapping values were found on coated text gloss and cover papers than on uncoated envelop and index papers, while for iGen3, higher trapping values on uncoated papers than on coated papers. Trapping is affected by ink tack, which determines the ink sequence during printing. Sheetfed offset inks are viscous inks with high tack and dry by polymerization. iGen3 utilizes dry toners, which dry by fusing. The color image, either spot color or process color, is built on the photoreceptor in a single pass. IOI process places toners of different colors on top of, as well as adjacent to, each other [3].

Table 4 Ink trapping Values

Speedmaster			
	Red	Green	Blue
Envelop	56%	88%	66%
Index	52%	89%	70%
Text Gloss	77%	89%	76%
Cover	82%	90%	77%
iGen3			
	Red	Green	Blue
Envelop	81%	86%	83%
Index	84%	88%	83%
Text Gloss	72%	68%	66%
Cover	72%	67%	65%

The color gamut graphs for iGen3 and Speedmaster are shown in Figure 4 and 5, respectively. The paper has less effect on iGen3 than on Speedmaster. Uncoated rough papers can still achieve as wide color gamut as coated smooth papers on iGen3; however, on Speedmaster, smooth paper surfaces are required to obtain wide color gamut. The iGen3 press uses a unique combination of electrostatic, acoustic, and mechanical forces applied simultaneously during the ink transfer step, which provides high image quality over a broad range of media from coated to uncoated, and heavy to light weight papers [3].

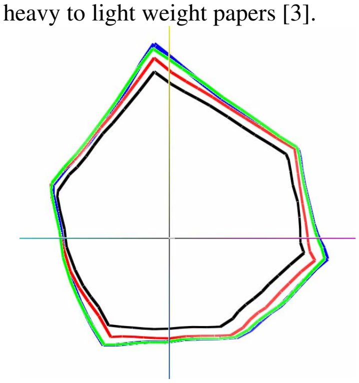

Figure 4. *Color gamut graphs of different papers printed on iGen3 (from inside to outside: black – envelop, red – index, green – text gloss, and blue – cover).*

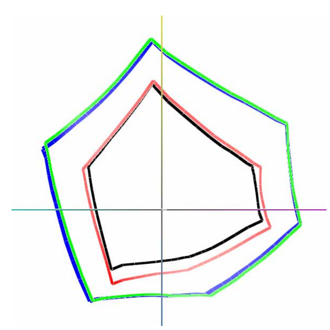

Figure 5. *Color gamut graphs of different papers printed on Speedmaster (from inside to outside: black – envelop, red – index, green – text gloss, and blue – cover).*

The color gamut graphs of iGen3 and Speedmaster on different papers are compared in Figure 6. On uncoated envelop and index papers, the color gamut of iGen3 is wider than that of Speedmaster. On coated text gloss and cover papers, the color gamut of Speedmaster is close to that of iGen3.

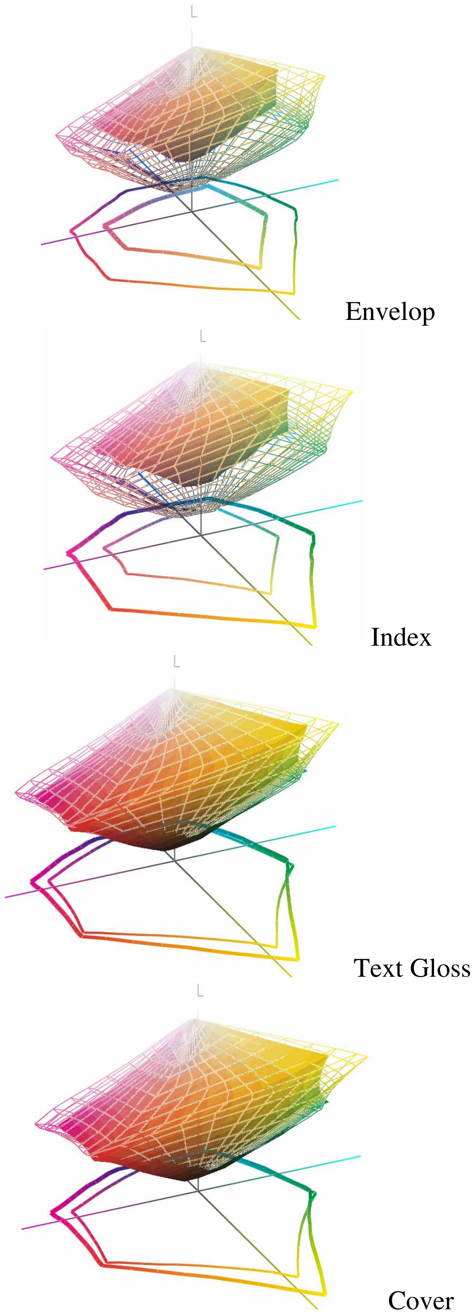

***Figure 6**. Color gamut graphs of Speedmaster (flat) and iGen3 (wire frame) on four papers.*

Conclusions

By comparing the print quality of the Xerox iGen3 110 with the Heidelberg Speedmaster SM 74, we found that

1. Reflection density was affected by paper surface roughness for both printing presses. Uncoated papers have lower densities than coated papers with the same ink film thickness.
2. Higher dot gains were found on Speedmaster than on iGen3 except for black color. However, dot gains curves of four colors have similar shape and small differences in magnitude for Speedmaster. Dot gain curves of iGen3 are very different in shape.
3. Higher print contrast values were found for iGen3 than for Speedmaster except for black color.
4. For Speedmaster, higher trapping values were found on coated text gloss and cover papers than on uncoated envelop and index papers, while for iGen3, higher trapping values on uncoated papers than on coated papers.
5. Wider color gamuts were achieved on iGen3 than on Speedmaster, especially on uncoated papers.

In conclusion, the print quality of dry-toner color electrophotography has been improved and can compete with offset printing. Despite its disadvantages of low speed and high cost, more and more electrophotographic presses will be used in production printing.

Acknowledgements

The authors greatly appreciate Ed Cowgill, Brian Overholt, and Roger Stout at Muncie Novelty/Indiana Tickets Company and Yu Ju Wu at Western Michigan University for their help.

References

[1] R. Loutfy, Digital Color Printing: The New Business of Printing, Proc. NIP18, pg. 5 (2002).
[2] H. Tolliver-Nigro, "Is the Future of Ink Making … Toner?", Ink Maker, September, pg. 35 (2006).
[3] R. Lux and H.-J. Yuh, Is Image-on-Image Color Printing a Privileged Printing Architecture for Production Digital Printing Application?, Proc. NIP20, pg. 323 (2004).
[4] L.K. Mestha, Control Advances in Production Printing and Publishing Systems, Proc. NIP20, pg. 578 (2004).

Biography

Renmei Xu received her MS in Material Science and Engineering (2001) and her PhD in Paper and Imaging Science and Engineering (2006) from Western Michigan University. She is now an Assistant Professor in Department of Technology at Ball State University and teaches courses in Graphic Arts Management Program. Her research has focused on microroughness of ink jet papers and print gloss, and gravure ink mileage.

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