Comparison of Print from Laser and Electromechanically Engraved Cylinder

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ABSTRACT

Five different paper substrates were gravure printed using electromechanically and laser engraved image carrier using toluene based publication gravure inks. Printability results show that using laser engraved cylinder especially different dot gain maximum was achieved, shifting form 50% dot at electromechanically engraved to maximum at 30 % for laser engraved image. Print mottle was measured by Tobias Mottle Tester and by Verity software. Verity software is new mottle measurement tool, processing digital images. It is using new algorithms, which respond uniformly to all levels of visually apparent mottle. Mottle was significantly lower at yellow, magenta and black laser engraved images, while cyan print from laser engraved cylinder had higher mottle on some of the substrates. The mottle differences were most obvious when printing without electrostatic assist – laser engraved image did not create mottle, or ink release from laser engraved cylinder is more consistent with or without ESA assist.

INTRODUCTION

Laser engraving of gravure cylinders is the latest and most exciting development introduced by the Daetwyler laser engraving system [Lupano, 2000]. The Daetwyler Direct Laser System (DLS), now being used in the gravure market, features galvanic plating of the zinc/chrome layers that meets the surface structure and durability requirements for the gravure process [Henning, 2001]. The laser beam, focused onto the cylinder surface, melts and vaporizes the image-carrier material and produces the cells. Laser engraving allows for larger variability in cell shapes and their sizes. By dynamically controlling laser beam diameter, width and depth of cells can be individually configured for publication and package printing. Laser-engraved cells are actually spherical in shape,

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providing improved ink release. For example, to achieve a comparable printing density, the depth of a laser cell is only approximately 2/3 of an electromechanically engraved cell [Lombardi, 1999]. Consequently, finer screens are possible, while still obtaining the required print density. With laser technology, it is possible to create variable shape cells. Laser engraving can produce plum bloom shaped cells, not achievable with electromechanical engraving [Sterkenburgh, 2003]. These new shapes actually provide for higher print density.

A zoom optics allows for a screen resolution from 178 to 1016 lpi. Laser engraved cylinders can reduce the influence of printing speed [Sterkenburgh, 2003] on print quality. Direct laser engraving is non-contact method, which does not cause wear of engraving tool and is therefore capable of producing consistent engraving [Henning, 2001]. It seems that laser engraving offers multiple benefits. The laser system operates 17 times quicker than current engraving machines [Lupano, 2000] and reaches speeds of 70,000 cells per second. Thus, with two laser beams in simultaneous operation, it can engrave 140,000 cells per second.

It is not just speed that the laser brings to the market. It is significantly improved quality in both tonal reproductions and quality line work. Compared to electromechanical systems, laser provides for higher and more uniform quality and shorter make-ready, with a minimum of color shift and moiré [Henning, 2001]. With the laser process, there is no traditional rosette pattern dot and, therefore, no limitations on screen angles and a more neutral gray balance is created. The vignette is printed as a continuous tone, even down to a 20 percent step. A phenomenon known as "chaining" can be sometimes seen in gravure printed vignettes. It appears between the solid and tonal areas where the solid breaks down into a series of dots. This is more apparent on dark colors such as dark blues and dark greens. With the advent of laser engraving this phenomenon does not occur. The vignette is printed as a continuous tone even down to a 20% step. It looks like a color print, therefore smoother vignettes, better flesh tones, and generally sharper images occur.

Although expensive to install, laser technology should not increase the cost of gravure, and because of greater repeatability, it will automatically show cost savings to the converter [Lupano, 2001]. The aim of this work was to compare printability results for laser and electromechanically and engraved image carriers.

EXPERIMENTAL

Printing

Four publication substrates [light weight coated (LWC), supercalendered B (SCB), supercalendered A (SCA), and Freesheet] and one packaging [Solid bleached sulfate (SBS) board] were printed from laser and electromechanically engraved cylinders. The screen ruling at electromechanically engraved cylinders (EE) was 140 lpi (lines per linear inch) for yellow, 175 for magenta, 175 for cyan and 225 lpi for black cylinder, with compression angles 45 ^{o}, 60^{o}, 30^{o}, and 45^{o}, respectively. The screen ruling at laser engraved cylinders (LE) (tone work) was engraved at 254 lpi (100 lc lines per centimeter) for all cylinders. Black engraving, the line work (LW) was engraved with the 278 lc Masterscreen pattern. The laser engraved cells were angled at 30 degrees. All of the cylinders were engraved at the same angle. The image on both cylinders was the same with small variations (IT 8.7/3 chart was included in laser imaged cylinders). A Cerutti pilot-plant rotogravure web printing press (Cerutti Model 118, Italy) was used to print test samples. Four process colors were printed at 305 m/min (1000ft/min) for LWC, SCB, SCA and freesheet. The speed of 600 ft/min was run for SBS board. Commercial toluene based coated group VI inks were employed. Their efflux time was 22 seconds on a Shell #2 efflux cup for yellow, magenta and cyan inks and 20 seconds for black ink. The same ink viscosity was used for both sets of cylinders.

Porosity, Roughness and Compressibility

Parker Print-Surf Model ME 90 (Messmer Instruments Ltd., U.K) was used for both porosity and roughness measurements. Porosity was measured using clamping pressure 500 kPa, roughness at 500 and 1000 kPa clamping pressure and using soft backing. The compressibility was calculated as the ratio of roughness at 500kPa and 1000 kPa clamping pressure.

Paper Optical Properties

Paper brightness was measured by Brightness-X-Rite 8400 instrument equipped with Color Master software. Paper CIE L*a*b* color coordinates were measured using X-Rite 530 Spectrodensitometer. Substrates opacity was measured according to TAPPI Standard T 425-om-91.

Image Analysis

Image analyses of magenta, cyan, and black dots were recorded at 5 % tone step using a Hitachi HV-C10 camera (Hitachi Denshi, Ltd., Japan). Computer software Image Pro Plus, Version 4.5 was used for image detail analysis.

Print Mottle

Print density mottle was measured using a Tobias Mottle tester with reflective density measurement head. Tobias mottle was compared to mottle measured using Verity 1A Multifunction 2003 software. Solid process colors were scanned by HP Scanjet 7400C scanner at 600 dpi resolution as input images for Verity software to calculate mottle. For mottle calculation in Verity 1A software, tile sizes 2-1024,2-64, 4-1024 and 4-64 were used. According to the instruction, tile size 4-64 represents visible mottle.

Reflective Density and Color Values
Reflective density, tonal responses, dot gain and CIE L*a*b* values were measured using X-Rite 530 Spectrodensitometer.

Specular Gloss
Specular gloss was measured by Gardner Gloss Meter with 60 degree geometry on solid colors and the gloss was calculated as average of five measurements in paper machine and five measurements in cross-machine direction.

RESULTS AND DISCUSSION

Four publication gravure papers (light weight coated (LWC), Supercalendered A (SCA) and B grade (SCB) and freesheet (FS) and one packaging grade (SBS

Table 1: Selected papermaking properties of paper/board substrates

SUBSTRATE	**PPS Roughness at 500kPa [μ]**	**PPS Roughness at 1000 kPa [μ]**	**Compressibility**	**PPS Porosity [mL/min]**
LWC 42 lb/ream	2.13	1.63	1.31	7.12
SCB 35 lb/ream	2.02	1.55	1.30	14.15
SCA 35 lb/ream	2.21	1.65	1.34	23.31
FS 45 lb/ream	1.98	1.48	1.34	16.46
SBS 81 lb/ream	3.58	2.53	1.41	1.46

Table 2: Selected optical properties of paper/board substrates

SUBSTRATE	**Specular Gloss 60 ^{o}**	**Brightness (Reflectance at 457 nm)**	**Opacity [%]**
LWC 42 lb/ream	17.16	71.50	86.89
SCB 35 lb/ream	14.51	65.78	88.56
SCA 35 lb/ream	15.88	68.19	87.42
FS 45 lb/ream	20.46	79.32	92.65
SBS 81 lb/ream	14.25	83.75	95.59

Board) were printed using electromechanically and laser engraved cylinders. Their papermaking properties are listed in the **Table 1 and Table 2**. Ink viscosity was not optimized for laser engraved cells for comparison reasons.

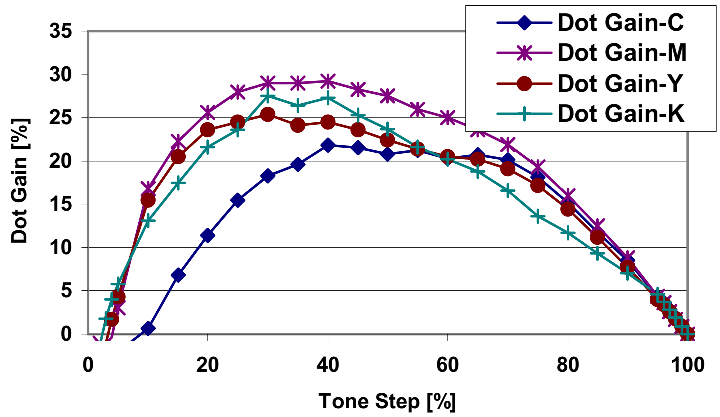

Figure 1: Dot gain of process inks on lightweight coated substrate printed with laser engraved cylinder (ESA off)

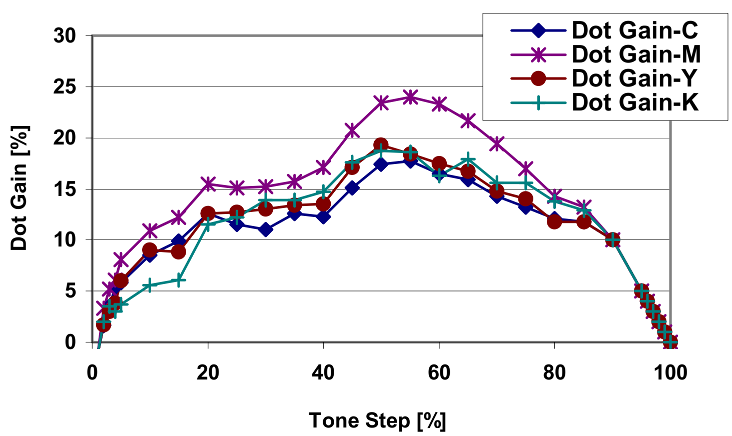

Figure 2: Dot gain of process inks on lightweight coated substrate printed with electromechanically engraved cylinder (ESA off).

Only toluene based publication gravure ink (Coated) was used for both types of image carrier. Optical density of solid prints was higher on all substrates for electromechanically engraved cylinder than for laser engraved one. Solid black showed opposite trend, while cyan and magenta achieved the same values.

Dot gain curves for laser engraved cylinders were generally smoother than those from electromechanically engraved cylinders (**Fig.1** and **Fig.2**). Maximum dot gain for laser engraved cylinders was found at 30 to 40% tone, while at electromechanically engraved print it was at 50% tone. Dot gain from LE cylinders (29.10-24.10 %) was greater than from EE cylinders (24.80- 19.98) on all substrates and all inks **(Table 3)**. Printing without electrostatic assist (ESA off) affects ink transfer from laser engraved cells less than from electromechanically engraved cells, which was obvious when subtracting average dot gain values with ESA on and ESA off **(Table 4)**.

Table 3: Average dot gain on all paper/board substrates (EE at 50% and at LE at 40% tone, dot gain for all substrates was averaged)

	EE ESA ON	EE ESA OFF	LE ESA ON	LE ESA OFF
Yellow [%]	19.98	18.10	24.54	23.94
Magenta [%]	24.80	21.60	29.10	28.70
Cyan [%]	20.70	18.60	24.10	21.86
Black [%]	20.80	18.98	27.68	27.54

Table 4: The difference in maximum average dot gain between ESA on and ESA off for electromechanically and laser engraved cylinders.

	Yellow	Magenta	Cyan	Black
Electromechanical	1.88	3.20	3.48	1.82
Laser	0.60	0.40	2.24	0.14

Print mottle can be measured as unevenness in print density, gloss or color. In this work, Tobias density mottle index and Verity mottle were measured. The higher the mottle index number, the worse the unevenness. Verity Multifunction software analyzes digital images, acquired by a sensitive scanner. The algorithm is built to calculate pixel intensity difference of a scanned image [Rosenberger, 2003 (A), Rosenberger, 2003(B)]. Verity Mottle is a function of the mean pixel luminance and the standard deviation of pixel intensity.

Verity IA Multifunction has the choice of equalization when measuring print mottle. Histogram equalization is a contrast enhancement technique which can help to obtain a new enhanced image with an uniform histogram. Equalization takes the image range of pixel luminance values and expands it to fit the 0 to 255 range by uniformly interpolating the pixel luminance values. Because the range is an image variable, using equalization in a measurement can cause a

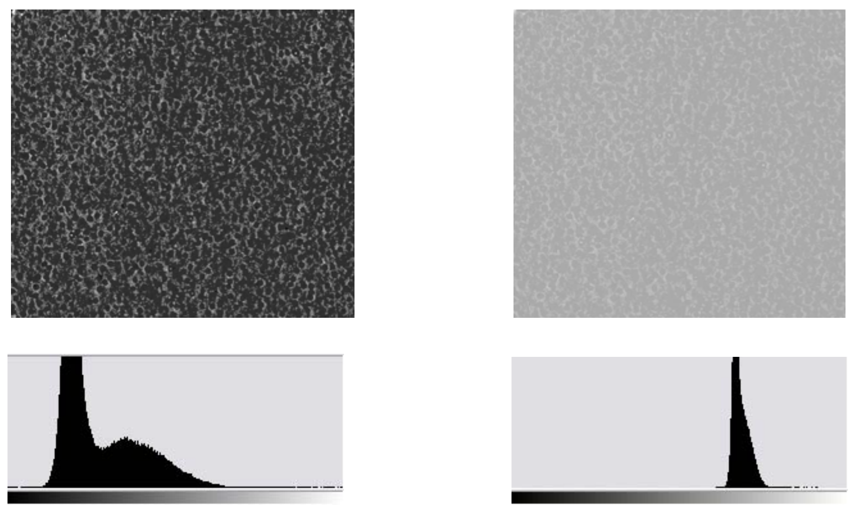

Figure 3: The difference between equalized and non- equalized image and mottle measurement by Verity software. Left: Equalized image and histogram Mottle Index = 356.6; Right Non-equalized image and histogram Mottle Index = 15.53

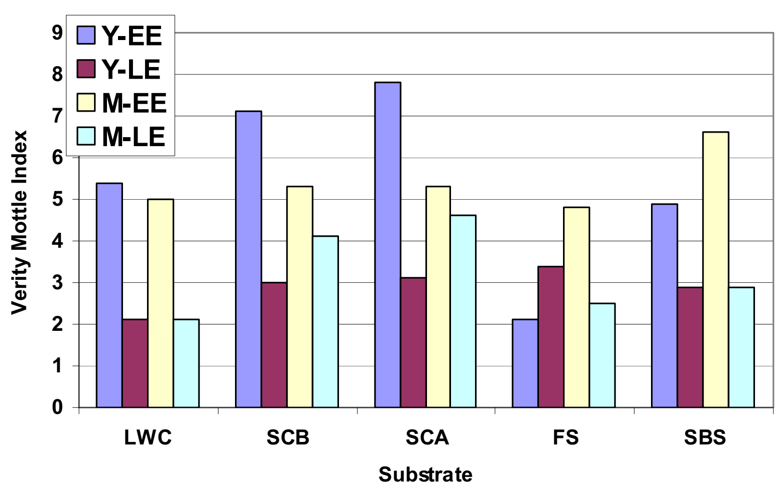

Figure 4: Visible mottle index (Verity IA Software) for yellow and magenta printed from both EE and LE cylinders (ESA on)

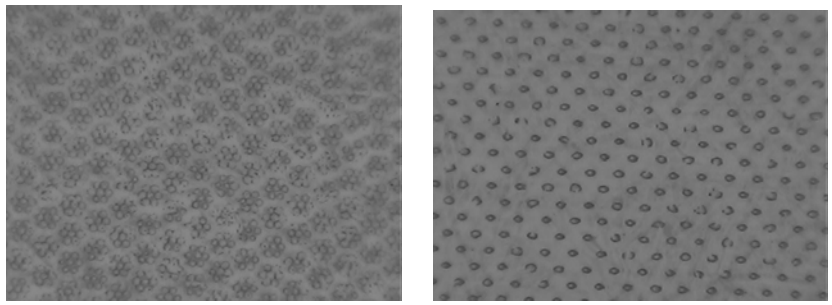

Figure 5: Black cell shapes at 5% tone from laser engraved (left) and electromechanically engraved cylinder (right) on freesheet (ESA on)

variance in the mottle measurement in the same set. Mottle is the nonuniformity of print density, color or gloss, which may be not visible at lower contrast. **Figure 3** shows the extracted image from solid yellow print. It is clear that the equalization amplified the unenvenness of the print which cannot actually be caught by human eyes. That means when the equalization is turned off, the measured mottle value is related to human vision. In further experiments, measuring mottle with Verity software, equalization function was turned off.
Lower mottle for laser engraved cylinders was found at all levels of electrostatic assist and all substrates printed with yellow, magenta and black **(Fig. 4)**. Cyan print from LE cylinder had higher mottle at SCA, SCB and freesheet at all ESA levels. In most cases, print showed lower mottle at ESA on than ESA off at both LE and EE cylinders.

The dot areas of cyan, magenta and yellow printed by laser engraved cylinders were smaller than the dot areas printed by electromechanically engraved cylinders on all substrates and ESA on (Data not shown). Dot areas of black printed by LE cylinders exhibited higher values than the dot areas printed by EE cylinders. All three process colors were printed from single shot laser beam,

Table 5: Specular gloss on solid yellow (Y), magenta (M), cyan (C) and black (K) with various levels of ESA on LWC substrate

ESA	**Y LE**	**YEE**	**M LE**	**M EE**	**C LE**	**C EE**	**K LE**	**K EE**
ON	33.8	32.2	32.6	30.4	31.2	35.7	34.2	29.9
25 %	31.4	27.0	31.6	27.2	29.5	29.0	33.1	26.1
OFF	30.7	27.3	30.7	25.3	28.1	25.7	32.8	24.1

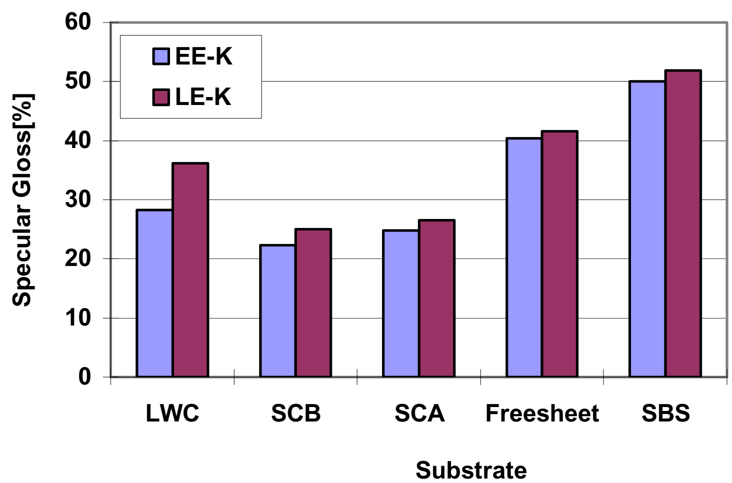

Figure 6: Specular gloss of solid black (K) on various substrates (ESA off) EE-electromechanically, LE laser engraved cylinders

while the black was engraved by multiple shot lasering. The illustration of black dots from multiple lasering is shown at **Figure 5**. Again, the ink viscosity was not optimized for laser engraved cells, but same viscosity was used for both types of engraving.

Specular gloss (60 ^{o}) is rather similar from both engravings when printing with ESA on **(Table 5)**. Only black print has much higher gloss from laser engraved cylinder **(Fig. 6** and **Tab. 5)**. With ESA 25% and ESA off, much better gloss is achieved from laser engraved cylinders at all colors, which shows better ink release, spreading and leveling off from laser engraved cylinder.

CONCLUSION

Comparison of gravure printability from laser and electromechanically engraved image carriers was done on four publication and one packaging gravure paper substrates. The same ink viscosity was used for electromechanically and laser engraved cylinders for comparison reasons- ink was optimized for electromechanically engraved cylinders. On all substrates and all process color inks, the dot gain was greater from laser engraved cylinders than from electromechanically engraved ones. The difference in dot gain with ESA on and ESA off was much lower for laser engraved cylinders for all inks and substrates, which means that ink transfer is much better from laser engraved image carriers.

Print gloss was quite similar from both engravings when printing with ESA on. Black print has much higher gloss from laser engraved cylinder. With ESA 25% and ESA off, much better gloss is achieved from laser engraved cylinders at all colors. Laser engraved cylinders produced lower print mottle on most substrates and colors. Comparing all printability features, it can be concluded that laser engraved image carriers produce better print quality than electromechanically engraved ones.

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