The Study of Missing Dots of Electromechanical and Laser Engraved Cylinders

Xiaoying Rong*, Alexandra Pekarovicova#

Keyword
Gravure, missing dots, electromechanical engrave, laser engrave

Abstract

According to the previous study, the printability of electromechanical engraved cylinder and laser engraved cylinder were different in terms of density, tone reproduction and mottle. In this study, the missing dots of two different engraved cell types were investigated. It showed that different cell structures had strong effect to ink transferring and the characteristics of missing dots. Lasers engraved cells were less affected by ESA (electrostatic assist). When there was no ESA applied, the laser engraved cells showed less missing dot area, which indicated better ink release from spherical shaped cells. ESA had more effects to coated substrates than supercalendered substrates.

Introduction

Electromechanical engraving is the most common method of engraving rotogravure cylinders. With the developing of direct laser engraving technology, this technology opens up new perspectives for rotogravure printing (Hennig, 2002).

As research shown (Rong, 2004), laser-engraved cylinders with round-shaped dots have better performance, which appears higher density, lower mottle, higher gloss and smoother tone reproduction. When considering tone reproduction, smoother tone curve is better for gamma correction. The tone curves also indicate that laser engraved cells are less affected by ESA (electrostatic assist). The direct laser system is also believed to achieve better ink release over electromechanically engraved cells, resulting in substantial ink savings (Gray, 2003).

*Graphic Communication Department, California Polytechnic State University, San Luis Obispo, CA 93405 email: xrong@calpoly.edu
#Department of Paper Engineering, Chemical Engineering and Imaging, Western Michigan University, Kalamazoo, MI 49008

Missing dot is an important quality issue, which related to ink release from the cells. Electrostatic assist (ESA) is commonly used to attract ink onto the substrates, which can help to reduce missing dots. Little research work has been done to investigate the method of qualifying missing dot.

Billeb and Ness (2002) investigated missing dots on SC-paper by separating the printed surface into grids. A mask was made to be the size of individual cell if there was no false surface. Then the proportion of false surface including totally missed dot were calculated. The grids were set with 5%, 10% and 20% of surface coverage. They found that surface structure of paper and printing pressure have the greatest influence on the missing dot. A PTS-DOMAS system (DOMAS) was designed to count the missing dots in highlight and shadow areas. By defining an “ideal“ dot, the system then calculated the proportion of missing dot area. The system additionally classifies the dots according to their area and ink density.

Because of the fact that the cell shapes of electromechanically engraved and laser engraved cylinders are significantly different, the differences in ink release are expected. Beside the difference between diamond shaped cells of electromechanically engraved and spherically shaped laser engraved cells, black cells on laser engraved cylinder are significantly different from laser engraved yellow, magenta and cyan cells. The masterscreen, as it is called, can follow fine text and shapes, and ensure a very sharp printing result. Each black cell is constructed as seven small spherical cells, which makes the black cylinder unique in tone reproduction and ink release. The differences between electromechanically engraved cells and laser engraved cells are shown in **Figure 1 and 2,** the masterscreen is illustrated in the **Figure 2** left.

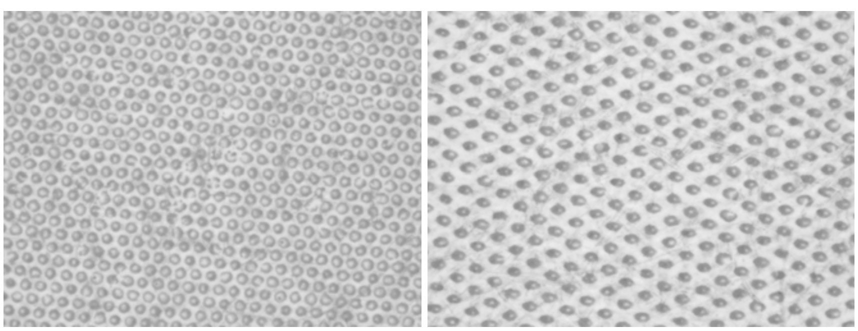

Figure 1: Laser engraved magenta cells (left) and electromechanically engraved magenta cells (right).

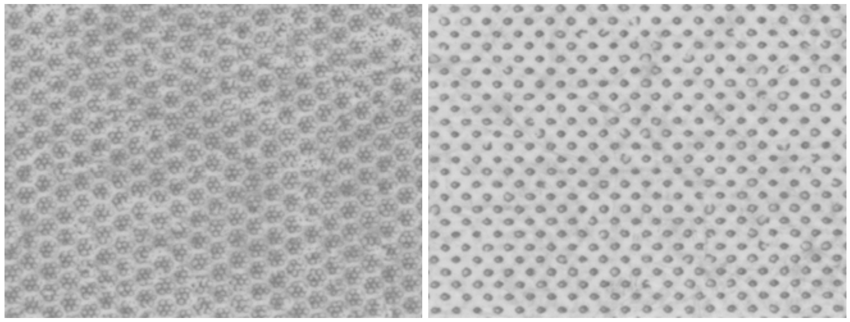

Figure 2: Laser engraved masterscreen black cells (left) and electromechanically engraved black cells (right).

This study was focused on evaluating ink transfer differences between electromechanically engraved cells and laser engraved cells, in terms of the number of missing dot and the missing dot area. ESA effects to ink transferring on different substrates were also discussed.

Experimental

1. Substrates

Publication grades included 42.63 lb. lightweight coated (LWC), 35 lb. supercalendered A (SCA) and supercalendered B (SCB), 45 lb. coated and supercalendered freesheet (FS). Solid bleached sulfate paperboard (SBS) 81 lb. represented packaging grade.

2. Printing Conditions and Cylinders

All substrates were printed on a four-color Cerutti web-fed gravure press. Two sets of cylinders were engraved electromechanically and by direct laser. The image on both cylinders was the same with small variations (IT 8.7/3 chart was included in laser imaged cylinders). The screen ruling at electromechanically engraved cylinders was 140lpi (lines per linear inch) for yellow, 175lpi for magenta, 175lpi for cyan and 225lpi for black cylinder, with compression angles 45^{o}, 60^{o}, 30^{o}, and 45^{o}, respectively. The screen ruling at laser engraved cylinders (tone work) was engraved at 254lpi (100 lc lines per centimeter) for all cylinders. Black engraving, the Line Work (LW) was engraved with the 278lc Masterscreen pattern. The laser engraved cells were angled at 30 degrees. All of the cylinders were engraved at the same angle.

Press speed was 1,000 feet per minute for all the substrates except SBS. SBS paperboard was run at 600 feet per minute. Electrostatic assist (ESA) was applied at 4 kV and 1.4 mA (ESA on), and ESA off. Impression pressure was

125 psi at 3/8 nip flat with an 85 durometer (Shore A) roller. All the settings were kept the same when printed with both sets of cylinders.

Viscosities of toluene-based publication inks measured as efflux time on Shell No. 2 cup, were set to 22 seconds for cyan, magenta and yellow, black ink was set to 20 seconds. ESA were set at on (4kV) and off to compare the print quality. All the settings were kept the same during the test run for both cylinder sets.

3. Analysis

Printed images on different substrates were captured by ImageXpert. Matlab® and ImageJ were used to calculate the missing dots and missing dot areas.

Methodology of Determining Missing Dots

Images captured by ImageXpert system were converted to binary information. Because of the effect of brightness of different substrates, it is hard to pre-select a gray level as threshold based on gray-scale histogram to separate background and foreground. The threshold level had significant impact to the binary appearance. One method relied on the concept of entropy was applied. This method defines the average amount of information (in *m*-ary units per symbol) obtained by observing a single source output. Entropy represents a quantitative description of the amount of information in a message based on the logarithm of the number of the possible equivalent messages (Gonzales, 2002). The average information per source output H(z), is

$$H(z) = -\sum_{j=1}^{J} P(a_j)\log P(a_j)$$

where, $P(a_j)$ is the probability of value a will occur in image with J possible gray levels. The suitable threshold level is chosen by maximizing the entropy of the black and white pixel classed simultaneously. This approach can ensure the combined entropy of the black and white pixel classes is optimized, which may avoid selecting a threshold level that renders the binary image nearly all white or all black (Davidson). **Figure 3** showed the original gray scale image and the binary image generated by entropy threshold.

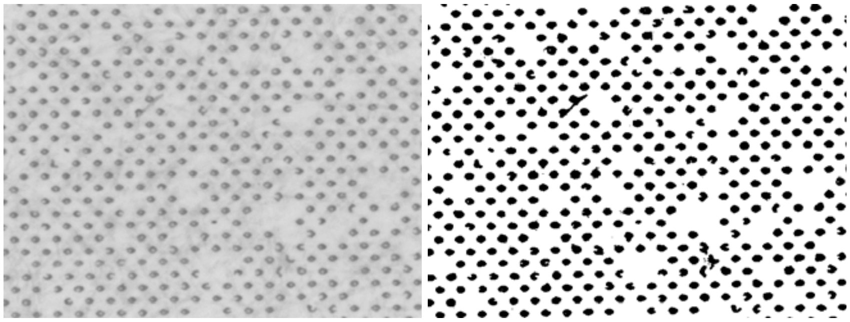

Figure 3:The gray scale image (left) and the binary image generated by entropy threshold (right).

While the binary image is extracted, the percentage of dot is calculated as:

dot% = (total pixels of black / total pixels of the image) *100%

The effects of ink transferring under different ESA conditions were compared based on the percentage of dot. The difference was reported as percentage of changing.

Effect of ESA % = (dot% ESA ON – dot% ESA OFF) / (dot% ESA ON)

To determine the number of missing dots, one complete dot was cropped from the binary image. The entire image was scanned row by row to compare with the cropped dot. A missing dot was determined by the algorithm: if there is no pixel valued as 1 in an area of cropped dot, missing dot counts plus one.

Missing dot area is somehow important in tone reproduction. To calculate the missing dot area, a perfect dot needs to be determined first. Because of the local smoothness and absorbency of each substrate are different, it is impossible to use one ideal shaped dot to calculate for all substrates. Since when ESA was applied, ink release from each cell was better than the release from the cells with no ESA. The average size of all printed dots on certain substrate with ESA applied was used to represent the ideal dot shape of this substrate. This dot size was also used to compare the missing area of prints with ESA off.

As shown in the **Figure 4**, the distance from the center of one cell to the center of the cell next to it is consistent. If the dot is symmetrical, the dot area of individual dot can be calculated as, dot area = total area of shadow, where O1, O2, O3 and O4 are the center of each dot.

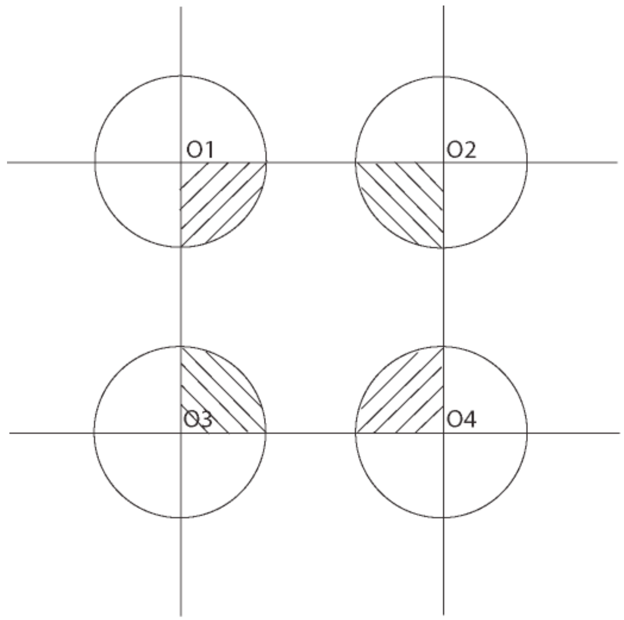

Figure 4. The mechanism of calculating ideal dot area from four adjoined dots.

The missing dot area was then calculated as:

Missing dot area = the ideal dot area – average dot area of entire image.

Results and Discussions

1. Dot Percentage Calculated from Binary Images

Gray scale images at step 10% were converted to binary images by entropy thresholds. Because of the surface properties of different substrates, it was hard to extract the dots without showing small amount of fiber. When the dot percentage was averaged from the entire captured image, the effect of isolated fibers shown in the binary image was ignored. The following table showed the effects of ESA to laser engraved cells and electromechanically engraved cells.

Black		LWC	SCB	SCA	Freesheet	SBS
Laser engraved	Effect of ESA [%]	16.34	9.39	9.14	18.43	16.62
Electromechanically engraved	Effect of ESA[%]	22.53	14.41	10.36	30.43	23.85

Table 1: The ESA effect on dot percentage change of black cells and on different substrates.

The data suggested that ESA had stronger effect to electromechanically engraved black cells than to laser engraved black cells. As shown in the Table 1, coated sheets include LWC, freesheet and SBS were more sensitive to ESA. The effect of ESA to missing dots was especially notable to freesheet no matter what kind of engraved cells were printed.

Laser engraved masterscreen black has special cell structure. Each cell contains 7 small spherical cells, which make the ink transfer a little different to the single cell. To identify the effect of ESA to single cell, 10% magenta of electromechanically engraved cells and laser engraved cells were evaluated by the same method. The results were reported in the following table.

Magenta		LWC	SCB	SCA	Freesheet	SBS
Laser engraved	Effect of ESA [%]	8.74	8.67	5.47	9.72	6.26
Electromechanically engraved	Effect of ESA[%]	17.56	17.29	14.45	22.85	4.60

Table 2: The ESA effect to dot percentage change of black cells on different substrates.

As shown in the data, magenta cylinders constructed with single cells had the similar trend as the black cylinders except printed on SBS. ESA had stronger effect to electromechanically engraved cylinder than laser engraved cylinder. Also, substrates played the similar role in keeping or skipping the dots except SBS. Coated substrates, LWC and freesheet showed more change when ESA was applied.

2. Missing Dot and Missing Dot Area Comparison

Because of the image quality, only freesheet samples were examined for missing dots comparison. Missing dots were reported as percentage of entirely missed dots and percentage of missing dot areas. The results were shown in **Table 3**.

Clearly, electromechanically engraved cells were consistent in term of missing dot area. For black cylinder, ESA ON had greater impact in reducing missing dots and missing dot areas. Magenta cylinder usually has lower resolution than black cylinder in electromechanical method. Magenta cylinder showed significant differences in missing dots. The lower resolution, which means the wider cell opening, improved ink release when ESA was not applied. Considering missing dot areas, black and magenta cylinders performed similarly.

		ESA ON		ESA OFF	
		Missing dot [%]	Missing area [%]	Missing dot [%]	Missing area [%]
Black	Electromechanically engraved	≅0	1.58	11.48	27.03
	Laser engraved	≅0	10.60	≅0	21.68
Magenta	Electromechanically engraved	≅0	3.43	1.80	25.50
	Laser engraved	≅0	4.16	1.89	13.00

Table 3: Missing dot and missing dot area of laser and electromechanically engraved cylinders.

Laser engraved black cells performed differently compared to magenta cells. There was no entirely missed dot on black cylinder, no matter ESA was on or off. The special structure of black cell may contribute to this. When comparing missing dot area, black cells missed significantly larger areas than magenta cells, which is simply spherical shaped. When there was no ESA applied, it showed the similar trend of missing dot area for black and magenta cells. Magenta cells showed smaller missing areas than black cells.

Interesting enough, when ESA was off, laser engraved black cylinder and magenta cylinder both appeared less missing dot areas than their counterparts of electromechanically engraved cylinders. When ESA was applied, electromechanically engraved cylinders showed less missing dot areas than laser engraved cylinders. This may explain that when ESA was off, the ink release from spherical shaped laser engraved cells was better than traditional diamond shaped cells. Diamond shaped electromechanically engraved cells may be benefited when ESA was applied.

Conclusions

The missing dot and missing dot area were studied on gravure printed substrates. ESA showed great effects on releasing ink from the cells. With the help of ESA, ink release was significantly improved regardless of the engraving methods and the cell shapes. Laser engraved spherical shaped cells were less effected by ESA. When there was no ESA applied, the ink release of laser engraved cells were better than diamond shaped electromechanically engraved cells. Because laser engraved black cells constructed differently as the other colors (masterscreen), there was no entirely missed dot observed even when ESA as off. This may contribute the appearance of black image when there is no ESA applied. Coated stocks like LWC, coated freesheet and SBS substrates affected more by ESA than supercalendered substrates.

Acknowledgements

The authors would like to thank the following companies and organizations in supporting this study. Keatings Gravure, Inc and Max Daetwyler, Inc. for engraving and transporting the cylinders. Printing Pilot Plant of Western Michigan University of running the test. ImageXpert for supporting image capture device and software. ImageJ for sharing free software.

References

Billeb T. and Ness Ch. (2002): “Untersuchungen zur Bedruckbarkeit von SC-Papieren im Tiefdruck“, Science and Technology, 3, 40-48

Davidson, M. D., Abramowitz, M.: Molecular Expressions Microscopy: Digital Image Processing – Binary Threshold Level Selection. Florida State University, http://micro.magnet.fsu.edu/primer/java/digitalimaging/processing/automaticthresholding/index.html

DOMAS: Digital Optical Measurement and Analysis System - Module: missing dots, http://www.igt.nl/igt-site-220105/index-uk/brochures/domas/DOMAS-Missing-Dots.pdf

Gonzalez, R.C., Woods, R.E. (2002): “Digital Image Processing”, Prentice Hall, 438-440

Gray T. et al. (2003): “Gravure Process and Technology“, Gravure Education Foundation and Gravure Association of America, 2nd Ed., Rochester, NY, 558

Hennig, G. and Frauchiger J. 2002: “New Engraving Technology Opens Up New Perspectives for Rotogravure Printing”, Flexo and Gravure Asia, 1, 6-9

Rong X. 2004: “Gravure Printability Comparison of Laser and Electromechanically Engraved Cylinders“, Gravure Magazine, April, 30-36