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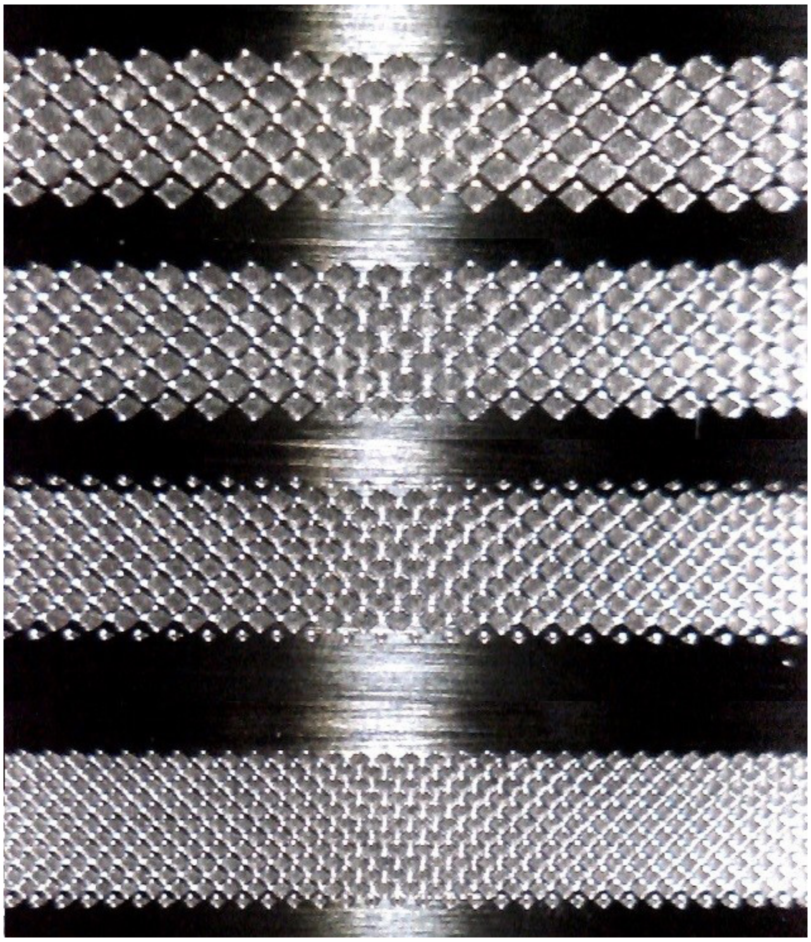

Figure 2. Different cell sizes on an image cylinder

# PRINTED DOT QUALITY IN RESPONSE TO DOCTOR BLADE ANGLE IN GRAVURE PRINTING

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## 1. Introduction

Although printing substantially contributes people's daily life, it is maybe the most underappreciated technology. When tens of millions of copies are needed, such as magazine (i.e. National Geographic, IKEA catalog), book, newspaper, packaging (i.e. cereal boxes, M&M's candies, cosmetics), or specialty items (i.e. furniture, flooring, flexible electronics) gravure printing is the preferred production technology [1-6].

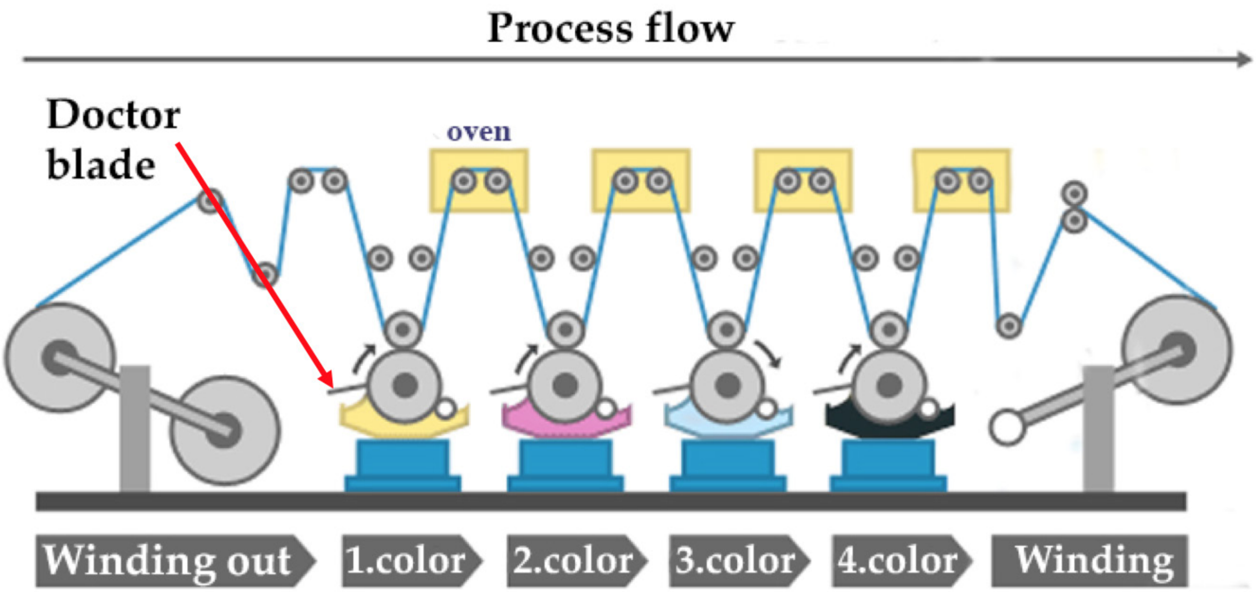


Figure 1. Web-fed gravure printing press schematic diagram [14]

Gravure is one of the five major printing technologies and its origin goes back to early seventeenth century [7,8]. Its advantages include high print quality, high-speed production and hardwearing image cylinders which allows duplicating in millions [8]. A very critical printing machine part that is called doctor blade (Figure 1) controls the amount of ink transfer from the image cylinder onto the substrate. The blade can contact the image cylinder at varied angles; however, an improper angle may cause major problems.

Ink viscosity is another factor that can influence the ink transfer [9]. Both water and solvent based inks are commonly used in gravure printing. They require viscosity range of 10 to 30 seconds (s.) – depending on the press conditions – when measured with the Shell cup viscometer #2 [10]. Solvent based gravure inks can be highly volatile chemicals. They can evaporate into the air [11], and cause reduction in ink viscosity. Having high viscosity can lead to uneven dispersion, as well as aggregation of pigment particles that cause ink transfer problems. Therefore, the first thing to do before the printing is to adjust the ink viscosity. It is also equally important to consider the compatibility between the size of cell openings on the image cylinder and the size of pigment particle in the ink. Pigment is the component that gives ink its color and the size of it varies based on the pigment manufacturer. On the image cylinder, there are recessed cells (Figure 2) that may be same in area but different in depth or vice versa or may be both different in cell shape, area and depth [12,13]. These variations permit delivering different ink volumes on a substrate. During printing, ink fills in the cavity of these cells, then doctor blade removes the excess ink from the outside surface of image cylinder before transferring it on the substrate. A rule of thumb for a given pigment size is that the opening must be three times bigger than the pigment particle size, so the particle can easily go in and out of the cell.

A traditional way to control the amount of ink transfer to the substrate is to measure the ink density. There are handheld density measurement devices that functions based on reflecting light (45$^o$) to the printed ink and measuring the percentage of light being reflected (0$^o$) back to the device. This is one way to monitor ink profile over the course of printing process, but the density data is limited, since it doesn't indicate information about color or dot attributes such as dot perimeter (P), area (A, size) and circularity (C, shape).

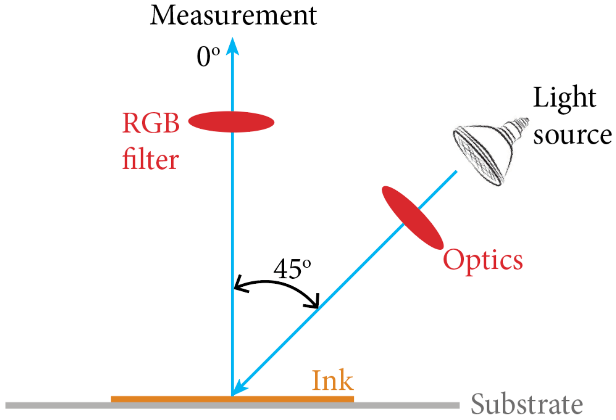


Figure 3. Schematic diagram of ink density measurement (45/0 direct)

The perimeter (total length of the dot boundary) and the area (the sum of areas of each pixel within the borders of the dots) can be used to calculate a circularity value [15]. Circularity is a dimensionless value and represents how a printed dot similar to a circle. It is calculated using the formula based on ISO 9276-6 in Equation 1:

$$C= \sqrt{(4.\pi.A/P^2)} \qquad (1)$$

Lower circularity value indicates a less circle like shape [15, 16].

Collecting data from the printed ink by incorporating image analysis through a high-resolution camera would assist receiving more details about the dot attributes. In this study, the doctor blade angle was positioned at three different levels to investigate its effect on printed dot quality by correlating density and image analysis.

## 2. Method and Materials

A 4-color gravure web-fed printing press (Cerutti: Italy) was used to print the test form in Figure 4 on a coated paper substrate. The ink solvent base was toluene. Print color order was yellow, magenta, cyan and black (YMCB) (Figure 1). Doctor blade angle was varied at three different levels and labeled as high, normal and low. The blade pressure was set to 40 psi. Printing speed was 650 feet/min. The viscosity of the toluene based ink was measured with the Shell cup #2.

Optical density of 100% black solid patch was measured 10 times with X-rite densitometer for each doctor blade angle setting. Printed black dot attributes (area, perimeter) of the 15% tone step were quantified using high-resolution overhead camera along with Image Pro Plus image analyzing software.

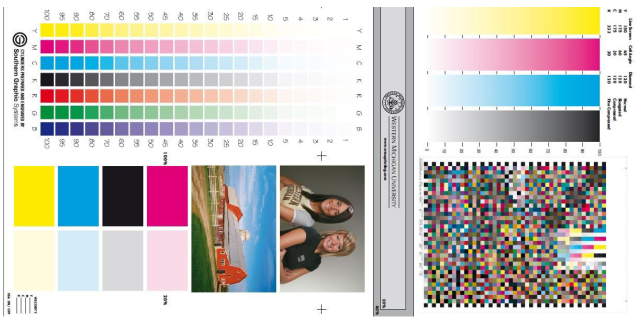

Figure 4. Test form for the print trial

## 3. Results and Discussions

Previous practices in lab has proved the target viscosity values presented in Table 1 is suited for 4-color Cerutti gravure printing press. Before the printing, the values were higher than the target viscosity. To reduce the viscosity, additional toluene was added into the inks until seizing the target value.

*Table 1. Viscosity data before and after printing*

| | Target | Before printing | After the adjustment |
|---|---|---|---|
| Yellow | 22 s. | 24 s. | 22 s. |
| Magenta | 22 s. | 25 s. | 22 s. |
| Cyan | 28 s. | 32 s. | 27 s. |
| Black | 19 s. | 23 s. | 19 s. |

Figure 5 and Table 2 represent 10 different density measurement that were collected from the 100% black color in response to the blade angle.  The high angle blade setting was exhibited slightly lower density, while the normal and low setting was averaged the same.

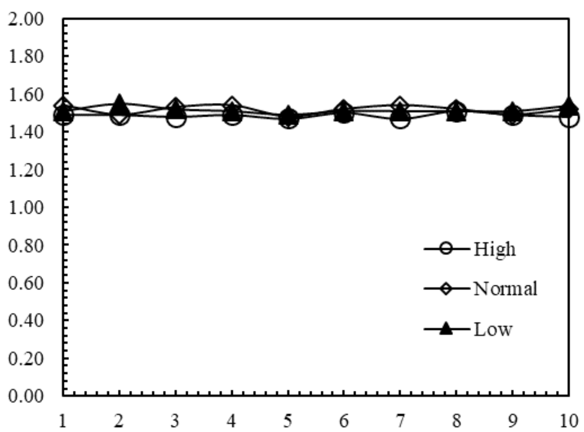


Figure 5. Density profile in response to doctor blade angle

*Table 2. Average density values*

| 100% black density | High | Normal | Low |
|---|---|---|---|
| Av. | 1.49 | 1.52 | 1.52 |
| Std. Dev. | 0.01 | 0.02 | 0.02 |

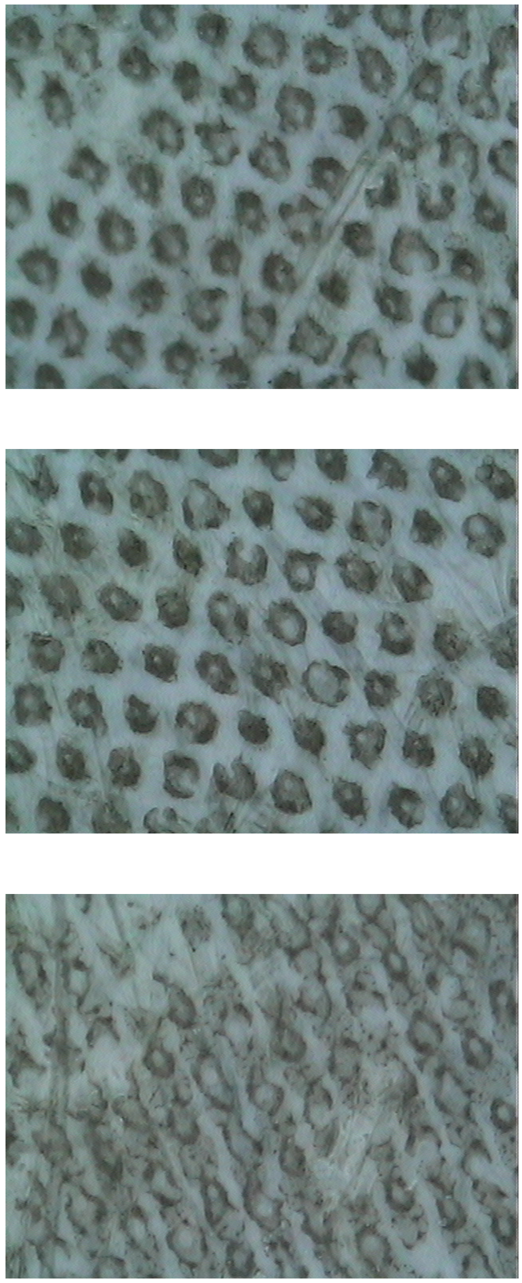

Figure 6. Printed dot images at high (top), normal (middle) and low (bottom) blade settings

After the density, the printed ink analyzed with a high-resolution camera. The magnified photos are presented in Figure 6. Even though the density profile was around the same, the printed dot shapes and missing dot amount did not correspond as identical. At low blade angle, the dot formation and density looked uneven, which causing overall image to appear mottled or grainy. At high blade angle, the dot shapes appear irregular. The normal angle setting was presented more uniform dot shape. Missing dots occurred at each blade angle, but the low angle setting had the higher amount, representing the inability of ink transfer from the engraved cell to the substrate.

*Table 3. Printed dot attributes from the Image Pro Plus Software*

| | Area (pixel) | | | Perimeter (μm) | | |
|---|---|---|---|---|---|---|
| Stats | High | Normal | Low | High | Normal | Low |
| Min | 10 | 10 | 10 | 7 | 7 | 7 |
| (Obj.#) | 17 | 73 | 84 | 231 | 73 | 84 |
| Max | 1279 | 2464 | 2395 | 273 | 289 | 435 |
| (Obj.#) | 463 | 247 | 590 | 170 | 67 | 590 |
| Range | 1269 | 2454 | 2385 | 266 | 282 | 429 |
| Mean | 490 | 899 | 187 | 95 | 101 | 53 |
| Std. Dev | 437 | 865 | 307 | 66 | 86 | 60 |
| Sum | 53932 | 89046 | 50157 | 10443 | 10001 | 14252 |
| Samples | 110 | 99 | 268 | 110 | 99 | 268 |

Table 3 shows that changing the blade angle from high to low affects the dot area and perimeter values. The sample size for the low angle is shown as 268, which is roughly three times more than the other blade angles. Since the image analysis software function based on threshold technique, the reason would be that the software detects any dark spot as a regular dot. By disregarding the low angle data, it can be stated that the normal blade angle enables better dot shape than the high blade angle. The circularity of high and normal angle is calculated as 0.83 and 1.05 respectively (Table 4), indicating normal angle dot shape is more uniform and circles.

*Table 4. Circularity results*

| | High angle | Normal angle | Low angle |
|---|---|---|---|
| Roundness | 0.83 | 1.05 | 0.91 |

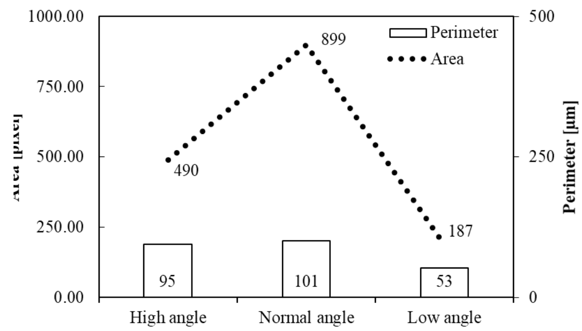


Figure 7. Printed dot attributes

## 4. Conclusion

In this study, doctor blade angle was positioned at three different levels to investigate its effect on printed dot quality. Although the gravure printing used in the study, the theory to check dot quality through image analysis can extent to the other printing systems named flexography, offset, digital and screen printing. The results showed that only looking at density value cannot provide sufficient information about dot quality. Incorporating an advanced camera was allowed further investigation and assisted quantifing printed dot area, perimeter and circularity. The dot attributes were undesired when the doctor blade angle was above or below the normal proper positioning.

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