Evaluation of Different Stencilmaking Methods for Screen Printing

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Abstract

Screen stencils for screen printing can be prepared using conventional film-based photographic methods or contemporary computer-to-screen (CTS) technologies such as inkjet, digital micromirror devices (DMD), and violet-blue diode laser. CTS increases efficiency and eliminates problems related with exposure and processing of film; however, the prices of CTS systems are still high and their reliability also needs to be improved. In film-based photographic methods, image film can be created photographically or printed digitally. The photographic methods involve an imagesetter and a film processor. The printing methods used recently are inkjet printing and thermal printing. Printing methods increase efficiency and eliminate photographic materials, but they might have quality issues. In this study, a Linotronic 330 imagesetter and a Fujifilm FG 550E film processor were used for the photographic method. An Epson Stylus® Photo R1900 printer was used for the printing method along with AccuRIP® software and AccuFast® film. Transmission density of inkjet-printed film can achieve as high as that of photographic film, but its dot gains are much higher. Streaks on solid area can also be observed. Both photographic and inkjet-printed films were used to expose screens coated with photographic emulsion. Another stencilmaking method is laser cutting, which has been used in industrial stencils, decorative lettering stencils, and graphic stencils. In this study, laser cutting was used to make stencils for process screen printing. A CO_2 laser cutter Model M-35 from Universal Laser Systems was used to remove the image area on the emulsion layer of knife-cut stencil film. Laser power and cutting speed were varied to obtain optimum results. The laser-cut stencil was moistened and attached to a screen. During this process, water dissolved emulsion on non-image areas it flowed to image area. Stencil thicknesses and surface roughness of all the screen stencils were measured and compared. Microscope images were also used to evaluate stencil quality. Advantages and disadvantages of the three stencilmaking methods were discussed.

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Introduction

Screen stencils for screen printing can be prepared using conventional film-based photographic methods or contemporary computer-to-screen (CTS) technologies. There are two types of commonly used film-based photographic methods, direct or indirect (Adam and Dolin, 2002). Direct methods usually include these steps: apply liquid emulsion or dry direct film to screen; dry screen; remove backing film if dry direct film is used; expose screen with positive image film; develop screen; dry screen. Indirect methods usually include these steps: expose indirect film with positive image film; develop stencil; adhere stencil to screen; dry screen; remove backing film. Positive image films have been generated photographically, which involves an imagesetter and a film processor. Recently, digital printing technologies have been developed to print the image directly on transparent film from digital files. The printing methods currently used are inkjet printing and thermal printing. Printing methods increase efficiency and eliminate photographic materials, but they might have quality issues.

There are three main categories of computer-to-screen (CTS) technologies: inkjet, digital micro mirror devices (DMD), and violet-blue diode laser (Coudray, 2005a). Inkjet systems use inkjet print heads to spray opaque ink or thermal wax onto coated screen to create an image, which blocks UV light during emulsion exposure. Ink or wax is then removed to let the image area open. DMD systems utilize DMD chips that are primarily installed in LCD projectors. The mirrors can switch on or off to either reflect UV light from a conventional light source directly onto the non-image area or deflect it away from the image area. Violet-blue diode laser systems are designed primarily for the CD market. They utilize direct-to-screen laser exposure. They have the potential to be the highest print quality, but production speed is not fast due to the low power of violet-blue lasers. Compared to conventional film-based methods, CTS technologies increase efficiency and eliminate problems related with exposure and processing of film (Coudray, 2005b); however, the prices of CTS systems are still high and their reliability also needs to be improved (Coudray, 2005a and 2006).

Laser cutting has been used in industrial stencil applications such as foil stencils for printing circuit boards, decorative lettering stencil applications for wall decoration and sign making, and graphic stencil applications such as craft stencils and airbrush stencils (Stencils Online, 2010).The laser cutting process produces stencils directly from digital data with no intermediate steps such as light exposure, thus size and positioning are very accurate.

The objectives of this study were to laser cut stencils for process screen printing and compare them with those produced using film-based photographic methods in which photographic and inkjet-printed films were both used.

Experiment

A single color test form as shown in Figure 1 was created for stencil making. It contains types of 4 to 30 points, lines of 0.25 to 10 points thick, vector and raster images, solid area, and tint areas.

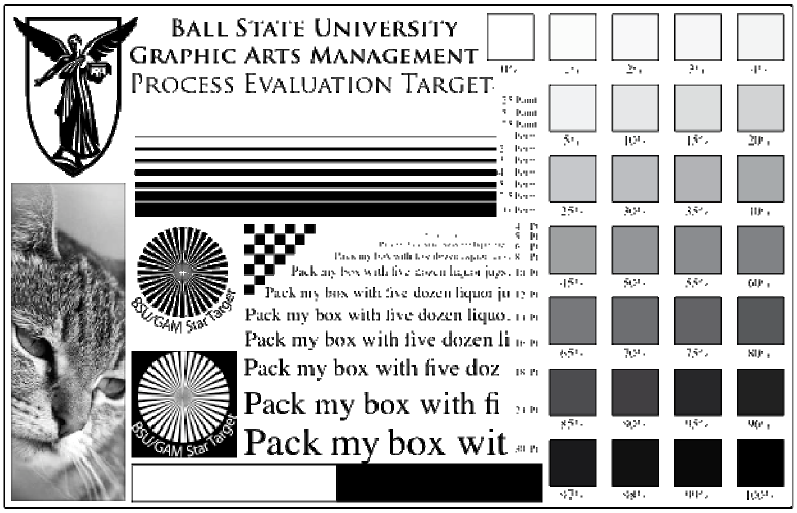


__Figure 1.__ Test form containing type, lines, images, and tints.

Aluminum frames and Sefar mono polyester fabric of 280/inch mesh count were used for all the screens. In direct photographic methods, photographic liquid emulsion from Ulano was applied onto both sides of the screen fabric manually using a scoop coater. Positive image films of the test form were photographically created and also inkjet printed. The halftone screen setting was 75-lpi screen frequency, 45° angle, and ellipse dot shape. A Linotronic 330 imagesetter and a Fujifilm FG 550E film processor were used for the photographic method. An Epson Stylus® Photo R1900 printer was used for the inkjet printing method along with AccuFast® film and AccuRIP® software version 1.01 from Fawkes Engineering. Heavy, medium, and light ink droplet size were all tested, but heavy ink droplet size was not used further because the ink layer was too thick and drying was very slow. Transmission densities of photographic and inkjet-printed films were measured with a Gretag D 200-II densitometer. Both films were placed on a coated screen and exposed for 240 seconds using a 40-1K Mercury Exposure System from nuArc Company. Exposed non-image area was hardened and unexposed image area was washed away.

Laser cutting was also used to make stencils out of water-soluble knife-cut stencil film from Ulano which has an emulsion layer coated on transparent backing polyester film. ACO_2 laser cutter Model M-35 from Universal Laser Systems removed the emulsion on the image area by means of evaporation. The resolutions on both directions were set at 1,000 per inch. Laser power and cutting speed were varied to find an ideal combination so that the laser beam cut all the way through the top emulsion layer but only a little of the backing film. The combination was found to be 20% power and 100% speed. After the stencil was laser cut, it was moistened with water and attached to the print side of a degreased screen. The backing film was removed after the screen was completely dry.

Stencil thicknesses, or emulsion on mesh (EOM), for all the screen stencils were measured using a Mitutoyo Micrometer. Surface roughness, Rz, was measured using a MitutoyoSurftest 211 Surface Roughness Tester. A Hitachi Tabletop MicroscopeModel TM-1000 was used to take images of lines, 25% tint areas, and 50% tint areas at various magnifications.

Results and Discussion

In film-based photographic methods, image quality of film is very important because stencils can never be better than the artwork used to generate them (Balfour, 2007, and Marsden, 2009). Film transparency and high transmission density on solid area ensures good light exposure. The film should have sufficient density (a high D_{max}) to block light from the image area, sufficient clarity (a lowD_{min}) to transmit light onto non-image area, and sharp edge definition (acutance) between the two.A D_{max} of 4.0 is ideal and D_{min} should be close to zero.

The maximum and minimum transmission densities of photographic and inkjet-printed films were listed in Table 1. The films used for inkjet printing have a high D_{min}, which means they are translucent, but not transparent. Photographic films have a lower D_{min} than inkjet-printed films. The D_{max} of inkjet-printed films depends on the setting of ink droplet size. With light ink droplet size, a D_{max} of only 1.27 was achieved, while 6.0 with medium ink droplet size. Therefore, medium ink droplet size was used to print image for screen exposure.

Table 1. *Transmission Densities of Photographic and Inkjet-Printed Films.*

	Photographic Films	Inkjet-Printed Films	
		Medium Ink Droplet Size	Light Ink Droplet Size
D_{min}	0.3	0.7	
D_{max}	5.1	6.0	1.27

Although solid density of inkjet-printed films can achieve higher than that of photographic films, the dot gains are much higher, as seen in Figure 2 and Figure 3. The tint areas and halftone image of cat on the inkjet-printed film appear much darker and dot gain is almost 50% in mid-tone. Although the film has a coating layer specially designed for inkjet printing, inkjet inks are fluid inks, so they spread on film surface, which causes dot gain. Excess dot gain of the film will cause dot gain on stencil, and eventually dot gain on printed image. Dot gains remain within 10% for photographic films.

Figure 2. *Comparison of photographic (left) and inkjet-printed (right) films.*

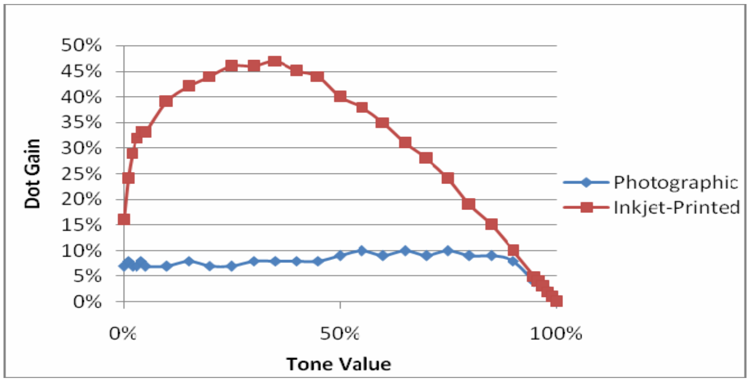


Figure 3. *Dot gain curves of photographic and inkjet-printed films.*

Image on photographic films have sharp image-non-image edge definition, as shown in Figure 4, while streaks in one direction can be observed on inkjet-printed films, which is probably due to the moving print heads. If the non-image area lacks clarity, the non-image area of the stencil will not be exposed correctly and hardened enough so might be removed during development.

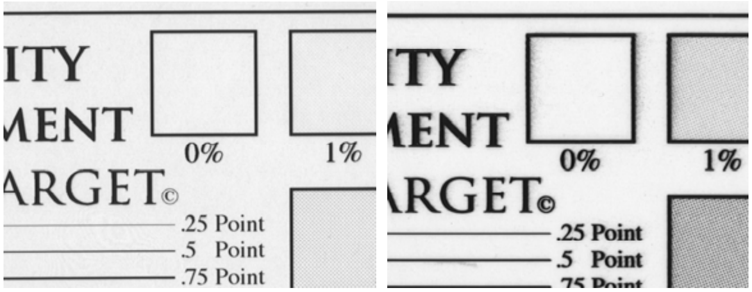


Figure 4. *Details of photographic (left) and inkjet-printed (right) films.*

A laser-cut stencil film is shown in Figure 5. The emulsion on image area evaporated due to heat generated by the laser beam, while the emulsion on non-image area remained on the backing film.

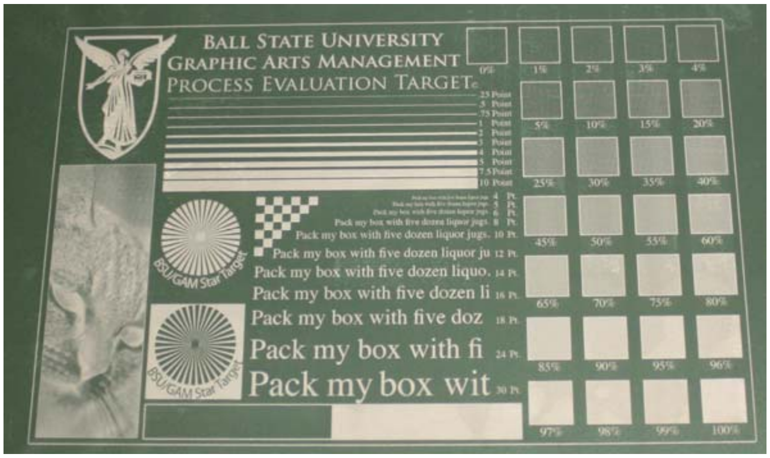


Figure 5. *A laser-cut stencil film.*

Photographic and inkjet-printed films were used to expose coated screens which were then washed to finalize the stencilmaking. The laser-cut stencil films were moistened and attached to a degreased screen. The backing film was removed after the screen was completely dry.The procedures of these different methods were compared in Table 2.

Table 2. *Procedures for Screenmaking.*

Photographic Methods		Laser Cutting Methods
Photographic Film	Inkjet-Printed Film	
Image film Process film Apply emulsion to screen Dry screen Expose screen Develop screen Dry screen	Print film Apply emulsion to screen Dry screen Expose screen Develop screen Dry screen	Laser cut stencil film Attach stencil to screen Dry screen Remove backing film

Laser cutting methods have fewer steps and stencils are created directly from digital files. However, there were difficulties during the process of attaching a laser-cut stencil film to a screen, which didn’t occur when using a knife to cut out shapes and then attaching the knife-cut stencil to a screen. The emulsion on laser-cut stencil film didn't adhere well to screen mesh, especially on the image-non-image edges. In order to find out possible reasons, a microscope image was taken, as shown in Figure 6. The emulsion layer has a smooth surface, while voids were formed on the backing film as a result of heat during laser cutting. It seems that the emulsion and the backing polyester film melted and blended together on the image-non-image edge. The emulsion is water-soluble, but polyester is not; therefore, blending of the emulsion and polyester probably made it difficult for the emulsion to adhere to screen mesh after moistened and be separated from the backing film after it dried.

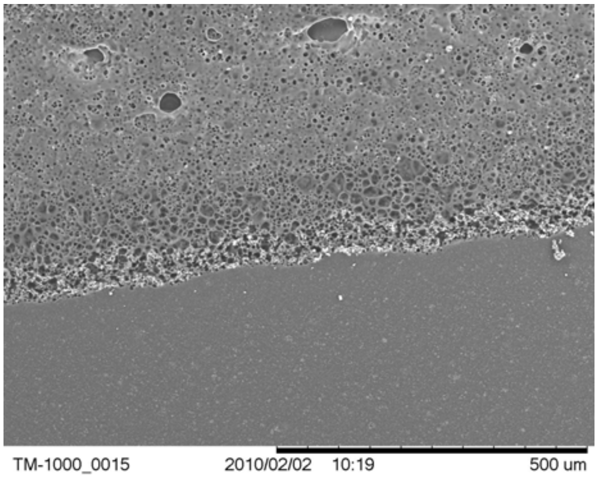
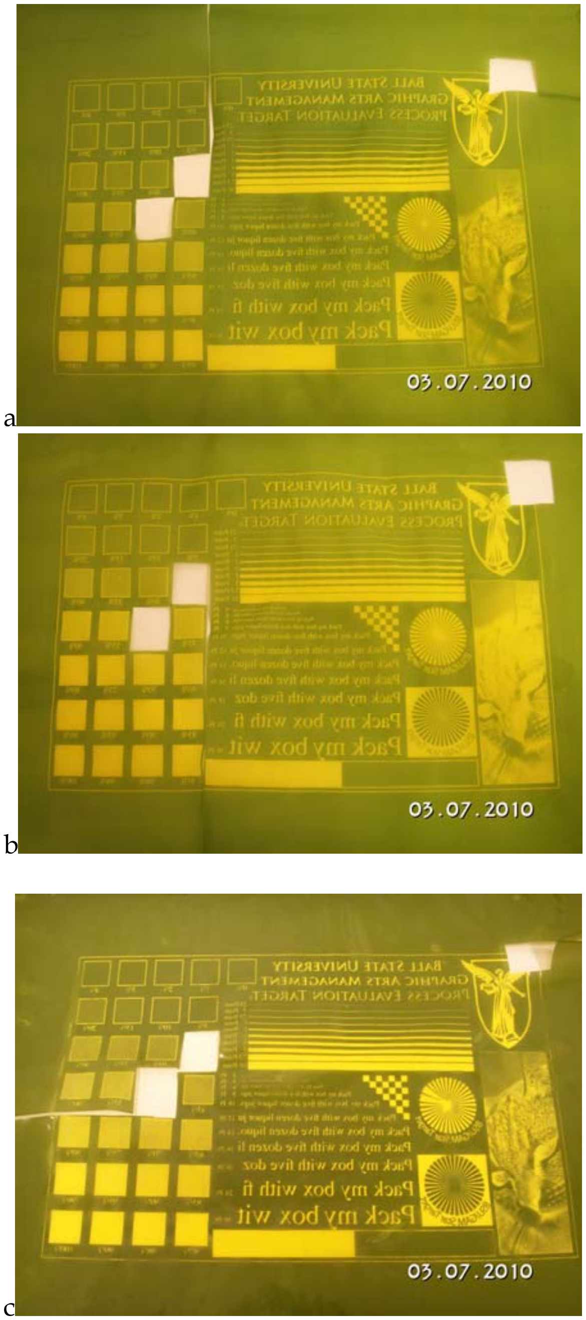


Figure 6. *Microscope image of a laser-cut stencil film.*

Three screens with three different stencils are shown in Figure 7. The first thing to be noticed is that the image on the photographic stencil exposed with inkjet-printed film has big dot gain when compared with the other two. Print quality is determined by stencil quality, which depends on the original artwork quality. If the artwork is compromised, the stencil will be, too.

The image quality of the laser-cut stencil is not as good as before it was attached to the screen. During the attaching process, it was difficult to control the amount of water needed to moisten stencil film and also the uniformity of applying water. Too little water will not allow emulsion to adhere to screen fabric, but too much water will dissolve emulsion on non-image area and cause it to flow onto image area. As shown in Figure 7c, bad emulsion adhesion is seen on the star target and emulsion flowing happened on the most left line.



- a Photographic stencil exposed with photographic film
- b Photographic stencil exposed with inkjet-printed film
- c Laser-cut stencil

Figure 7. *Comparison of three screens with different stencils.*

Image quality of the stencils was further evaluated using microscope images in Figure 8–13. The photographic stencil exposed with photographic film has good image quality with straight lines, uniform halftone dots, and sharp edge definition. The photographic stencil exposed with inkjet-printed film lacks sharp edge definition due to ink streaking happened during inkjet printing as shown in Figure 4. Dot gain can be clearly observed in Figure12, where the image area is much bigger than 50%. On the contrary, dot loss is found for the laser-cut stencil, where the image area is a little smaller than 50%. It is because water dissolved emulsion and it flowed to image area when the stencil was moistened and attached to a screen. That is also the reason why the edge is saw-toothed and the halftone dots have nonuniform sizes and shapes. However, dot gain usually happens during screen printing. It will be interesting to see if that will compensate dot loss of laser-cut stencils.

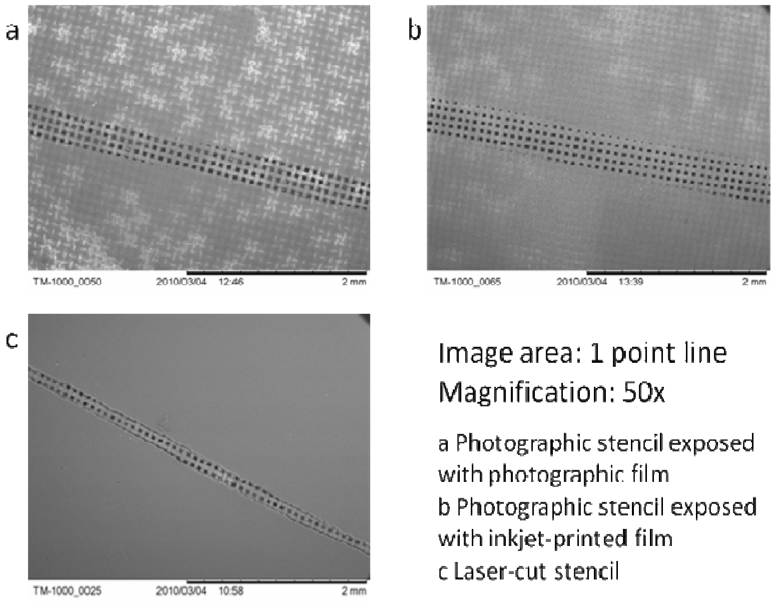


Figure 8. *Microscope images of the 1-point line at 50X magnification.*

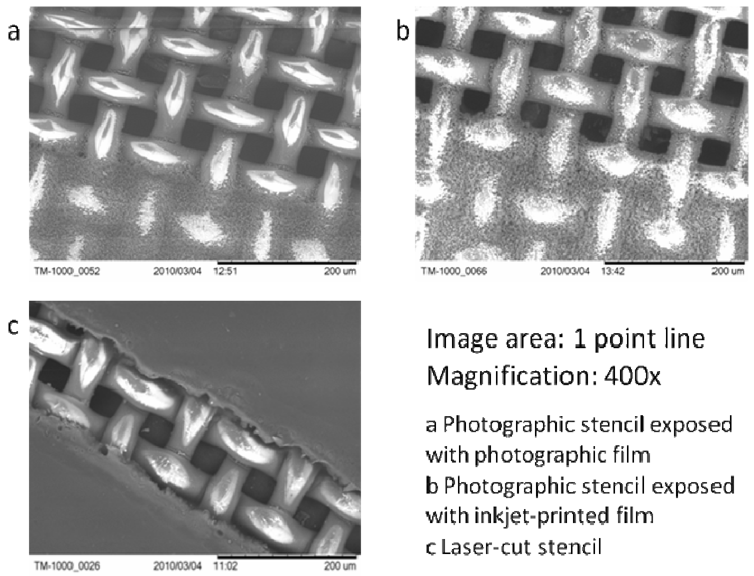


Figure 9. *Microscope images of the 1-point line at 400X magnification.*

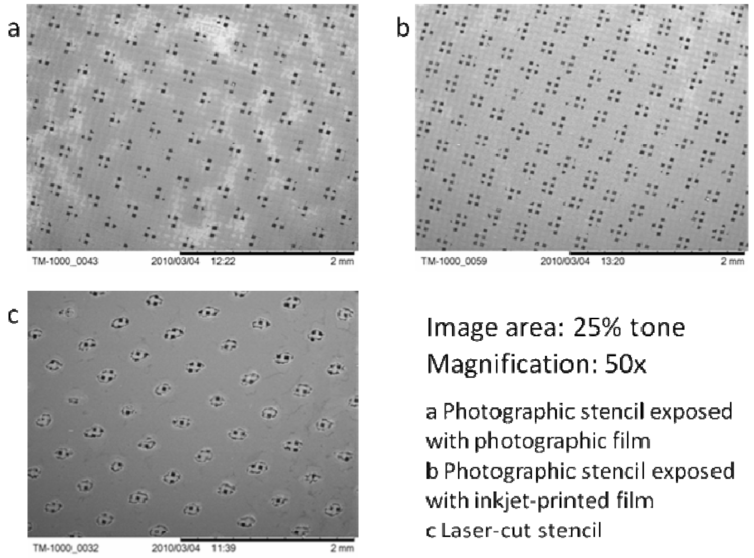


Figure 10. *Microscope images of the 25% tone area at 50X magnification.*

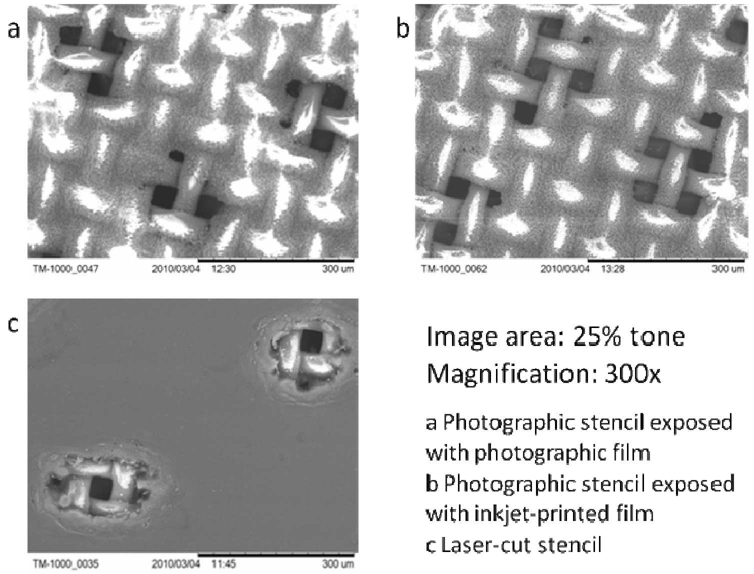


Image area: 25% tone
Magnification: 300x

a Photographic stencil exposed with photographic film
b Photographic stencil exposed with inkjet-printed film
c Laser-cut stencil

Figure 11. *Microscope images of the 25% tone area at 300X magnification.*

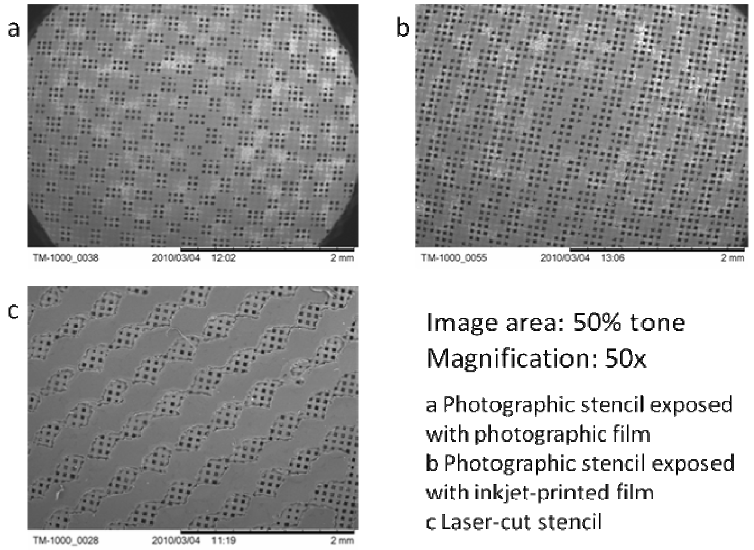


Image area: 50% tone
Magnification: 50x

a Photographic stencil exposed with photographic film
b Photographic stencil exposed with inkjet-printed film
c Laser-cut stencil

Figure 12. *Microscope images of the 50% tone area at 50X magnification.*

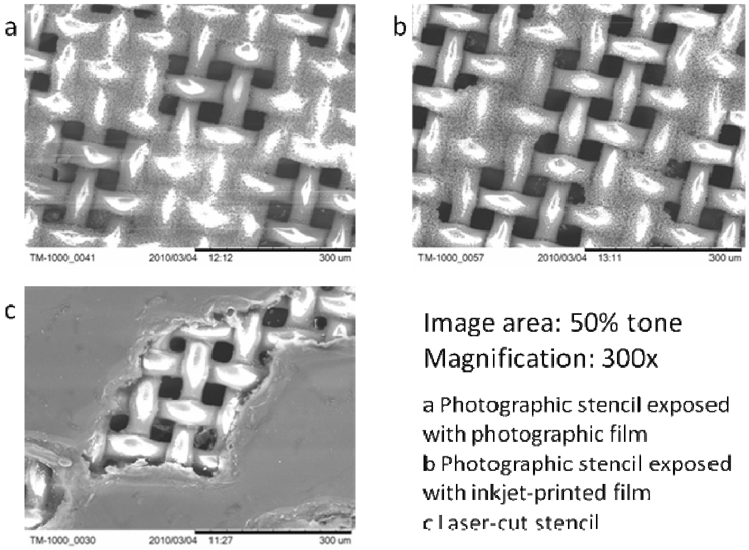


Figure 13. *Microscope images of the 50% tone area at 300X magnification.*

There are two stencil properties that influence print quality and ink deposit: surface roughness (Rz value) and stencil thickness (EOM) (Balfour, 2007, Dennings, 2006a, and Marsden, 2009). Rz affects a print's edge definition, and for high-quality printing, a value close to 5 microns is necessary. Stencil thickness regulates ink deposit. If the stencil is too thick, high-resolution details may not print at all. EOM should not exceed 10% of total mesh thickness for high-resolution line or halftone artwork. Measured Rzand EOM values of photographic and laser cut stencils are listed in Table 3.

Table 3. Stencil Properties of Photographic and Laser-Cut Stencils

	Surface Roughness, Rz μm	Stencil Thickness, EOM μm
Photographic Stencils	18.67	1.57
Laser-cut Stencils	0.38	11.18
Note: mesh thickness = 24 μm		

The emulsion for photographic stencils was coated on screens manually, so stencil surface is very rough, evidenced by a high Rz value of 18.67 microns. However, EOM can be varied when using manual coating methods. The EOM of photographic stencils is within 10% of total mesh thickness (25.57 μm). Laser-cut stencils are exactly opposite to photographic ones. Their surface is very smooth with a very low Rz value because stencil film was used. However, the thickness of emulsion layer is almost one third of total mesh thickness (35.18 μm).

Conclusions

The advantages and disadvantages of the three different stencilmaking methods used in this study are compared in Table 4. Photographic methods using photographic films are not environmentally friendly, but they can achieve high quality and are good for high-resolution line or halftone artwork. Methods of inkjet printing films and laser cutting stencils are environmentally friendly, but they have quality issues and are limited to general printing applications not involving fine lines or halftones until those issues are solved.

Table 4. *Comparison of Advantages and Disadvantages.*

		Advantages	Disadvantages
Direct Photographic Methods	Photographic Films	High quality Variable stencil thickness	Chemicals for film processing Rough stencil surface
	Inkjet-Printed Films	Elimination of film exposure and processing Variable stencil thickness	Film translucency Dot Gain Rough stencil surface
Laser Cutting Methods		Increased efficiency Elimination of film Smooth stencil surface	Adhering problem Emulsion flowing High stencil thickness

Next step of this study will be using the screens with photographic and laser-cut stencils for process screen printing and compare their print quality.

Acknowledgments

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Literature Cited

Adams, J.M. and P.A. Dolin. 2002. *Printing Technology* (Delmar, Albany, NY), 5th ed., pp. 302–311.

Balfour, R. 2007. "In Pursuit of the Perfect Stencil," *Screen Printing,* October, pp. 82–88.

Courdray, M. 2005a. "Computer to Screen Update," *Screen Printing,* July, pp. 22–25.

———. 2005b. "Advantages of the Computer-to-Screen Workflow," *Screen Printing,* November, pp. 20–22.

———. 2006. "The Realities of Implementing Computer-to-Screen Imaging," *Screen Printing,* August, pp. 36–39.

Dennings, D. 2006a. "Standardization in Screenmaking, Part 1," *Screen Printing,* January, pp. 42–47.

———. 2006b. "Standardization in Screenmaking, Part 2," *Screen Printing,* February, pp. 34–40.

Marsden, D. 2009. "Standardizing Stencil Production," *Screen Printing,* December, pp. 22–25.

Stencils Online. 2010. Available from http://www.stencilsonline.com/. Accessed on January 18, 2010.