Flexographic Platemaking Using Rapid Prototyping Technologies

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Abstract: Flexographic plates are commonly made from photopolymer material by photographic process, which involves film. Digital platemaking technologies have been developed due to rapid growth of flexographic printing and some have involved the use of rapid prototyping (RP) technologies. There are two types of RP, additive and subtractive. Additive technologies, such as 3D printing (3DP), fused deposition modeling (FDM), stereolithography (SLA), selective laser sintering (SLS), build a model by successive addition and cohesion of horizontal cross-sections. Therefore, they can be used to build a plate directly, or build a matrix which is filled with liquid photopolymer and exposed to make a plate. Subtractive technologies, such as computer numerical control (CNC) machining, laser machining, work by removing part of the model. Therefore, they can be used to remove the non-printing areas of a plate. In this study, three RP technologies were applied in flexographic platemaking. A 3D printer was used to build matrices with powder, which were then infiltrated in five different ways to improve durability and surface finish. The matrices infiltrated by wax and low viscosity cyanoacrylate had better release properties. The plates made from a wax-infiltrated matrix had best surface finish. An FDM machine was also used to make matrices by extruding acrylonitrile-butadiene-styrene (ABS) plastic. The matrices were filled with liquid photopolymer and exposed by UV light to make plates. A laser engraver was used to make plates from cured sheet photopolymer by removing the non-printing areas. A plate was also made from sheet photopolymer through photographic process. The minimum line width was 0.0055" for the laser engraved plates, 0.007" for the plate made through photographic process, 0.01" for the plates made with the matrices built on the FDM machine, and 0.02" for the plates made with the matrices built on the 3D printer and infiltrated by wax and low-viscosity cyanoacrylate. All the plates were printed on a flexographic press. The print quality of the laser engraved plates and the plate made through photographic process is better than that of the plates made with the matrices. The results indicate 3DP and FDM should be limited to producing flexographic matrices where fine detail is not needed, whereas direct laser engraving of a plate may result in fine detail.

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Introduction

Flexographic plates are commonly made from photopolymer material by photographic process, in which a photopolymer layer is exposed by ultraviolet (UV) light through a film negative that is transparent in printing areas and opaque in the non-printing areas. Removing unexposed photopolymer results in a plate with a relief image. However, photographic materials based on silver halide chemistry are costly and bring environmental issues because they require wet processing involving chemical solutions. Film quality as well as the contact between film and photopolymer during exposure also affects plate quality, such as distortion, loss of sharpness, dot gain, etc.

Digital platemaking technologies have been developed due to the rapid growth of flexographic printing. The prepress operations from imaging, stripping, and cleaning, to retouching, storing film, and proofs are minimized into a one-step process (Bolan, 2001). Other benefits of direct-to-plate (DTP) technology includes less distortion, better registration, finer dots, and higher line screens (Dahbura, 2004). Some digital technologies use laser-imageable plates. Their differences are in the way the imaging process is done. One type of laser-imageable photopolymer plates have an infrared (IR) absorbing (for example, carbon black) top layer which can be ablated by IR laser. Photopolymer without a carbon black layer is cured with UV exposure and unexposed photopolymer is washed off (Kanga, 2002). In another type of laser-imageable plates, a thin film doped with a UV absorber is laminated to a photopolymer layer. The film is ablated by a laser to create an *in situ* negative (Yang, et al., 2005). Another digital technology is direct laser engraving, in which a printing relief is engraved directly by means of a laser. It was used to make rubber plates first, and there are different types of plate-medium available now (O'Brien, 1988, Roddy, 1996, and Parr, 2006). Inkjet printing technology has also been used in flexographic platemaking in different ways. One method is to use an UV-absorbing ink to print the image, which is used as the exposure mask (De Voeght, et al., 2006). Another method is to digitally build up a plate by ink jetting UV-curable fluid onto a substrate via an offset blanket and forming the plates by successively polymerizing the ink jet fluid (Figov and Dvoretzki, 2006).

The use of rapid prototyping (RP) technologies to make flexographic plates has also been studied (McLean, et al., 2004 and Lozo, et al., 2007). RP refers to a class of technologies for quickly producing initial physical models, typically based on digital data. The primary advantage for industry is reduced time-to-market for a new product. Designers can quickly create three-dimensional (3D) tangible prototypes of their designs, rather than just two-dimensional (2D) pictures, which provide excellent visual aids for communicating ideas with co-workers or customers. Prototypes can also be used for design testing and RP allows them to be made faster and less expensively. There are two types of RP approaches common in the industry, subtractive and additive. Subtractive technologies, such as computer numerical control (CNC) machining, work by removing part of the model. However, objects with complicated internal features cannot be manufactured by subtractive means, so additive technologies are more capable in those applications.

Additive processes typically build a model by successive addition and cohesion of horizontal layers, creating a solid object from the bottom up rather than machining it from the outside. Among the more common additive RP technologies are stereolithography (SLA for stereolithography apparatus), selective laser sintering (SLS), 3D printing (3DP), and fused deposition modeling (FDM). Their main differences are in the way layers are built to create models. SLA utilizes a vat of liquid photopolymer that solidifies when exposed to UV light. On each layer, a UV laser beam traces a cross-section pattern on the surface of the liquid photopolymer, which solidifies and coheres to the layer below. SLS uses a high power laser to selectively fuse small particles of plastic, metal, or ceramic powders into a solid object. 3DP is actually an application of inkjet printing technology, where an inkjet printhead is used to deposit a layer of material. In some 3D printers, layers of a fine powder are selectively bonded by "printing" a binder from the inkjet printhead in the shape of each cross-section pattern. The binder can be clear or colored, so this technology allows for the printing of full color prototypes. The finished model can be infiltrated to improve durability and surface finish. Typical infiltrants include cyanoacrylate, epoxy, wax, and for a certain formulation of powder, water. Alternately, some 3D printers feed liquids, such as photopolymer, through an inkjet printhead to form each layer of the model. An UV lamp is mounted in the printhead to cure each layer as it is deposited. 3D printers are generally faster, more affordable and easier to use than other additive RP technologies. The FDM machine employs an extrusion nozzle that moves in the x-y plane. The nozzle is heated to melt thermoplastic filaments and deposit the material onto a build platform to form a layer. The platform then moves down, and the next layer is built. (Palm, 2002)

In addition to these 3D RP technologies, a variety of technologies are used where only a 2D geometry is required, as with laser machining. A carbon dioxide laser cutter/engraver works by generating a laser beam through the excitation of CO_2 gas. The laser light that is emitted is coherent, monochromatic, and projects in a nearly parallel beam, giving it little power loss over distance. The machine uses mirrors to reflect this beam to a lens, which focuses the beam on the workpiece. Different materials are laser cut or engraved by different mechanisms: some melt and vaporize, some burn, and others de-polymerize to some extent.

Each RP technology has limitations which inhibit its use depending on the contexts. If a working model is required, the technology must support the functional parameters of the part. So a wax-based model of heat-resistant part serves only as a concept model or an industrial design prototype to demonstrate look and feel of a product, rather than as the first example of a functioning part. Furthermore, with some RP technologies, material cost can be rather high. However, RP technologies are now common in many industries, including manufacturing, human health products, and education. In an educational environment, RP technologies may serve to empower novice users without the need for advanced mechanical skills. RP also facilitates design and problem-solving education, and allows for rather quick testing of several design alternatives. Because RP technologies are being increasingly used in non-prototyping applications, they are often collectively referred to as solid freeform fabrication, computer automated manufacturing, or layered manufacturing.

The name *flexography* indicates that flexographic plates are elastic, with Shore A durometer hardness in range of 20-80. Subtractive RP technologies can make a plate by removing the non-printing areas. Some additive RP technologies, such as SLA and 3D printers using UV-curable liquids, can build the plate directly (McLean, et al., 2004). However, those technologies that do not use elastic materials can build a matrix, into which liquid photopolymer is poured to create a relief plate when it hardens under UV exposure (Lozo, et al., 2007).

In this study, the research plan was to: 1) build matrices using 3DP and FDM technologies and make plates by exposing matrices filled with liquid photopolymer; 2) laser engrave plates directly; 3) make a plate using photographic process for comparison; 4) test the plates on a flexographic press.

Experimental

3DP and FDM

3DP and FDM machines use 3D files, unlike the 2D files used for laser engraving and photographic process. That is, in order to have a raised circle on the plate, a 3D cylinder needs to be subtracted from the rectangular prism of the matrix, leaving a cylindrical indentation into which the liquid photopolymer is poured.

A right-reading test form was designed to create matrices, which was then transformed into a 3D object file by subtracting 3D geometries from a rectangular prism, as shown in Figure 1. This was designed to produce a matrix for a 0.067” thick plate with a relief height of 0.023”. The 3D object was reduced by 93.77% in length to account for distortion for a 50-tooth flexographic plate cylinder, with the resulting matrix to produce a plate measuring 3.8” wide and 5.9” long. The layout contained isolated lines at 0, 45, and 90 degrees, with line thickness ranging from 0.01” to 0.10” by steps of 0.01”. Text with thin and thick strokes was also included with text heights ranging from 0.05” to 0.40” in increments of 0.05”.

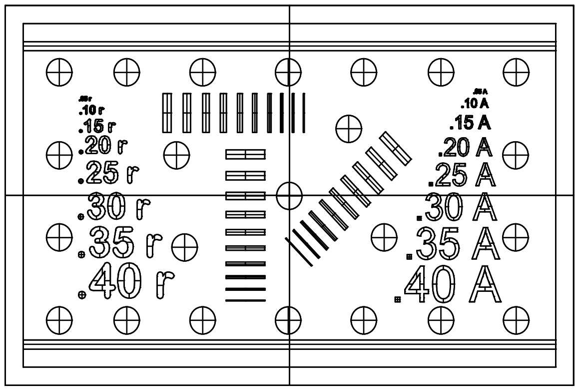

Figure 1. Top view of the 3D object file for the matrix.

Matrices were created using the Spectrum Z®510 3D Printer from Z Corporation with their zp®140 powder and zb®60 clear binder. The layer thickness was 0.004" in the z axis. The resolution in the x-y plane was 600 x 540 dpi. Better quality was observed when the matrix was built face down, opposite the orientation used to pour liquid photopolymer into the matrix.

Several matrices were built and infiltrated with different materials to compare surface finish. These included

1. spraying with water;
2. spraying with a clear fast dry Spray Paint from Wal Mart, which contains aliphatic hydrocarbons, ketones, and toluene;
3. dribbling of ZBond 101 from Z Corp, which is cyanoacrylate with a medium viscosity;
4. dribbling of NHP316 cyanoacrylate from NHP Co., which has a much lower viscosity;
5. dipping in Paraplast X-TRA paraffin wax from Z Corp, which has low viscosity and a melting point of 122°F/50°C.

Matrices were also created using the Stratasys 1650 FDM with P500 ABSi model material (a translucent acrylonitrile butadiene styrene). The nozzle temperature was 260°F. The layer thickness was 0.010", and there were 48 strands per linear inch laid down to construct the matrices. Mold release spray was used to improve the release properties.

Two types of liquid photopolymer, CHLF180SP Clear (Shore A durometer hardness of 80 when cured) and CHFlexstamp (Shore A durometer hardness of 40/50 when cured), from Verbatim were poured into the matrices. A polymeric film with 0.005" thickness was laid on the top and a rod was used to roll the liquid into the matrix in an attempt to achieve uniform plate thickness. Matrices filled with liquid photopolymer were exposed in the exposure apparatus of an Anderson & Vreeland Stack Water Flexo System for 6 minutes. Cured polymer plates were then peeled away from the matrices, where possible, trimmed, and immersed in a 1-2% solution of post-exposure salt during a 6-minute post-exposure to remove tackiness.

Laser Engraving

A reverse-reading negative test form was created to laser engrave a plate directly, as shown in Figure 2. The layout contained lines at 0, 45, and 90 degrees, with line thickness ranging from 0.1 to 1 point in increments of 0.1 point, and then to 4 point in increments of 0.5 point. Text was also included with text sizes ranging from 2 to 14 point.

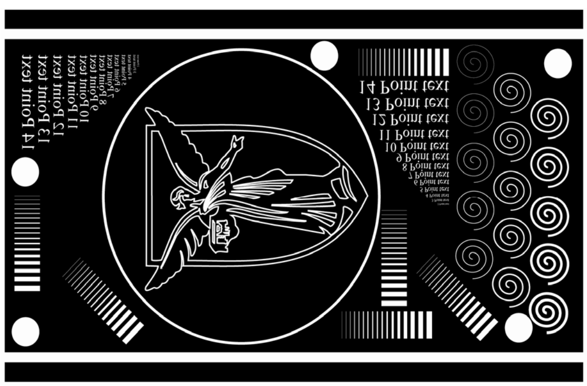

Figure 2. Test form for laser engraving.

Cosmolight® CLH170F sheet photopolymer from Toyobo was used for laser engraving. The plate thickness was 0.067” and it was cured in the exposure apparatus of an Anderson & Vreeland Stack Water Flexo System for 6 minutes prior to engraving. The image was engraved using an M-35 Laser Engraving and Cutting System from Universal Laser Systems Inc., which was upgraded to a 45 watt CO_2 laser and had a measured power output of 40.2 watts. A 1.5” focal length lens was used, producing a 0.003” diameter circular beam. The engraving process was done using the following settings: 100% power, 25% speed (full speed is 45 inches per second), 500 pulses per inch (x-axis), 500 lines per inch (y-axis), and the “Rubber Stamp Wide” raster engraving mode, creating a stepped shoulder. After engraving, the plates were washed with warm water.

Photographic Process

A plate was made through photographic process for comparison purpose. The right-reading positive version of the test form in Figure 2 was used to make negative film with screen ruling of 133 lpi. The same sheet photopolymer and exposure equipment were used. Back exposure time was 25 seconds, face exposure 6 minutes, washout 18 minutes, drying 20 minutes, post-exposure 6 minutes, and anti-tack exposure 4 minutes.

Printing

All the plates were printed on a Mark Andy 830-7c flexographic press, which is a narrow web press. Water-based black ink from Werneke Ink and a coated paper stock were used.

Results and Discussion

One of the matrices built by the 3D printer is shown in Figure 3. It is apparent that indentations with fine details is not as deep as the rest, which means that plates made from this matrix will have lower relief heights for those fine details.

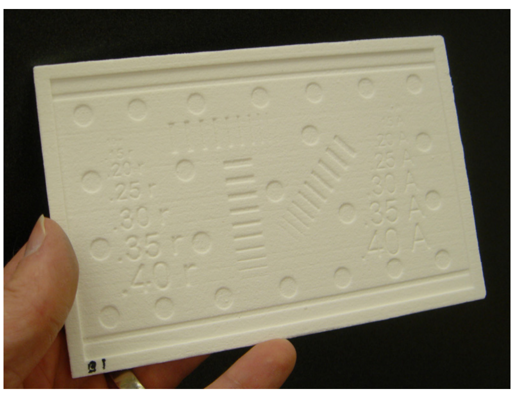

Figure 3. A matrix built by the 3D printer.

Among the five different infiltrants, water and paint spray were the easiest to apply, but the finished matrices had a very rough surface. After they were filled with liquid photopolymer and exposed, the plate could not be peeled away from the matrices. Liquid photopolymer actually infiltrated the matrices because the surface was still porous. The matrices infiltrated by ZBond 101, which is cyanoacrylate with a medium viscosity, had a smoother surface. However, small amount of it sometimes stayed inside the indentations and changed the dimensions. The matrices infiltrated by low-viscosity cyanoacrylate also had smooth surface and its low viscosity prevented the problem caused by ZBond 101 from happening. Wax-finished matrices had the smoothest surface and no dimensional changes were noticed. The matrices infiltrated by cyanoacrylate and wax had good release properties and the plates could be easily peeled out.

One of the matrices built by the FDM machine is shown in Figure 4. It does not have the depth problem as the matrix built by the 3D printer. However, it has a grooved surface because it is made up of strands of ABS, so the plate made from this matrix also has grooved surface. The mold release spray was too thin to smooth the surface. Other methods of surface treating need to be investigated.

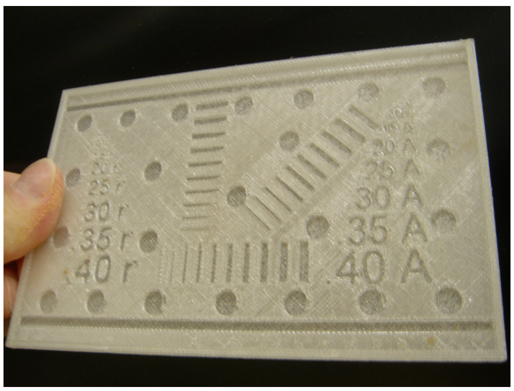

Figure 4. A matrix built by the FDM machine.

A plate made by direct laser engraving is shown in Figure 5. The surface of the raised image areas is very smooth because they were not touched by the laser beam during engraving. However, some of the very fine details like 0.0014” wide lines did not show because the diameter of the laser beam was 0.003”.

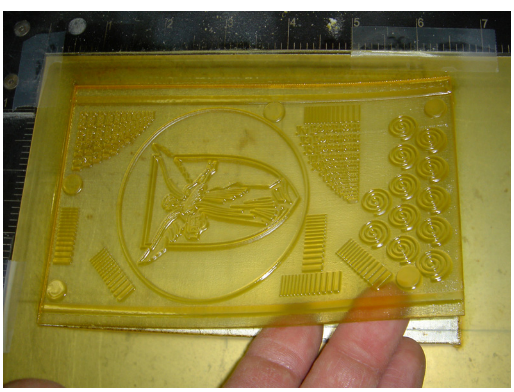

Figure 5. A laser engraved plate.

All the plates were compared by the minimum isolated line width, which was 0.0055” for the laser engraved plates, 0.007” for the plate made through photographic process, 0.01” for the plates made with the matrices built on the FDM machine, and 0.02” for the plates made with the matrices built on the 3D printer and infiltrated by wax and low-viscosity cyanoacrylate. The print quality of the laser engraved plates and the plate made through photographic process is very close, and better than that of the plates made with the matrices because of their better surface smoothness, as shown in Figure 6. Some fine details are missing on the printouts using the plates made with matrices because of too low relief heights on these locations.

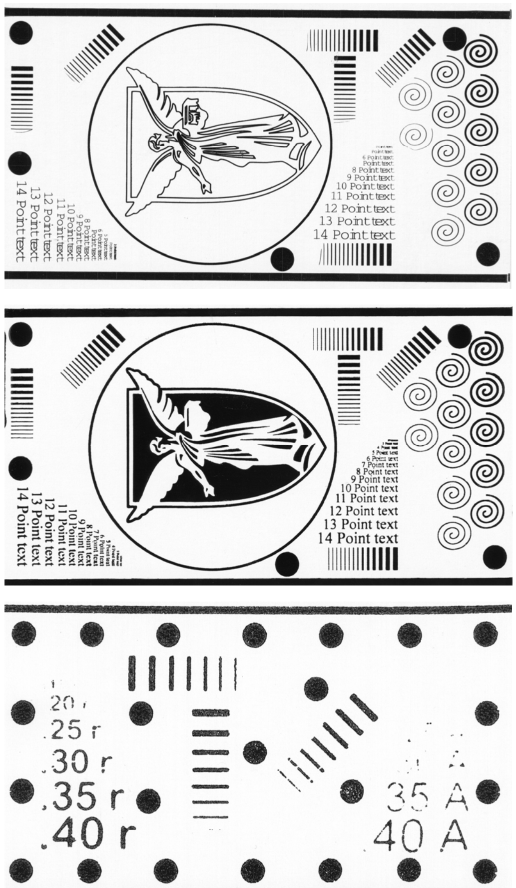

Figure 6. Printed images using the plate made through photographic process (top), the laser engraved plate (middle), the plate made with the 3DP wax-infiltrated matrix and CHLF180SP liquid photopolymer (bottom).

Conclusions

RP technologies were able to be applied in flexographic platemaking. 3DP and FDM, two additive RP technologies, were able to create matrices which were then filled with liquid photopolymer and exposed by UV light to make plates. Laser engraving, a subtractive RP technology, was able to make plates directly by removing the non-printing areas. The results indicate 3DP and FDM should be limited to producing flexographic matrices where fine details are not needed, whereas direct laser engraving of a plate may result in fine details.

Further study will be done to improve the surface quality of the matrices built by 3DP and FDM. Other additive RP technologies need to be investigated in order to find a way to build the plates directly.

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