A STUDY OF PRINTING PLATE MOULD DEVELOPMENT BY USING 3D PRINTERS FOR MICRO-FLEXOGRAPHIC PRINTING PROCESS

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ABSTRACT: Micro-flexographic is a new printing technique that has been implemented by combining flexographic printing and micro-contact printing technique. Flexographic printing is generally a high-speed production in roll to roll printing technique widely used in the graphic printing industry. Micro-contact printing technique is usually employed to produce fine solid line structures in micro to nano scale. Mould preparation for printing plate is also one of the vital parameters in micro to nano scale image printing. A precise mould could be used to produce the most accurate printing plate for micro-flexographic printing. The three dimension (3D) printer has the capability of producing fine solid lines below 100 μm in width and gap on master mould for the printing industry. This research elaborated the use of various 3D printers to produce a master mould for micro-flexographic printing. This paper investigated the capability of multiple 3D printers in creating micro to nano fine solid lines in the master mould for future development and application of printing in the electronic, graphic and bio-medical field.

KEYWORDS: *Micro-Flexographic, Printing Process, Micro-Contact*

1.0 INTRODUCTION

Printing could be defined as a process of reproducing text structures and images by using a master form or mould. In the printing industry, there are two types of technology which are conventional and digital technology. The traditional model of printing mainly consists of flexographic, screen printing, offset and gravure by which the image is transferred to the substrate [1]. On the other hand, the digital printing method does not require printing plates. Digital printing is operated by an image that is sent directly to the printer and used options such as toner or liquid ink [2]. This process is mostly used to print on paper, cardboard, plastic or other substrates. Each of the printing process has particular benefits, depending on applications and purposes.

Flexographic printing is a popular printing method used to create graphic and electronic device on various substrates such as thin films and foils by using conductive ink, and it could produce fine solid line image. This printing method is commonly used in the paper printing industry where it uses flexible photopolymer [3] printing plate wrapped around rotating cylinders on web press in order to transfer ink from plate to the targeted substrate. The applications of flexographic printing are mostly in electrical and electronic industries such as antenna, printed circuit board (PCB), automotive industry [4], biodiesel storage [5], thermal system [6] and Radio Frequency Identification (RIFD). It is also widely used in the food packaging industry and bio-medical industry.

Micro-contact printing is a low-cost printing method which is able to print in nano to micro. It is a process of transferring materials from an elastomeric stamp to substrate when both come to a conformal contact. The substrate can be a paper [7], polymer, fabric, thin film and others. Polydimethylsiloxane (PDMS) stamp is a replica mould used in the micro-contact printing process. It has many applications such as microelectronics, surface chemistry as well as cell biology and others [8].

In this era, radio frequency identification technology is rolling out into mainstream applications that help speed the handling of manufactured goods and materials. RFID (Radio Frequency Identification) has the capability of doing identification from a distance unlike earlier barcode technology, and it could do so without a line of sight. RFID tags support a larger set of unique IDs than bar codes, and could incorporate additional data such as manufacturer, product type, and even measure environmental factors such as temperature [9].

Moreover, RFID system could discern many different tags located in the same general area without human assistance. RFID Tag mainly has three parts, such as an antenna, a semi-conductor chip attached to the antenna, and some form of encapsulation. A micro-sized antenna is required to improve the radiation efficiency, to minimize transmission loss and cost [10]. The micro-sized antenna could be achieved through micro-flexographic printing machine which is able to print fine solid lines.

This study was conducted to solve the aforementioned problem, contributing to the progress and the improvement of RFID technology. As for the beginning step, a precise mould was needed to produce the pattern of miniaturized antenna. The mould could be produced by the latest three dimension (3D) printers at low cost [11]. Thus, the main purpose of this study is produce a master mould with solid fine lines that could be used for micro-flexographic printing.

2.0 METHODOLOGY

In methodology, the method of conducting experiments is discussed in detail. This section describes the suitable methodology to achieve the objective of this research which is the method of preparing low cost printing plate mould for micro-flexographic printing machine, and to produce fine line features below 100 micrometres on printing plate mould. Three-dimensional (3D) printing method was tested and fully utilized to conduct the title of the project to develop a mould for the printing plate. On the other hand, an optical microscope (OM) was used for the analysis of microstructure [12] and fine line features. The lowest fine lines on the printing plate mould was observed and evaluated. All the findings were recorded for analysis and future use.

Before preparing the master mould, the virtual design of the printing plate mould structure was developed. It was done by Solidworks software installed in computer at the Computer Aided Design (CAD) laboratory. The exact design from the initial sketch was transferred to Solidworks software. Mainly, two types of designs were drawn, which were spiral square design and straight line design. After the designs of the master mould were done, the master mould was produced by using 3D printer as and advanced technology in Additive Manufacturing [13].

In Solidworks software, typically, the building of a model started with a two dimensional (2D) sketch. The sketch consisted of geometries such as points, lines, arcs, conics and splines. Furthermore, the size and location of the geometries were defined by adding dimensions to the sketch [14]. Moreover, relations were used to define attributes, for example, tangency, perpendicularity, parallelism, and concentricity.

The first design was a square spiral shape with a 100 μm of width and gap. The gap between each line was 100 μm and the length of line increased by 1 mm in each spiral. The depth of each line was 100 μm. The size of the master mould was made to be 20 mm x 20 mm. The design of the square spiral mould was illustrated in Figure 1.

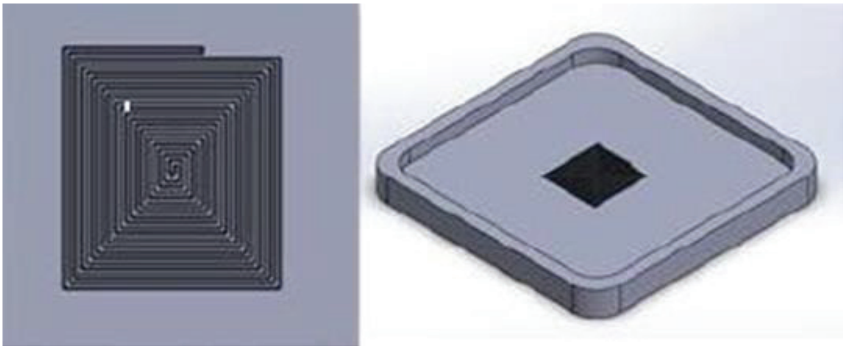


Figure 1: Spiral square design

The second design was straight line pattern of 100 μm, 110 μm and 120 μm for both lines' width and gap. The depth of each line was 100 μm, and the length was 10 mm. The size of the master mould was made to be 20 mm x 20 mm as shown in Figure 2.

Figure 2: Straight lines design

After the design was finalized, the master mould was prepared. The preparation of the master mould was done by using the three different types of 3D printers. The 3D printers used for the experimental process were Cubicon Single 3DP-110F, Raise Pro N2 plus and MyVista Cube 200.

According to the specifications of this Cubicon Single 3DP-110F, the printed object size was 240 mm x 190 mm x 200 mm. The layer height setting was 150 to 300 micrometre and minimum 100 micrometre, and the filament diameter was 1.75 millimetre (mm). The filaments were Acrylonitrile Butadiene Styrene (ABS) and Polylactic Acid (PLA). The nozzle diameter of this 3D printer was 0.4 mm.

Furthermore, the Raise Pro N2 plus was able to produce a printed object size of 305 mm x 305 mm x 300 mm. The layer height setting was 10 to 250 micrometre, and the filament diameter was 1.75 millimetre. The filament types were HIPS (High Impact Polystyrene), Polylactic Acid (PLA) and Thermoplastic Polyurethane (TPU). The nozzle diameter of this 3D printer was 0.2 to 0.8 mm standard.

On the other hand, MyVista Cube 200 had a capacity of producing a printed object size of 200 mm x 200 mm x 200 mm. The layer height setting was 0.1 to 0.4 mm, and the filament diameter was 1.75 millimetre. The filament types were Acrylonitrile Butadiene Styrene (ABS), Polylactic Acid (PLA) filament and Thermoplastic polyurethane (TPU) filament. The nozzle diameter of this 3D printer was 0.4 mm standard.

3.0 RESULTS AND DISCUSSION

In this study, the experiment was conducted to see if those Three Dimension (3D) printers were able to print the lowest micro scale pattern of master mould for the printing plate. Moreover, the experiment was conducted to investigate whether the dimensions of the printed master mould was the same as the designed master mould using Solid works software. In this experiment, an optical microscope was used to inspect the micro scale pattern on the master mould.

The experiment started with 3D printing of the spiral square pattern on the mould plate. The structure had the smallest dimension of 100 μm for width, gap and height. In order to print very fine lines, several requirements were needed to be fulfilled beforehand. First, a suitable filament was chosen according to the specification of the 3D printer.

1.75 mm ABS filament was chosen for Cubicon Single 3DP-110F printer. ABS filament was seen to be a very flexible, strong and sturdy material. A spool of ABS filament was loaded into the 3D printer. The filament was fed to extrusion head once the nozzle has achieved the operating temperature, and the filament was melted in the nozzle. The material that exited extruder was in high temperature. The material was pliable and can easily be formed while it was hot [15]. However, as it cooled, it quickly became solid and retained its shape.

In this research, optical microscope (OM) was used to determine the exact dimensions of fine lines on master mould produced by the Three Dimension (3D) printers. The image results obtained from Optical Microscope were illustrated in Figures 3 to 5.

Figure 3 shows the actual line width results obtained for the spiral square model and straight line model produced by Cubicon Single 3DP-110F printer. The actual width obtained was slightly different from the expected width.

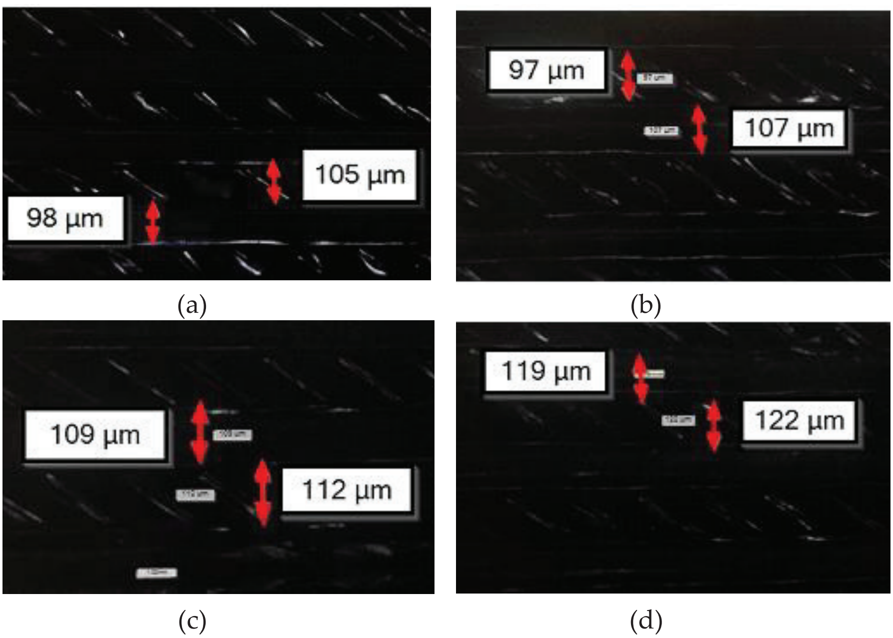


Figure 3: Actual lines width results produced by Cubicon Single 3DP-110F printer: (a) square spiral shape with a 100 µm width and gap, (b) straight lines pattern of 100 µm width and gap, (c) straight lines pattern of 110 µm width and gap and (d) straight lines pattern of 120 µm width and gap

Figure 4 shows actual line width results obtained for the spiral square design and straight line design produced by Raise Pro N2 Plus. However, the actual width obtained was slightly different from the expected width.

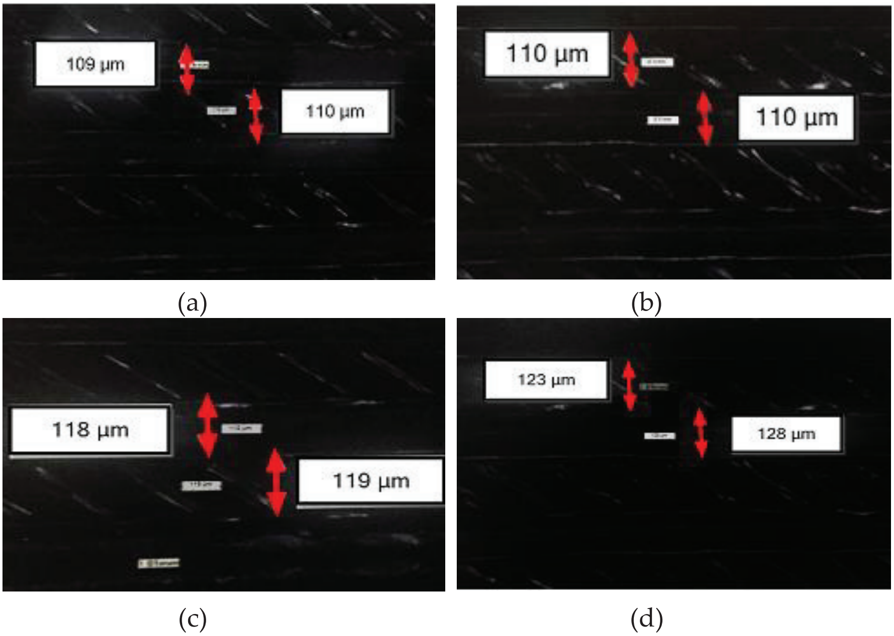
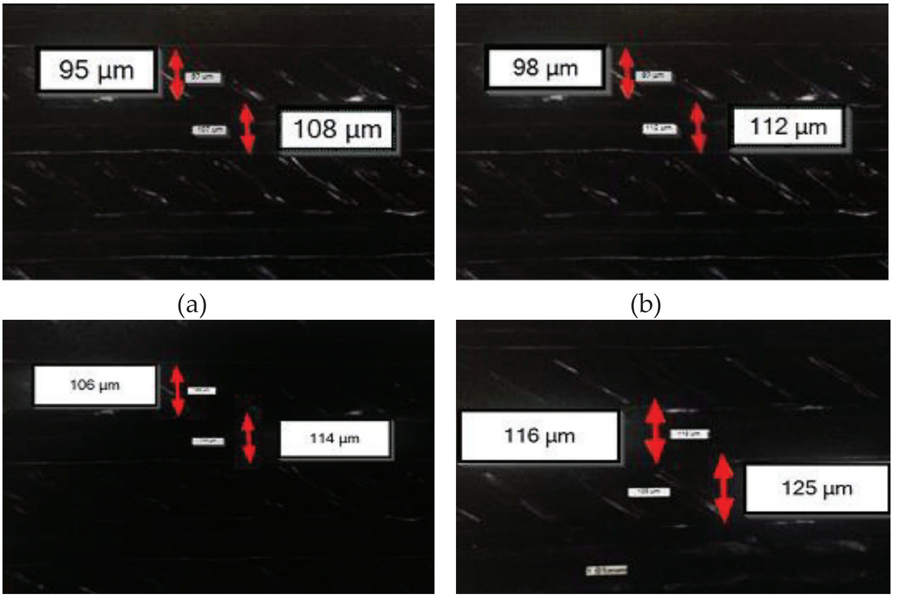


Figure 4: Actual lines width results produced by Raise Pro N2 Plus printer: (a) square spiral shape with a 100 µm width and gap, (b) straight lines pattern of 100 µm width and gap, (c) straight lines pattern of 110 µm width and gap and (d) straight lines pattern of 120 µm width and gap

Figure 5 shows the actual line width results obtained for the spiral square model and straight line model produced by MyVista Cube 200 printer. The actual width obtained was slightly different from the expected width.

The bar charts in Figures 6 to 8 show the comparison of the results of the actual width of lines of printing plate mould formed with the design width in micrometre (µm). From the figures, it could be seen that the actual widths of fine lines formed on master mould were slightly different from the design width. This difference in width could be due to some factors while carrying out the experiment.



(a) (b) (c) (d)

Figure 5: Actual lines width results produced by Myvista Cube 200 printer: (a) square spiral shape with a 100 µm width and gap, (b) straight lines pattern of 100 µm width and gap, (c) straight lines pattern of 110 µm width and gap and (d) straight lines pattern of 120 µm width and gap

There were four different types of lines design had been used in the experimental testing. First design was referred to square spiral design shape and second designs were referred to three straight lines pattern with different width. First experiment was tested by using Cubicon Single 3DP-110F printer. The actual lines width were decreased comparing to design width as shown in Figure 6.

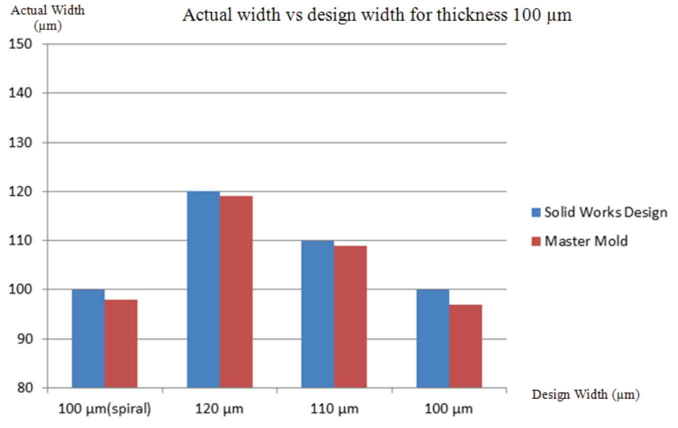


Figure 6: Microstructure analysis result for Cubicon Single 3DP-110F printer

While, the second experiment showed that the actual lines width were increased comparing to design width as shown in Figure 7. This experiment was done using Raise Pro N2 Plus printer. The highest lines width increased was at straight lines pattern with 100 µm width.

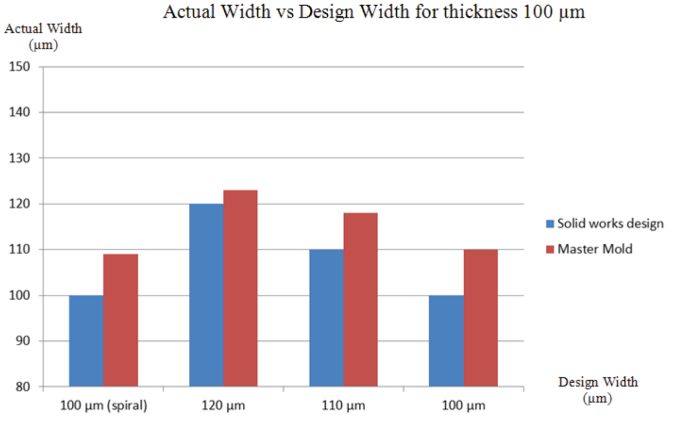


Figure 7: Microstructure analysis result for Raise Pro N2 Plus printer

The last experiment testing was done using Myvista Cube 200 printer. Figure 8 showed the actual lines width that had been printed decreased comparing to design width which had been designed using Solidworks software. This experiment showed the same pattern of lines width decreased with the first experiment.

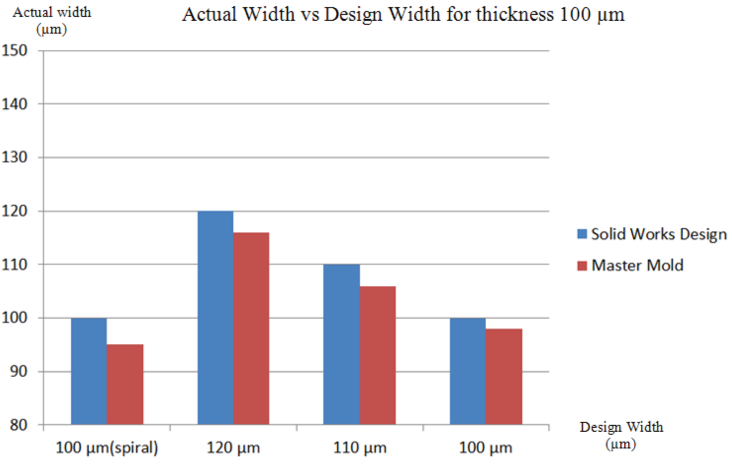


Figure 8: Microstructure analysis result for Myvista Cube 200 printer

Structure analysis from Optical Microscope clearly showed that lines produced from the experiment were consistent in all spots of fine solid lines. This was due to several factors that affect the lines formed. One of the factors was ABS material that extruded into very thin filaments from the nozzle of the 3D printer was uneven. The line dimensions of 120 µm, 110 µm, and 100 µm were slightly different from the design since the standard nozzle diameter was 400 µm (0.4 mm).

4.0 CONCLUSION

The results obtained from the experiment are the actual line width and gap produced on the master mould. The fine line width and gap of printing plate are determined by line width and gap of master mould. From this study, several conclusions could be summarised as follows:

i. The lowest fine line width for spiral square shape is 95 µm, produced from MyVista Cube 200 printer.
ii. The lowest fine line width for straight line pattern is 97 µm, produced from Cubicon Single 3DP-110F printer.
iii. Micro-flexographic is a good candidate for printing micro to nano fine lines with printing plate mould property, printing plate, substrates and process parameters being the main role for a successful implementation.
iv. This research study is practically used in electronic printing industry that aims on printing multiple micro fine solid lines, where it is applicable in other printing industry like graphic printing or biomedical research.

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