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Surface Finish Effects Using Coating Method on 3D Printing (FDM) Parts

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Abstract. One of three-dimensional (3-D) printing economical processes is by using Fused Deposition Modelling (FDM). The 3-D printed object was built using layer-by-layer approach which caused “stair stepping” effects. This situation leads to uneven surface finish which mostly affect the objects appearance for product designers in presenting their models or prototypes. The objective of this paper is to examine the surface finish effects from the application of XTC-3D coating developed by Smooth-On, USA on the 3D printed parts. From the experimental works, this study shows the application of XTC-3D coating to the 3-D printed parts has improve the surface finish by reducing the gap between the layer

1. Introduction

In product design and development cycle, prototyping process is one of the important stages before it can go for manufacturing process. The quality of prototype is ranging from low to high fidelity. Vijay et al. [1] defined the prototypes deal with three aspects of interest:

- The implementation of the prototype from the entire product itself to its subassemblies and components.
- The form of the prototype from virtual to the physical prototype.
- The degree of the approximation of the prototype from a rough representation to an exact replication of the product.

Rapid prototyping (RP) is one of the emerging manufacturing techniques nowadays. It is a freeform manufacturing process that allows users to fabricate real physical part directly from a computer-aided design (CAD) model. Compared with other manufacturing processes, RP has several advantages such as it does not require any tooling to fabricate the part, less human intervention and ability to produce complex part. There are three common RP technologies - Fused Deposition Modelling (FDM), Strereolitography Apparatus (SLA), and Selective Laser Sintering (SLA).

Three-dimensional printing is a new advanced development of rapid prototyping technology and widely used by industrial designers and engineers. It is generally referred as a smaller system of RP and intended to be easily used and networked in an office environment [2]. Fused Deposition Modelling-based 3-D printing receives a significant demand around the world owing to several advantages offered by this technology such as wide variety of materials available, quick material change, low maintenance cost, quick production of thin parts, a tolerance equal to ±0.1 mm, no supervision, no toxic materials, very compact size, and low temperature operation [3]. Fused Deposition Modelling technique is prominent as an additive manufacturing technology which is commonly used in 3-D printing machines. It works by feeding molten thermoplastic material into the heated extruder to build physical form layer-by-layer. Figure 1 shows the schematic diagram of the FDM machine

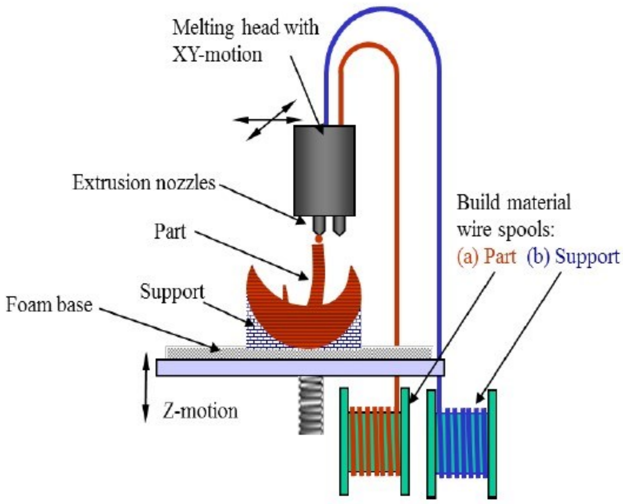

Figure 1. Schematic diagram of FDM [4]

Surface finishing of the FDM parts is very crucial in producing high fidelity prototypes and moulding.. For prototypes, low quality of surface finishing will affect the level of exactness compared with actual product. This situation will influence the decision making process because designers and engineers do not receive the right information when developing a new product. The common problem occurs in FDM technique is the layer remain visible on the surface after the fabricating process end. This problem is called stair stepping effect. This condition requires the FDM parts to undergo post-treatment process before it can be fully eliminated.

2.Previous works

To summarize the process of rapid prototyping, there are five steps that need to follow. Figure 2 exhibits the five main steps in rapid prototyping process.

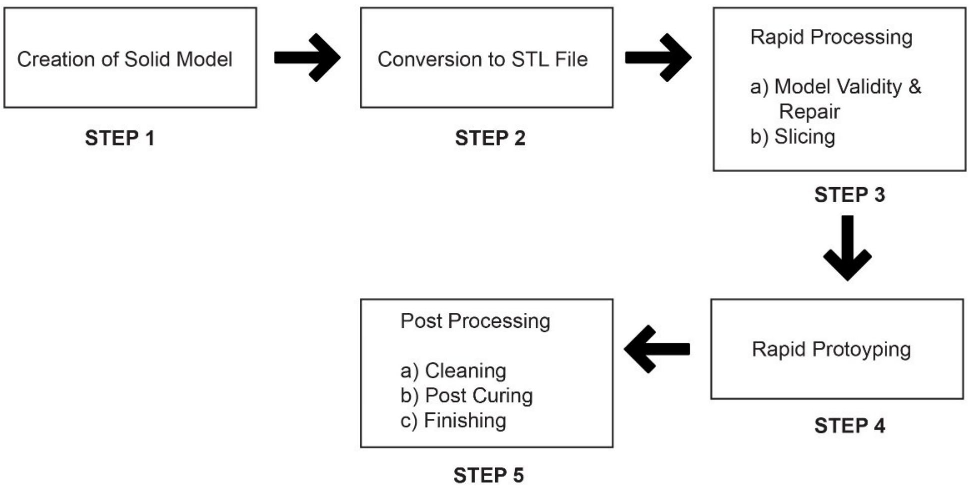

Figure 2. Five steps in the process of rapid prototyping [5]

Many past researchers have performed various types of study to improve the surface finish of FDM parts. Based on Figure 2, research on improving surface finish of FDM parts can be classified into rapid and post processings. Rapid processing is the step involved before the rapid prototyping process begins while post processing is after the process is completed. Gurpal and Parlad [6] had divided method of improving surface finish into four categories, namely:

- Optimization of build orientation.
- Slicing strategy (layer thickness)
- Fabricators parameterization optimization
- Post-treatment

Besides those parameters, Ongjan et al. [7] in their study had introduced two additional factors that can leave an impact on the surface quality:

- Extrusion speed
- Extrusion temperature

The primary goal of their research was to investigate the influence of extrusion speed and temperature to the surface quality. Implementation of rapid processing step does not fully remove layer visibility on the surface. However, it will reduce necessary post processing step. Reducing post processing step will reduce the manufacturing time and cost of the product.

Surface quality of the FDM parts can be enhanced by applying post processing step. Post processing step involves various methods such as sanding, chemical finishing, blasting and painting. Galantucci et al. [8] in their study used chemical finishing process to reduce the surface roughness of FDM parts. During chemical finishing process, specimen was immersed in dimethylketone (acetone). The author observed significant improvement in surface roughness of the treated specimen. A different approach has been proposed by Ivan et al. [3] to improve the quality of FDM parts surface finish. In their research, they had applied blasting technique where pre-treated sample was blasted with sodium-bicarbonate (SB) and glass beads (GB). Based on the results, this technique showed a minimal influence on the surface quality of the parts. This is in accordance to the aim of the present study which is to improve the surface finish of 3-D printing (FDM) parts by using surface coating method. Figure 3 illustrates the effect of various layer thicknesses on the stair stepping effect.

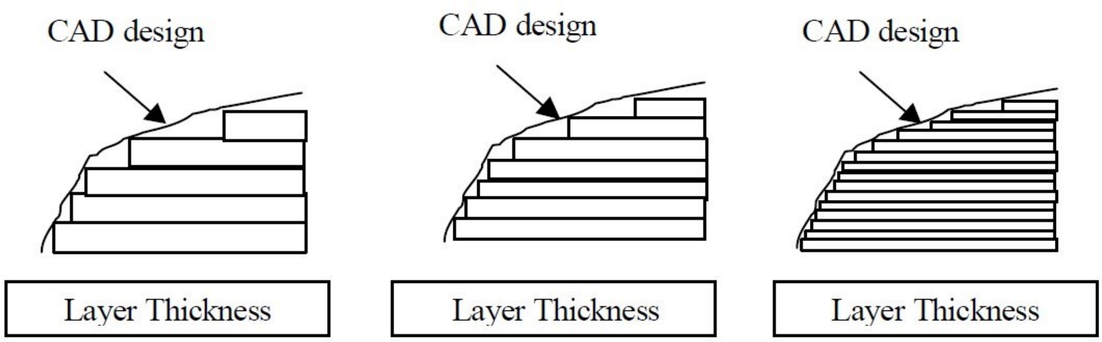

Figure 3. Effect of layer thickness to stair stepping effect [9]

Therefore, this study was intended to propose the application of surface coating method to remove the stair stepping effect. It works by fill the gap between the layer with XTC-3D.

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3.Experimental work

3.1. Specimen preparation

To carry out the experimental work, a 3-D data of tested sample was prepared using CAD software. The dimensions of the tested sample – width, height and length are shown in Figure 4.

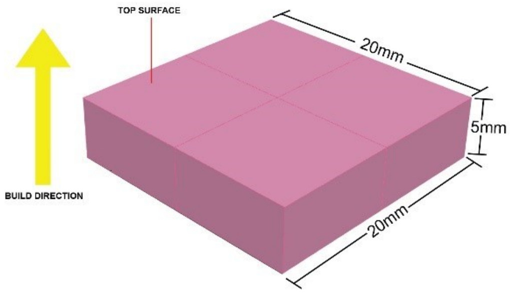

Figure 4. The dimensions of tested specimen

From the CAD software, the 3-D data was converted into Stereolitography format (STL). This data format is universal for 3-D printing software and it converts CAD data into triangulation mesh. Later, STL data was loaded into 3-D printing software, Flashprint. In this software, all printing paramaters were set according to the machine default setting that includes printing resolution, layer height, infill, shell, speed, and temperature. The parameters setting is shown in Table 1. After that, STL data was sliced into series of layer.

Table 1. Parameters setting

Parameters	Value
Infill	15%
No of Shells	2
Temperature	220°C
Layer Thickness	0.18 mm
Print Speed	60 mm/s

Three tested samples were produced using a 3-D printer from Flashforge Dreamer, USA. The printer has specified 230 x 150 x 140-mm build size and layer thickness ranging from 0.1 to 0.5 mm. It also has built precision ±0.2 mm. Material that has been used to produce this part is Acrylonitrile Butadiene Styrene (ABS). This material comes in the form of filament with 1.75-mm diameter. Figure 5 depicts the slicing process of STL file using flashprint software.

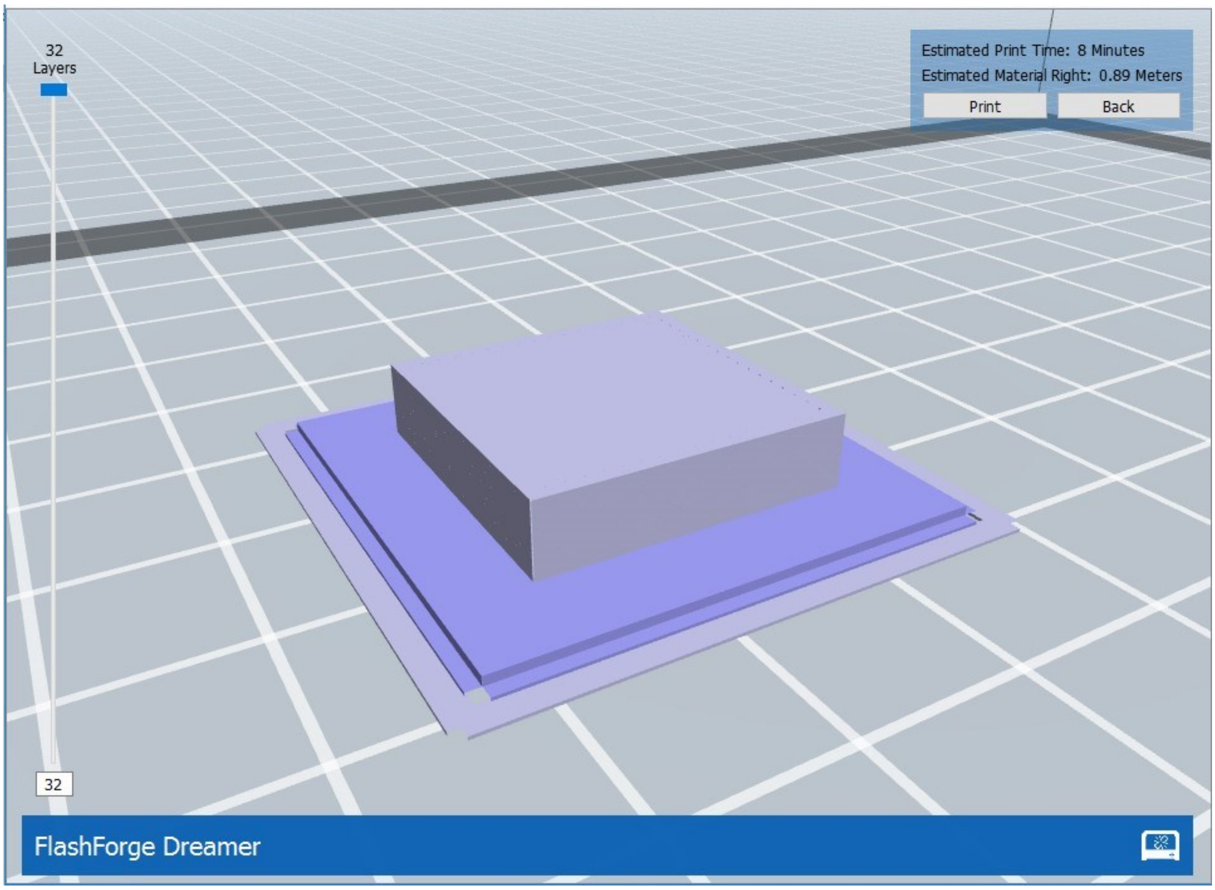

Figure 5. Slicing process of STL file using flashprint software

Based on Figure 5, the STL data was sliced into 32 series of layer. In general, it takes approximately 8 minutes to complete the printing process. Total amount of material used in this fabrication process is 0.80 meters.

3.2. Surface Coating

In this phase of experimentation, 2 out of 3 tested parts will undergo surface coating process. Chemical coating that has been chosen is XTC-3D from Smooth-On, USA. According to the manufacturer, this material is low cost, and easy to work on any 3-D printing surfaces such as FDM, SLS and SLA. It cures to hard, and impact resistant coating that can be sanded, primed and painted. All the three parts will be undergoing different layer of coating number as stated in Table 2. Brush method was used to apply the coating on the FDM parts surface.

Table 2. Three-dimensional samples with different coating layer numbers

Sample	A	B	C
XTC 3D coating Layer	0	1	2

For the first phase of the coating process, sample B and C were undergoing one layer of coating. After all samples were fully cured, second layer of coating was applied to sample C only. For each coating process, all parts were left to be cured at room temperature (27°C). Figure 6 shows the main process flow of experimental work conducted in this study. The coating process is stopped at the second layer to maintain sample dimensional accuracy.

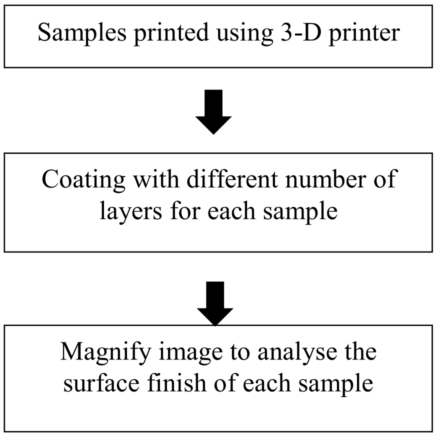

Figure 6. Process flow of experimental work

In this paper, the top layer of the sample will only be used for the comparison. A magnified image of each sample at 45X was captured using XOPTRON XST6 Stereo Microscope and were analysed using Solution Lite software. To capture and analyse the cross-sectional image of the tested parts, precision cutter was used to cut the part. The rationale of this process was to ensure the authors can observe and analyse the printed part and evaluate the coating layers.

4.Result and Discussion

As far as the effect of coating method on the surface finishing was concerned, the results of study exhibited that sample A has series of layer visible on the surface as illustrated in Figure 7. The reverse was seen for sample B and C in Figure 8 and Figure 9, respectively, which showed that the application of XTC-3D on the sample surface has fill the gap between the layer caused the better surface finish.

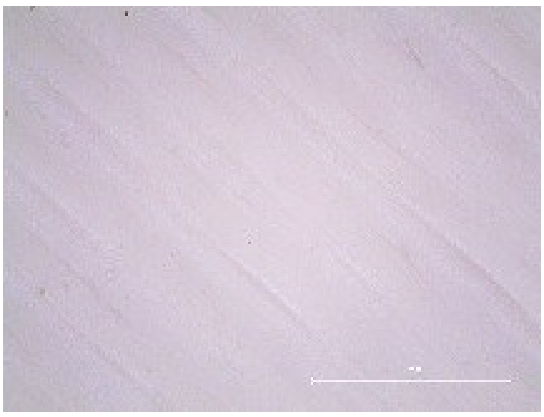

Figure 7. 45X magnifier images of 3-D print sample A

Figure 8. 45X magnifier images of 3-D print sample B

Figure 9. 45X magnifier images of 3-D print sample C

Each sample shows a significant discrepancy of surface finish quality between one another. Sample A promoted some uneven surfaces which may possibly cause by the "stairstepping" effect from the layer-by-layer process. Sample B, however, depicted a contradict finding where the surface finishing was considerably improved by the application of one layer XTC-3D coating. A similar situation was observed in Sample C where it exhibits a better surface finishing performance with two layers of XCT-3D application. Figure 10 shows the cross section of Sample C.

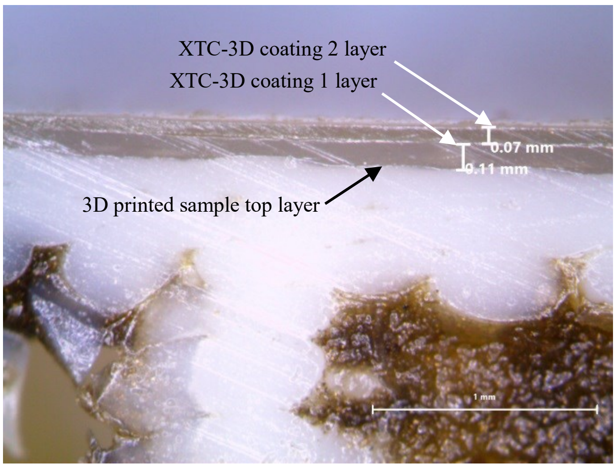

Figure 10. The cross section of Sample C

From the cross-sectional image, it shows that by applying the XTC-3D, the “stairstepping” effect was reduced to obtain a better surface finish. However, several more additional layers might be advantageous to have a better quality of surface finishing. Albeit the surface finishing could be improved, it is however noteworthy that the accuracy of part dimensions may indirectly affected and this could possibly place a major concern of issue.

5.Conclusion

“Stairstepping” effect is a common defect found in 3-D printing parts especially in FDM machine. This study shows that by applying XTC-3D coating, the surface finish can significantly be improved. However, further studies shall be conducted using different parameters of 3-D printer setting such as layer and printing resolutions, and others. The results of present study may contribute to a more economical application of XTC-3D in terms of surface finish performance.

Acknowledgments

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