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Effect of layer thickness on surface roughness of lattice structure manufactured using FDM

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ABSTRACT – This research investigated on the effect of layer thickness on surface roughness of lattice structure fabricated using fused deposition modeling (FDM) technique. Variations of layer thickness of the FDM machine in this study were 70 µm, 200 µm and 300 µm. Examinations on the surface quality of the printed lattice blocks were conducted with observation and measurement with optical microscope. Surface roughness was calculated using standard formulation and measured by 3D non-contact profilometer. The result shows that increased in layer thickness also increased the surface roughness. This finding will be useful in analysis of mechanical properties of lattice structure material.

1. INTRODUCTION

Lattice structure is a complex design of repeating struts and nodes in forming a certain structure. In recent years, lattice structure has started to raise interest among researchers. The excellent characteristics of lattice structure makes it desirable for industrial application such as in lightweight structures [1], as energy absorbers [2] and in tissue engineering [3]. The manufacturing complexity of this structure can be overcome by additive manufacturing (AM) or also known as 3D printing. AM is capable to produce lattice structure with a wide range of material and dimensional scales. There are various AM techniques suitable for lattice structure fabrication such as material extrusion and powder bed fusion [4]. In this research, material extrusion technique which is fused deposition modeling (FDM) was utilized.

Surface finish is one of the most important factors in additive manufacturing. There are a lot of research assessed on the influence of process parameters on the print quality of FDM [5-6]. Past research found that the process parameters of FDM has influenced the print quality as well as the mechanical performance of lattice structure [6]. Therefore, this paper reported the relation of process parameters on the surface quality of the FDM printed lattice structure.

2. METHODOLOGY

Lattice structure with body-centred-cubic (BCC) arrangement was fabricated as in previous study [7]. The identification name for each lattice structures cube was based on its process parameters and strut diameter. The definition of the identification name was print strength/print pattern/layer thickness (µm)/strut diameter (mm). Table 1 concludes the identification names. In this study, the Almost Solid print strength is equivalent to 4.5 MPa yield strength.

Table 1 Samples ID and process parameters.

Sample ID	Print Pattern	Print Strength	Layer Thick-ness (µm)	Dia-meter (mm)
As/Hc/70/1.6	Honey-comb	Almost Solid	70	1.6
As/Hc/200/1.6	Honey-comb	Almost Solid	200	1.6
As/Hc/300/1.6	Honey-comb	Almost Solid	300	1.6

As = Almost Solid, Hc = Honeycomb

The surface quality was analysed by optical microscope. The average roughness (Ra) values were calculated based on standard formula [8], as in Equation (1).

$$R_a = \frac{1}{L}\int_0^L |z|\, dx \qquad (1)$$

Definition of node area, effective length and cross section for strut measurement can be referred in Figure 1. The average strut diameter measurement was taken along section A-A'. Meanwhile, the minimum and maximum diameter of strut was taken from cross section B-B'.

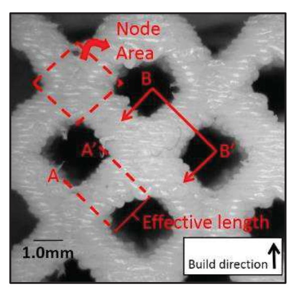


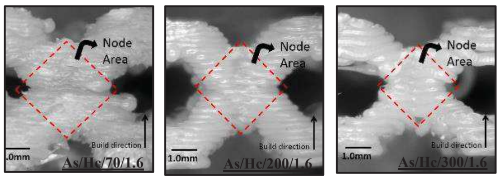
Figure 1 Details of node area, strut effective length and strut cross section.

For data comparison, Ra value for strut was measured using 3D non-contact profilometer and compared to that of Ra measured as in Equation (1).

3. RESULTS AND DISCUSSION

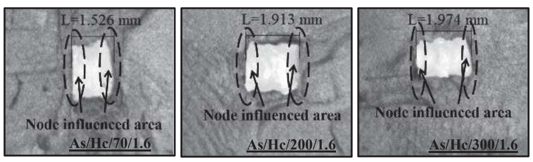
Figure 2 shows that the formation of node area differs for each layer thickness. Larger node area was found in lattice structure with lower layer thickness. As shown in Figure 3, strut effective length for lattice structure with lower layer thickness is shorter. This signifies that the node area increases as the layer thickness decrease. This is due to more material deposition in lower layer thickness as described in the previous study [7].

The minimum and maximum strut diameter of lattice structure were measured and recorded as in Figure 4 while strut diameter along strut effective length was recorded in Figure 5. All measured data were tabulated in Table 2.



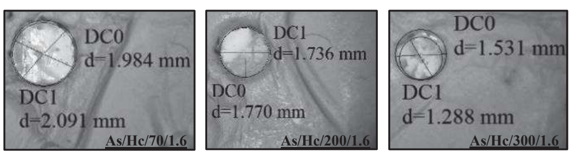
(a) (b) (c)

Figure 2 Node area in lattice structure with layer thickness of (a) 70 µm, (b) 200 µm and (c) 300 µm.



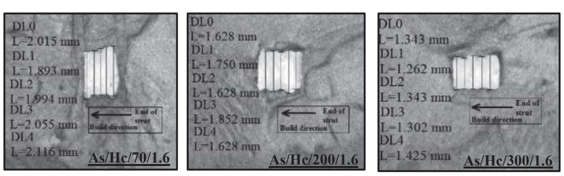
(a) (b) (c)

Figure 3 Strut effective length of lattice structure with layer thickness of (a) 70 µm, (b) 200 µm and (c) 300 µm.



(a) (b) (c)

Figure 4 Minimum and maximum diameter cross section of lattice structure with layer thickness (a) 70 µm, (b) 200 µm and (c) 300 µm.



(a) (b) (c)

Figure 5 Single strut diameter of lattice structure with layer thickness (a) 70 µm, (b) 200 µm and (c) 300 µm.

Table 2 Data of measured strut diameter and length.

Layer thick-ness	Strut Effective length (mm)	Single Strut Dia. (mm)	Min Dia. (mm)	Max Dia. (mm)
70µm	1.526	2.0146	1.984	2.091
200µm	1.913	1.6972	1.736	1.770
300µm	1.974	1.335	1.288	1.531

In this study, surface roughness was analyzed by finding the average roughness (Ra) of the single strut for each lattice structure with different layer thickness. As been discussed previously, the node formation of lattice structure with different layer thickness affected the strut effective length. Hence, the Ra value for strut with and without node influenced area were calculated using Equation (1). On top of that, the Ra values which were measured with profilometer were also recorded for comparison. Table 3 shows the Ra values for strut, with and without the effect of node influenced area as well as the measured Ra value with profilometer.

Table 3 Ra values for lattice structure's struts.

Layer thick-ness	Ra with effect of node influenced area (µm)	Ra without effect of node influenced area (µm)	Ra measured from profilometer (µm)
70µm	91.17	25.3	13
200µm	58.33	61	22.73
300µm	88.17	77.83	29.59

Ra value for strut diameter with the effect of node influenced area gave inconsistent result as shown in Figure 6. This is due to the default setting of the machine parameter during node formation of lattice structure with different layer thickness. However, if the effect of node influenced area was not considered, the Ra value increased as the layer thickness increased which is similar to that of measured Ra value by using profilometer.

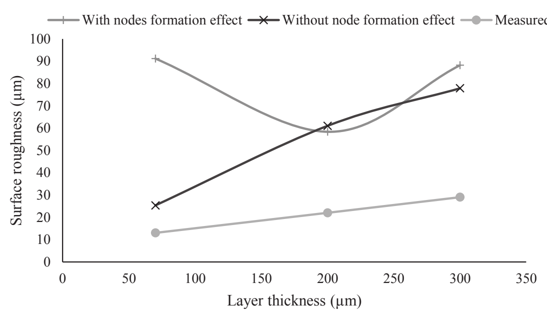


Figure 6 Layer thickness effect on surface roughness of lattice structure's struts.

4. CONCLUSION

In this research, the effect of layer thickness on the lattice structure formation was studied. It showed that variations in layer thickness affected the surface roughness and strut diameter of lattice structure. It was found that surface roughness of lattice structure was in the range of 10 to 90 µm, depending on the node influenced area. Thus, this result will be taken into consideration in the analysis of mechanical properties of lattice structure material.

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