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Fabrication of polymer lattice structure using additive manufacturing for lightweight material

R. Hasan[1,2,*], M.K. Baharudin[1], M.M. Nasarud'din[1], M.R. Alkahari[1,2]

[1)] Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2)] Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[*]Corresponding e-mail: rafidahhasan@utem.edu.my

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ABSTRACT – This paper reports on the development of polymer lattice structure as lightweight material manufactured using additive manufacturing technology, which is 3D printer. Models of 3D body-centered-cubic (BCC) lattice structure were developed using SolidWorks software for several geometries that match with the capability of CubePro 3D printer. Polymer lattice structure block with dimension 20x20x20 mm^3 has been successfully fabricated. The dimension of a unit cell for the lattice structure is within the range of 10^{-3} meter. The realization of the polymer lattice structure using the 3D printer can contribute to further research in lightweight material with high load-bearing capacity.

1. INTRODUCTION

Lattice structure is a three dimensional periodicity open-cell cellular structure. It contains straight struts of uniform thickness, consistent joint angle, and in symmetrical arrangement. Lattice structure exists in wide range of materials, be it from natural creation such as in wood and bone, as well as from common modern metallic and polymer compounds. It is classified as lightweight material due to its low specific density as compared to the bulk material. There are many methods can be used to fabricate lattice structure from any kind of material, and one of them which receives increasing attention from researchers is by using rapid additive layer technique [1, 2]. An advantage of using the additive layer technique is the formation of lattice structure can be down to 10^{-6} meter scale. Thus, a material with high specific stiffness can be obtained.

One type of popular periodic lattice structure is the body-centered-cubic (BCC) arrangement. Although this type of arrangement has been always discussed in many researches, there are still a lot of new findings that can be explored, especially in terms of process and properties relationship. Thus, the aim of this study is to successfully produce the BCC lattice structure from polymer material which is acrylonitrile-butadiene-styrene (ABS), by utilizing the available additive layer technology which is 3D printer from CubePro. A successfully fabricated polymer BCC lattice structure block is important in order to analyse the performance of the material and compare with other study [1].

2. METHODOLOGY

The stages in this study involve the design of BCC lattice structure, confirmation of struts' diameter size and fabrication of lattice structure block.

2.1 *Design of lattice structure*

A unit cell of BCC lattice structure is shown in Figure 1, where L = length of unit cell, A = length of strut, H = diagonal distance at surface, θ = angle of strut from surface, α, β, γ = angle of strut from axes x, y, z respectively.

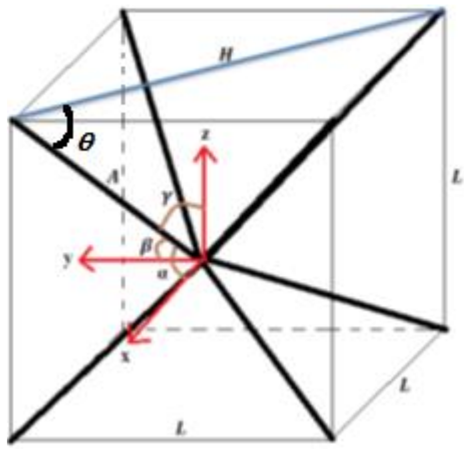

Figure 1 Unit cell of BCC lattice structure.

Model of BCC lattice structure was developed using SolidWorks software, and saved in .STL file.

2.2 *Confirmation of strut's diameter size*

The capability of CubePro 3D printer to produce lattice structure with as small as possible unit cell was tested. Strut diameter of 0.3 mm or 300 μm was assigned in the confirmation run of the printer.

2.3 *Fabrication of lattice structure block*

A complete BCC lattice structure block with dimension 20x20x20 mm^3 was fabricated. The layer resolution was 200 μm, the print strength was almost solid and the print pattern was diamond. The default fill spacing was used throughout the fabrication.

3. RESULT AND DISCUSSION

The angle θ of BCC strut was found as 35.26°. Thus, the angle of α, β, γ was 54.74°. The unity of unit cell was further confirmed with Equation (1) [3].

$$cos^2\alpha + cos^2\beta + cos^2\gamma = 1 \qquad (1)$$

After the confirmation run, it was found that the 0.3 mm diameter size was not possible to be fabricated using the CubePro 3D printer. It was realized that the diameter of strut for lattice structure must be larger than 0.5 mm, since the diameter of cartridge wire for the injection process is known to be as 0.5 mm. The scrapped printing of the lattice structure block with 0.3 mm strut diameter size is as shown in Figure 2.

Figure 2 Scrapped printing lattice structure.

The BCC lattice structure block was then designed with 1.0 mm strut diameter size. Due to the enlargement of strut diameter, the number of unit cell in the block was also reduced. Table 1 shows the findings in this study.

Table 1 Details of BCC lattice block fabrication.

Strut diameter	No. of cell	Fabrication status
0.3 mm	8 x 8 x 8	Fail
1.0 mm	4 x 4 x 4	Success

Figure 3 and Figure 4 show the SolidWorks model and the success fabrication of polymer BCC lattice structure block using CubePro 3D printer, respectively.

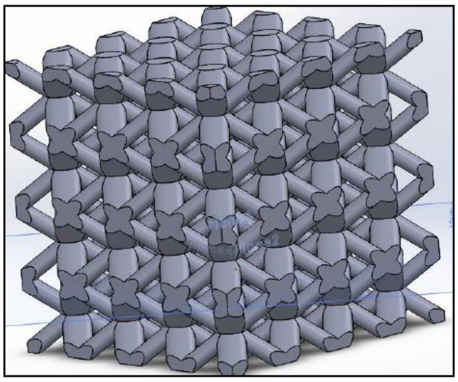

Figure 3 SolidWorks model of BCC lattice block with 1.0 mm strut diameter.

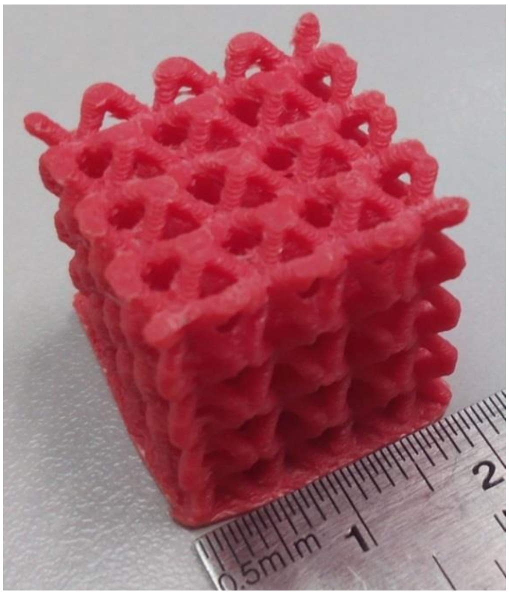

Figure 4 Fabricated ABS polymer BCC lattice structure block with 1.0 mm strut diameter.

4. SUMMARY

The polymer BCC lattice structure block with dimension 20x20x20 mm^3 was successfully fabricated using the CubePro 3D printer. However, the number of cell which is able to be produced is only 4 x 4 x 4 due to the strut diameter size of 1.0 mm. The dimension of a unit cell for the lattice structure is within the range of 10^{-3} meter. Although the CubePro 3D printer machine is not capable to produce lattice structure down to 10^{-6} meter scale, the potential of lightweight material from this study can still be further analyzed. Effects of fabrication parameters on the mechanical properties of the structure will contribute to the knowledge field.

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