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Production of Open-Cell Foam Using Additive Manufacturing Method and Porous Morphology Effects

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Abstract. In this study, 3D printed open-cell foam were produced and reconstructed from open-cell metal foam structure using a tomography scanning method and two different additive manufacturing technologies. The materials used in the 3D printing were nylon powder and plastic acid. The porous morphology and surface finish of the 3D printed foams were investigated using a microscope. The results showed that the surface finish and structure strength depend on the printing process, used material and foam size. This study found that laser-sintering technology would have smoother pores with lesser residue than stereolithographic. However, the ligaments of the small-size 3D printed foam were fragile and could be easily broken.

Keywords: 3D printing · Porous media · Morphology

1 Introduction

An open-cell metal foam was a structure made of a solid matrix from metallic material with interconnected pores. Normally, the pore size was determined in terms of PPI (pores per inches) where the greater the PPI, the smaller the pore size.

Its unique porous structure provides advantageous properties such as lightweight, high surface area, and good thermal conductivity, thus it was possible for diverse industries such as medical, aerospace, and automotive [1]. However, since the cost of metal foam is quite high, a lot of numerical studies have been preferable to understand the metal foams under different conditions. Alternatively, another cheaper solution such as additive manufacturing method (3D printing) can be proposed for more experimental studies. Unfortunately, the complicated structure of the metal foam with random pore-ligament construction could not be easily drawn using CAD software. Thus, it is challenging to

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produce open-cell foam using the additive manufacturing method without a detail image of an open-cell metal foam. However, thanks to Computed Tomography (CT) scanner and additive manufacturing technologies [2], a prototype sample with the exact design parameters of a real object can be produced. The tomographic image is collected by the scanner from the translated X-ray beam on the object [3]. For the additive manufacturing method, there are many different technologies available in the market, such as selective laser melting, fused deposition modeling, and electron-beam melting [4]. In this study, the open-cell foams were produced using the CT-scan and two different 3D printing technologies. This study produced the exact same porous structure of metallic foam to enable further experimental investigations for diverse applications, e.g., thermoacoustic system, heat exchanger and sound absorber. Note that, further modifications on the 3D printed foam and experimental conditions must be applied to suit the nature of those applications. As a first step, this study focused on morphology of the printed foams obtained using different 3D printer technologies and materials.

2 Methodology

The production process includes 3D scanning of a 5 PPI metal foam using a CT scanner and reconstruct the 3D model in Blender and SOLIDWORKS software. The detail properties of the 5 PPI aluminium metal foam could be found in [4]. In the present study, three different sizes of 3D printed foams were produced, with the first one is 7.5 mm long, and the other two foams were enlarged with a scale of 4 and 8 from the first one. Figure 1(a) shows the CAD image of the open-cell foam constructed using Blender software and Fig. 1(b) shows the 3D printing process using the stereolithography (SLA) method. Note that this study used two different additive manufacturing technologies: the SLA and Selective Laser Sintering (SLS). The SLA method used Flashforge CreatorPro and Polylactic Acid (PLA) type filament, printing at a temperature range from 190 °C–200 °C. Meanwhile, the SLS technology used nylon powder (FS 3300 PA) with a bulk density of 0.48 g/cm^3 and melting point at 183 °C. The 3D printed form and its porous structure was examined using a RS Pro USB Wi-Fi microscope with 1280 × 1024 pixels, and up to 200× magnification.

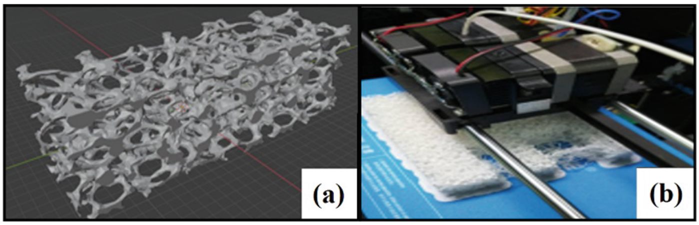

Fig. 1. (a) CAD drawing and (b) printing process (stereolithography).

3 Result and Discussion

Figure 2 shows the 3D printed foams produced using different 3D printing technologies and materials. The yellowish 3D sample in Fig. 2(a) shows the smallest sample of the 3D printed foams in this study, with some damaged structures in red circles. The smallest foam means it also has the thinnest and most fragile ligament construction. For a hollow or porous structure, the shape can be easily deformed. Thus, producing 3D printed open-cell foam as small as the original metallic foam using the abovementioned techniques with the proposed material was impractical. In this case, the foam ligament should be more than size 2.0 mm to maintain those complicated porous structures. Meanwhile, Fig. 2(b) shows the other foam sizes (scale factors; 4 and 8). The yellowish and larger foam was produced from nylon while the pure white foam was from PLA. Regardless of the used material, the larger 3D printed foam was stronger, and the interconnected region (lump) was nicely connected (Fig. 2(c)). However, close observation showed that the Flashforge printer with PLA would cause more residues (thin strings within the porous structure) as shown in Fig. 2(d), unlike the foam produced from SLS with a smoother surface as shown in Fig. 2(e). Under a microscope with 100× magnification, the layering effects from the SLS process could be seen as expected in Fig. 2(f). Hence, the surface roughness of these 3D printed foams should be expected to be higher than the original metallic open-cell metal foam. From [5], the average roughness of the nylon parts is 34.0 ± 7.6 μm. Note that, the surface roughness would be important parameters for certain applications with a major concern of pumping power or contact surface. However, by manipulating the pore size and external shape, this lightweight 3D printed foam would be promising for aerospace (e.g., cabin interior, tray table and arm rests) and automotive industries (e.g., door sill and internal parts of door panel).

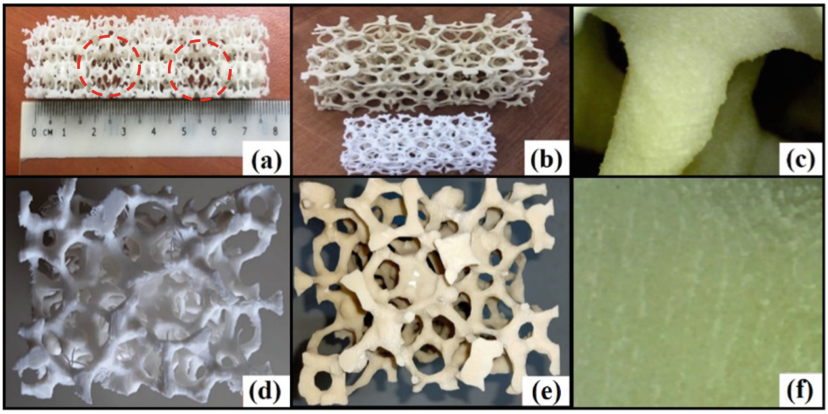

Fig. 2. 3D printed foam (7.5 cm original sample), (b) Enlarged samples with scales of 4 and 8, (c) Interconnected pore-ligament region (d) Sample using Flashforge Creater Pro, (e) Sample using SLS and (f) Foam surface.

4 Conclusion

The original form of open-cell metal foam has been successfully produced using two different additive manufacturing methods; SLS and SLA. However, the ligament and pore sizes of 3D printed foams could not be as small as the metallic ones. The ligaments could be broken easily but was showing a stronger form in larger form sizes. The morphology of these foams depends on the printing process and material, where SLS with nylon powder produced a smoother finish surface than SLA with PLA material.

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