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Variations in diameter of struts for micro-lattice structure manufactured using selective laser melting

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ABSTRACT – This paper highlights the dimension of diameter for titanium alloy Ti-6Al-4V micro-lattice structure material with body-centered-cubic (BCC) struts' arrangement, manufactured using additive layer technology, which is selective laser melting (SLM). Direct measurements and simple count analysis were done on the material. Variations in diameters were averaged and the value was compared to that obtained from other formulations. The result shows that there are variations in struts' diameters of micro-lattice structure manufactured using SLM, which can affect the material's performance under load bearing capacity. The finding can be useful to the developments of both micro-lattice structure and additive layer technology researches.

1. INTRODUCTION

The use of the titanium alloy Ti-6Al-4V in the manufacture of micro-lattice structure using the selective laser melting process (SLM) for use as a light-weight load bearing material in sandwich structure cores suggests that this material has a promising future as a candidate of aerospace material. The study of the SLM Ti-6Al-4V micro-lattice structure block is one of the early steps that support the efforts of introducing this novel material into the real aerospace applications [1]. An important performance issue in aerospace sandwich construction is the foreign object impact (FOI) performance such as a result of dropped tools, hail and bird strike [2].

It was observed that the SLM Ti-6Al-4V BCC micro-lattice blocks failed along 45° angle diagonal plane under compression loading [1]. The localized failure in this material has motivated this study to focus specifically at the geometry of the struts. Based on mechanical property of struts which has been reported in other study [3], it can also be concluded that the geometry of the SLM Ti-6Al-4V BCC micro-lattice blocks relates to the structural strength and mechanical properties of the whole micro-lattice structure [4]. Thus, the deliverable of this study is the determination of diameter for BCC micro-lattice structure blocks. The finding is important to be used in FEA analysis on structural performance of this material.

2. METHODOLOGY

The diameter of struts in SLM Ti-6Al-4V BCC micro-lattice blocks was determined using direct measurement as well as shadow measurement method, which the explanation can be found in other report [1]. The surface roughness and circularity of the struts can also be determined using similar procedure. Figure 1 shows an SEM image of the strut arrangements in the 45° angle diagonal plane of the as-received micro-lattice block (with SLM parameter of 160 W x 1000 µs). The struts' diameters can be directly measured from the image.

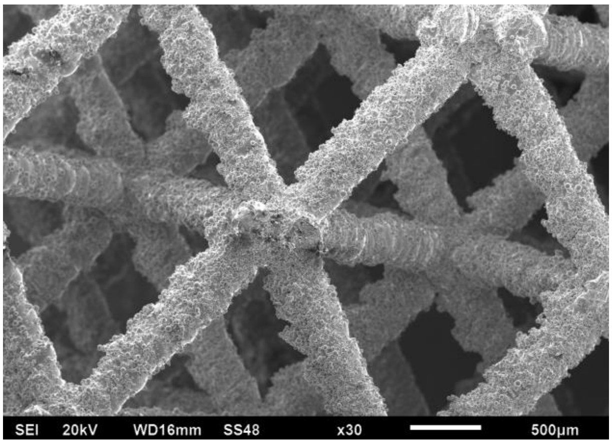

Figure 1 Struts arrangements in 45° angle diagonal plane of the as-received SLM Ti-6Al-4V BCC micro-lattice block (160 W x 1000 µs).

3. RESULTS AND DISCUSSION

For direct measurement, strut diameters for 50 struts (average of three readings per strut) were measured and distributed as shown in Figure 2.

From the figure, it can be seen that most of the strut diameters in the as-received micro-lattice block were between the ranges of 360 to 379 µm. Besides, a noticeable number of strut diameters were between the ranges of 380 to 399 µm. Thus, from direct measurement, the average diameter of the struts was found to be (374.24 ± 17.7) µm. Meanwhile, using the shadow measurement method [1], the average strut diameter for the as-received micro-lattice blocks was determined as (373.1 ± 29.95) µm, with minimum and maximum values of 321 µm and 429 µm respectively.

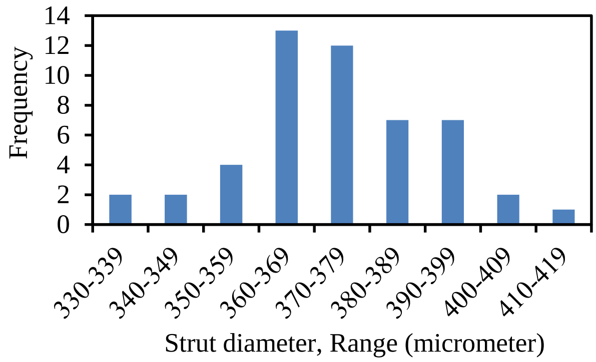

Figure 2 Distribution of strut diameters in as-received SLM Ti-6Al-4V BCC micro-lattice block (160 W x 1000 µs).

The strut diameter values which were determined using direct and shadow measurement methods, were then compared to estimation values obtained from Kude and Khairnar [5] formulation (Equation 1) as well as Tsopanos et al. [6] revised equation (Equation 2).

$$Diameter = 2\left(\sqrt{\frac{A^2+B^2}{2}}\right) \quad (1)$$

$$d = \sqrt{\frac{m_b}{\rho_t.\pi.N_1 \times N_2 \times N_3.L.\sqrt{3}}} \quad (2)$$

Where A and B are the maximum and minimum measured radii, respectively; m_b is mass of the block, L is the cell length, ρ_t is density of Ti-6Al-4V taken as 4430 kg/m^3, and N_1, N_2 and N_3 were the number of cells along the width, length and height directions.

Table 1 compares the results of struts' diameters which are determined from direct and shadow measurement methods as well as by using the formulation of Kude and Khainar [5] and Tsopanos et al. [6].

Table 1 Diameter of struts in SLM Ti-6Al-4V BCC micro-lattice block from several methods.

Method	**Diameter value**
Direct measurement	(374.24 ± 17.7) µm
Shadow measurement	(373.1 ± 29.95) µm
Kude and Khairnar [5] formula	378.87 µm
Tsopanos et al. [6] revised equation	339 µm

If the value from direct measurement is being used as a reference, the differences of other values are found to be not more than 10%.

4. SUMMARY

The findings show that there were variations in struts' diameters of SLM Ti-6Al-4V BCC micro-lattice structure blocks, which were due to the selective laser melting process itself [6]. These geometrical variations were eventually affecting the deformation behavior and collapse of the material [1].

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