Establishment of Laser Sintering Technique for Titanium Powder

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Abstract

This paper investigates the characteristic of single-layered and multi-layered compacts made by selective laser sintering using titanium powder (TILOP45 and TILOP150, Sumitomo Titanium Corp.) There were few defects in smooth surface of laser sintered specimen in vacuum as compared to the laser sintered specimen in argon. Maximum tensile strength of single-layered compact was about 200MPa. Multi-layered compacts show the density of around 75% and the adhesive bonding was not observed between layers, resulted in 70MPa of maximum bending strength and 50MPa of maximum tensile strength.

Keywords: selective laser sintering, titanium, vacuum atmosphere, surface texture, shrinkage, strength

1. Introduction

A selective laser sintering (SLS) process is one of the die free processes. This SLS process enables to fabricate the complicated products directly from the powders. Although SLS process has many features, many unsolved technical subjects are also left.

In this study, as a basic research for applying SLS process to making the artificial bone, surface texture, shrinkage and mechanical strength were investigated by using single-layered and multi-layered compacts with titanium powders.

2. Experimental and Results

An experimental apparatus is illustrated in Fig. 1. The main feature of this equipment is to prevent the oxidation during forming by decompressing the inside of the chamber, so laser sintering is possible in vacuum atmosphere. A 20W Q-SW pulsed YVO_4 laser was employed and scanned by galvanometer scanner.

Multi-layered rectangular specimen (3 x 1.05 x 6~45mm) and hemisphere specimen (radius: 3,6,9mm) were built to measure the shrinkage with the laser power of 15W and pulse frequency of 100kHz. Shrinkage of laser sintered compact was measured by CNC video measuring system.

Fig. 2 shows SEM images of the surface of single-layered compact with laser power of 16W. The surface along the laser scan in vacuum is almost flat and smooth. On the other hand, there are many defects with rough surface by argon. This may be caused by the surface tension of melted metal during the laser sintering, which in argon is larger than that in vacuum.

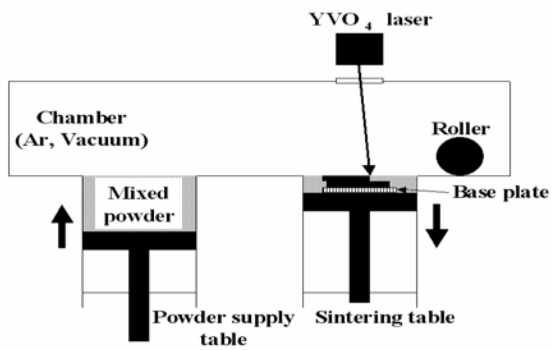

Fig. 1. Schematic illustration of the experimental apparatus

Fig. 3 shows three-dimensional bird's-eye view of surface for the sintered compacts with the laser power of 16W and the scan rate of 10mm/s. The maximum height of surface roughness in vacuum was 26μm, which was lower than that (57μm) in argon.

Shrinkage of the laser scanning direction of rectangular specimens built with the laser power of 15W and the laser scan rate of 10mm/s is shown in Fig. 4 with the triangle mark. L_x and L_{x0} in Fig. 4 show the measurement size and the design size (6~45mm), respectively. In Fig. 4, size shrinking occurs in all specimens because the powders are sintered by laser irradiation. In such a case, the shrinkage becomes large at the small size of L_{x0}. Since the design

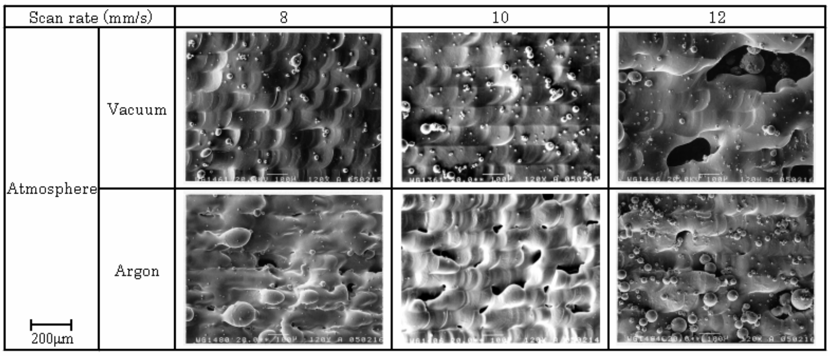

Fig. 2. SEM images of the surface of specimens

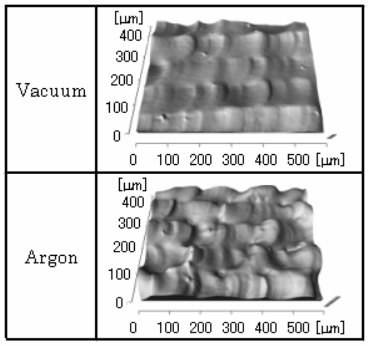

Fig. 3. DSEM images of the surface of specimens

size is small, it is considered that the sintering proceeds easily by the preheating effect of powders. As overall tendency, the shrinkage is increasing almost linearly up to 24mm of L_{x0}, and reaches a constant level over that. By feedback of this tendency, the design size was modified so that the sintered compact size might turn into the ideal size. Shrinkage of rectangular specimen using the modified design size is shown in Fig. 4 with the circle mark. The shrinkage becomes in a fixed value in all specimens, and the value is approximately 1.00. Thus, it is possible to bring the sintered compact size close to the ideal size precisely using the modification from the investigation the tendency of shrinkage before.

Fig. 5 shows the maximum bending strength of specimen (2.5× 3.5×40mm) built with the laser power of 15W. The laser scanning direction is longitudinal. Testing is carried out in two ways, one is to apply loads in the direction parallel to the lamination (a), and the other is in the direction vertical to the lamination (b). As a result of the density measurement of bending specimens before bending test, the density was increased as the scan rate became slow. From this, the maximum bending strength is also increasing as the scan rate becomes slow. From the reference [2], the bending strength of human being's bone is approximately 50~200MPa. The multi-layered compact built in this study only satisfies the lower limit. Although the improvement in bending strength was expected by decreasing the scan rate, it was difficult because the exfoliation between layers occurred. Therefore, in order to increase the bending strength further, laser sintering conditions, sintering atmosphere, powder characteristics should be optimized.

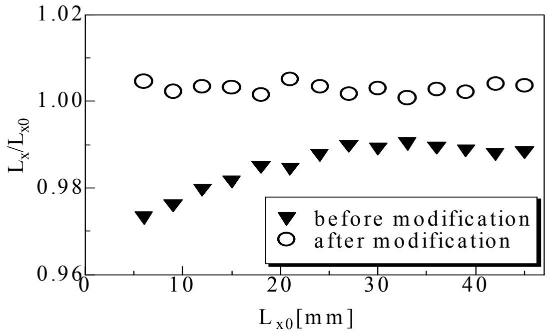

Fig. 4. Shrinkage of the rectangular Specimes

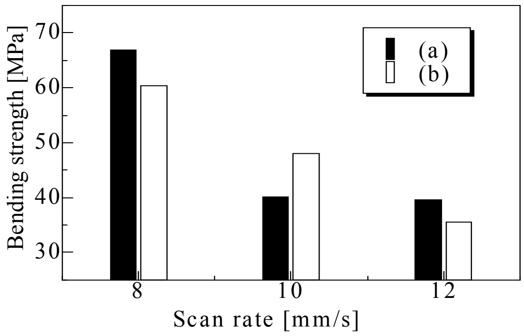

Fig. 5. Bending strength of the multi-layered specimens

3. Conclusion

In single-layered compact, the surface was smooth and the tensile strength was also enough by vacuum laser sintering. In multi-layered compact, dimensional control will be possible by knowing the tendency of shrinkage of the sintered compact by laser irradiation. However, the mechanical properties were not enough because of the lack of bonding between layers. Therefore, it will be necessary to optimize the laser sintering conditions as the next subject.

4. References

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