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Abstract

Optimization of process parameters for TMPS lattice structures

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In implant engineering triply periodic minimal surface (TPMS) lattices provide a way to replicate bone structures with varying densities. Laser powder bed fusion shows potential for producing such lattices with the biocompatible alloy Ti6AL4V. Research has concentrated on mechanical properties, mostly without focusing on underlying process parameters [1]. However, these parameters influence dimensional accuracy and porosity of the implants, which effects mechanical as well as biomedical properties. This study examines process parameters for gyroid lattices.

A design of experiment approach with a central composite design was used. Design factors were wall thickness (100 µm/-500 µm/900 µm) and pore size (600 µm/1000 µm/1400 µm). As process factors laser power (P) (110 W/135 W/160 W) and scan speed (v) (750mm/s/1000 mm/s/1250mm/s) were examined. 26 specimens were manufactured without repetition in different build jobs and powder recycling stages. Porosity was analyzed with an algorithm applying black/ white comparison to micrographs. Dimensional accuracy was evaluated based on CT images and a target/actual comparison.

The identified optimized process parameters regarding porosity are the highest applied settings for laser power and the lowest for scan speed. The highest volume energy density leads to lowest porosity. These results prove relationships known from dense structures, were larger areas, here thicker walls, need a higher energy input to completely melt the powder. With a too low energy input lack of fusion porosity was discovered for medium/ thicker walls.

The determined optimized parameters regarding dimensional accuracy are the lowest applied settings for laser power and the highest for scan speed. They are same for all wall thicknesses/ designs under examination. Thus, the lowest volume energy density leads to the highest accuracy. Due to lower power and retention time of the laser the melt pool is smaller resulting in higher values. Moreover, among specimens with same wall thickness higher accuracy was observed for parts with the largest designed pore size (1400 µm). Melted material has a higher thermal conductivity than unmolten powder. For specimens with larger designed cavities, the boundary area between these two material conditions is larger and thus reducing heat accumulation. Hence, a less sintered on powder and dross formation at down skin area was noted.

In summary, parameters for TPMS lattices vary based on the optimization target. Thus, also in implant engineering the used case definition is vital. For multivariate optimizations, giving porosity and accuracy same weights, the determined factors lie between the single target optima. Powder recycling stage showed a significant influence on porosity.

Author's statement

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