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Abstract

Mechanical and metrological characterization of two different porous β-titanium cellular structures made by laser powder bed fusion

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The necessity to reduce the long-term harmful elements and the request to decrease even more the stiffness has pushed the researchers to move from Ti-6Al-4V to β-Ti alloys. The metastable β Ti- 21S alloy permits to achieve a very low elastic modulus (50-80 GPa) with a good mechanical strength and a high ductility. With the aim to reduce the "stress shielding effect" it is necessary to introduce porosity inside the prosthetic device by using cellular structures produced by additively manufacturing (AM) technologies. The prosthetic device must be designed to guarantee a continuous connection between bone and implant during the patient's life. In case of femoral implant, that is subjected to a fatigue bending condition, the lateral detachment is avoid only by using auxetic cellular structures (negative Poisson's ratio) on the part that undergoes tensile state and a common cellular structure with a positive Poisson's ratio on the internal part [1]. In addition, selection of a TPMS cellular structure for the internal part permits to improve the osseointegration thanks to the high surface area and good permeability [2]. In this work, the manufacturability and mechanical properties of two different structures in β-Ti21S alloy manufactured via LPBF are investigated. In detail, two different unit cell size are considered for auxetic and TPMS cellular structures: auxetic 2.5 mm (with a/b ratio equal to 1.0, the θ equal to 10° and relative density of 0.26), auxetic 3.5 mm (with a/b ratio equal to 0.5, the θ equal to 5° and relative density of 0.20), gyroid skeletal TPMS 2.5 mm (relative density equal to 0.34) and gyroid skeletal TPMS 1.5 mm (relative density equal to 0.28). The TRUMPF TruPrint 2000 LPBF machine is used. X-ray Micro-CT is used to characterize the printed samples and a 3D image analysis software is used to evaluate the strut or ligament thickness and pore size. 5 times loading-unloading compression tests between 20 and 70% of the yield stress on three samples for all conditions are performed and the experimental stabilized elastic modulus of around 0.96 GPa and 0.08 GPa is determined in case of auxetic 2.5 and 3.5 respectively. Differently, elastic modulus of 5.8 GPa and 5.7 GPa are obtained in case of TPMS 2.5 and TPMS 1.5 respectively. All the different geometries permit to avoid the stress shielding effect thanks to the low elastic modulus.

Author's statement

Conflict of interest: A.T., G.D.'A., and F.R. are employees of Trumpf Additive Manufacturing Italia s.r.l.
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