Transactions on Additive Manufacturing Meets Medicine
Trans. AMMM, Vol. 4, No 1, Suppl. 1, Article ID 658, 1 Page

Abstract

3D metrological characterization of functionally graded porous β titanium cellular structures to reproduce the complex internal human bone architecture

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Laser powder bed fusion (LPBF) is one of the most widely used additive manufacturing (AM) techniques in the biomedical industry. The necessity to guarantee similar mechanical properties and biocompatibility of human bone is one of the most important issues in case of surgical implant design and biomaterials definition. Ti-6Al-4V extra low interstitial (ELI) is the most widely used biomaterial due to its high strength and corrosion resistance, combined with biocompatibility. However, the presence of long-term harmful elements such as Al and V and the too high elastic modulus that promotes the 'stress shielding effect' make it necessary to identify new Ti alloys [1]. A recent study has investigated a new titanium alloy, namely β-21S, that shows a very low elastic modulus of 52 GPa with a good mechanical strength and a high ductility. Since the elastic modulus is still too high with respect to human bone, cellular structures produced by AM were proposed for biomedical applications. Auxetic cellular structures, which are structures characterized by a negative Poisson's ratio, seem to be very interesting [2]. In addition, the idea of creating a functionally graded porous structure (FGPS) to reproduce even better the human bone has become of particular importance in recent years [3]. In this work, the manufacturability of two different auxetic FGPS in β-Ti21S alloy manufactured via LPBF is investigated. In detail, auxetic FGPS with aspect ratio equal to 1.5 and relative density gradient of 0.34, 0.49, 0.66 in case of θ equal to 15 ° and a gradient of 0.40, 0.58 and 0.75 in case of θ equal to 25° are designed. CAD design is carried out using nTopology software. The 3D SISMA MYSINT 100 LPBF machine (Sisma S.p.A., Vicenza, Italy) by means of the XY strategy, a laser power of 200W and a spot size of 55 μm are used. X-ray Micro-CT (Research Group 3D Innovation, Stellenbosch University, South Africa) is used to characterize the printed auxetic FGPSs and a 3D image analysis software (Object Research Systems, Montreal, Canada) is used to evaluate the strut thickness and pore size. Comparison with CAD design highlights an under sizing effect on strut thickness and pore size in both auxetic FGPSs due to deviations from ideal geometry that induce changes to the observed parameters as measured by CT imaging. Quasi-static compression mechanical tests are carried out using a servohydraulic Instron machine and the elastic modulus of around 4.6 and 2.3 GPa is determined for θ equal to 15° and 25°, respectively.

AUTHOR'S STATEMENT Authors state no conflict of interest.

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DOI: 10.18416/AMMM.2022.2209658