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Abstract

β titanium novel porous hip implant design for stress shielding reduction

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Metal Additive Manufacturing (MAM) has gained significant interest in the biomedical field, particularly for the production of prosthetic devices. In recent years, there has been a focus on the industrial production of prosthetics using the LPBF (Laser Powder Bed Fusion) technique. These LPBF-manufactured endoprostheses exhibit complex geometries and can incorporate specific textures and porous structures to enhance osseointegration. The industry standard material for MAM prosthetic devices is Ti6Al4V due to its proven biocompatibility and mechanical properties. However, recent studies have demonstrated that novel Ti-alloys, such as β Ti-21S, exhibit equivalent biocompatibility while having a lower elastic modulus compared to Ti6Al4V [1]. In this study, the authors developed an industrially relevant application of the β Ti-21S alloy in the design process of a lattice-based hip prosthetic. Lattice structures, which are based on the replication of a unitary cell in space, known as metamaterials, allow for design freedom in MAM. By tuning the cell parameters and topology, valuable variations in the mechanical properties of the porous component can be achieved, including a reduction in the elastic modulus, negative Poisson's ratio, or maximization of the surface area [2].

Two different cell topologies, namely TPMS and auxetic, were selected to improve the bone-prosthetic interface. Considering the bending loading condition of hip implants, both compressive and tensile volumes within the implant were identified. Inspired by a previous study [3], an auxetic cell topology, capable of exhibiting a negative Poisson's ratio, was chosen for the tensile volume to induce lateral expansion and enhance mechanical adherence of the device. The hip implant underwent various design stages, with its mechanical performance evaluated through solid Finite Element Analysis (FEA). To enhance computational efficiency, lattice components were modeled using the homogenization technique. The homogenized properties of TPMS and auxetic lattices were validated using suitable cubic lattice specimens. The designed prosthetic was subjected to investigation of different biomechanical indices, and the results showed a significant reduction in stress shielding and bone mass loss compared to the Ti6Al4V bulk equivalent.

AUTHOR'S STATEMENT

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