Probabilistic Finite Element Analysis of a Bespoke Titanium Implant Fabricated using Additive Manufacturing Technology

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Electron Beam Melting (EBM) additive manufacturing technique is an active principle employed for the fabrication of bespoke medical devices. EBM also has potential to generate porous lattice structures for bone replacement implants. These structures facilitate osseointegration, and the stiffness of these structures can be matched to that of the bone, eliminating stress-shielding effects, typical within current implants [1]. Mechanical properties of these structures critically depend on porosity [2], and their intricate structure presents a key challenge for accurate modelling and numerical analysis [3].

This study analyses a canine limb-sparing implant, with an integrated lattice structure, manufactured in Ti-6Al-4V ELI alloy using the EBM technology. The research aim is to determine the technical risk associated with the implant through probabilistic numerical analysis. A series of boundary conditions are employed on the implant in order to investigate the robustness of the design. The output stress and strain values are then employed to further examine fatigue life parameters under cyclic loading of the implant. The probabilistic numerical analysis has successfully identified the location of a key failure mode (yield stress limit) and the modelling correlated to veterinary case-study observations. In regard to the lattice structure, it is shown that the structure does provide mechanical integrity to the implant assembly, but the geometry requires significant simplification while modelling. This is primarily due to: (a) the limitations of CAD tools in generating NURB surfaces from point cloud data; and (b) the node and element count associated with these small structures makes the model computationally expensive.

References:

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