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Abstract

Influence of cell size on the mechanical and fatigue behavior of EBM-manufactured Ti-6Al-4V gyroid structures for revision hip implants

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This study investigates the mechanical behavior of additively manufactured Ti-6Al-4V gyroid structures, specifically designed for revision hip implants. Triply periodic minimal surfaces (TPMS) are promising lattice structures due to their continuous geometry and favorable mechanical performance. While extensive studies have focused on compressive loading, bending behavior, critical for the structural integrity of these porous structures, remains largely unexplored. Understanding bending and fatigue behavior is essential for designing safe and durable implants.

This work analyzes gyroid specimens with cell sizes of 3 mm, 4 mm, and 5 mm fabricated by electron beam melting (EBM). All samples were geometrically characterized to evaluate manufacturing deviations and ensure reliable interpretation. Mechanical testing under quasi-static and cyclic bending was complemented by digital image correlation, infrared thermography, and the direct current potential drop method to enable multi-modal characterization of damage initiation and evolution.

The results reveal a pronounced influence of cell size on stiffness, strength, and fatigue behavior. A reduction in cell size results in a 2.6-fold increase in stiffness and a twofold increase in strength compared to the largest cell size. Specimens with smaller cells exhibit superior resistance to cyclic loading, with fatigue life increased by 32%. The applied multi-modal measurement approach provides detailed insights into crack initiation and propagation mechanisms.

These findings improve the understanding of structure–property relationships in gyroid-based TPMS structures and support the design of optimized porous implants for load-bearing applications.

AUTHOR'S STATEMENT

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