

Effect of Lattice Design and Multi-Material Arrangement on Compressive Load Performance Towards Sustainable Additive Manufacturing of 3D Complex Component

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Abstract

This study investigates the mechanical behaviour and deformation characteristics of Triply Periodic Minimal Surface (TPMS) lattice structures fabricated using Fused Deposition Modelling (FDM) for potential application in prosthetic leg sockets. The selection of three TPMS geometries, Lidinoid, Diamond, and Schwarz P, is according to smooth surface topology, uniform stress distribution, and interconnected porous structure that is suitable for load-bearing biomedical applications. The lattices were designed as a 4×4×4-unit cell array in a uniform wall thickness of 2 mm, forming a 40 mm × 40 mm × 40 mm cube. PETG and PCTG were chosen for their biocompatibility and printability; also, PETG can provide higher stiffness and strength, while PCTG contributes by improving their ductility and impact resistance. Samples were tested in single-material and multi-material formations (A-A-B-B and A-B-A-B) to evaluate their mechanical performance. The compression testing assessed strength, stiffness, strain, and energy absorption. The component configurations will exceed the target load capacity of 1.5–2.5 kN, which is more than 58%, even with the compressive stress values within the minimum requirement of 90 MPa. Measured strain (31–33%) and energy absorption (29.3–35.6 J) indicated acceptable deformation and impact dissipation. Lidinoid structures demonstrated superior compressive strength and deformation consistency. Overall, TPMS-based PETG/PCTG designs show strong potential for semi-structural prosthetic socket wall applications and possibly for supporting 3D complex components towards a sustainable additive manufacturing approach.

Keywords

Triply Periodic Minimal Surface, Fused Deposition Modelling, Lattice Structures, Prosthetic Leg Socket and Sustainable Additive Manufacturing.