Additive Manufacturing of Architected Inconel 718 Structures: Comparative Strength and Failure of TPMS and Beam Designs

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Additive manufacturing (AM) enables the fabrication of complex geometries, including lattice structures, which offer potential for lightweight yet mechanically efficient components in aerospace, energy, and medical sectors. This study investigates the mechanical performance of Inconel 718 lattice structures fabricated via Laser Powder Bed Fusion (L-PBF). Five distinct unit cell types were evaluated: three triply periodic minimal surface (TPMS) geometries—Schoen Gyroid (SG), Schwarz Diamond (SD), and Schwarz Primitive (SP)—and two beam-based structures—body-centred cubic (BCC) and beam diamond (BD). Lattice specimens with similar volume fractions (~18–20%) were produced using EOS M290 and post-processed according to EOS-recommended heat treatment.

Compressive and tensile tests were conducted to compare peak strength and failure modes. Results indicate TPMS structures outperform beam lattices in both tensile and compressive strength, with the SP structure showing the highest compressive stress (~1752 MPa) and SD achieving the greatest tensile strength (~817 MPa). Failure analysis revealed brittle fracture characteristics across all lattices, with beam structures failing predominantly at beam-node intersections and TPMS samples showing localised shearing near the load interfaces.

These findings highlight the mechanical advantage of TPMS geometries over conventional beam lattices in static load-bearing applications, and support the use of AM Inconel 718 lattices for components requiring high strength-to-weight ratios.