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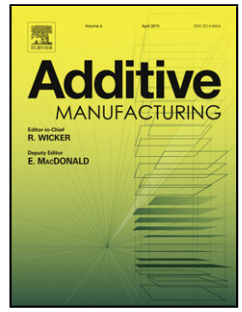

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Energy absorption characteristics of metallic triply periodic minimal surface sheet structures under compressive loading

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Abstract

Designing metallic cellular structures with triply periodic minimal surface (TPMS) sheet cores is a novel approach for lightweight, multi-functional structural applications. Different from current honeycombs and lattices, TPMS sheet structures are composed of continuous and smooth shells, allowing for large surface areas and continuous internal channels. In this paper, we investigate the mechanical properties and energy absorption abilities of three types of TPMS sheet structures (Primitive, Diamond, and Gyroid) fabricated by selective laser melting (SLM) with 316L stainless steel and classify their failure mechanisms and printing accuracy with the help of numerical analysis. The results reveal that the properties and deformation mechanisms strongly depend on the unit cell geometry. TPMS sheet structures are found to exhibit superior stiffness, plateau stress and energy absorption ability compared to body-centred cubic lattices, with Diamond-type sheet structures performing best. Linear and post-yielding mechanical behaviour of TPMS sheet structures as predicted by explicit finite element models is in good agreement with experimental results. The simulation results also show that Diamond and Gyroid sheet structures display relatively uniform stress distributions across all lattice cells under compression, leading to stable collapse mechanisms and desired energy absorption performance. In contrast, P-type structures display rapid diagonal shear band development followed by localized wall buckling. Lastly, an energy absorption diagram is developed to facilitate a systematic way to select optimal densities of TPMS structures for energy absorbing applications.

Keywords: *Additive manufacturing; Energy absorption; Finite element modelling; Selective laser melting; Triply periodic minimal surface (TPMS)*

1. Introduction