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Optimizing Energy Absorption of Additively Manufactured Inconel 718 Gyroid Lattices under Quasi-Static and Dynamic Loading: The Critical Role of Heat-treatment

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Extended Abstract

Abstract

The advent of Laser Powder Bed Fusion (LPBF) has enabled the fabrication of Triple Periodic Minimal Surface (TPMS) metamaterials, such as Gyroid lattices, favored for their superior energy absorption capabilities. While Inconel 718 (IN718) offers high strength and thermal resistance, its as-built microstructure—characterized by columnar grains due to additive manufacturing process—poses significant challenges for post-processing. Standard heat treatments designed for bulk material often induce brittle failures in thin-walled lattice structures, compromising their structural integrity. This study systematically evaluates the microstructural evolution and mechanical response of LPBF IN718 Gyroid lattices under four distinct heat treatment strategies involving solution, super-solvus, and homogenization steps. Mechanical performance was assessed via hardness measurements, quasi-static compression, and high-strain-rate testing (250 s^{-1}) using a Split Hopkinson Pressure Bar (SHPB). Results indicate that treatments performed below the solvus temperature failed to dissolve segregations, leading to premature brittle failure and shear banding. In contrast, treatments involving a homogenization step at 1100°C successfully induced full recrystallization into isotropic equiaxed grains. Specifically, the strategy combining homogenization with double aging (HT 4) proved optimal. It united the ductility of a recrystallized matrix with precipitation hardening, resulting in the highest stable stress plateau. Under dynamic loading, this optimized treatment demonstrated a 30.3% increase in energy absorption compared to the as-built state. These findings highlight that high-temperature homogenization is essential for maximizing the crashworthiness of additively manufactured superalloy lattices.

Keywords:

Lattice structure Additive manufacturing Heat treatment Split Hopkinson pressure bar Inconel 718