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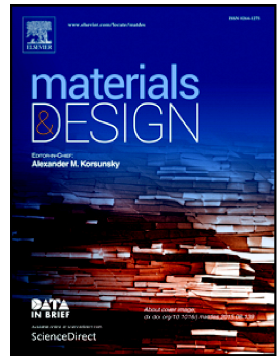

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Evaluation of Topology-optimized Lattice Structures Manufactured via Selective Laser Melting

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Abstract

Selective laser melting (SLM) technology can manufacture complex lattice structures, which effectively reduces the manufacturing constraint and significantly increases the design freedom for lattice structure. In this study, additive manufacturing and topology optimization are combined for designing Face Centre Cube (FCC), Vertex Cube (VC), and Edge Centre Cube (ECC) structures, which are manufactured via SLM technology. Mechanical performance is evaluated, and a Gibson-Ashby model is developed to predict the performance of the three structures including different levels of porosity. The results show that FCC and VC lattice structures have better mechanical behavior compared with that of the ECC lattice structure; however, their energy absorption efficiency is inferior to that of the ECC lattice structure. Comparisons between various SLM built lattice structures made from 316L stainless steel prove that the performance of topology-optimized lattice structures is superior to the majority of lattice structures. This result verifies the feasibility of lattice structure unit selection via topology optimization technology. Various work conditions are simulated for topology optimization to obtain a lightweight lattice structure with optimal performance under specific conditions.

Keywords: lattice structures; topology optimization; selective laser melting; mechanical characterization

1. Introduction

As a superior integrated structure-function engineering material, metal lattice material has excellent mechanical properties: ultra-lightweight, high specific strength, high specific rigidity, high durability, and high energy absorption rate. This material also has excellent functional properties. Several special structures also have functions such as shock absorption, heat dissipation, acoustic absorption, and electromagnetic shielding. Metal lattice materials with both superior structural and functional properties have wide applications in fields such as biological/medical sciences and aviation/aerospace industries [1-5].

Conventional metal lattice material manufacturing methods include melt foaming method, powder metallurgical method, and infiltration casting method [1-5]. However, it is difficult for conventional manufacturing methods to produce complex, delicate lattice structures with strict porosity constraints, optimal apertures, and the required mechanical properties. From a manufacturing process's perspective, it is of particular importance to create a new manufacturing method for lattice metal structure creation to improve the performance of porous metal structures and reduce cost.

Currently, additive manufacturing technology (3D printing) is becoming mature and viable for lattice structure manufacturing. As one of the most promising additive manufacturing technologies, selective laser melting (SLM) is known for its high level of degree of freedom in manufacturing. SLM technology enables layer-by-layer production of metal parts based on a three-dimensional model. A computer controls a laser beam that scans along a planned path to melt metal powder. Layered accumulation can produce geometries of almost any shape. Based on the process characteristics of additive manufacturing technology, the design process is controlled effectively, and the processing technique is optimized to obtain components with nearly 100% compactness [7-11]. This technology overcomes the design constraint of conventional