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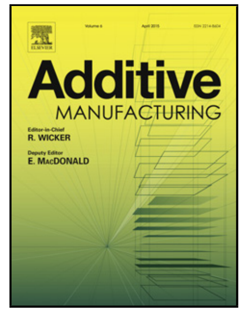

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Experimental and Analytical Investigation of Mechanical Behavior of Laser-Sintered Diamond-Lattice Structures

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Abstract

Typically, additive manufacturing (AM) processes are limited to a single material per build while many products benefit from the integration of multiple materials with varied properties. To achieve the benefits of multiple materials, the geometric freedom of AM could be used to build internal structures that emulate a range of different material properties such as stiffness, Poisson's ratio, and elastic limit using only a single build material. This paper examines a wide range of properties that can be achieved using diamond lattice structures manufactured from Nylon 12 with a commercial laser sintering (LS) process. Stiffness and energy absorption were measured for all lattices and the stiffness response was compared to finite element analysis (FEA). Simulation shows agreement with experimental results over a stiffness range of four orders of magnitude once a correction factor is applied. Experimental results also show a wide range of energy absorption for diamond lattice structures and a significant increase in the effective elastic limit of the build material, which compensates for the low ductility of many AM materials. The elastic limit decreases with an increasing *t/L* ratio meanwhile the degradation under cyclic loading is relatively independent of the *t/L* ratio. Extrapolating this data into lattice structures made from metal, these same structures could mimic a wide range of "fully" dense and porous materials with just the use of a single material. Since the diamond lattice is a cellular structure, the voids can also be filled with other materials or structures to add secondary control of embedded functions such as energy storage and sensing.

Keywords: additive manufacturing (AM), cellular structure, diamond lattice, energy absorption, laser sintering (LS), multi-material systems

1. Introduction

Efficient designs minimize material consumption by seeking to use material only where necessary. However, traditional manufacturing techniques impose many geometric constraints that limit design freedom [1]. Cellular structures combine solid material and void space to reduce effective density [2]. Cellular structures are highly efficient and used widely in nature (honeycombs, bone, wood, and coral) but not readily manufacturable using traditional techniques. Furthermore, cellular structures can create combinations of properties that are distinct from the properties of the constituent materials and are highly dependent on both the relative percentage of void space and solid material as well as the topology of these structures. This combination creates a metamaterial with the ability to exhibit effective properties not found in nature. [3-5]

In an effort to mimic natural cellular structures, early synthetic cellular structures were fabricated by foaming processes [6, 7]. However, foamed materials are stochastic and often anisotropic making it difficult to control local properties and structure [8, 9]. If the manufacturing process could control the distribution of material in a repeatable and predictable manner by specifying the topology of material and void space, properties like density, Poisson's ratio, and stiffness could be tuned spatially and exhibit properties that are not easily obtained in nature; such as an auxetic structure [10].