World Academy of Science, Engineering and Technology
International Journal of Mechanical and Materials Engineering
Vol:19, No:05, 2025

Investigation of Scaling Laws for Stiffness and strength in Bioinspired Glass Sponge Structures Produced by Fused Filament Fabrication

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Abstract : Various industries, including civil engineering, automotive, aerospace, and biomedical fields, are currently seeking novel and innovative high-performance lightweight materials to reduce energy consumption. Inspired by the structure of Euplectella Aspergillum Glass Sponges (EA-sponge), 2D unit cells were created and fabricated using a Fused Filament Fabrication (FFF) process with Polylactic acid (PLA) filaments. The stiffness and strength of bio-inspired EA-sponge lattice were investigated both experimentally and numerically under uniaxial tensile loading and are compared to three standard square lattices with diagonal struts (Designs B and C) and only non-diagonal struts (Design D) reinforcements. The aim is to establish predictive scaling laws models and examine the deformation mechanisms involved. The results indicated that for the EA-sponge structure, the relative moduli and yield strength scaled linearly with relative density, suggesting that the deformation mechanism is stretching-dominated. The Finite element analysis (FEA), with periodic boundary conditions for volumetric homogenization, confirms these trends and goes beyond the experimental limits imposed by the FFF printing process. Therefore, the stretching-dominated behavior, investigated from 0.1 to 0.5 relative density, demonstrate that the study of EA-sponge structure can be exploited for the realization of square lattice topologies that are stiff and strong and have attractive potential for lightweight structural applications.

Keywords : bio-inspiration, lattice structures, fused filament fabrication, scaling laws
Conference Title : ICWAM 2025 : International Conference on Welding and Additive Manufacturing
Conference Location : Crete, Greece
Conference Dates : May 27-28, 2025