Design of bio-inspired glass-sponge lightweight cellular structures and manufacture via 3D printing continuous flax fiber biobased composite for energy absorption application

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Abstract

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In the context of reducing CO2 emissions, various industries, including construction, automotive, aerospace and biomedical sectors are actively seeking for innovative lightweight and environmentally friendly materials and structures.

Nature has severely outpaced humans in developing optimized structures regarding to environmental stresses. Euplectella Aspergillum sponge (glass-sponge) has a complex multiscale architectured lattice structure. That organisation permits to withstand hydrodynamic forces due to deep depths (from 150 to 5000m), uneven loads because of dynamics currents and fend off marine predator attacks. Therefore, the sea sponge assures a high mechanical properties in bending and torsion, while maintaining toughness and lightness (1). The present work aims to study the bio-inspired glass-sponge design for energy absorption applications.

3D printing, particularly Fused Filament Fabrication (FFF), enables the creation of complex structures. The incorporation of continuous natural fiber into composite cellular structure offers the potential for significant weight reduction while maintaining high mechanical strength. The continuous flax fiber reinforced PLA composite will be used due to its lower environmental impact, lightweight nature and comparable specific properties when contrasted with synthetic fiber reinforced composite (2)(3). Our approach leverages in-nozzle impregnation to achieve precise orientation and placement of continuous flax fibers, drawing inspiration form sea sponge design to develop optimized composite structures (4).

To attempt the objective, three designs are proposed: **Design A**, a simple square structure; **Design B**, a Design A coupled to a cross distributed in checkerboard pattern; **Design C**, a bio-inspired structure made up of a Design A coupled to a double diagonal distributed in checkerboard pattern. The study employs Digital Image Correlation (DIC) to investigate the impact of structural density on deformation modes (in-plane and out-plane) and energy absorption under uniaxial compression loading. Ultimately, this research aims to establish the link correlating structural design and relative density with mechanical performance, advancing the development of sustainable, high-performance composite materials.

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Keywords

Lattice composite structures, Bio-inspiration, Glass-sponge, Fused filament fabrication, Compressive test

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