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Mechanical Characterization and Energy Absorption of Sandwich Structures with 3D-Printed PET Cores Featuring Cellular Topologies for Marine Application

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Introduction

Composite sandwich structures are relevant in aerospace, automotive, marine, and packaging sectors owing to their low density, high specific stiffness, and energy-dissipation capacity. Core topology governs stiffness, strength, and failure modes. Auxetic geometries, characterized by a negative Poisson's ratio, improve shear resistance, indentation tolerance, and energy absorption. Additive manufacturing expands the design of complex core structures but introduces anisotropy, porosity, and printing-orientation sensitivity.

Objectives

- Characterize the mechanical behavior of PET cores;
- Assess the influence of the E-glass fiber face sheets on stiffness and energy absorption;
- Validate the compression results using finite-element analysis;
- Classify the failure modes. .

Methodology

Four core topologies—circular, elliptical, re-entrant honeycomb, and bicellular—were designed in SolidWorks in uniaxial and biaxial configurations and fabricated from PET by 3D printing (215 °C nozzle, 70 °C bed, 0.4 mm nozzle, 0.2 mm layer, 50 mm/s). Panels were assembled by bonding two-layer E-glass fiber face sheets to the core. Specimens were tested per ASTM C365 (compression), C393 (bending), and D6110 (Charpy impact) on an INSTRON EMIC 23-50; energy absorption was computed from the force–displacement curves.

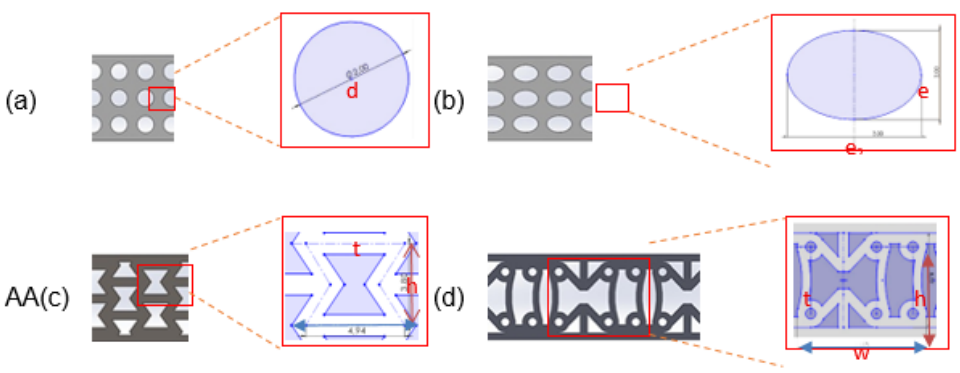


Figure 1. Core profiles and unit-cell geometries: (a) circular d = 2 mm, (b) elliptical e_1 = 2 mm, e_2 = 3 mm, (c) re-entrant honeycomb t = 0.42, h = 3.80, w = 4.94 (mm), and (d) bi-cell t = 0.89, h = 8.22, w = 1.1 (mm).

Results and Discussion

Auxetic geometries exhibited the highest energy absorption, approaching 70% under compression. The uniaxial bicellular configuration absorbed 69.9 J under compression and the biaxial elliptical configuration 79.3 J. Under bending, the uniaxial circular and elliptical configurations reached 6233 MPa and 4941 MPa. Delamination, buckling, and localized deformation were observed, the re-entrant geometry showing greater plasticity. Numerical validation under compression agreed with the experiments, with errors below 15%.

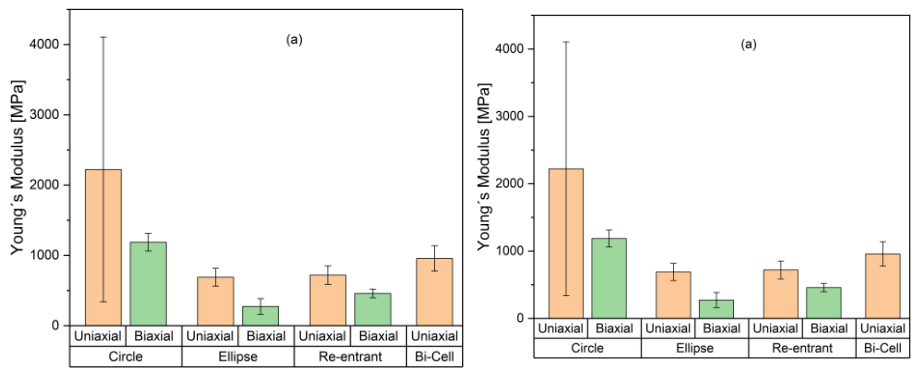


Figure 2. Young's modulus: (a) cores; (b) sandwich structures.

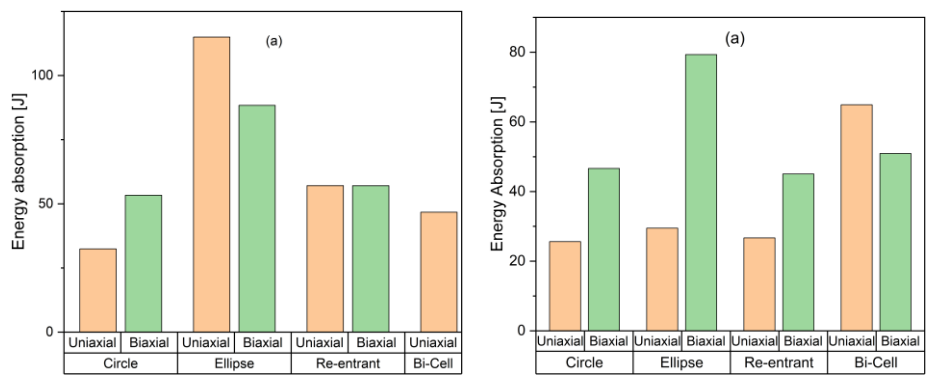


Figure 3. Energy absorption (compression test): (a) cores; (b) sandwich structures.

Conclusions

Core topology and printing orientation govern the mechanical performance of sandwich structures. The uniaxial circular geometry achieved the highest flexural stiffness in both cores (2221 MPa) and sandwich panels (6233 MPa). No single geometry was optimal across all tests: the uniaxial ellipse maximized core energy absorption (114.98 J), the biaxial ellipse performed best under compression (79.32 J), and the uniaxial re-entrant geometry excelled in flexure. Compressive strength was more material- than topology-dependent; the circular configuration showed the best impact performance (5551 J).

References and Acknowledgments

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