Stacking Sequence Optimization for Enhanced Vibro-Acoustic and Mechanical Performance in Carbon/Flax Hybrid Composites

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Abstract

Designing lightweight structures for the automotive and marine industries often requires navigating a difficult trade-off between structural rigidity and vibro-acoustic comfort. Carbon fiber reinforced polymers (CFRP) are favored for their exceptional specific strength, yet their inherent stiffness often results in limited vibration damping and acoustic insulation. Conversely, natural flax fibers possess a unique hollow (lumen) microstructure that facilitates high internal friction, offering superior energy dissipation potential. This research investigates a synergistic hybridization strategy, combining synthetic carbon and natural flax fibers to develop sustainable composites with "tunable" vibro-acoustic properties.

In this study, five distinct hybrid configurations-ranging from rigidity-oriented to damping-focused and core-effect designs-were manufactured using the Vacuum-Assisted Resin Infusion (VARI) method. The research systematically evaluates how stacking sequences influence mechanical integrity and Sound Transmission Loss (STL) across different weight groups. Comprehensive mechanical characterization, performed via ASTM D3039 tensile and ISO 14125 flexural tests, reveals that while carbon skins maximize load-bearing capacity, the strategic integration of flax UD and non-woven felt layers is intended to fundamentally shift the acoustic resonance profile.

Acoustic performance is currently being evaluated using an impedance tube according to ASTM E2611 to validate the role of specific stacking sequences as "acoustic filters". Preliminary mechanical data suggest that shifting flax layers to the exterior surfaces provides a path to high-damping structures, with targets of up to 90% improvement in damping ratios compared to pure carbon references. This work aims to provide essential design data for implementing sustainable hybrid composites in noise-sensitive applications, such as electric vehicle body panels and marine hulls, offering a viable method to reduce the industrial carbon footprint without compromising structural reliability.

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