Multicriteria Design of Lower-Carbon Hybrid Composite Type V Hydrogen Pressure Vessels

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Abstract

Reducing the embodied carbon of high-pressure hydrogen storage is essential for sustainable mobility, but replacing carbon fibre in linerless Type V vessels can increase thickness and mass. This study proposes a multicriteria method for targeted hybridization of carbon/epoxy laminates with basalt/epoxy, flax/epoxy and ultra-high-molecular-weight polyethylene (UHMWPE)/epoxy plies. A thin-cylinder model based on Classical Laminate Theory evaluates stacking sequences for fibre angles from 15° to 90°. For each architecture, the minimum admissible thickness is determined by enforcing a Tsai-Wu first-ply failure index below unity and a simplified leak index based on transverse and in plane shear stresses. Areal mass and cradle-to-gate carbon impact are then estimated. The screening identifies 45°-55°, particularly around 50°, as the most promising range. Targeted substitution of 90° plies preserves admissibility while reducing carbon/epoxy plies by approximately 58%. A 700-bar finite-element assessment further shows that a uniform 50% carbon-50% basalt architecture increases thickness and mass while providing limited carbon benefit. Environmental performance must therefore be optimized at laminate level before detailed damage, leakage, manufacturing and life-cycle validation.

Keywords

Hydrogen Storage, Type V Pressure Vessel, Hybrid Composites, Carbon Footprint, Classical Laminate Theory, Tsai-Wu, Finite-Element Analysis.