Fiber-Optic Structural Monitoring for Space Composites: Quick-Pack Integration and Birefringent Sensors

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Abstract

Future spacecraft require lightweight structures capable of withstanding severe thermo-mechanical environments while continuously reporting their condition. Fiber Bragg Grating (FBG) sensors are attractive because of their low mass, compactness, electromagnetic immunity, and multiplexing capability. Their industrial adoption, however, is limited by two main challenges: reliable structural integration and strain–temperature decoupling.

The integration challenge is addressed through the Quick-Pack, a composite-compatible insert that protects, positions, and routes optical fibers and FBG arrays during manufacturing [1]. The concept enables controlled sensing paths, limits bending-induced attenuation, facilitates fiber and connector integration, and reduces specialized lamination operations. Different materials, groove geometries, and manufacturing strategies are investigated, focusing on partial curing before co-curing. Differential Scanning Calorimetry determines the degree of cure required for stable fiber fixation, while peel tests quantify the resulting interfacial performance. Cure-kinetics modelling predicts the evolution of the degree of cure with temperature and time, whereas rheological characterization identifies resin-flow conditions compatible with manufacturing.

The second challenge is addressed through birefringent polarization-maintaining FBGs based on PANDA and Bow-Tie fibers for thermo-mechanical decoupling [2, 3]. Together, Quick-Pack integration and birefringent sensing support the industrial applications of fiber-optic monitoring systems, enabling their adoption in real scenarios for aeronautical and aerospace composite structures.

Future space applications include satellite panels, deployable booms, antenna reflectors, solar-array substrates, pressure vessels, propellant tanks, and off-Earth habitats. Current work focuses on a retractable telescopic sleeve for on-orbit refueling with shape-memory-alloy rotary actuation [4, 5]. FBG arrays with Quick-Pack will be used to monitor the structural response and deployment process.

References

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