Advancing Composite Aerostructures: A Lifecycle Approach from Joint Design and Repair to AI-Powered Inspection

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Research Overview

Modern aerospace composites offer exceptional strength but little tolerance for error: each joint, repair, and inspection defines structural integrity.
This research integrates design, repair, and inspection into a verified lifecycle framework.
Core Challenge: Joints and repairs remain weak points that limit performance and increase cost.
Strategic Goal: Shift from reactive repair to proactive, AI-based design and inspection, ensuring every laminate and adhesive is created with verification in mind.

Industry Relevance

Applications: Wings, spars, fuselage panels, and control surfaces.
Cross-Sector Impact: Applicable to automotive, wind-energy, and defence structures.
Industrial Benefit: Lighter joints, faster validated repairs, and AI-assisted inspection reduce cost, downtime, and human error.
Outcome: A certifiable, damage-tolerant composite framework ready for digital-twin integration.

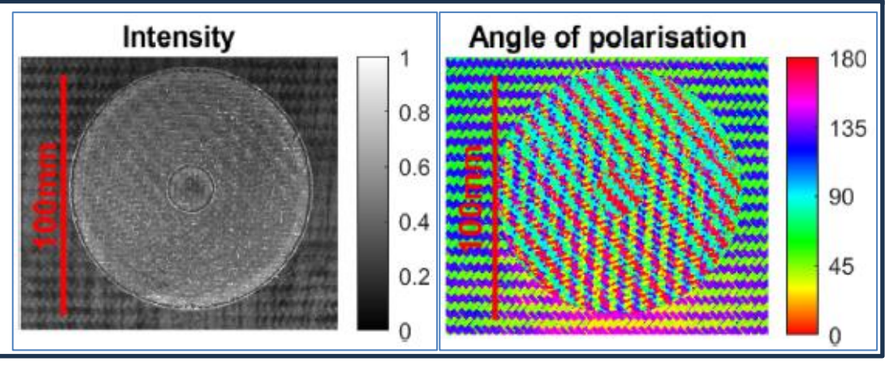
Methods & Technologies

Experimental: Impact, shear, buckling, and pin tests evaluate residual strength and repair recovery on stepped, scarf, and hybrid bonded-bolted joints.
Numerical: Finite element models with progressive and cohesive damage predict delamination, adhesive failure, and joint performance.
Inspection & AI: Machine-learning vision (YOLOv11-Seg) automates defect detection/classification under polarised and dome lighting.
Facilities: Drop tower, 100 kN Instron, ultrasonic C-scan, and DIC enable full-field validation.

Innovations

Polarisation image of a stepped scarf under inspection lighting.

Joints: Quasi-isotropic CFRP lugs outperform aluminium; 5% MCF epoxy improves stiffness and load transfer.
Repairs: Ramped scarf achieves 12% higher load; variable-length scarf restores 80% strength and full stiffness.
Inspection: Machine-learning vision detects surface defects, and a tactile whisker sensor identifies barely visible impact damage with 100% accuracy.



Opportunities

Partnerships: Collaboration with aerospace, MRO, and robotics or NDT partners to validate repair and inspection methods.
Benefits: Proven composite lifecycle framework that cuts downtime, improves reliability, and integrates AI inspection.
Collaboration Base: UWE Bristol's composites and digital engineering labs offer testing, data analytics, and industrial support.
Funding: Open to joint projects, industrial PhDs, postdocs, and collaborative grants in composites and AI inspection.

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