Bio-inspired composite adherends: enhancing the impact performance of adhesive joint

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Introduction

Biostructures found in nature exhibit exceptional mechanical properties such as strength, toughness, and damage resistance. Despite attempts to replicate these properties in carbon fiber-reinforced laminate (CFRP) materials, mimicking the intricate structures of natural organisms remains a formidable challenge. This study explores bio-inspired Carbon Fiber Reinforced Plastic (CFRP) laminates as adherends in bonded single lap joints (SLJs), mimicking the helicoidal structure of the mantis shrimp's dactyl club.

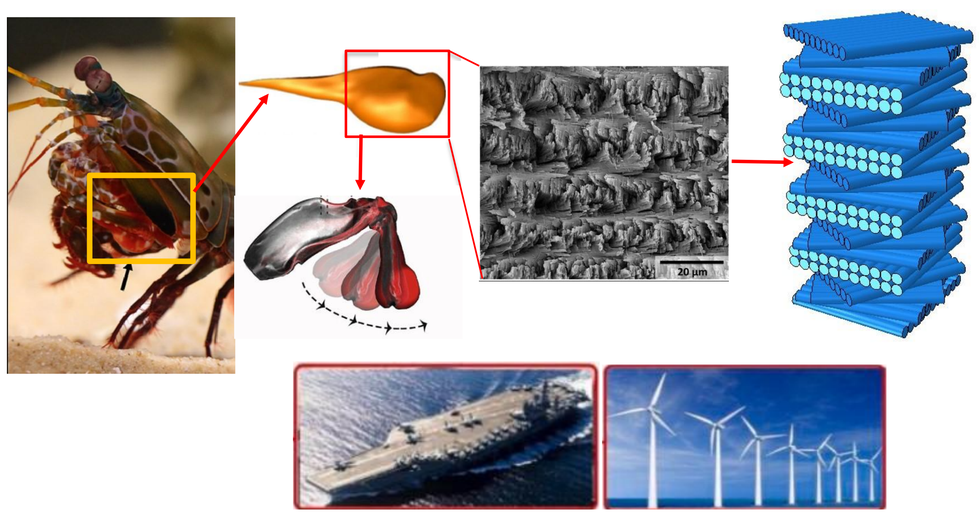


Figure 1 – Bio-inspired stacking sequence and its applications [1].

Experimental details

1. Adherends layup

- UD — Unidirectional (UD) $[0]_{20}$
- G — Gradual helicoidal $[0/5/15/60/90/90/60/15/5/0]_S$
- H — Conventional helicoidal $[0/20/40/60/80/100/120/140/160/180]_S$
- QI — Quasi isotropic $[0/+45/-45/90/0/+45/-45/90/0/+45]_S$

2. Manufactured Single Lap Joints (SLJs)

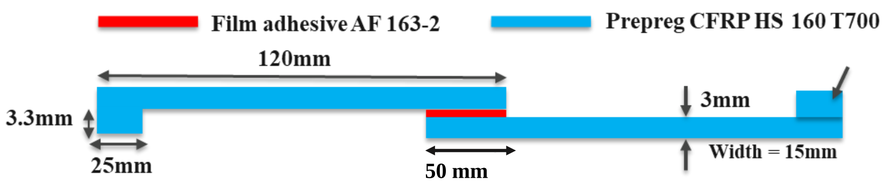


Figure 2 – Schematic of manufactured SLJs.

3. Testing method

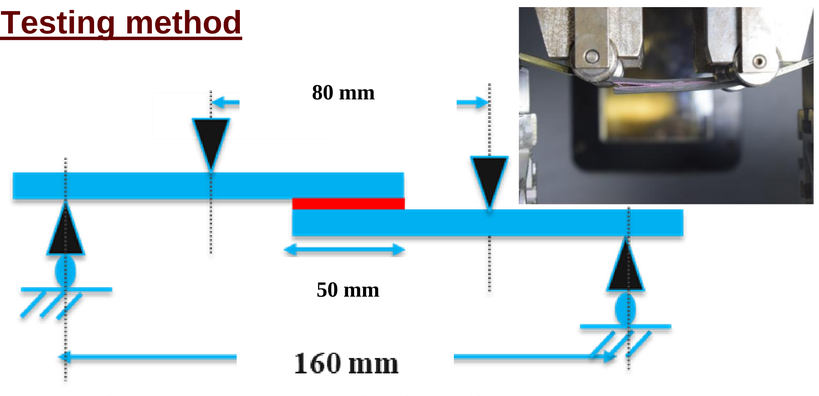


Figure 3 – Four-point bending test set-up.

Results and discussion

AS shown in Figs. 4 and 5, UD joints exhibited brittle through-thickness fracture and limited energy absorption, while multidirectional G, H, and QI architectures promoted more complex damage paths. G-type joints achieved approximately twice the impact strength of conventional UD joints. QI laminates showed increased susceptibility to early delamination due to abrupt fibre-orientation changes, whereas helicoidal laminates provided smoother stiffness transitions and delayed damage initiation.

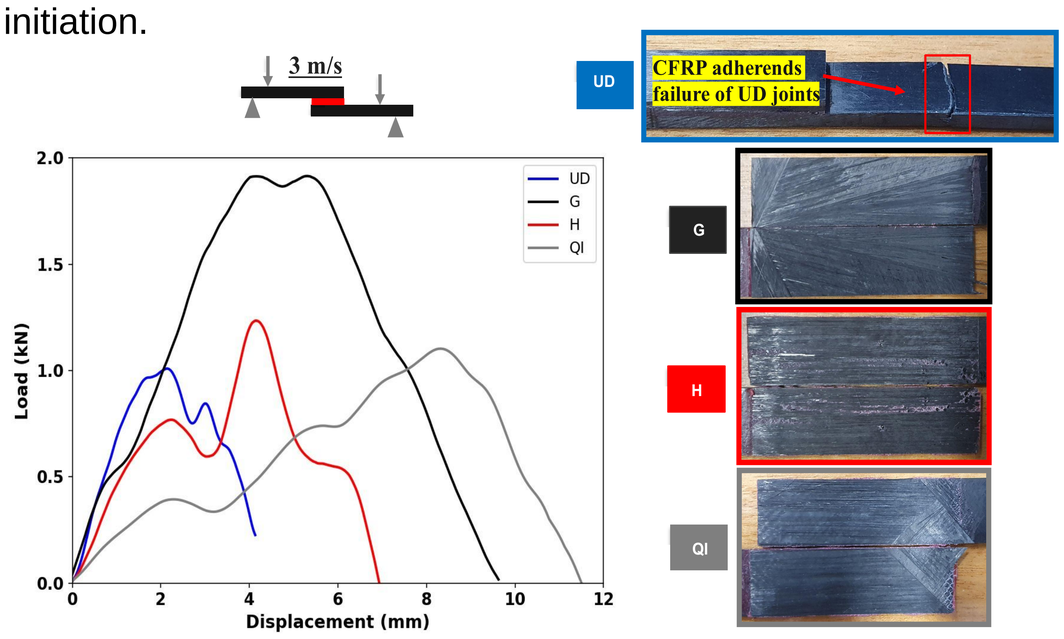


Figure 4 – Impact four-point bending average load–displacement and failure mechanisms.

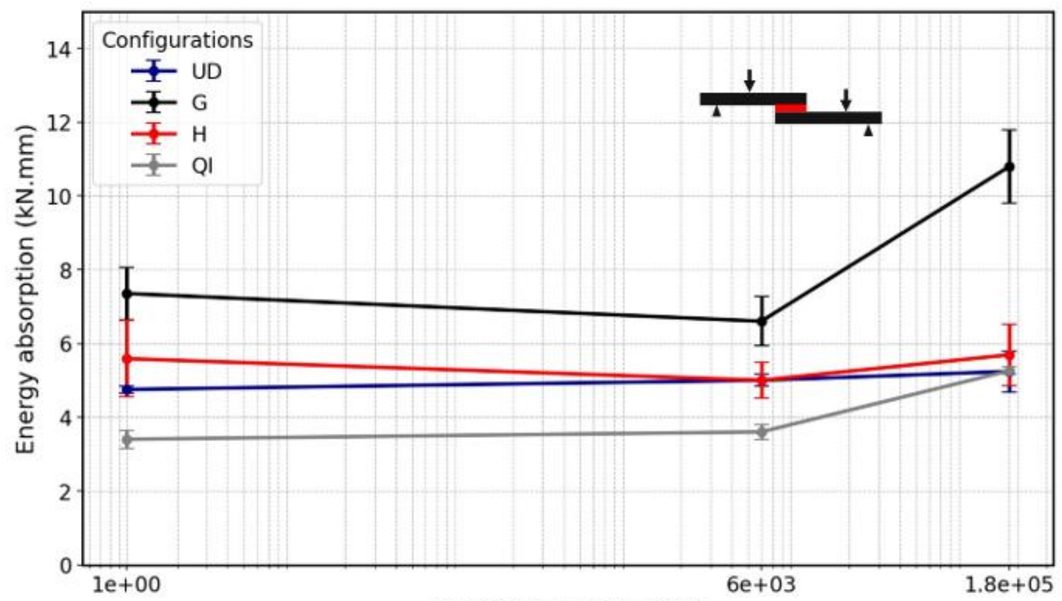


Figure 5 –Summary of experimentally obtained energy absorption for identified joint types.

CONCLUSION

- G-type joints: ~2× higher impact strength than UD joints.
- Multidirectional laminates: Improved damage tolerance and energy dissipation.
- Helicoidal laminates: Delayed damage initiation compared to QI laminates.

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[1] Malekinejad, H.; Carbas, R.J.C.; Akhavan-Safar, A.; Marques, E.A.S.; Ferreira, M.; da Silva, L.F.M. Bio-Inspired Helicoidal Composite Structure Featuring Graded Variable Ply Pitch under Transverse Tensile Loading. J. Compos. Sci.. 2024, 8, 228.