The performance of adhesive joints with bent composite adherends

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INTRODUCTION

Adhesive bonding is increasingly used in the transportation industry for its design flexibility, vibration damping, and ability to join dissimilar materials. While composite materials like carbon-fiber-reinforced polymers (CFRPs) offer high strength-to-weight ratios, delamination, driven by high peel stresses, remains a primary failure mode in CFRP single lap joints (SLJs).

PROBLEM IDENTIFICATION

This study investigates the mitigation of delamination in composite SLJs through the introduction of curved adherends and non-uniform adhesive layer thicknesses. Asymmetric stacking sequences induce warpage during curing due to thermal expansion mismatches, resulting in thicker adhesive edges. These thicker edges generate higher compressive thermal stresses, which are intended to counteract delamination. Combining the geometric and thermal stress modifications, the goal is to reduce peel stresses and improve overall joint performance.

EXPERIMENTAL METHODOLOGY

- <u>Adhesive</u>

Scotch Weld AF 163-2k adhesive, a film-form modified epoxy supplied by 3M Company, was used in this study. It is characterized by high fracture toughness and peel strength

- <u>Adherend</u>

Texipreg HS 160 T700, a commercially available unidirectional prepreg CFRP material.

- <u>Joint geometry</u>

Figure 1 illustrates the specimen geometry analyzed. The geometry parameters used: : L_T = 215 mm, L_0 = 25 mm, t_s = 3.20 mm, $t_{a,min}$ = 0.2 mm, $t_{a,max}$ = 1.0 mm and h = 1.4 mm.

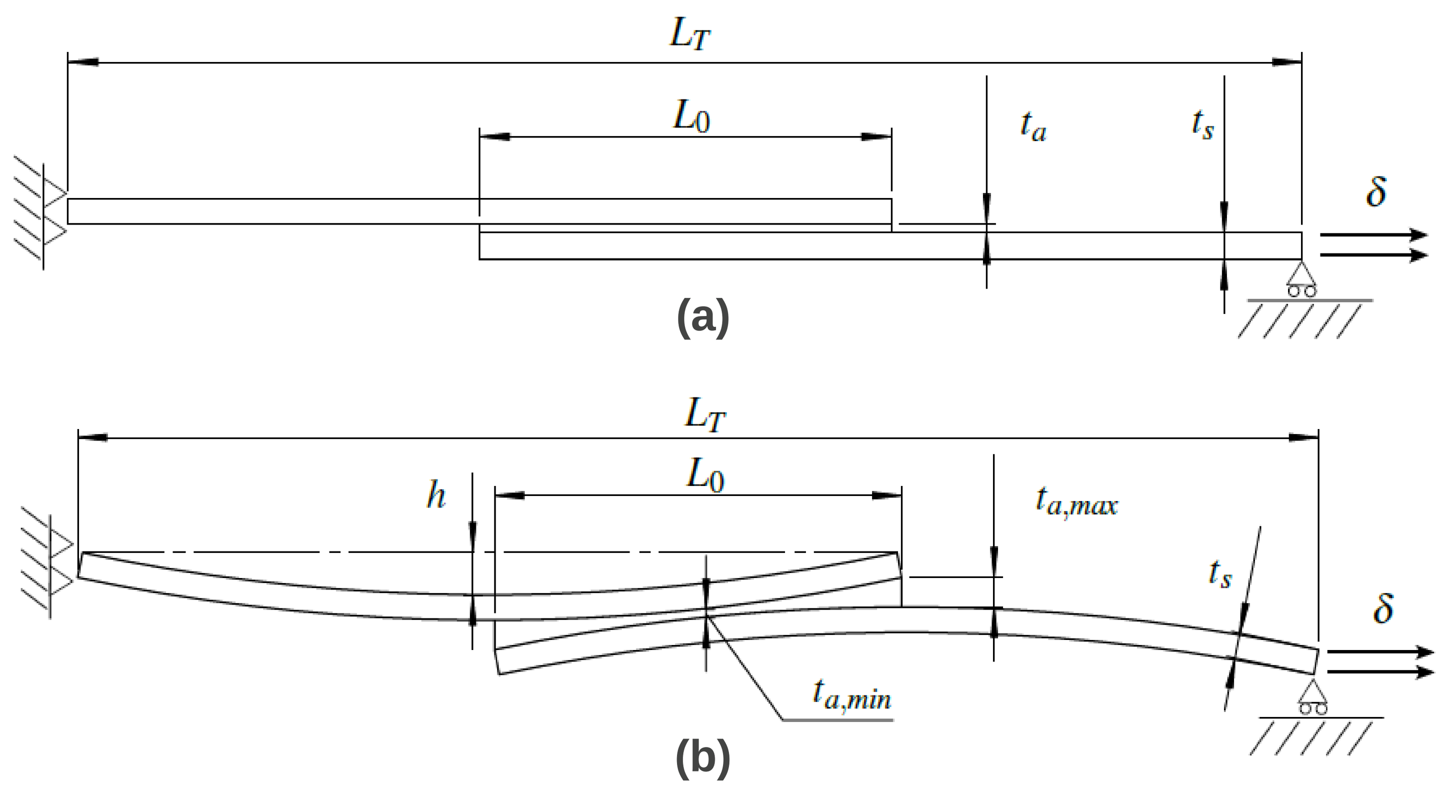

FIGURE 1. SLJ specimen geometry. (a) Planar SLJ. (b) Curved SLJ.

Asymmetric layups of 0° and 90° layers induce curvature in the adherends. This curvature, visible in Figure 2, results from the curing process. Specifically, a $[0^o_{10}/90_{11}]$ layup was used.

FIGURE 2. Warpage deformation in a [0º/90º/0º/90º] composite plate is caused by the orthotropic coefficients of thermal expansion.

RESULTS

The joints were subjected to quasi-static testing to analyze their failure load. Figure 3 illustrates the failure modes, revealing delamination in the conventional CFRP SLJ and cohesive failure in the other two configurations. Analysis of the *P*-δ curves demonstrates that the curved SLJ achieved a failure load comparable to the 0.2 mm reference configuration, while significantly exceeding that of the 1.0 mm configuration.

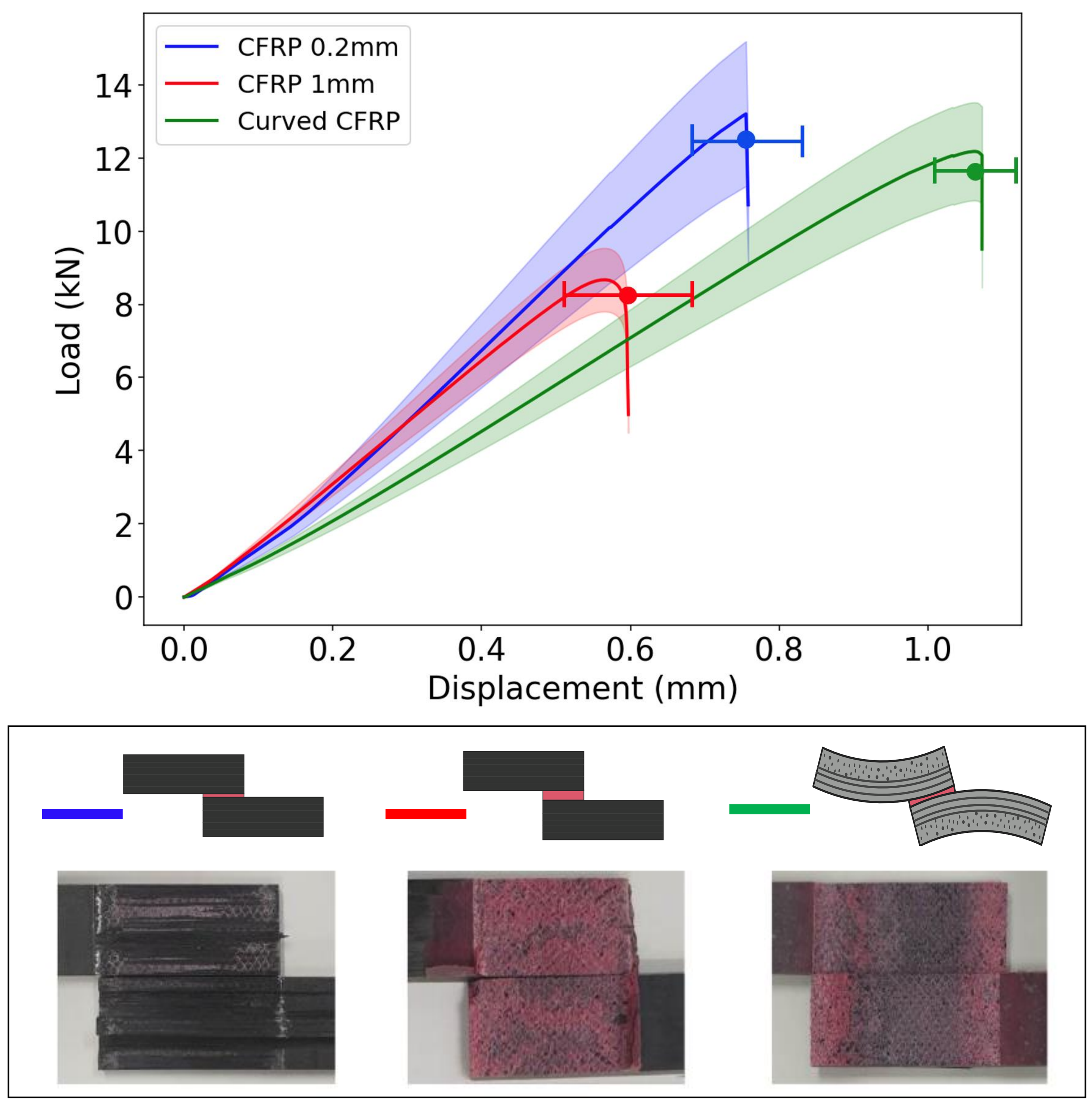

FIGURE 3. P–δ curves obtained experimentally for the three configurations and typical failure mode for each configuration.

CONCLUSION

- The curved joint exhibited cohesive failure due to residual thermal stresses from curing and its geometry.
- Increased adhesive thickness in planar SLJs resulted in cohesive failure, but a 22.1% reduction in failure load.
- This design mitigated tensile peel stresses, preventing delamination and maintaining a failure load comparable to conventional CFRP SLJs, thus improving performance.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the Portuguese Foundation for Science and Technology (FCT) for supporting the work through the Project No. PTDC/EME-EME/2728/2021 'New approaches to improve the joint strength and reduce the delamination of composite adhesive joints'.

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DRMS2025 2ND INTERNATIONAL CONFERENCE ON DURABILITY, REPAIR AND MAINTENANCE OF STRUCTURES
MARCH 13-14, 2025 - PORTO, PORTUGAL