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Strategies to reduce delamination in composite adhesive joints using hybrid-CFRP adherends

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INTRODUCTION

This study investigated hybrid adherends made of carbon fiber reinforced with different materials in a single-lap joint (SLJ) configuration. The aim was to understand how the thermal residual stresses generated during curing affect the peel stresses within the overlap region. The numerical analysis was conducted using the ABAQUS finite element software package. The resulting models were validated using data obtained from experiments.

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EXPERIMENTAL DETAILS

A structural adhesive Scotch Weld AF 163-2K was used, is a modified epoxy that is supplied in film form. The cure used was at 130˚C for a duration of 1 hour.

The composite material used was a unidirectional prepreg CFRP (carbon-fiber reinforced plastic), specifically the Texipreg HS 160 T700, featuring a ply thickness of 0.15 mm.

The geometry of the single lap joint (SLJ) is illustrated in Figure 1, with the adherend thickness t_s = 3.15 mm, the minimum adhesive thickness $t_{a,min}$ = 0.2 mm, the overlap length L_0 = 25.0 mm and the total distance between grips L_T = 215.0 mm. For the curved joint (h = 1.4 mm) with a varying adhesive thickness ranging from 0.2 mm at the middle of the overlap ($t_{a,min}$) to 1.0 mm at the edges of the overlap ($t_{a,max}$).

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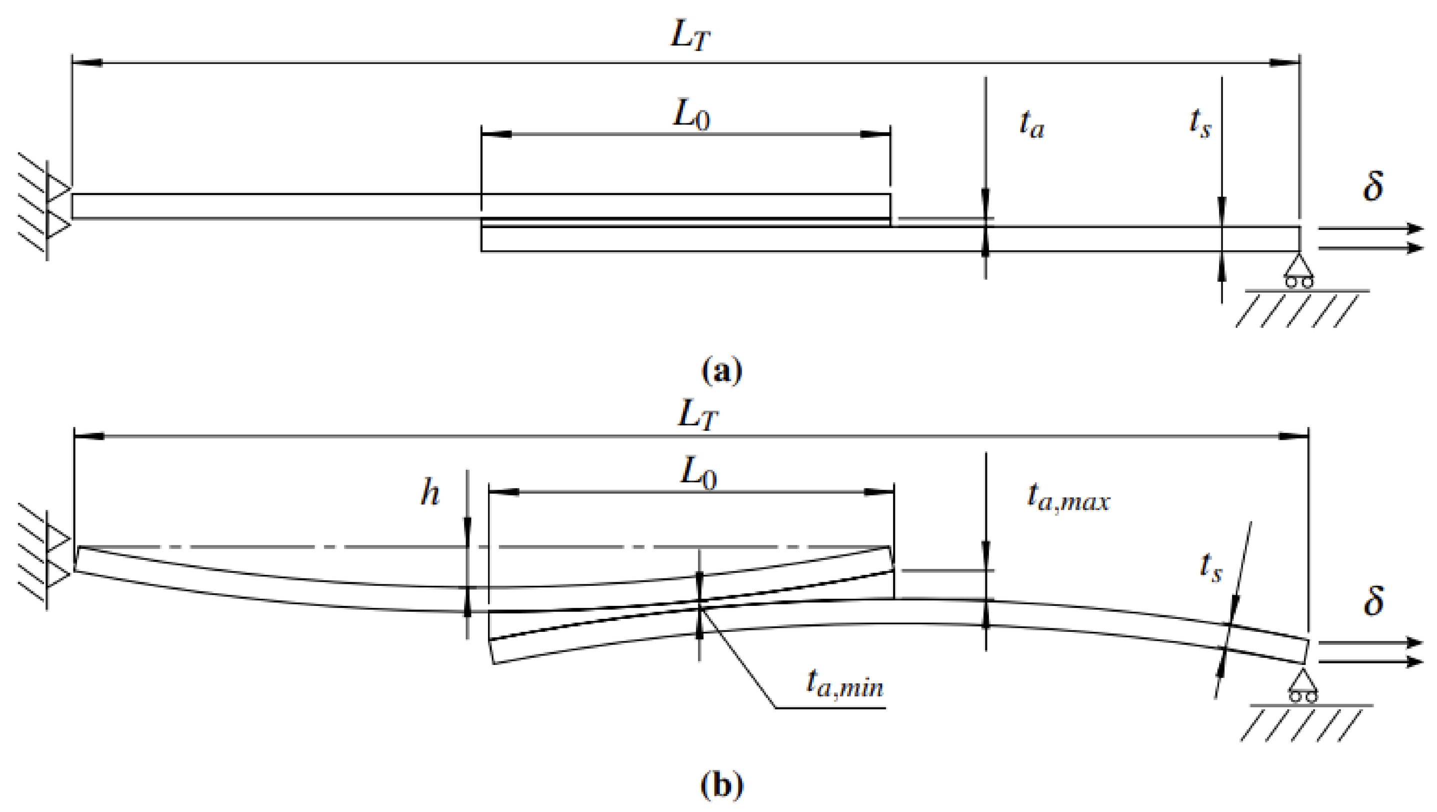

FIGURE 1. SLJ specimen geometry. (a) Planar SLJ. (b) Curved SLJ.

Residual stresses play a significant role in composite materials and greatly influence the behaviour of composite structures. The curvature of the adherends is obtained through asymmetric layups of 0° and 90° layers. This leads to the curvature of the adherend after curing as seen in Figure 2. In this case a layup of $[0°_{10}/90°_{11}]$ was used.

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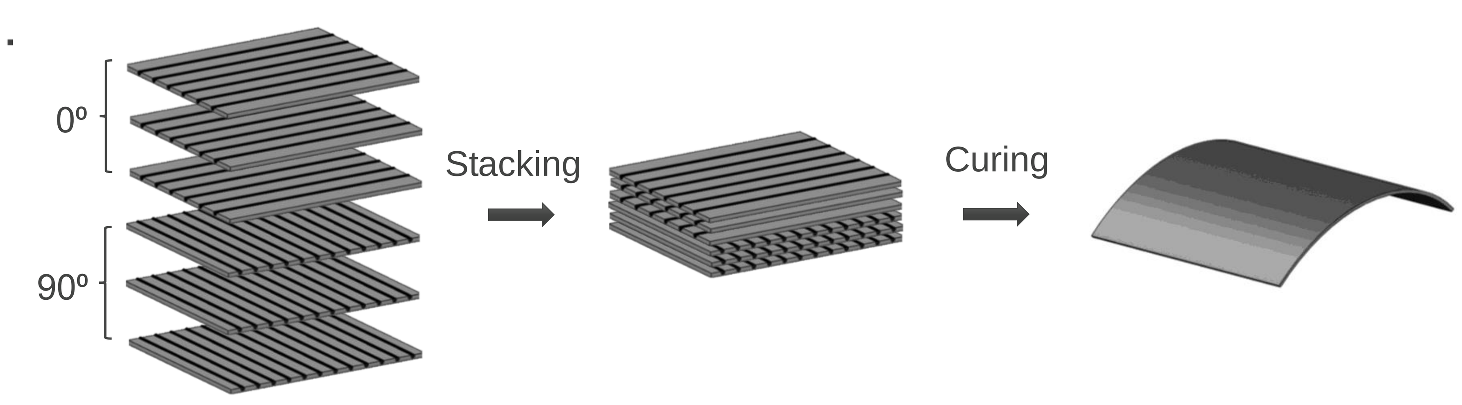

FIGURE 2. Deformation caused by orthotropic coefficient of thermal expansion and chemical shrinkage.

NUMERICAL DETAILS

Each configuration was simulated using the ABAQUS CAE software, employing a design space within the program. The models were developed using an appropriate computational mesh and used solid sections using four-node plane strain (CPE4) elements, while the cohesive layers were modelled using cohesive (COH2D4) elements, to simulate the behaviour of the joint and predict its failure, as can be seen in Figure 3.

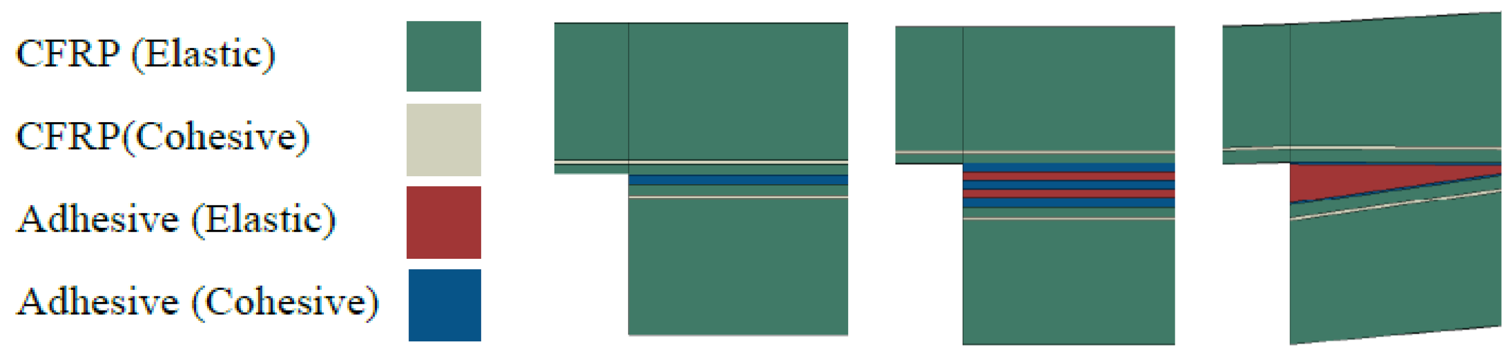

FIGURE 3. Section assignment of the numerical models used.

RESULTS

The results of the failure modes can be seen in Figure 4, where delamination was obtained for the conventional CFRP SLJ, while cohesive failure was obtained for the other two configurations. It is evident that the curved SLJ exhibits a failure load that is comparable to the reference 0.2 mm configuration. For the XFEM models, the crack domain is located within the adhesive layer and an elastic isotropic formulation with plane strain (CPE4) elements was used.

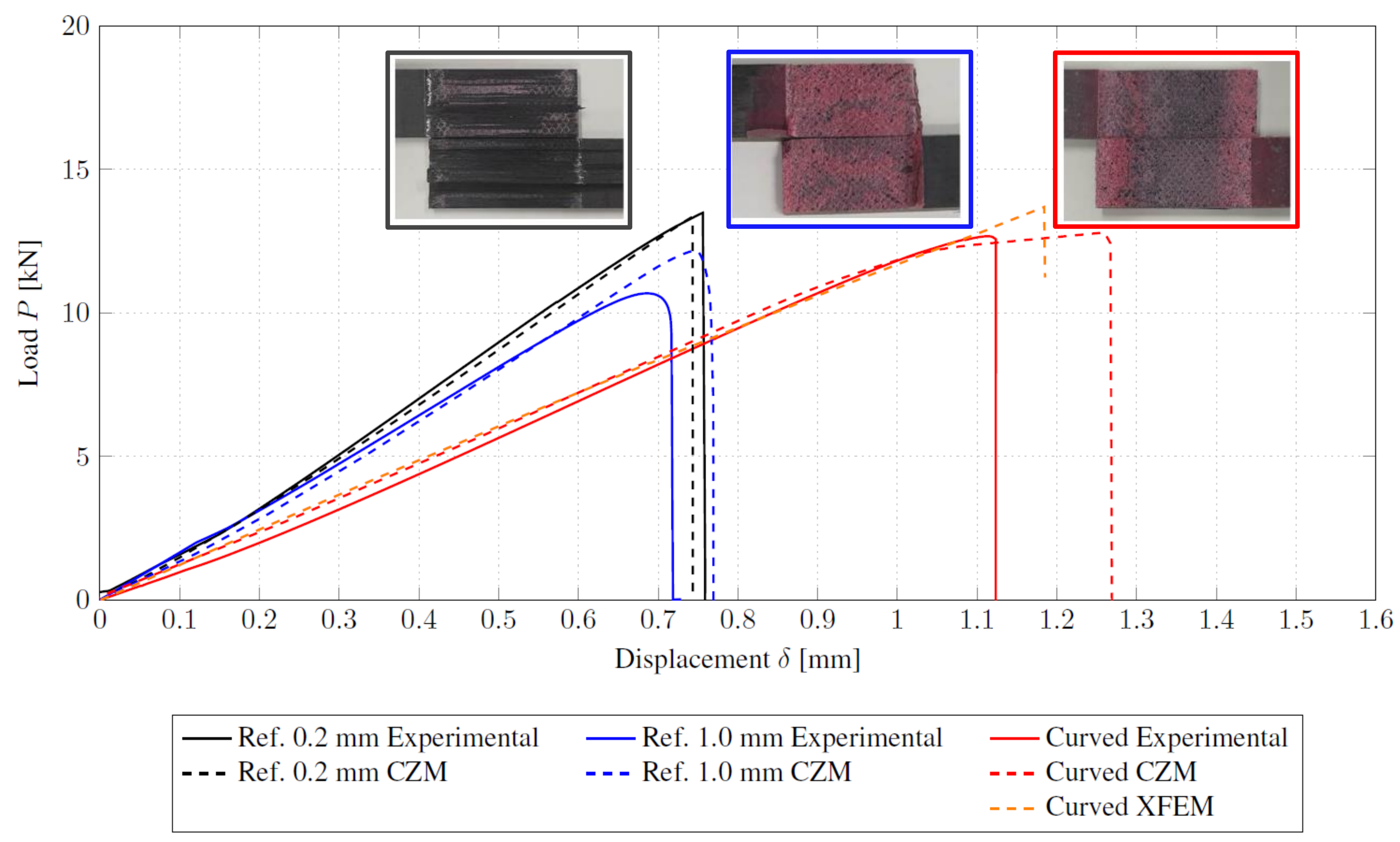

FIGURE 4. Load - displacement curves obtained experimentally and numerical for all configurations.

CONCLUSION

- The curved joint exhibited a cohesive failure mode due to the combined effect of compressive residual thermal stresses resulting from the curing process and the curved geometry of the joint.
- Increasing the adhesive thickness in planar SLJs resulted in a transition to a cohesive failure mode, decreasing 22.1% in the failure load for these thicker adhesive configurations.
- The numerical models exhibited a good correlation (failure load and failure mode) with the experimental results.

ACKNOWLEDGEMENTS

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