Approaches to prevent delamination in CFRP adhesive joints

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Introduction

Adhesive bonding is widely used in several industries due to its numerous advantages over traditional mechanical fastening methods. Compared with mechanical fastening methods, adhesive bonding provides a uniform stress distribution, and this leads to a significant improvement of the joint strength performance. Furthermore, adhesive bonding is the most efficient technique used to join composite adherends, presenting several advantages over conventional mechanical joining methodologies, However, the issue of delamination still poses a significant challenge to the full application of this technology in the industry [1].

In this study different techniques to prevent the delamination of the composite adherends were studied. Numerical simulations and experimental testing were conducted to compare the performance between the different joints studied. The performance of the joints was assessed in carbon fiber reinforced polymer (CFRP) single lap joints. The numerical analysis was carried out in the ABAQUS commercial software, allowing to better understand performance of adhesively bonded composite joints.

Experimental methodology

Adhesive

The adhesive utilized in this study was the Scotch Weld AF 163-2k, provided by 3M Company. This material is a film-form modified epoxy known for its high fracture toughness and peel strength.

Adherend

In all of the tested configurations, the unidirectional prepreg CFRP material used was Texipreg HS 160 T700, a commercially available product.

Additionally, an aluminium alloy from the 2024-T3 Alclad series, supplied by AMI Metals, was used for one configuration.

Joint Geometry

Figure 1 illustrates the geometry of the specimens and the material distribution in the adherends that were utilized for the tests. The geometry parameters adopted were: L_T = 215 mm, L_0 = 25 mm, t_s = 3.20 mm, t_a = 0.2 – 1.0 mm and width of 15 mm.

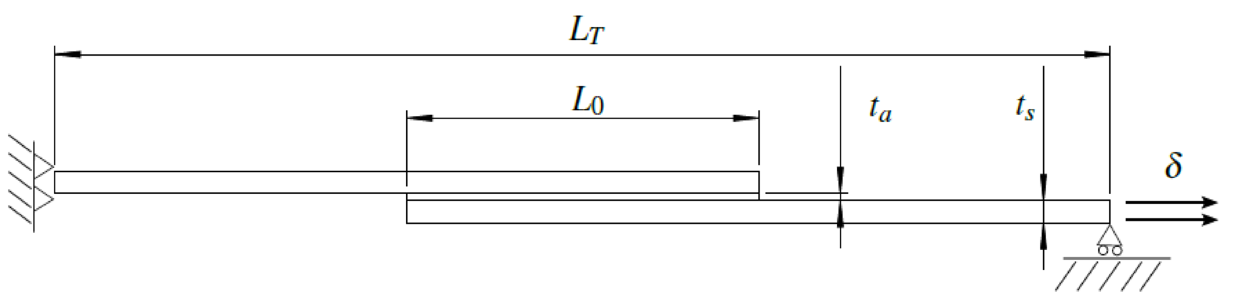

Figure 1 – SLJ specimen geometry.

The curvature of the adherends was obtained through asymmetric layups of using two different approaches of curved joints using CFRP-aluminium $[0°_{19}/\mathrm{Al}_{0.4mm}]$ and only CFRP with different orientations $[0°_{10}/90°_{11}]$. This leads to the curvature of the adherend after curing as seen in Figure 2.

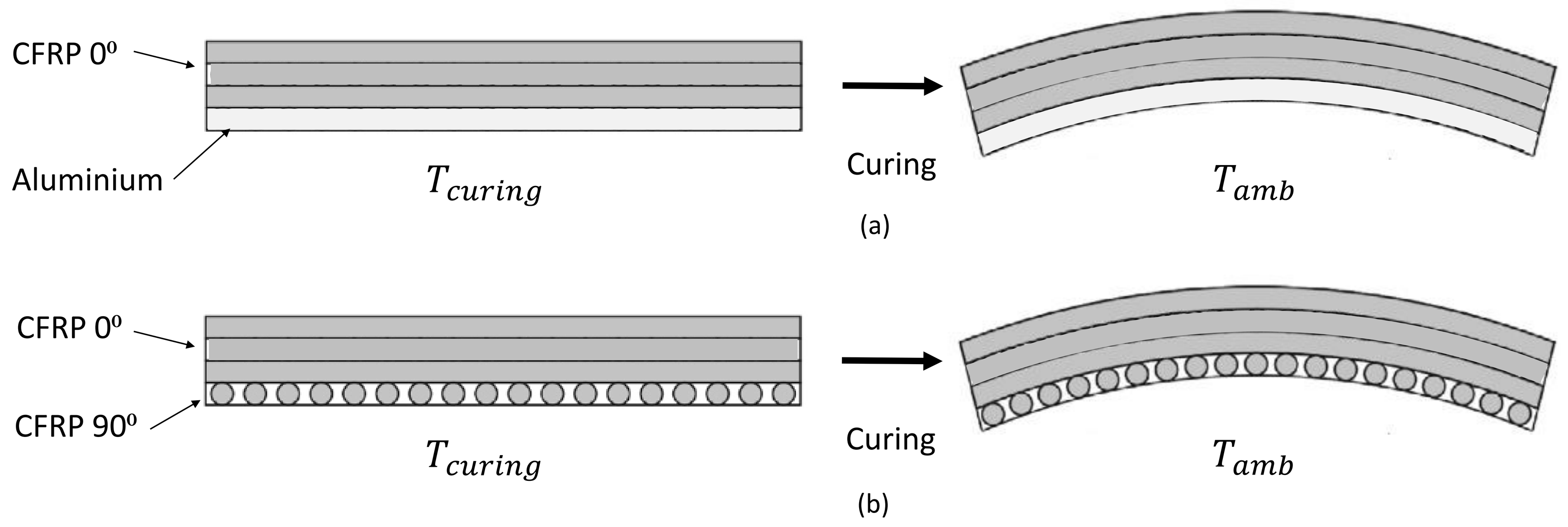

Figure 2 – Warpage deformation caused by orthotropic coefficient of thermal expansion: a) [0°/0°/0°/Al] and b) [0°/0°/0°/90°], adapted from [2].

Results

All configurations were simulated using ABAQUS CAE software. The failure mode and failure load were predicted using cohesive zone modelling (CZM) and thermal residual stresses were incorporated into the models using a thermal step.

The experimental and numerical failure modes can be seen in Figure 3, where delamination was obtained for the conventional CFRP SLJ, while cohesive failure was obtained for the other two curved configurations.

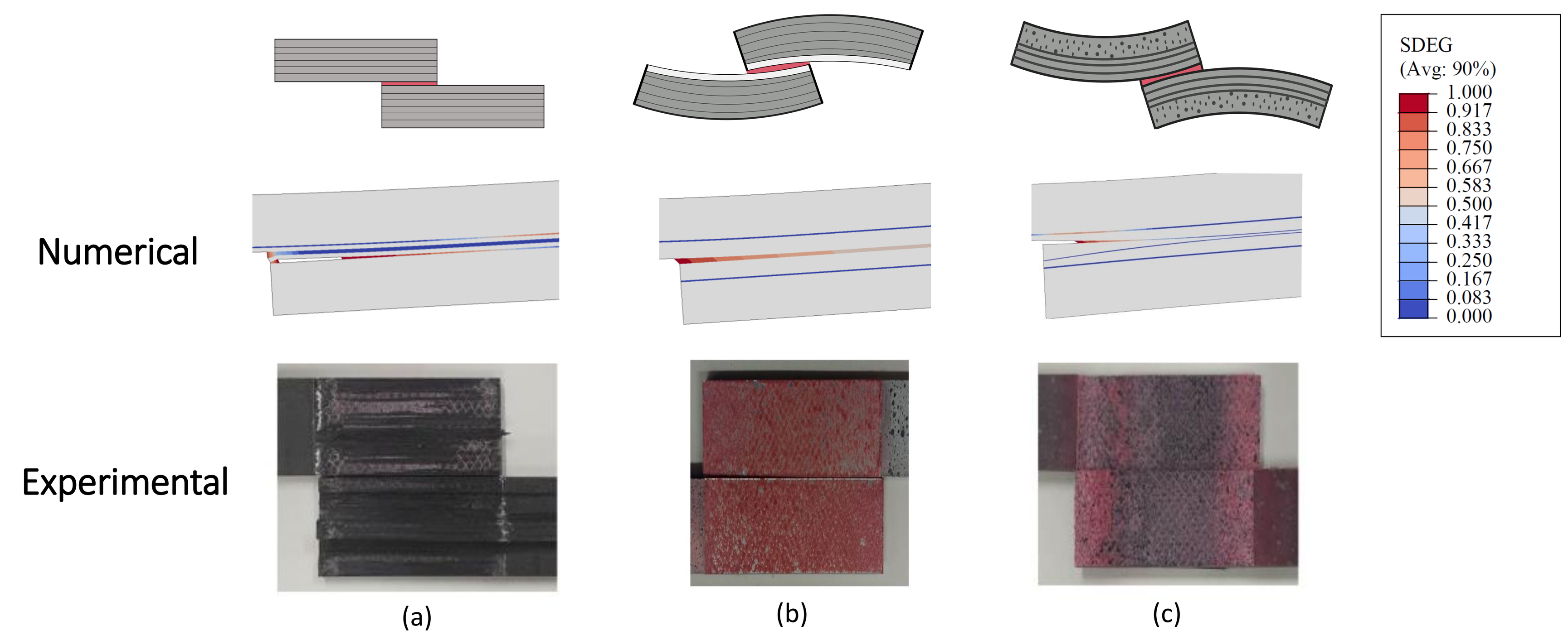

Figure 3 – Failure modes obtained for all configurations.

Figure 4 compare the curves and the curved SLJs exhibits the best performance.

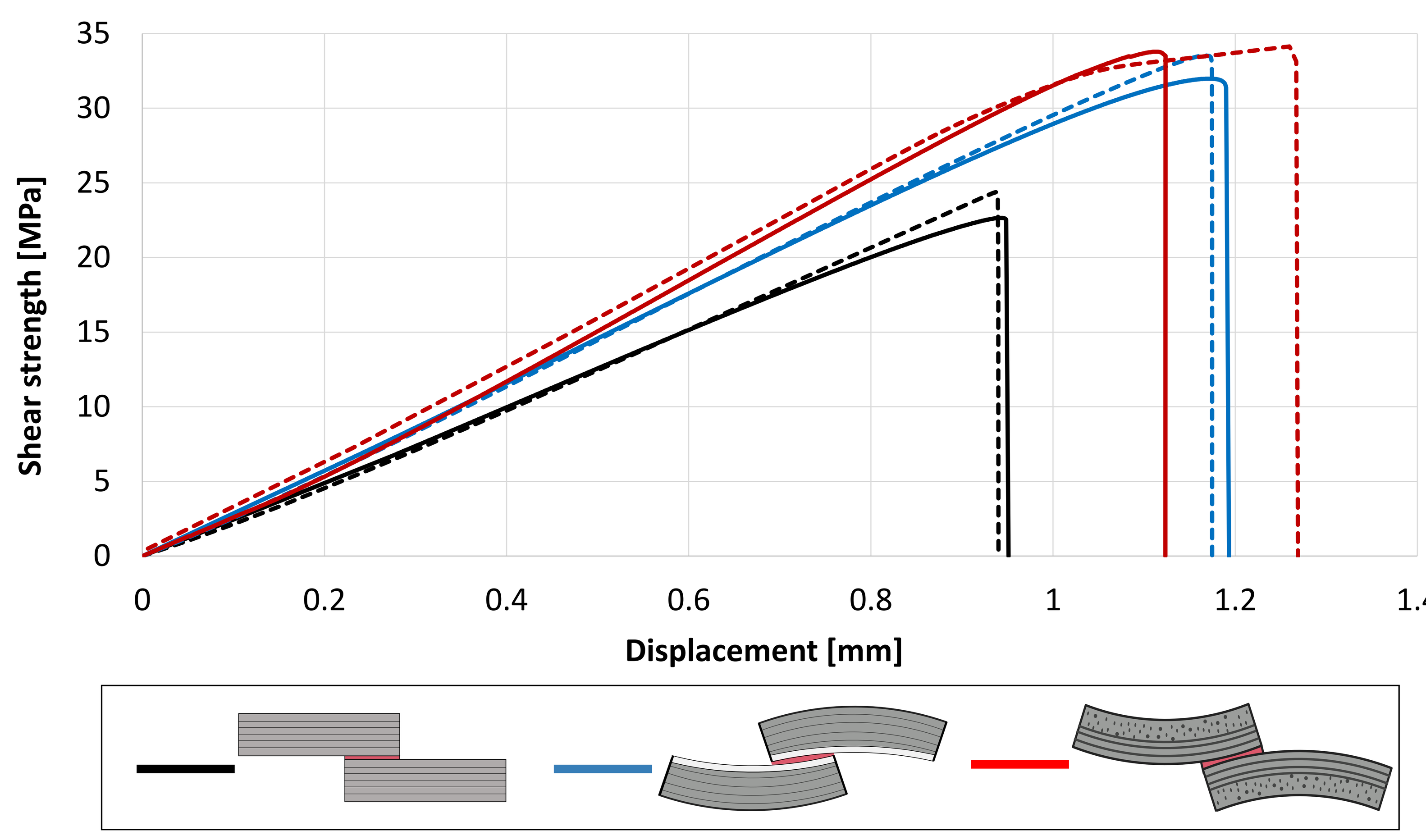

Figure 4 – Shear strength – displacement curves obtained experimentally for the three configurations

Conclusions

- The cohesive failure mode observed in the curved joint can be attributed to the combined effect of compressive residual thermal stresses generated during the curing process and the curved geometry of the joint.
- This configuration effectively reduced the tensile peel stresses that typically lead to delamination, resulting in a prevention of delamination and an improved failure mode. Additionally, It is noteworthy that the failure load of the curved joint showed an improve in more than 30%.

References

[1] da Silva, L. F. M., Öchsner, A., & Adams, R. D. (2018). Handbook of Adhesion Technology (2nd ed.). Springer Berlin Heidelberg.

[2] Liu, Z., Zheng, X., Fan, W., Wang, F., Ahmed, S., & Yan, L. (2022). An alternative method to reduce process-induced deformation of CFRP by introducing prestresses. Chinese Journal of Aeronautics, 35(8), 314-323.

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