The effect of different metallic laminates on the strength of CFRP SLJs using metal laminate adherends

R.J.C. Carbas (INEGI, Portugal), F. Ramezani, E.A.S. Marques, L.F.M. da Silva

Advanced Joining Processes Unit

Introduction

The use of composite materials in transport industry has increased in the last years as more efficient structures are required to meet tight energy consumption and emissions targets. However, the main problem associated to composite materials is the onset of delamination, which greatly reduces joint strength [1]. In order to avoid or retard this problem the use of hybrid metallic laminates is possible, combining the best properties of FRPs and metal alloys. The use of hybrid composite-metallic adherends aims to increase the joint strength in the through thickness direction, minimise peel stresses and limit delamination [2]. The objective of this work was to evaluate the performance of hybrid joints, bonded with different metallic laminates (Al and Ti) by comparing them against a reference joint using a conventional Carbon fibre reinforced polymer (CFRP) adherend. Numerical models were developed, using the ABAQUS software, to study the behaviour of all joints studied. The numerical predictions of failure loads and modes were compared to the experimentally obtained results.

Experimental details

Materials:
- Adhesive: AF 163-2.K (3M), modified epoxy structural adhesive, knit supported;
- CFRP: unidirectional 0° carbon-epoxy composite, HS 160 T700. Manufactured using manual lay-up method;
- Titanium: aluminium alloy Ti-6Al-4V. This specific alloy is used in the aeronautic industry.
- Aluminium : 2024-T3 Alclad, with copper being the main alloying metal.

Cure process:
- 130 °C during 60 minutes.

FML configuration:
- Thickness of the adherends: 3.2 mm;
- Ratio in volume: 50% of metal and 50% of CFRP.

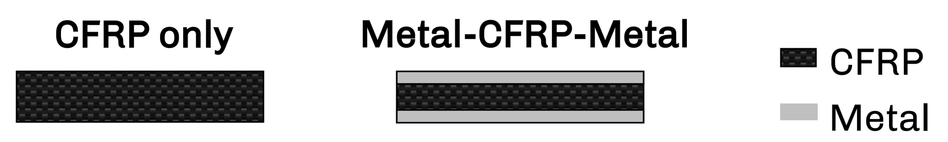

Figure 1 – Lay-up configurations

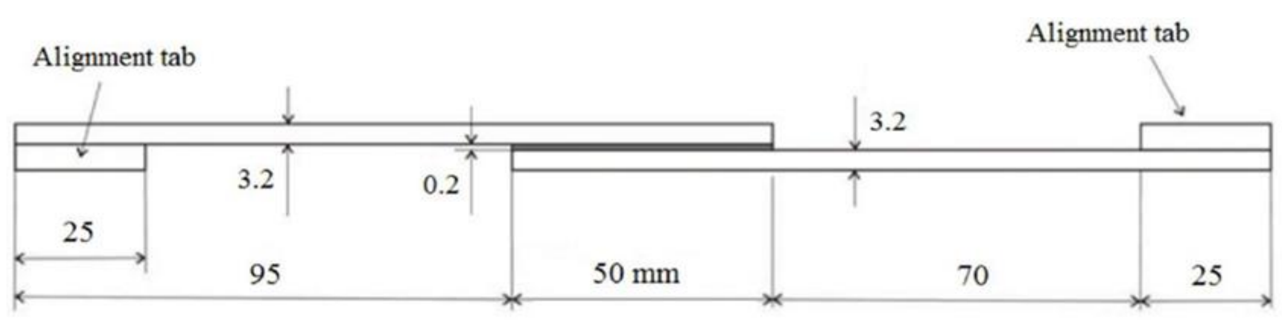

Figure 2 – SLJs geometry .

Study of the adherend's stiffness

- Elastic analysis in 2D models developed in ABAQUS® software;
- Solid elements (CPE4R) were used.

Maximum peel stresses in a hybrid joint with the variation of the Young's modulus of the material used compared with the variation of material's densities.

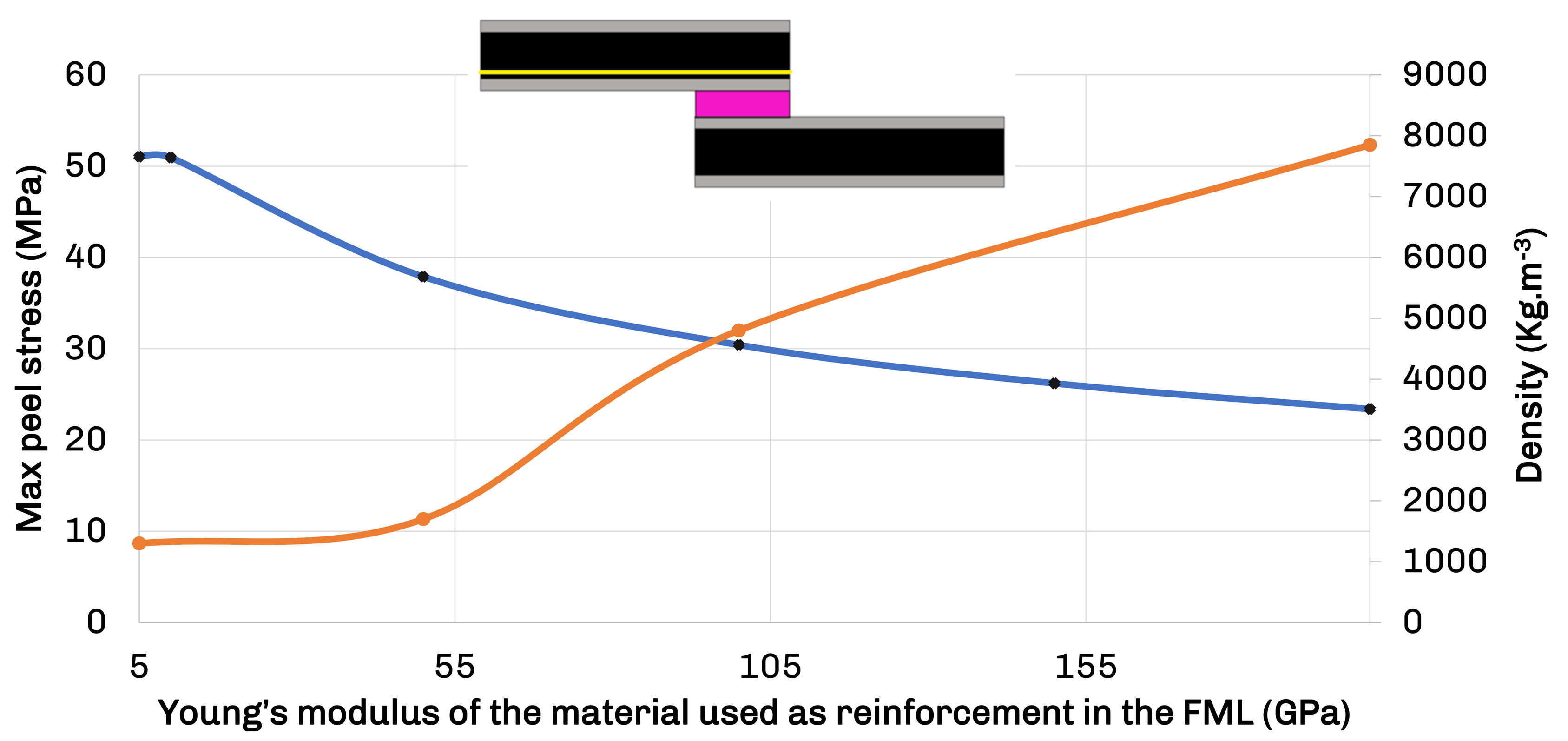

Figure 3 – The peel stress vs density as a function of Young's modulus.

Experimental results

The SLJs were tested in a servo-hydraulic MTS model 8810 test machine with a capacity of 100 kN, at room temperature and constant displacement rate of 1 mm/min.

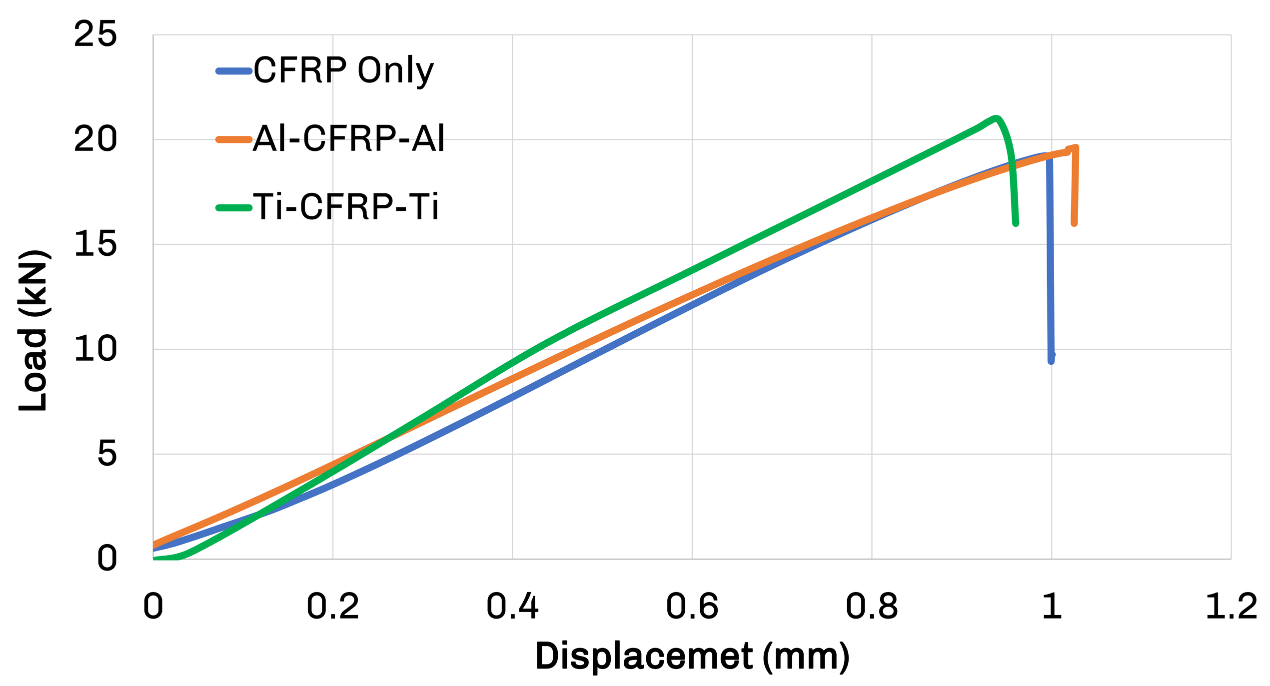

Figure 4 – Typical load-displacement curves of SLJ's.

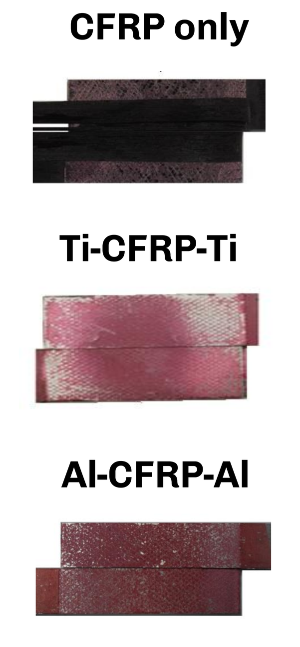

Figure 5 – Failure mode of SLJ's.

Numerical results

- 2D analysis in ABAQUS® software;
- Solid elements were used for elastic sections (CPE4R);
- Cohesive elements with traction separation laws (COH2D4) [3].

Figure 6 – Schematic numerical model used.

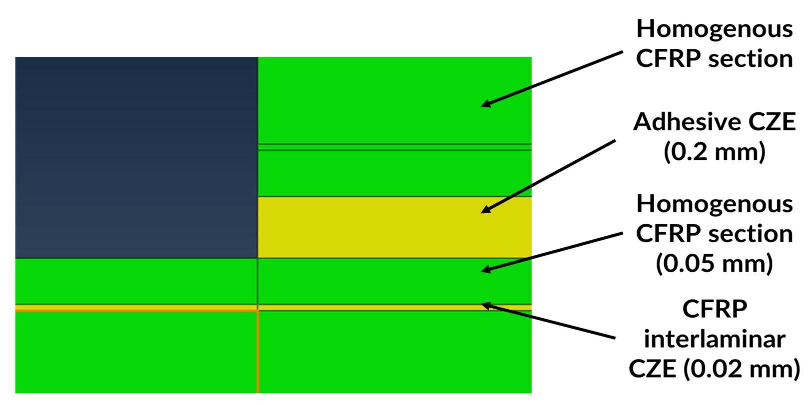

Figure 7 – Numerical model details.

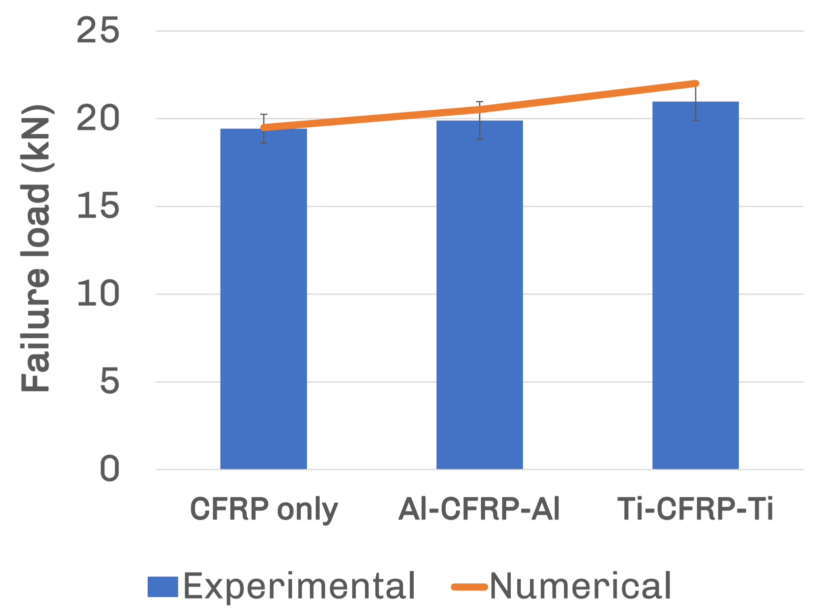

Figure 8– Numerical and experimental failure load.

Conclusions

- The work employed an approach based on a concept similar to FML, using metal plies and showed a good improvement;
- The configuration Ti-CFRP-Ti showed the best performance (higher failure load), when compared to the basic CFRP only configuration;
- Both adherends reinforced with metal layer prevented the delamination and cohesive failure was obtained;
- In terms of the simulation of the tensile testing of the joints, the numerical results were acceptably coherent with the experimental results. Regarding the failure mode obtained numerically for the configurations under study, the results were, in every case, coherent with the experimental results.

References

[1] L.F.M. da Silva, A. Öchsner, and R.D. Adams. Handbook of Adhesion Technology, (Springer-Verlag, Berlin, 2011)
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[3] L.F.M. da Silva, and R.D.S.G. Campilho, Advances in Numerical Modelling of Adhesive Joints, (Springer-Verlag, Berlin, 2012)

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