The performance of hybrid composite joints reinforced with different metallic laminates adherends configurations

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Introduction

The use of composite materials in industry is growing due to various technological advances in composite materials accompanied by improvements in the structural adhesives used to bond them [1]. Fibre metal laminates (FMLs) are hybrid composite structures based on thin sheets of metal alloys and plies of fibre reinforced by polymeric materials. The fibre/metal composite technology combines the advantages of metallic materials (fatigue and corrosion characteristics) and fibre reinforced matrix systems (low bearing strength, impact resistance and reparability characteristics) [2]. Due to their advantages, FMLs are finding great use in most commonly in aerospace applications.

The aim of the present study was to study the effect of metallic laminate amount in the strength and failure mode of hybrid joints and to improve the peel strength of composite materials, as well as the adhesive joint strength itself. Using an epoxy matrix reinforced with carbon fibres as the composite material, its structural modification was performed by inserting aluminium, during the production of the FML, in order to improve the through thickness properties of the composite.

Experimental details

Materials:

• Adhesive: AF 163-2.K (3M), modified epoxy structural adhesive, knit supported;

• CFRP: unidirectional 0º carbon-epoxy composite, HS 160 T700. Manufactured using manual lay-up method;

• Aluminium : 2024-T3 Alclad.

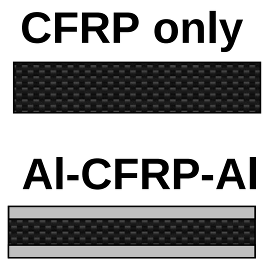
Cure process:

• 130 °C during 60 minutes.

FML configuration:

• Thickness of the adherends: 3.2 mm;

• Ratio in volume: 20% CFRP to 40% Aluminium.



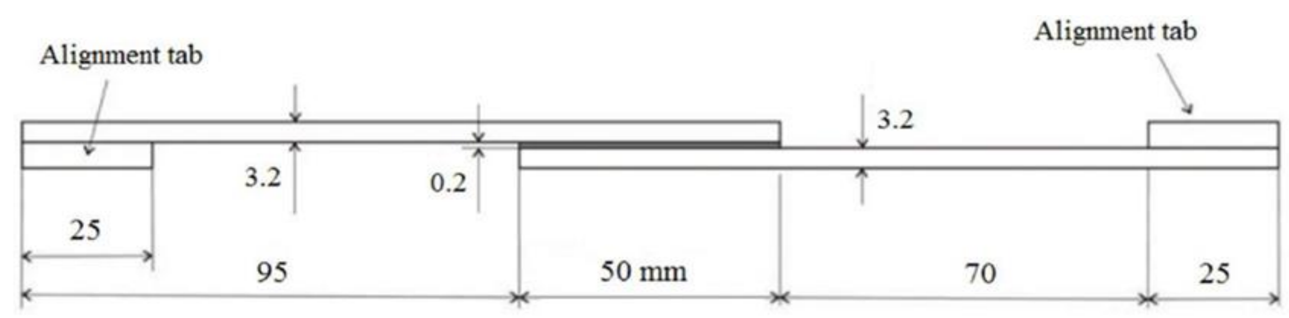


Figure 1 – SLJs geometry.

Characterization of the adhesive

• Bulk testing according to ASTM D1002-01;

• TAST (Thick adherend shear test) accordingly to ISO 11003-2;

• DCB (Double Cantilever Beam) testing accordingly to ASTM D3433-99;

• ENF (End Notched Flexure) testing.

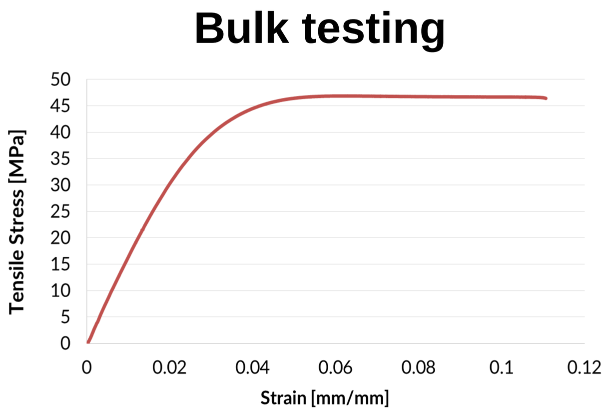


Figure 2 – Tensile stress-strain curve.

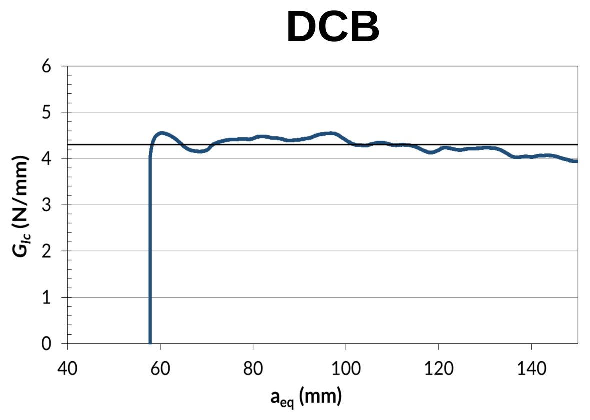


Figure 3 – R-curve obtained for the DCB test.

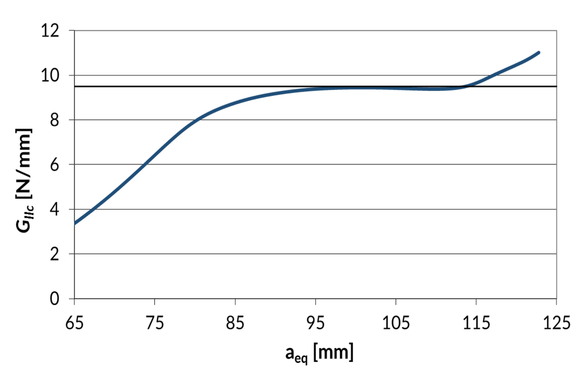


Figure 4 – R-curves obtained for the ENF test .

Table 1 – Mechanical properties of AF 163-2K.

Young's modulus (MPa)	Tensile strength (MPa)	Shear modulus (MPa)	Shear strength (MPa)	Fracture energy mode I, G_{IC} (N/mm)	Fracture energy mode II, G_{IIC} (N/mm)
1521.9 ± 118.3	**46.9** ± 0.6	**159.73** ± 41.9	**46.9** ± 2.57	**4.05** ± 0.07	**9.77** ± 0.21

Experimental results

The SLJs were tested in a servo-hydraulic Instron model 8810 test machine with a capacity of 100 kN, at room temperature and constant displacement rate of 1 mm/min for static loading and 0.1 m/sec for high rate loading.

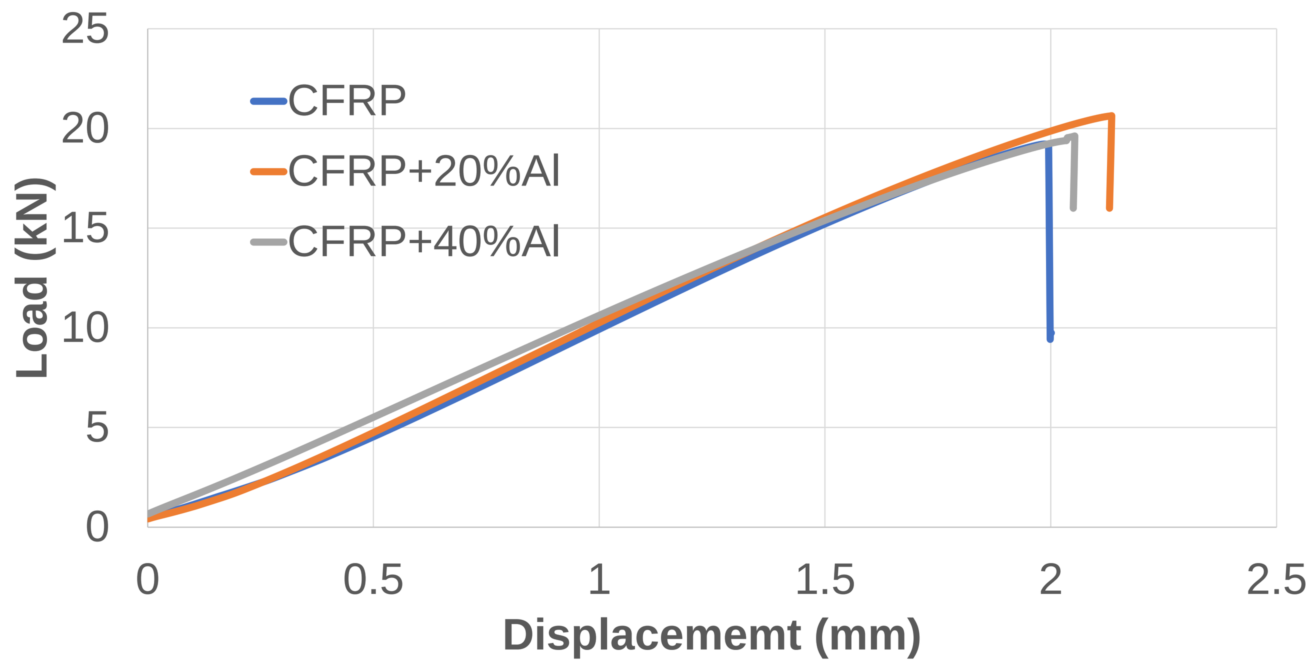


Figure 5 – Load-displacement curves of SLJ's reinforced with aluminum with static loading.

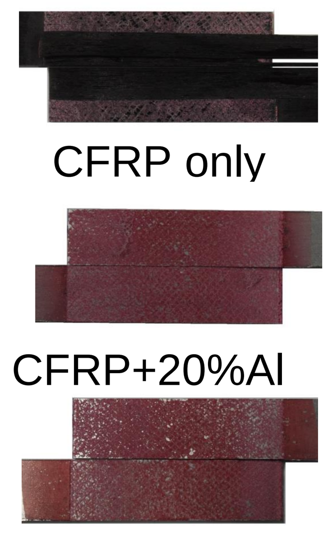


Figure 6 – Failure mode of SLJ's with static loading.

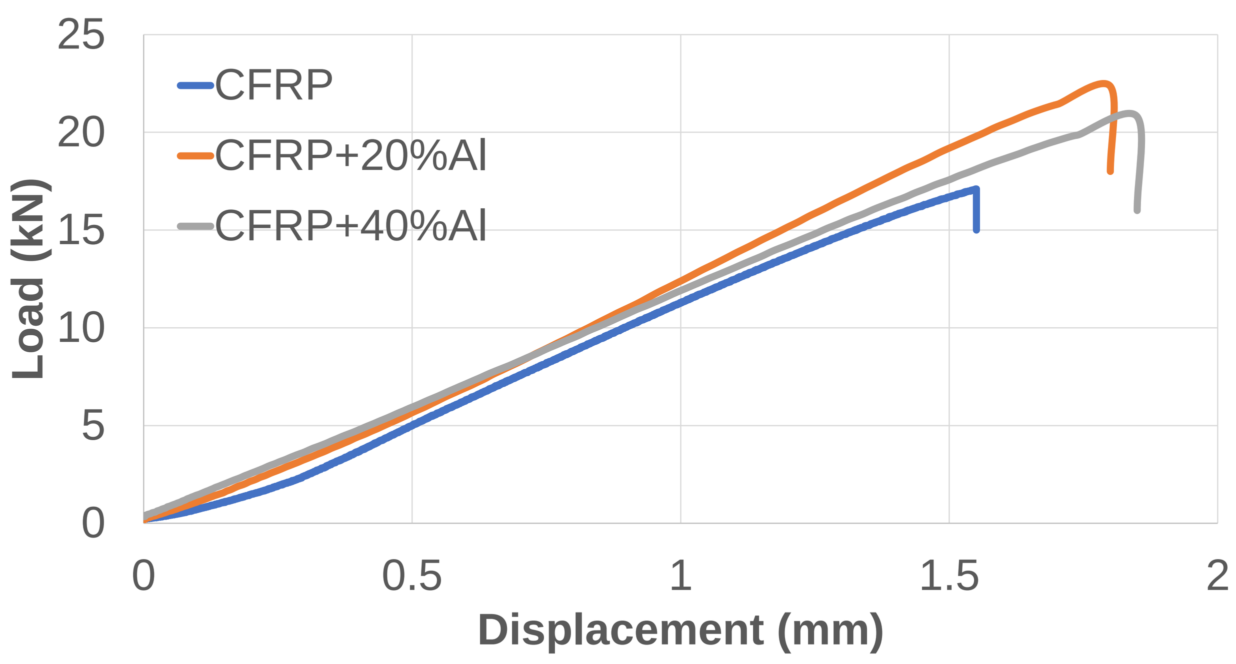


Figure 7 – Load-displacement curves of SLJ's reinforced with aluminum with high-rate loading.

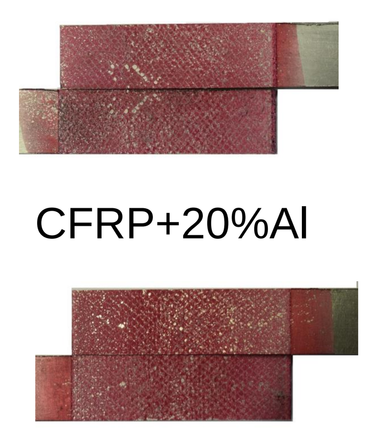


Figure 8 – Failure mode of SLJ's with highrate loading.

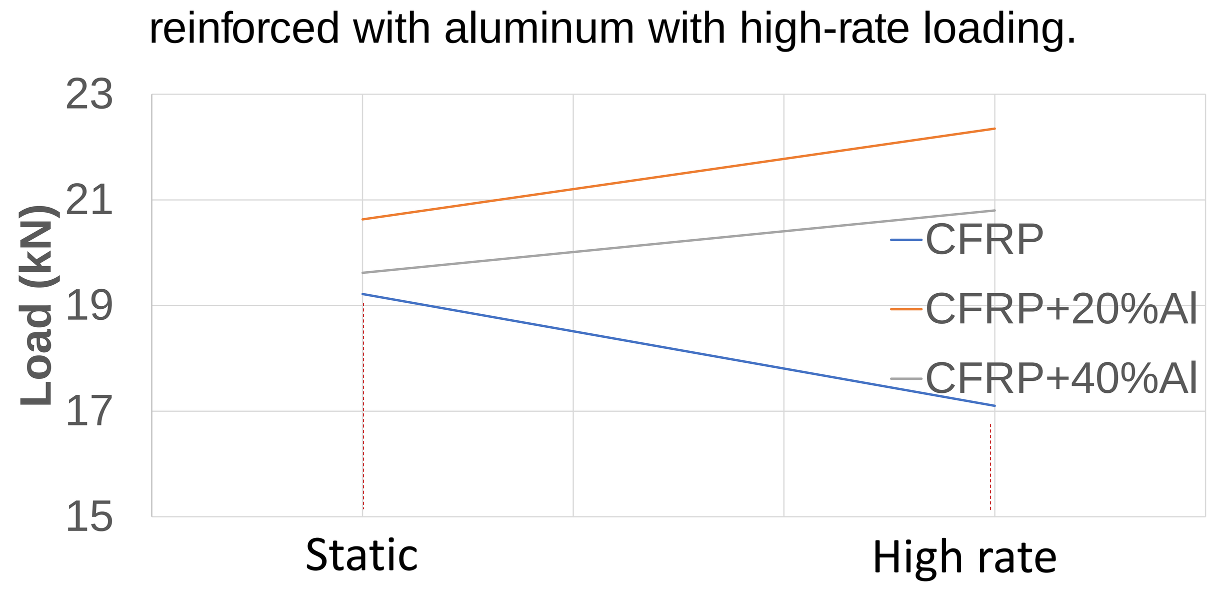


Figure 9 – Effect of strain rate on SLJ's failure load.

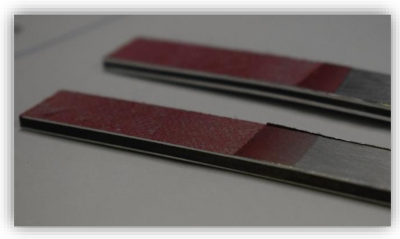


Figure 10 – Plastic deformation in adherends after failure.

Conclusions

- The work employed an FML approach using different amount of aluminium plies.
- The configuration where the best results were reached was the configuration using 20% of aluminium in the adherend for both static and high rate loading, where the failure load presented by the specimens tested had a good improvement, when compared to the basic CFRP only configuration. Moreover all configurations reinforced with aluminium had cohesive failure.
- Plastic deformation has been observed in the adherends after failure.
- In higher strain rates, the failure load increases in joints reinforced with aluminium whilst it decreases in the basic CFRP only configuration.

References

[1] L.F.M. da Silva, A. Öchsner, and R.D. Adams. Handbook of Adhesion Technology, (Springer-Verlag, Berlin, 2011).

[2] L.B. Vogelesang and A. Vlot, Journal of Materials Processing Technology 103, 1 (2000).

Acknowledgements

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