The strength of hybrid SLJs reinforced with different thickness of polymeric laminate

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Introduction

The use of carbon fibre reinforced polymer (CFRP) in structural application has increased exponentially in several industries. The main problem associated to CFRP materials is the phenomenon delamination that can conduct to a premature failure of the structures, severely inhibiting the use of its full potential and leading to inefficient and over-designed structures [1]. The most effective technique to increase the peel strength of composite materials is to reinforce the CFRP with though laminates (e.g. though adhesive). The reinforced composite adherends aims to increase the joint strength in the through thickness direction, minimise peel stresses and preventing the delamination [2].

In this work the performance of different bonded joints was evaluated, considering the effect of different thicknesses of a tough laminate. The hybrid joints with different thickness of reinforcement were compared with joints, using only CFRP or only though material. The joints were experimentally tested at different rate.

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;

Cure process:

- 130 °C during 60 minutes.

FML configuration:

- Thickness of the adherends: 3.2 mm;
- Ratio studied: CFRP – Adhesive

CFRP	Adhesive
100	0
90	10
80	20
60	40

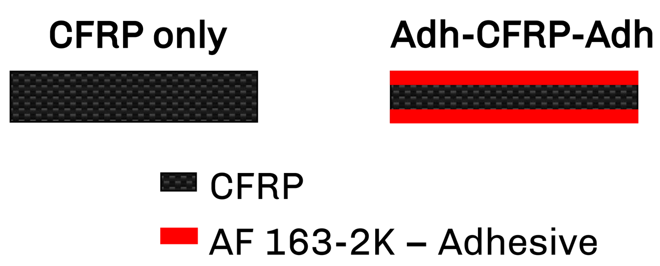

Figure 1 – Lay-up configurations.

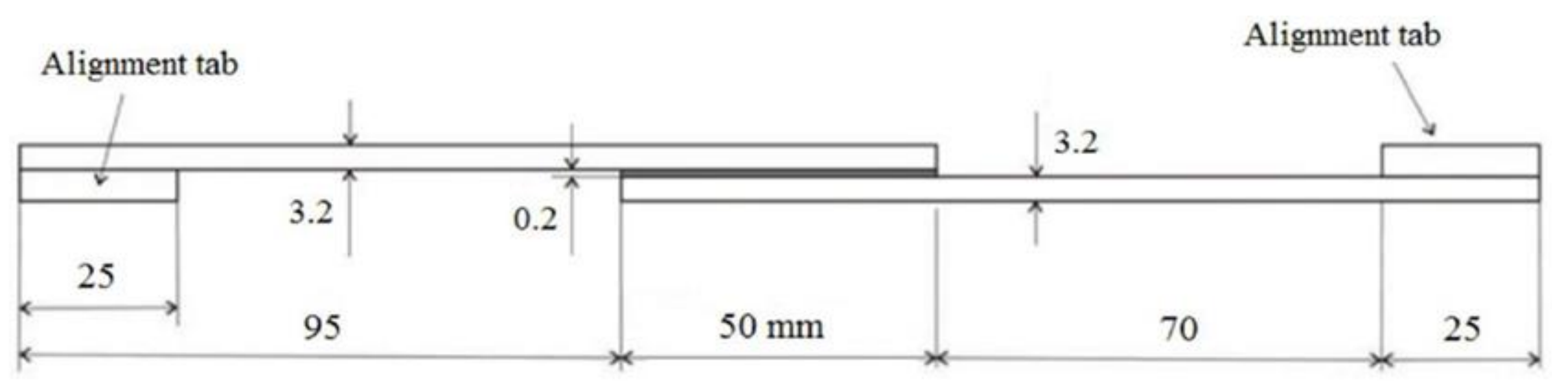

Figure 2 – SLJs geometry .

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 for static and 0.1 m/s for high rate loading.

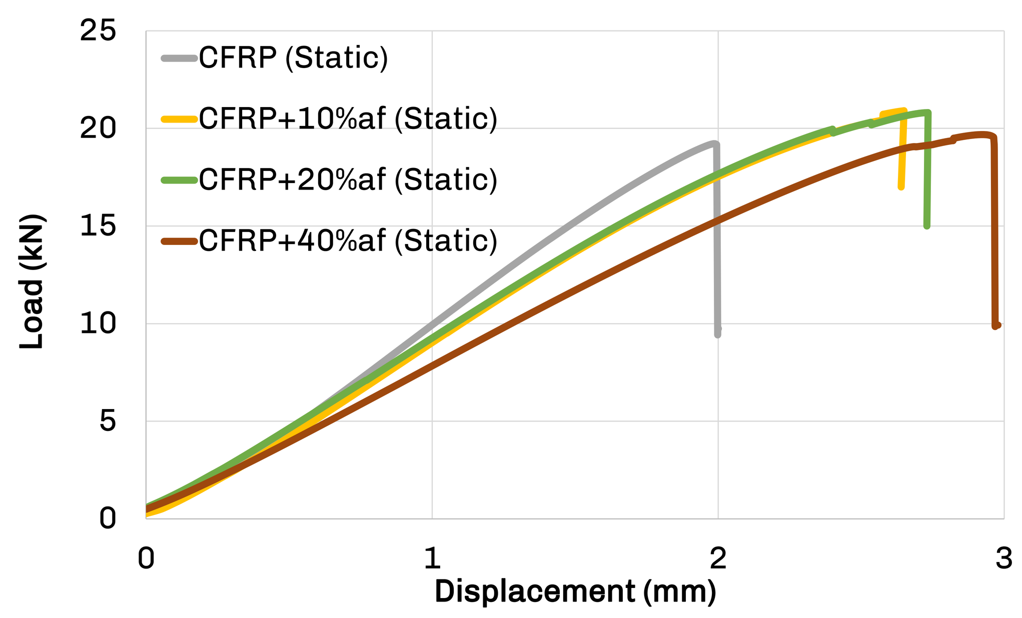

Figure 3 – Typical load-displacement curves of SLJ's under static loading.

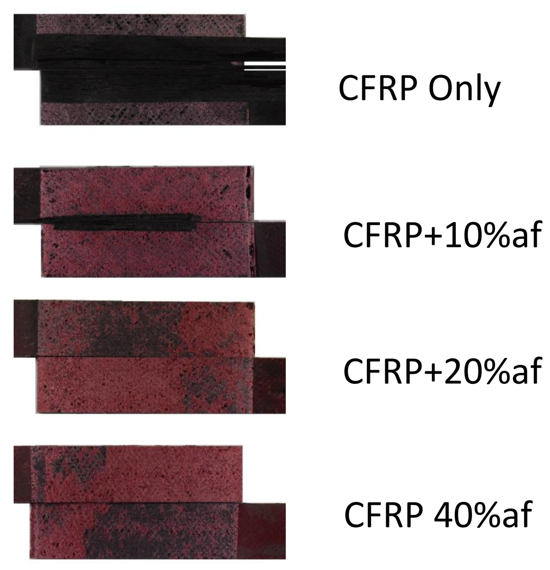

Figure 4 – Failure mode of SLJ's under static loading.

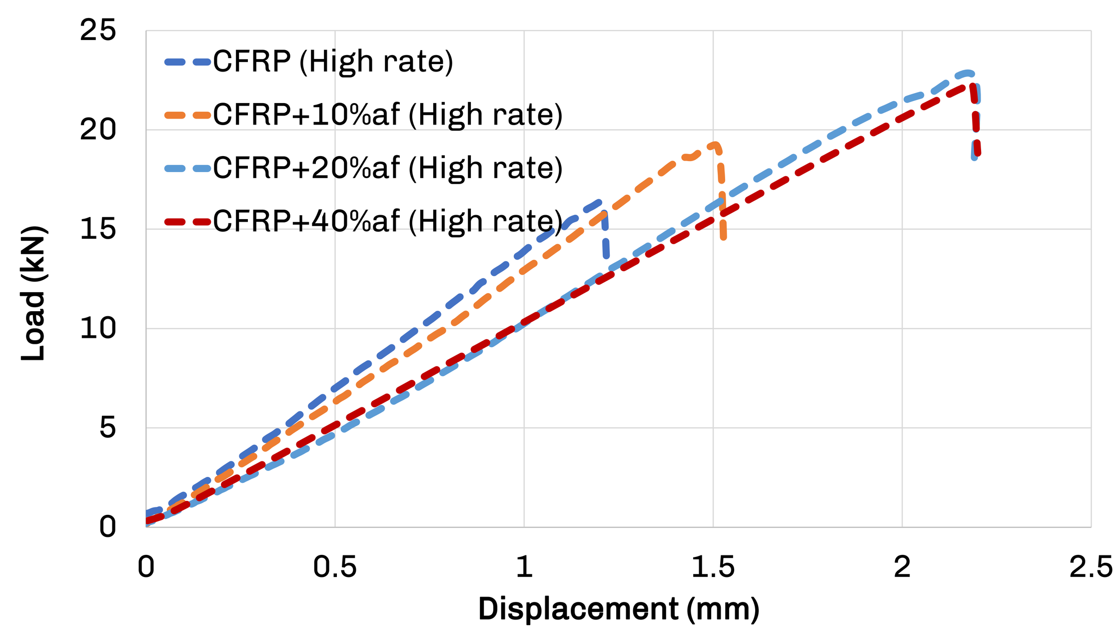

Figure 5 – Typical load-displacement curves of SLJ's under high rate loading loading.

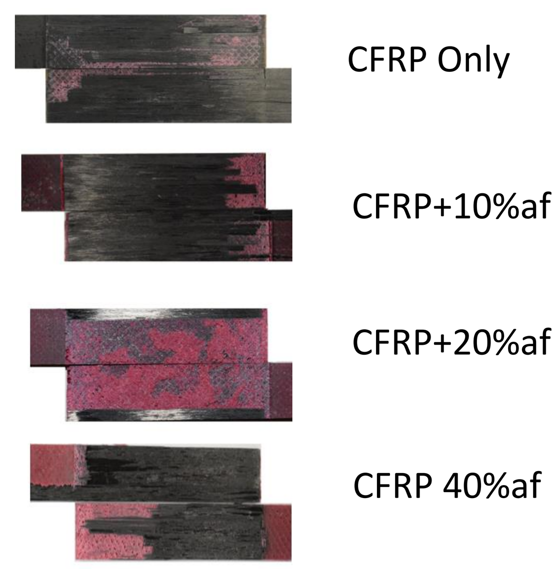

Figure 6– Failure mode of SLJ's under high rate loading.

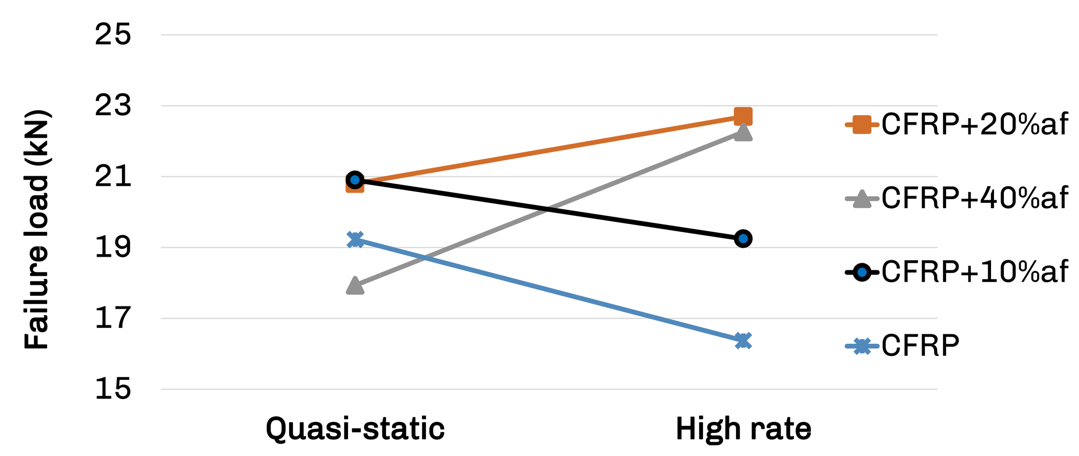

Figure 7 – Effect of strain rate on failure load

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.

Table 1 – Mechanical properties of AF 163-2K for quasi-static conditions.

Young's modulus (MPa)	Tensile strength (MPa)	Shear strength (MPa)	Fracture energy mode I, G_{IC} (N/mm)	Fracture energy mode II, G_{IIC} (N/mm)
1521.9	46.9	46.9	4.05	9.77

Table 2 – Mechanical properties of AF 163-2K for impact conditions.

Shear strength (MPa)	Fracture energy mode I, G_{IC} (N/mm)	Fracture energy mode II, G_{IIC} (N/mm)
46.9	4.05	9.77*

Conclusions

- This study adopted an approach based on a concept similar to FML, using adhesive plies instead of the metal plies in the single lap joints;
- In case of the failure mode configurations with 20% and 40% adhesive in the adherend present cohesive failure in the bondline;
- The configuration where the best results were reached was the configuration with 20% adhesive in the adherend, where the failure load presented by the specimens tested had a good improvement, when compared to the basic CFRP only configuration;
- The effect of strain rate is more noticeable in joints with 40% adhesive in the adherend.

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

R. J. C. Carbas would like to thank the Portuguese Foundation for Science and Technology (FCT) for supporting the work presented here, through the individual grant CEECIND/03276/2018.