The performance of hybrid laminate joints under different strain rate

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Introduction

Composite materials are used widely in industry due to its high performance, however they show a low peel strength. The low peel strength of composite materials can conduct to premature damage when used in adhesive joints. In the literature there are several techniques to improve the joint strength and prevent delamination, such as the use of adhesive fillet. However, it is also important to improve the peel strength of adherend itself, and use of inserts through the thickness or reinforcement of the material with different laminates during the manufacturing [1]. The reinforcement of laminate materials with thin layers of tough materials allows to improve the peel strength of adherend. This type of laminate materials allows to improve the peel strength and when used in joints will prevent or delay the delamination and increase the joint strength [2].

In this study, different hybrid adherends were assessed in a single-lap joint (SLJ) configuration under different strain rates. The hybrid adherends of carbon fiber reinforced polymer (CFRP) were reinforced with aluminium layers during the manufacturing process (CML) to increase the peel strength of composite materials and increase the joint strength of composite adhesive joints. The ABAQUS software was used to carry out the numerical analysis to better understand the influence of strain rate in the performance of hybrid adhesive joints.

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;
- Metal: Al2024 T3 Alclad aluminium alloy

Cure process:

- 130 °C during 60 minutes.

FML configuration:

- Thickness of the adherends: 3.2 mm;
- Ratio studied: 75% CFRP / 25% Aluminium (volume)

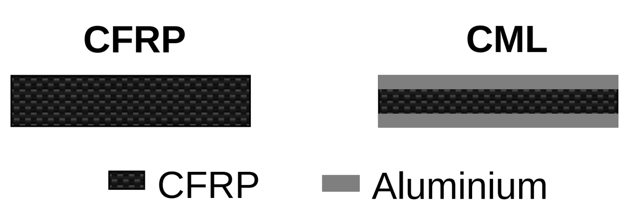


Figure 1 – Lay-up configurations.

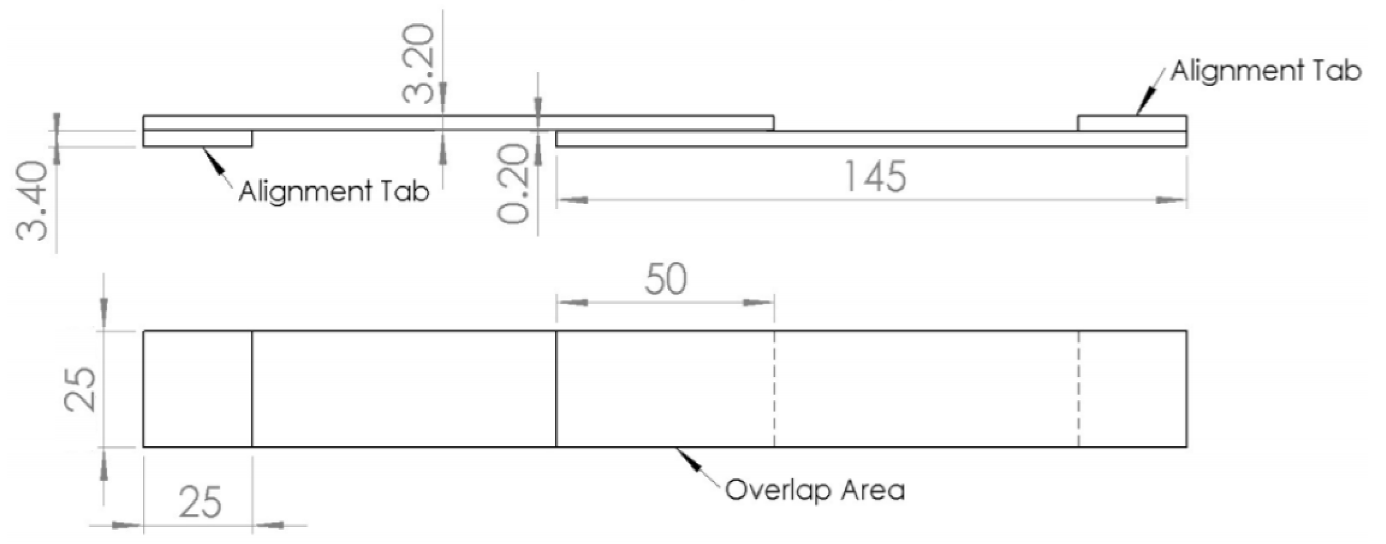


Figure 2 – SLJs geometry.

Numerical details

- 2D analysis in ABAQUS® software; Static general and Dynamic explicit;
- Solid elements - for elastic sections (CPE4R);
- Cohesive elements – for adhesive and cohesive sections of CFRP (COH2D4);
- Triangular cohesive law.

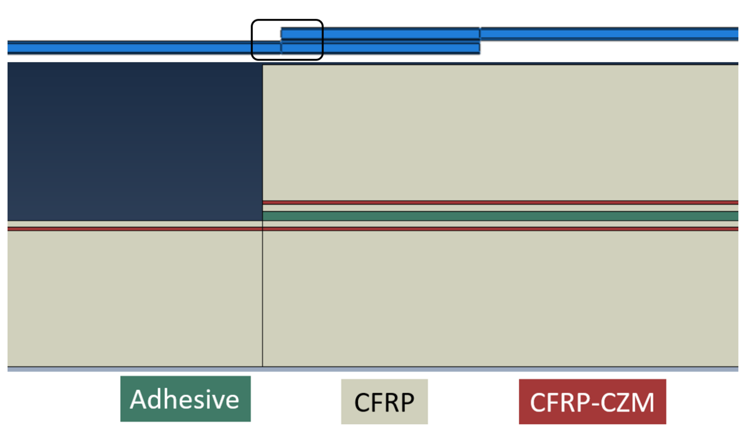


Figure 3 – CFRP numerical model.

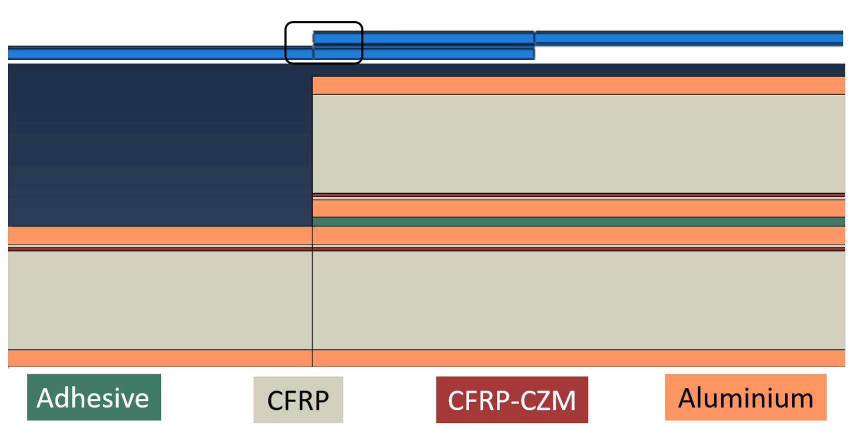


Figure 4 – CML numerical model.

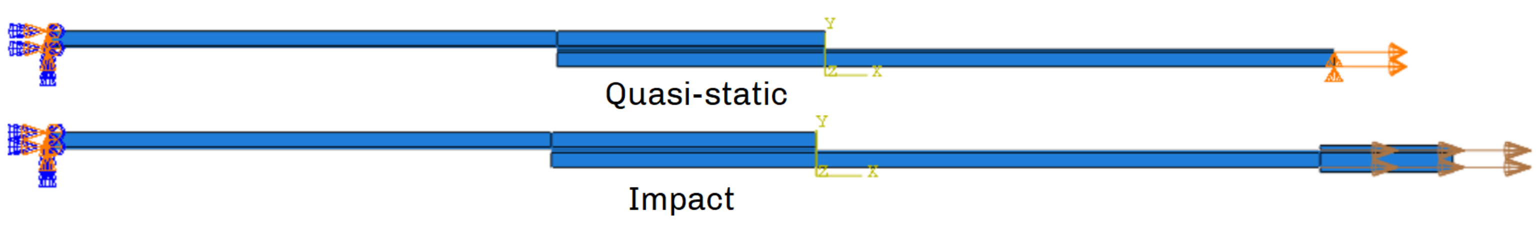
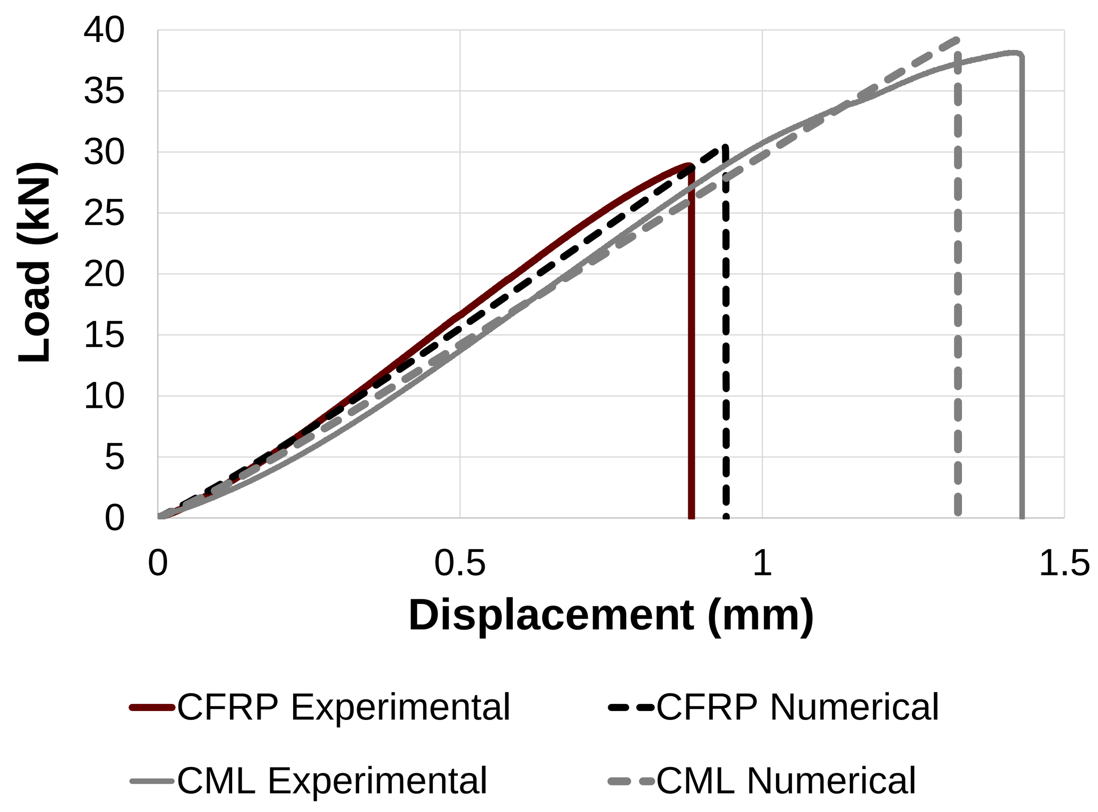


Figure 5 – Numerical model – boundary conditions.

Experimental results

The SLJs were tested under quasi-static condition (1 mm/min) and under impact conditions (3 m/s).



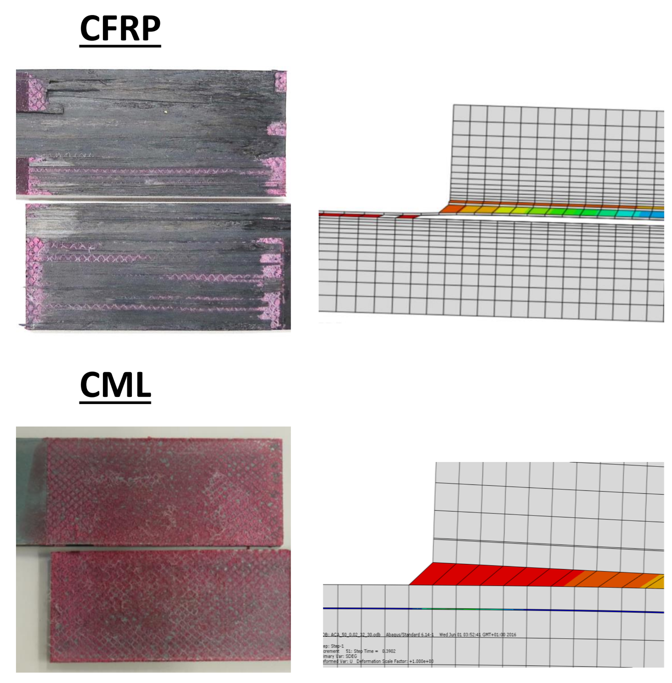
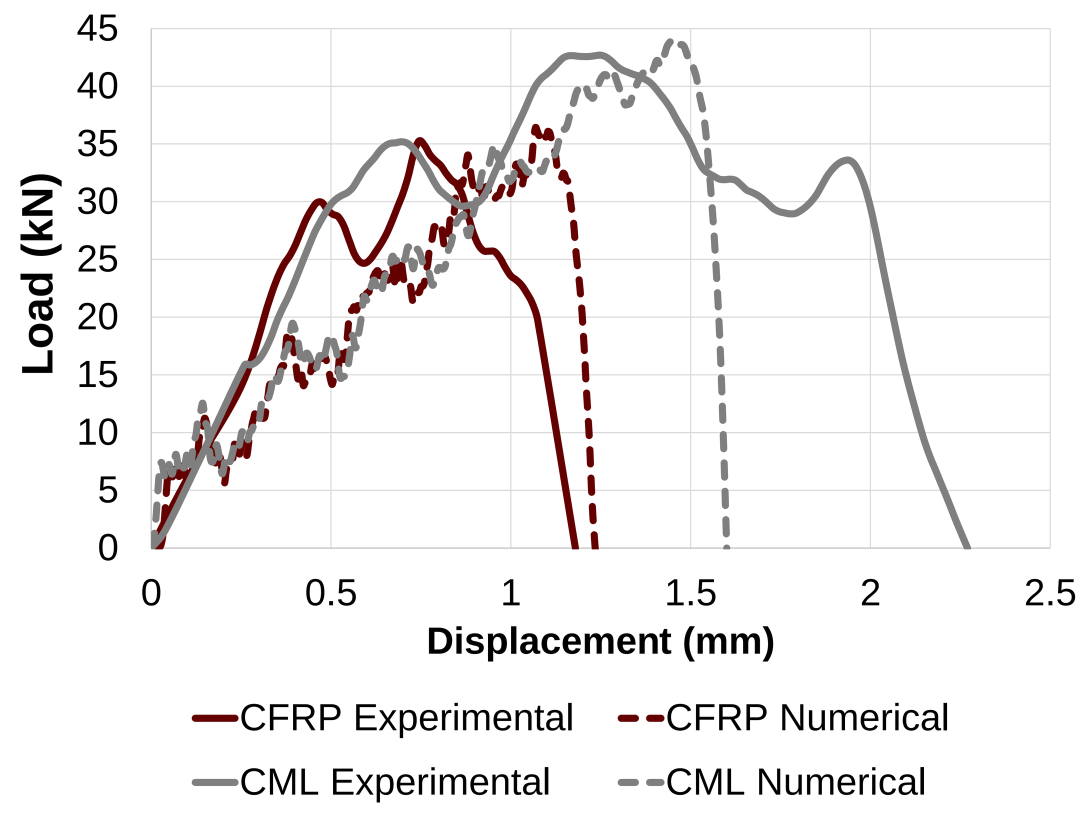


Figure 6 – Failure mode of SLJ's under quasi-static loading.

Figure 7 – Typical load-displacement curves of SLJ's under quasi-static loading.



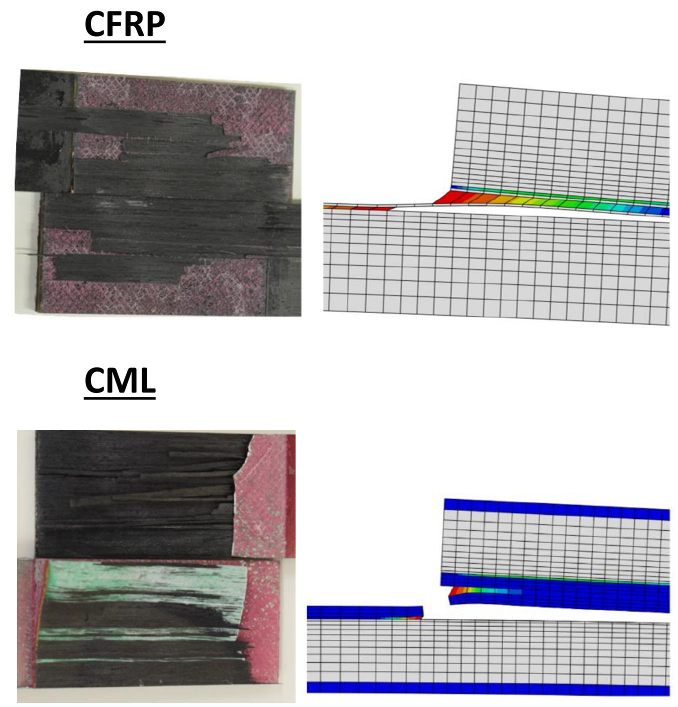


Figure 8– Failure mode of SLJ's under impact loading.

Figure 9 – Typical load-displacement curves of SLJ's under static loading.

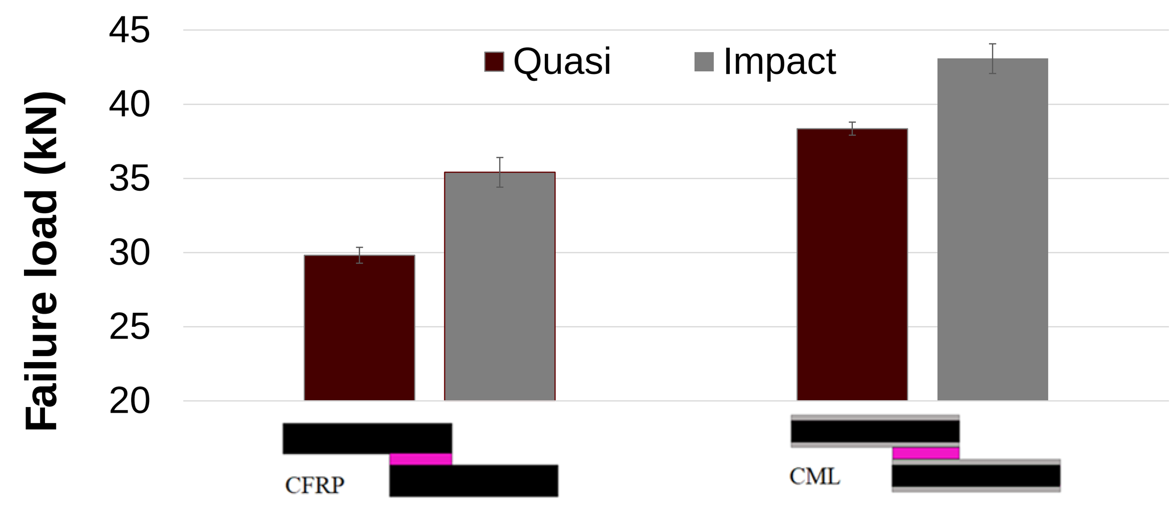


Figure 10 – Effect of strain rate on failure load.

Conclusions

- The reinforced SLJs delayed the onset of delamination, increasing the failure loads and absorbing more energy under impact;
- The reinforcement technique using metal laminates shows a joint strength improvement of 20% when compared to the basic CFRP only configuration;
- The numerical results were coherent with the experimental results obtained.

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).

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