Optimization of CFRP joints with fibre metal laminates

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Abstract

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 (high bearing strength, impact resistance and reparability characteristics) and fibre reinforced matrix systems (high strength and stiffness, fatigue and corrosion characteristics)[2]. Due to their advantages, FMLs are finding great use in most commonly in aerospace applications.

The aim of the present project is to use a concept similar to that used in FML to increase the peel strength of composite materials and increase the joint strength of composite adhesive joints. Carbon fibre reinforced plastic (CFRP) composites will be modified by including one or several aluminium sheets during the laminate manufacture to enhance the composite through the thickness properties. The objective is to identify the joint configuration that gives the best joint strength improvement in relation to the CFRP only reference joint.

Experimental details

Adhesive:

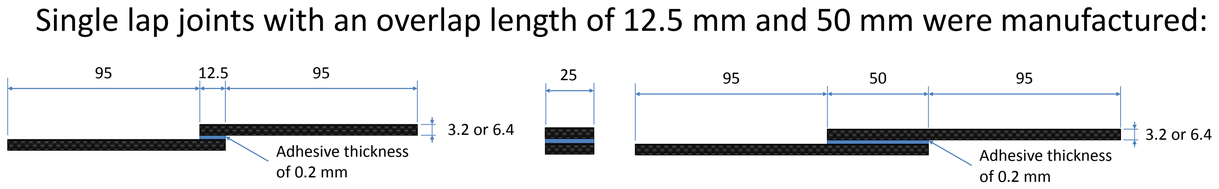
The adhesive used in this study is Araldite® AV138M1 / Hardener HV 998 supplied by HUNTSMAN. This is a two-part epoxy adhesive which is brittle and Neto, et al. [3] observed that it produces delamination on CFRP substrates.

Aluminium:

The aluminium alloy 2024-T3 was chosen for this study because it is a high strength alloy and has very good fatigue resistance. The 2024 alloy's main applications are aircraft structures and parts for the transportation industry.

Joint design:

Single lap joints with an overlap length of 12.5 mm and 50 mm were manufactured:



Adherend design:

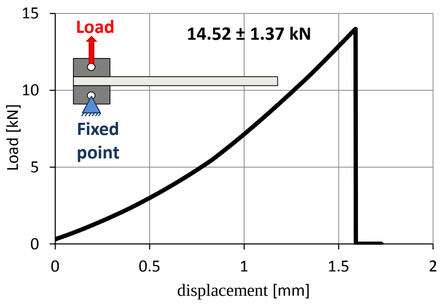
The layup of was designed so as to maintain a ratio of 3:1 (by volume), CFRP to metal alloy. This ratio is a preliminary value, chosen because the object of this study is to reinforce the transverse properties of CFRPs.

Surface treatment:

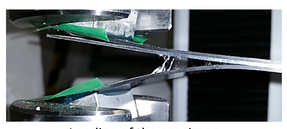
The influence of the surface treatment was a point of this study. In order to evaluate the bond quality between aluminium and CFRP. The lay-up used in order to evaluate the bond properties is the one marked c) in the figure above.

The three surface treatments considered are: *as supplied, sand blasted* and *Phosphoric acid anodisation* (PAA).

While the first two surface treatments did not have success at facilitating the adhesion between CFRP and aluminium the PAA treatment exhibited good adhesion properties, three types of tests were used in order to evaluate them: Traction test in mode I, three point flexural bending and peel test with pre-crack.



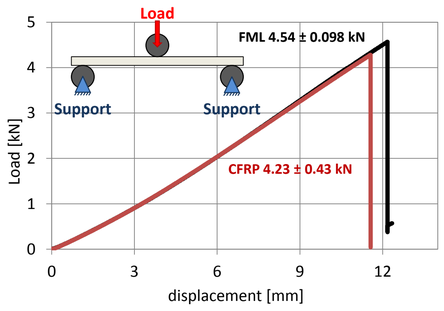
Traction test in Mode I



Loading of the specimen

Failure surface

Peel test with pre-crack

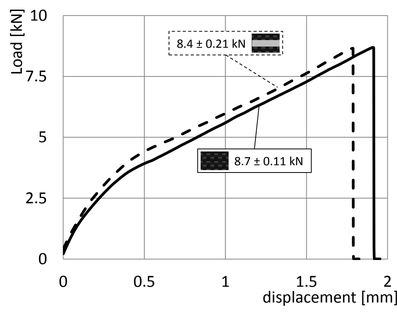


Three point bending

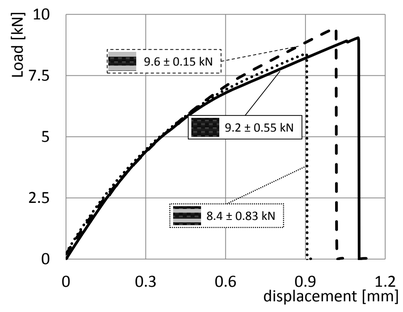
Experimental results

The SLJs were tested in an INSTRON® model 3367 universal test machine with a capacity of 30 kN, at room temperature and constant displacement rate of 1 mm/min.

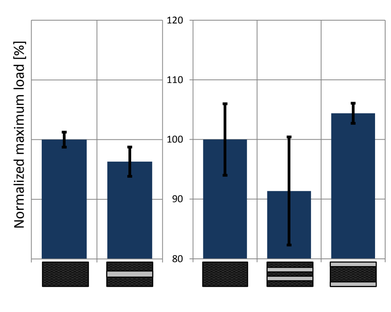
Results for SLJs with 12.5 mm overlap (cohesive failure):



3.2 mm adherends

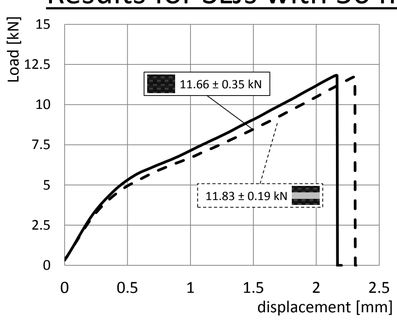


6.4 mm adherends

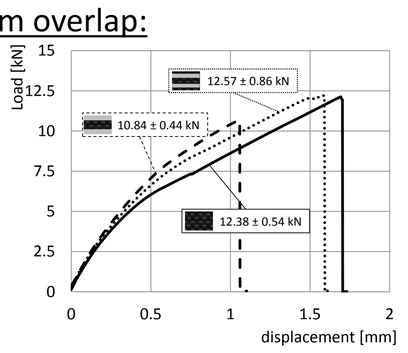


3.2 mm adherends | 6.4 mm adherends

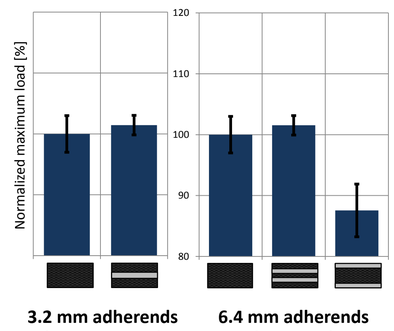
Results for SLJs with 50 mm overlap:



3.2 mm adherends (delamination)



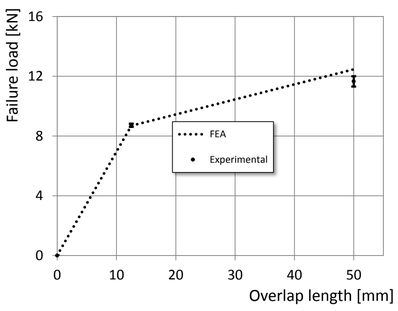
6.4 mm adherends (cohesive)



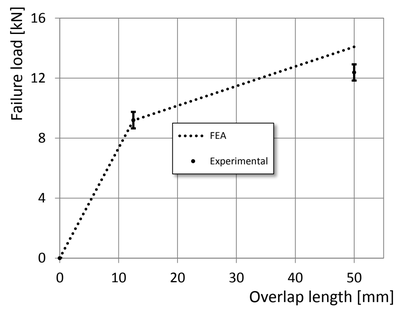
3.2 mm adherends (delamination) | 6.4 mm adherends (cohesive)

Numerical analyses

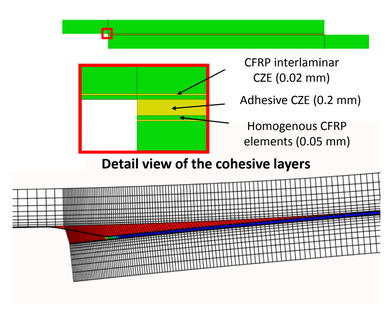
Firstly, a finite element model using CFRP substrates was developed using ABAQUS ® 6.13. The model, which uses cohesive elements to allow delamination, was validated using the experimental data obtained for the reference joint.



3.2 mm adherends



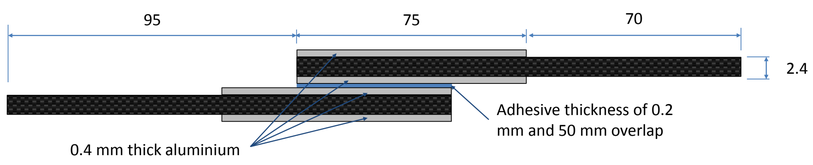
6.4 mm adherends

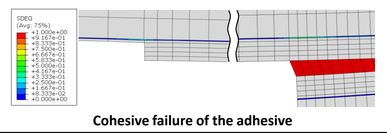


Delamination of the CFRP adherend

Optimisation of the FML joint:

To optimize the FML joint a finite element model was again developed using ABAQUS® 6.13 but with FML substrates. This optimization model was based on the previously validated model to ensure accuracy.





Cohesive failure of the adhesive

Conclusions

- PAA is the best surface treatment to use in order to bond aluminium to a CFRP laminate, during the cure process.
- Using thicker adherends higher failure loads can be obtained.
- The numerical model developed in ABAQUS® is a good approximation of the studied joints.
- The optimised model prevents the delamination of the CFRP substrate and increases the joint strength

Acknowledgments

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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).

[3] J A B P Neto, R D S G Campilho, Lucas F M da Silva, *International Journal of Adhesion and Adhesives* 37: 96–101, 2012.