# Study of composite joints with toughened adherends reinforced by thin-ply

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## Introduction

It has been demonstrated that a possible solution to reduce delamination in a unidirectional composite laminate lies in the replacement of conventional carbon fibre reinforced polymer layers with optimized thin-ply layers, creating hybrid laminates [1]. This leads to an increase in the transverse tensile strength of the hybrid composite laminate. This study investigates the performance of hybrid composite laminate reinforced by thin-plies when used as adherends in bonded single lap joints. Two different composites with the commercial reference "Texipreg HS 160 T700" and "NTPT-TP415" were used as the conventional and thin-ply respectively.

## Experimental methodology

The adhesive used in this work was an epoxy structural adhesive, supplied in film form, with the commercial reference "Scotch Weld AF 163-2k" (3M, Saint Paul, Minnesota, USA). A unidirectional prepreg carbon-epoxy composite with a ply thickness of 0.150 mm was selected, with the commercial reference "Texipreg HS 160 T700" (Seal Spa, Legnano, Italy). Finally, an unidirectional 0° oriented carbon-epoxy prepreg composite with a ply thickness of 0.075 mm was selected for use in this work, serving as the thin-ply material. This material has the commercial reference "NTPT-TP415" (North Thin-ply Technology, Poland). The SLJs were tested using an Instron 8801 servo hydraulic testing machine with a load cell of 100 kN, at a constant crosshead speed of 1 mm/min. Schematic design of the specimen and its configurations is presented in Figure 1 and 2 respectively.

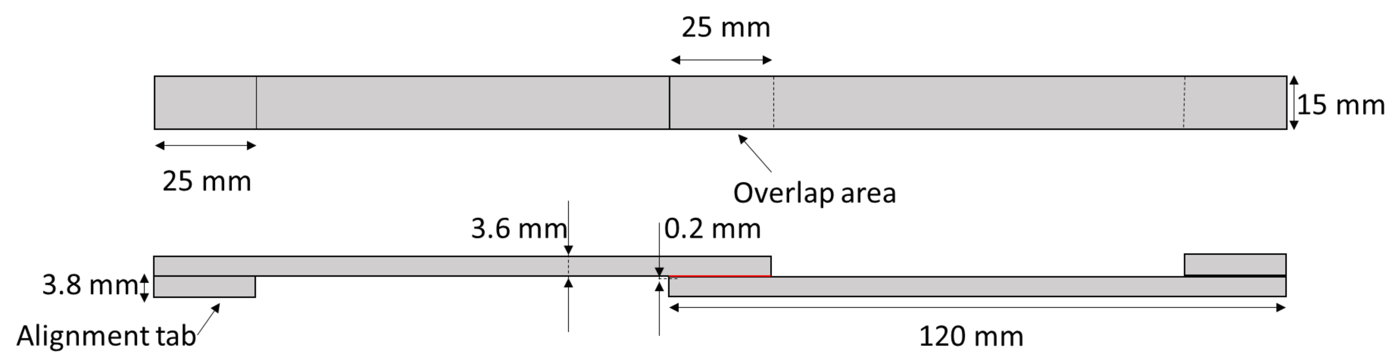



Figure 1 – Single lap joint geometry.

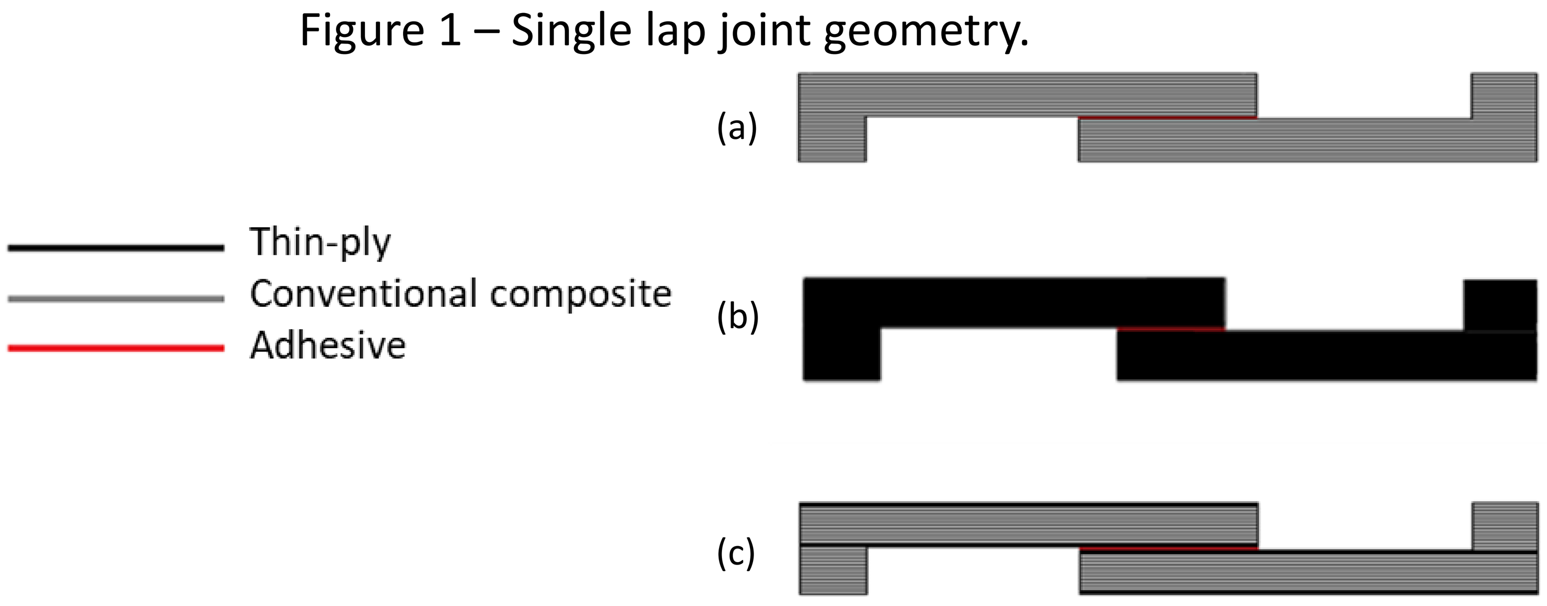
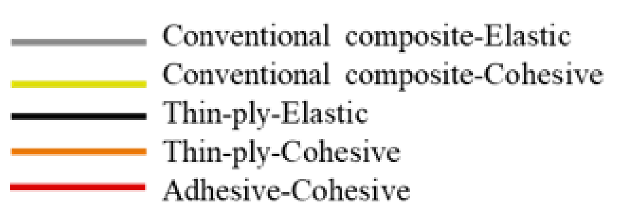



Figure 2 – Schematic design of (a) conventional composite, (b) thin-ply, and (c) hybrid joint (25% thin-ply) joint.

## Numerical study

A two-dimensional, statically loaded model was used to simplify the problem under analysis and reduce the computational time The left end of the joint was fixed while a displacement was applied in the right end to replicate the testing fixtures. A cohesive zone model (CZM) was used to model the adhesive behaviour, employing 4 node elements cohesive quadrilateral elements. Figure 3 presents the final failure mode obtained for the configurations numerically.



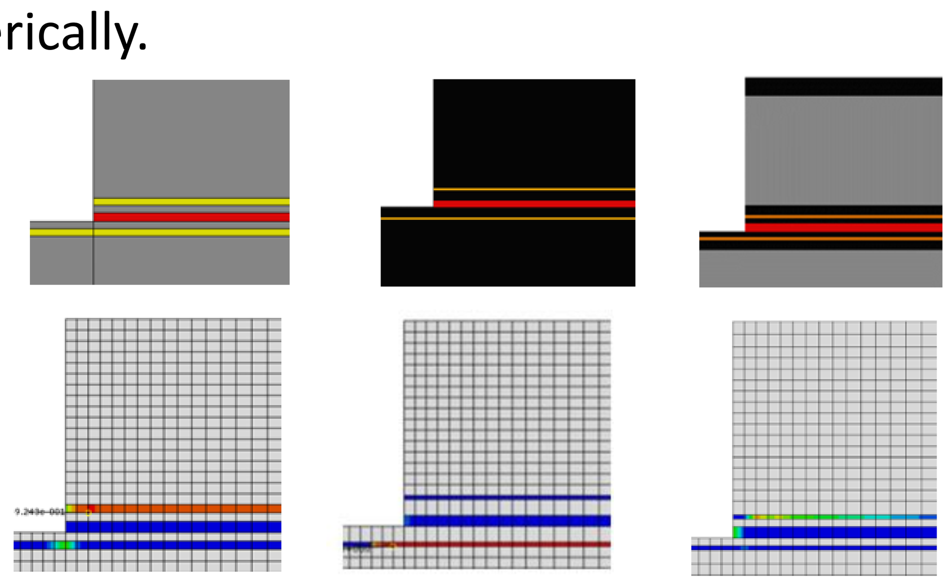




Figure 3 –SDEG at failure load for (a) conventional composite, (b) thin-ply and (c) hybrid (25% thin-ply) joint (equivalent load for each configuration is 5.4, 9.2 and 10.0 kN respectively)

## Experimental result

Figure 4 shows representative experimentally obtained load-displacement curves for the studied configurations. The hybrid (25% thin-ply) joint presented the highest failure load, with around a 90% increase in joint strength compared to the reference conventional composite configuration.

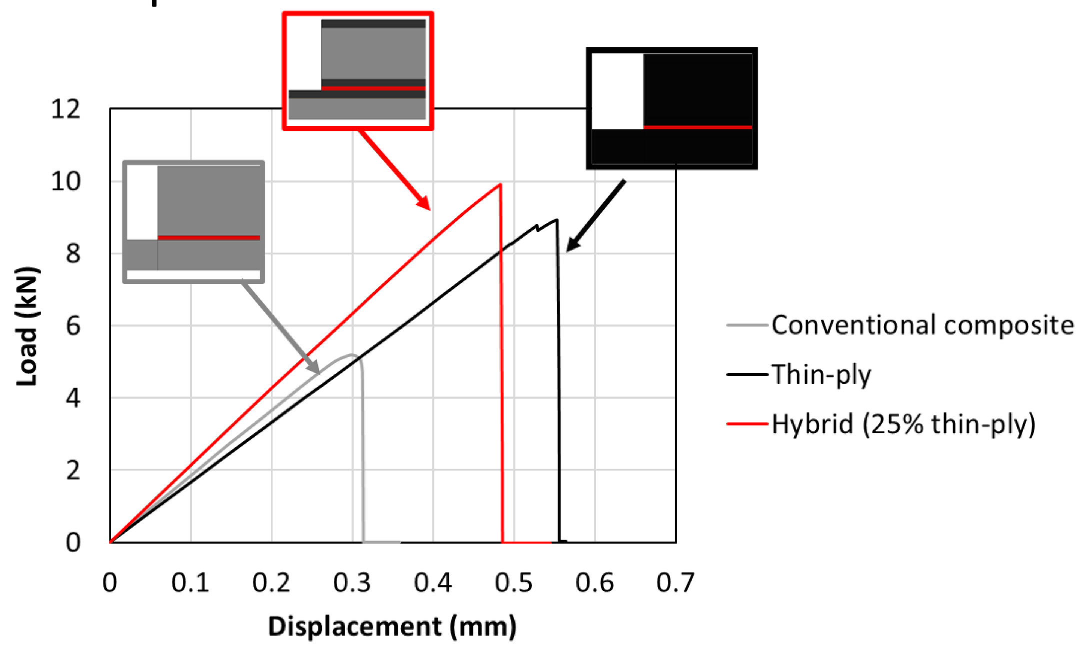



Figure 4 – Representative load-displacement curves for reference conventional composite, thin-ply, and hybrid (25% thin-ply) joint.

According to the experimental observation, damage initiation occurs in the adherend for the reference conventional composite and thin-ply joint, while for the hybrid (25% thin-ply) joint damage initiation occurs in the adhesive layer (Figure 5) .Damage propagates as a combination of delamination and cohesive failure for all configurations. However, a more limited amount of delamination was obtained for the hybrid joints (Figure 6).

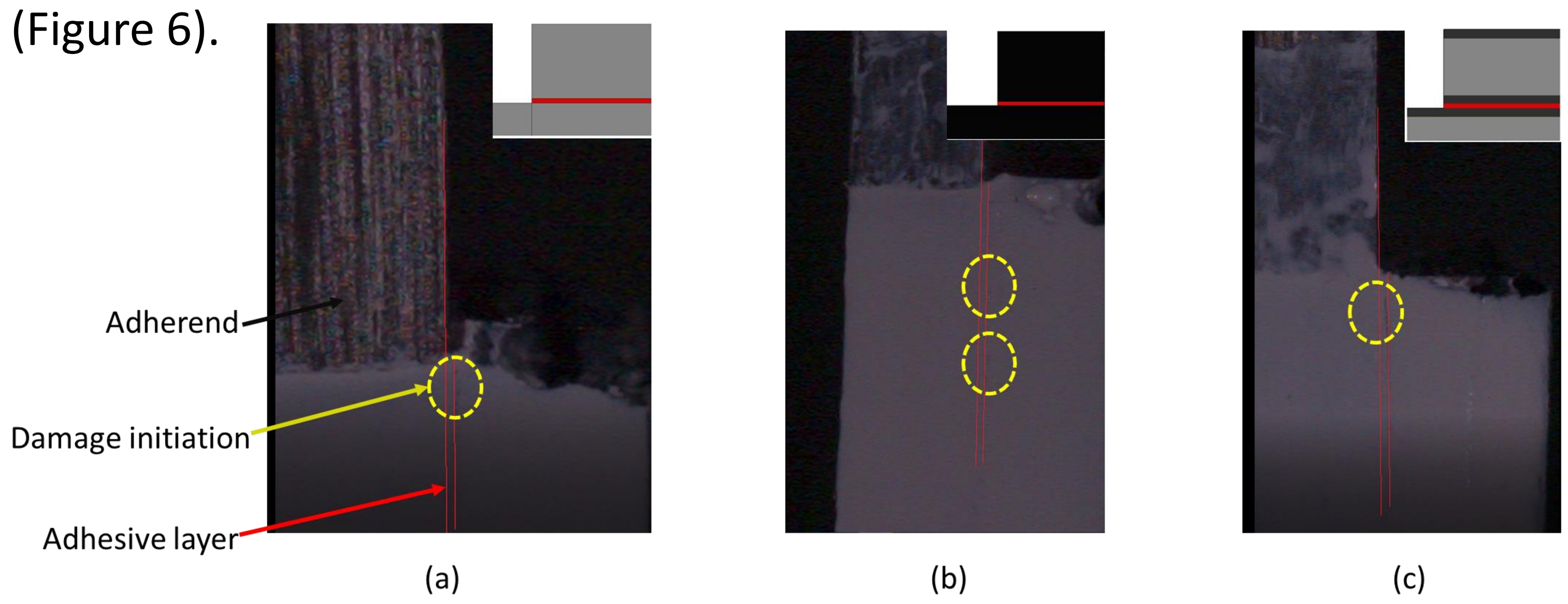



Figure 5 – Damage initiation for (a) conventional composite, (b) thin-ply and (c) hybrid (25% thin-ply) joint.

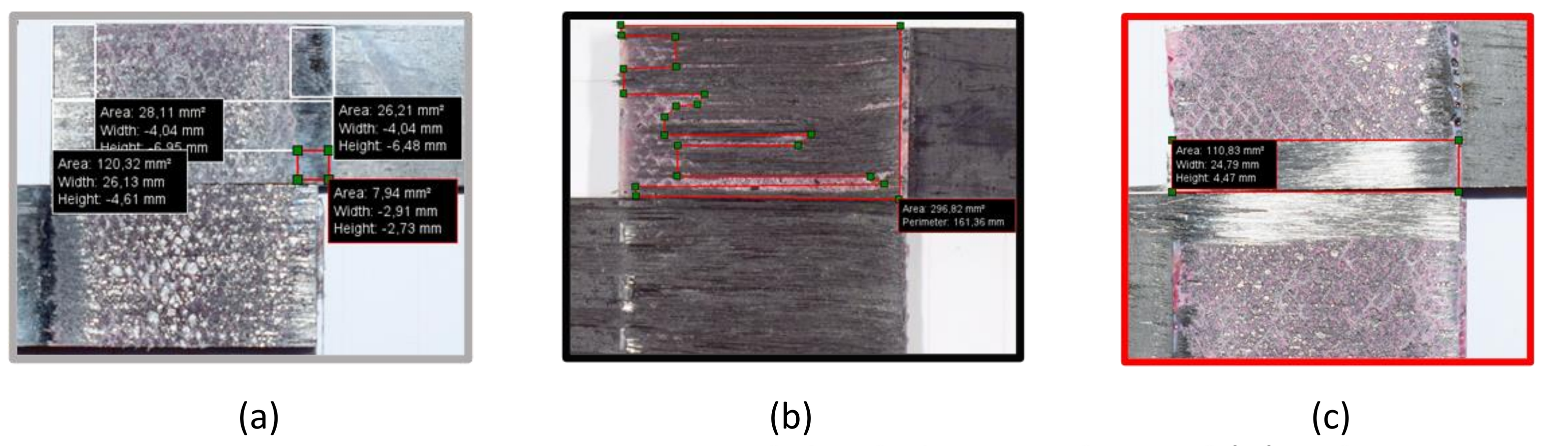



Figure 6 – Representative images of the failure surface of (a) reference conventional composite, (b) thin-ply, and (c) hybrid (25% thin-ply) joint.

## Conclusions

- An increase of about 90% in the failure load was found for the hybrid joint reinforced by thin-ply, when compared to the reference conventional composite joint.
- According to the experimental observation, damage initiation occurs in the adherend for the reference conventional composite and thin-ply joint, while for the hybrid (25% thin-ply) joint damage initiation occurs in the adhesive layer.

## References

[1] Ramezani, F., Carbas, R.J., Marques, E.A., Ferreira, A.M. and da Silva, L.F., 2023. A study of the fracture mechanisms of hybrid carbon fiber reinforced polymer laminates reinforced by thin-ply. Polymer Composites, 44(3), pp.1672-1683.

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