Toughened CFRP laminates using thin-ply

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ADVANCED JOINING PROCESSES UNIT

Introduction

Thin plies can be generally defined as composites with the ply thicknesses less than 100 µm and ply areal weight less than 100 g/m2 [1]. Thin-ply composites are rapidly gaining interest in the composite and high-performance industries e.g. aerospace, mainly due to increased design possibilities and improved performance in various loading conditions [2]. Different methods have been used in order to prevent delamination or increase the failure load in single lap joints with CFRP adherends, e.g. by reinforcing laminates using adhesives or metal laminates [3]. Studies have shown that, with the use of thin plies, the damage onset inside the composite moves away from the adhesive interface towards the mid-thickness of the adherend [4].

This work studies the effect of reinforcing 0˚ unidirectional conventional CFRP blocks using thin ply under tensile loading. Hybrid CFRP blocks with different configurations were studied. Conventional CFRP is toughened by adding thin plies on laminates topes. In this case CFRP blocks reinforced with 10%, 25% and 50% of thin ply is studied (which as an example is labeled as CFRP+25%Thin ply).

In this work, HS 160 T700 by CIT and TP415 by NTPT are used as conventional CFRP and thin plies respectively. Experimental results show that toughened hybrid blocks present higher failure load under tensile loading since thin plies provides higher ductility in hybrid composite laminates.

Experimental details

Materials:

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

• Thin ply: unidirectional 0° Thin ply , TP415 by NTPT, Manufactured using manual lay-up method;

Cure process:

• 130 °C during 60 minutes.

Hybrid laminate configuration:

• Thickness of the blocks: 3.2 mm;

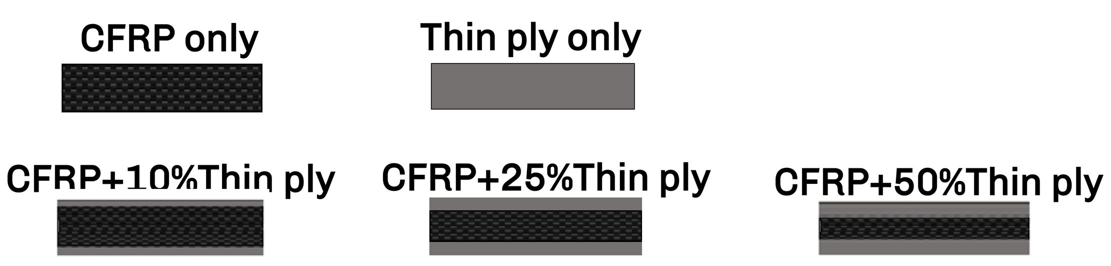

Figure 1 – Lay-up configurations.

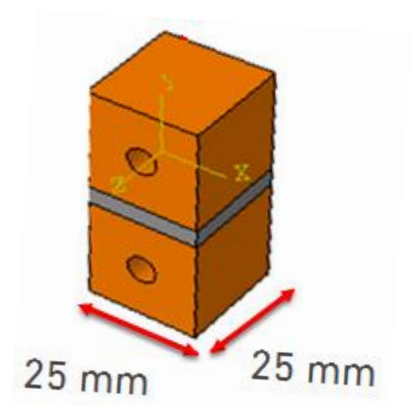

Figure 2 – Schematic design of CFRP block attached to steel blocks.

Table 1 – CFRP and thin ply elastic orthotropic properties.

Material	E_1 (GPa)	σ_1 (MPa)	E_2 (GPa)	σ_2 (MPa)	G_{12} (GPa)	σ_{12} (MPa)
CFRP	109.0	-	8.9	40	4.35	35
Thin ply	160.6	1430	8.9	43.3	5.07	71.2

Digital Image Correlation (DIC)

DIC is performed on conventional CFRP, Thin ply and hybrid block (CFRP+25%Thin ply). The block are coloured in with following by black spackles using air brush. The stress-strain curve is plotted below for the mentioned configuration.

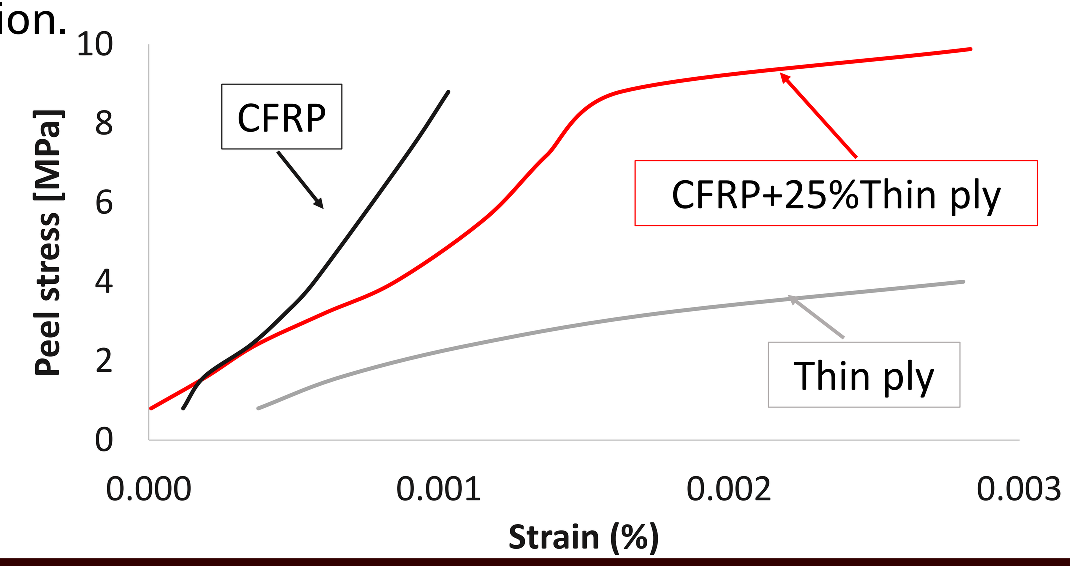

Figure 3 – Stress-strain curve for CFRP, Thin ply and hybrid block.

Optical observation

Optical observation was performed for CFRP and thin ply showing resin the rich area and the fibre rich area in CFRP and well distributed fibres in thin ply, compared to CFRP.

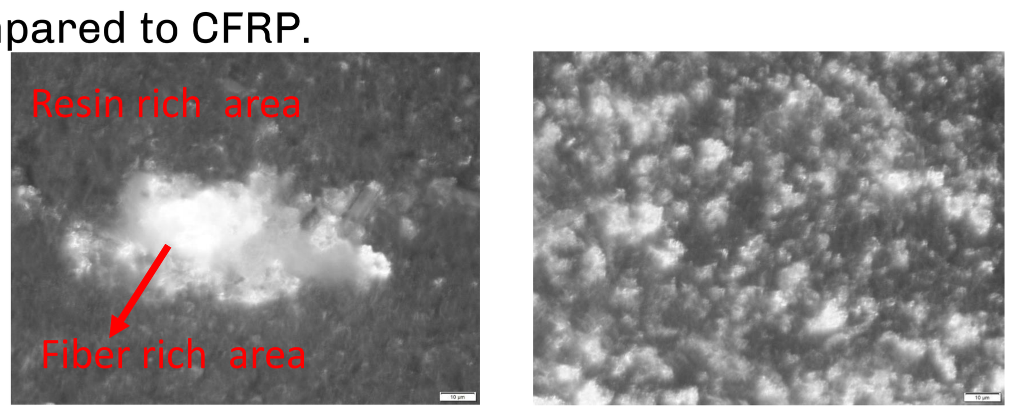

Figure 4 – Optical observation for CFRP and thin ply.

Experimental results

The SLJs were tested in a servo-hydraulic MTS model 8801 test machine, with a capacity of 100 kN, at room temperature and a constant displacement rate of 1 mm/min.

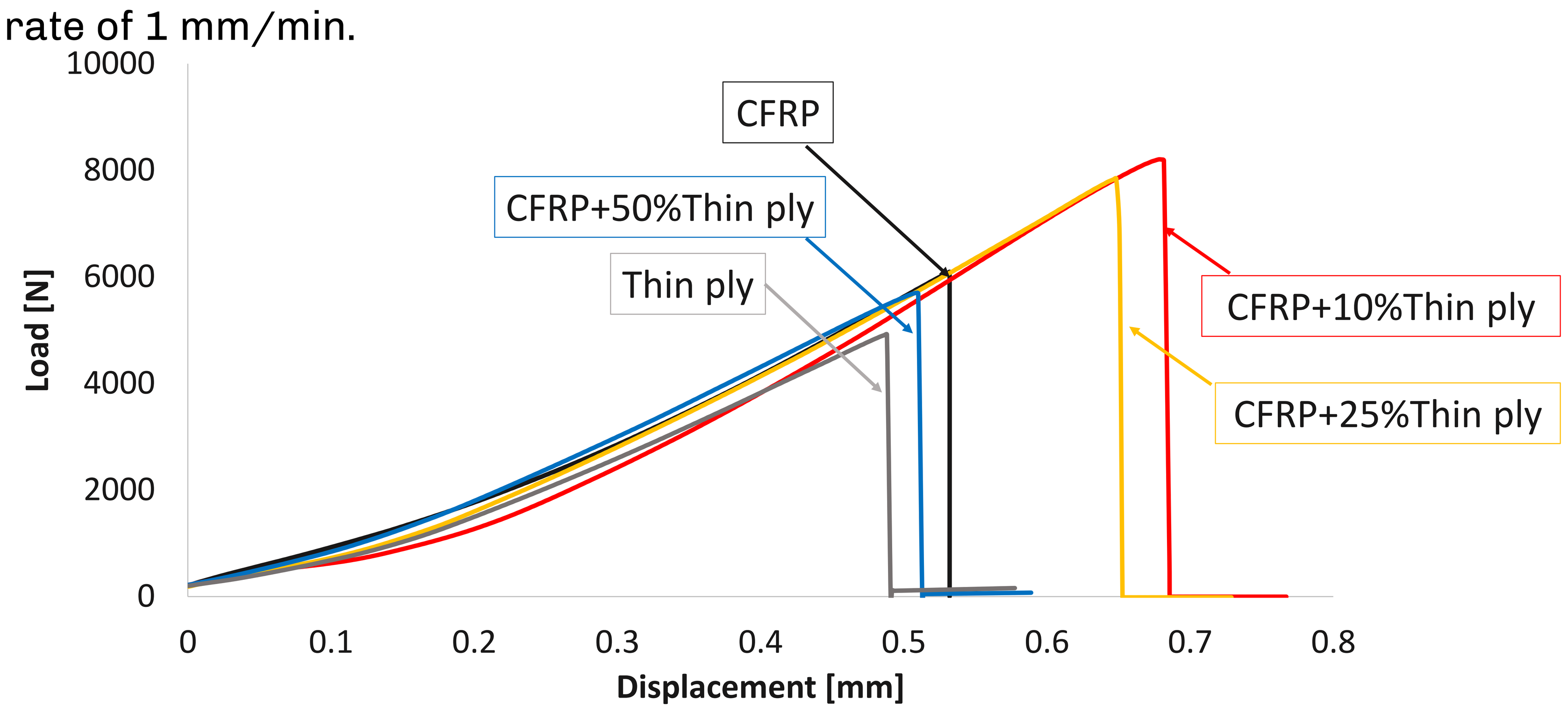

Figure 5 – Load-displacement curve for CFRP, thin ply and hybrid blocks.

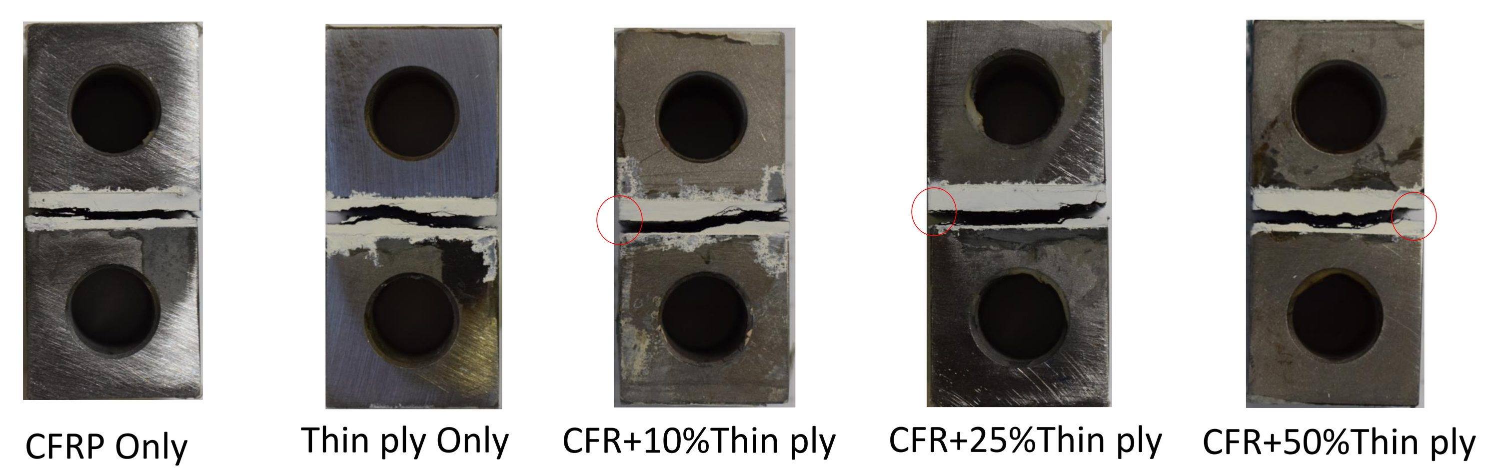

Figure 6 – Failure mechanism of all configurations.

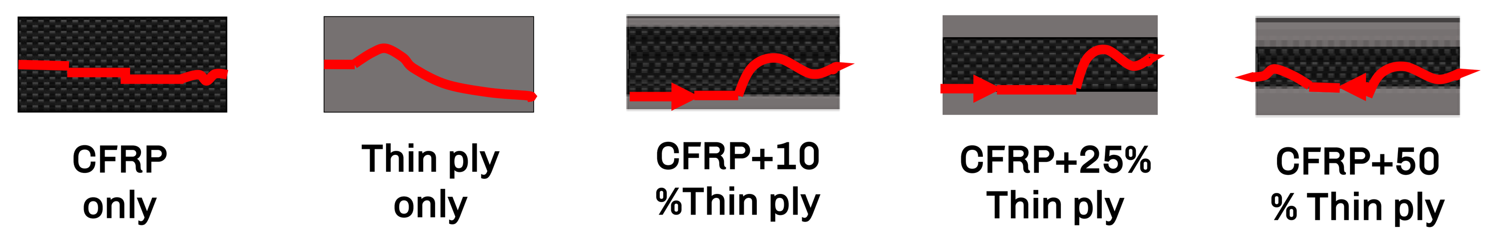

Figure 7 – Main failure mechanisms in hybrid blocks.

Conclusions

- This work studied toughened CFRP laminated using thin plies considering different configurations. According to experimental result hybrid laminates present higher failure load since thin plies provides higher ductility for composite laminates.
- Due to experimental result CFRP+10% presents the highest failure load with almost 30% increase in failure load compares to the reference CFRP laminate.
- Moreover the failure mechanism is studied in hybrid blocks, which occurs in two main types. First, the failure state in one side at the interface of the CFRP and the thin ply and propagates through the CFRP. Second, the failure starts in the CFRP, propagates in the interface of the thin ply and the CFRP and again propagated through the CFRP.

References

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Acknowledgements

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