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Mechanical characterization of a newly developed cycloolefin-based adhesive

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1. Introduction

This study mechanically characterizes a novel cycloolefin-based hot-melt adhesive, LS-XU, through bulk tensile and thick adherend shear tests (TAST) to determine its tensile and shear properties. Fracture behavior was assessed using double cantilever beam (DCB) and end-notched flexure (ENF) tests.

2. Methodology

2.1 Bulk tensile test

Dumb-bell bulk specimens were prepared following the DIN 53504 standard (Fig. 1), with slight modifications to match the adhesive film thickness. Six samples were tested at 10 mm/min, and strain was measured using digital image correlation (DIC).

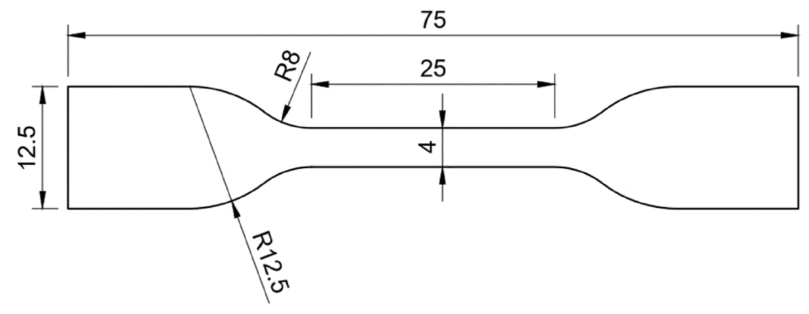


Figure 1. Bulk specimen drawing (dimensions in mm)

2.2 TAST

The TAST follows the ISO 11003-2:1993 standard (fig 2). The substrates were measured to ensure an adhesive thickness of 0.25 [mm]. Tests were performed at 1 mm/min, and strain was measured using both a high-resolution extensometer and DIC.

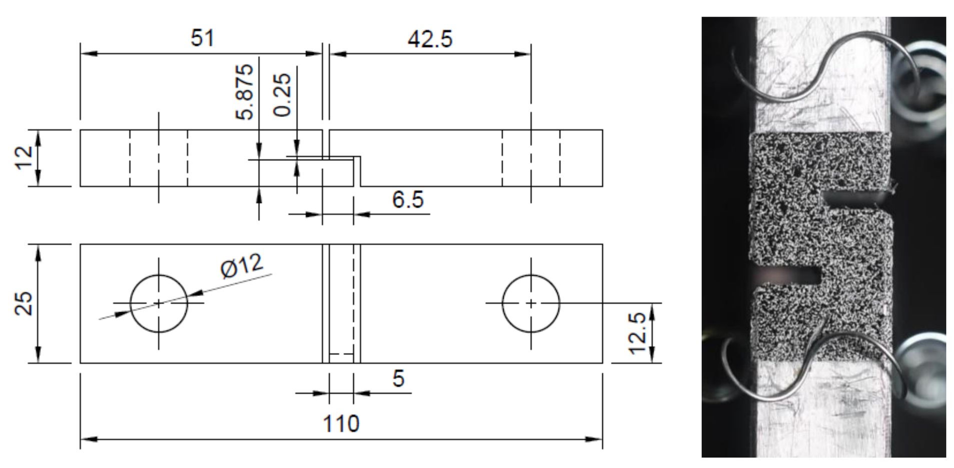


Figure 2. TAST specimen drawing (dimensions in mm) (left) and testing setup (right).

2.3 DCB and ENF

The DCB test, following ASTM D3433 (Fig. 3), was conducted on aluminium (12 mm thick) and CFRP (4 mm thick) specimens, both measuring 297×25 mm. ENF tests were carried out on CFRP specimens (500×25×4 mm). Tests were performed at 2 mm/min, and the J-integral was used to determine the apparent fracture energy in modes I [1] and II [2].

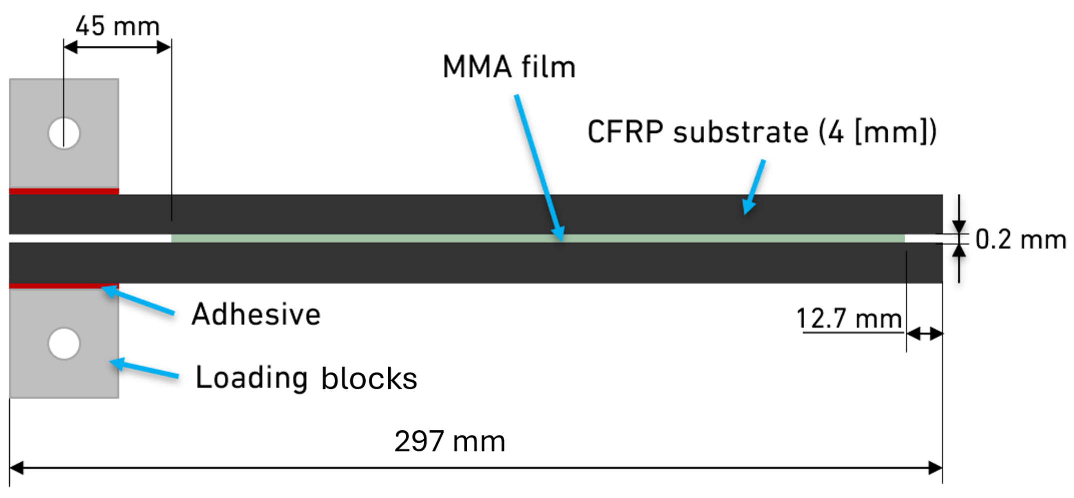
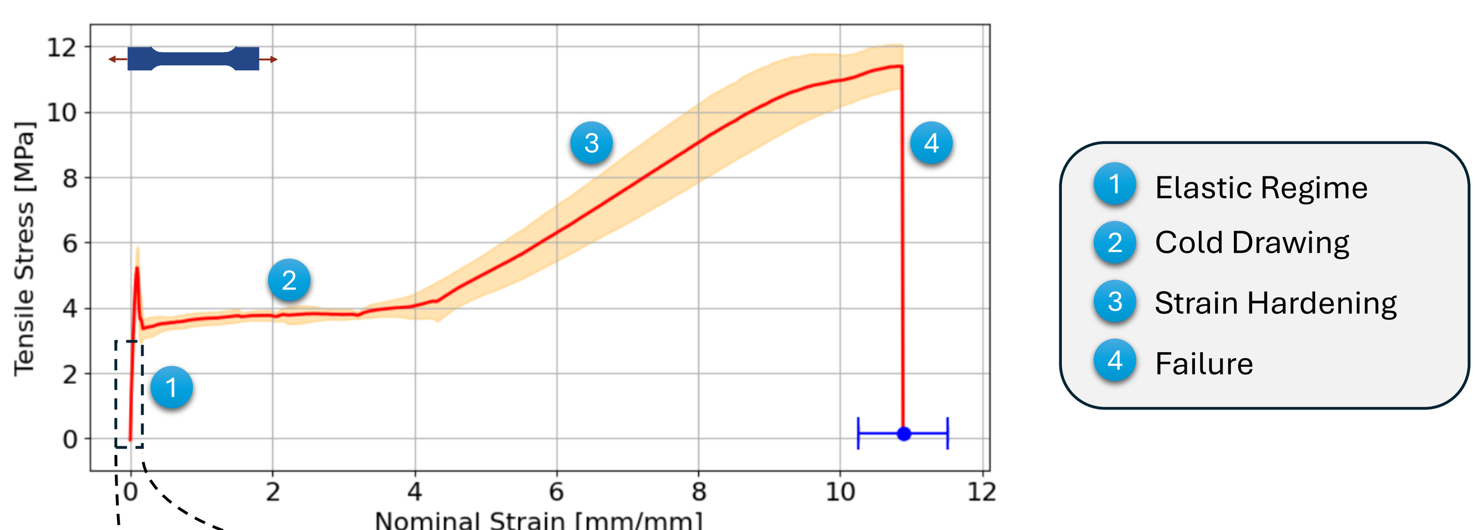


Figure 3. CFRP DCB specimens with loading blocks.

3. Results

3.1 Bulk tensile test

The bulk curve exhibits four stages: elastic regime, cold drawing, strain hardening, and failure. DIC data were combined with machine measurements to extract the tensile properties (Fig. 4).



Property	LS-XU
E [MPa]	230.18 ± 8.08
σ_y [MPa]	5.49 ± 0.36
σ_r [MPa]	10.86 ± 1.48
ε [-]	10.66 ± 0.83
ν [-]	0.47 ± 0.02

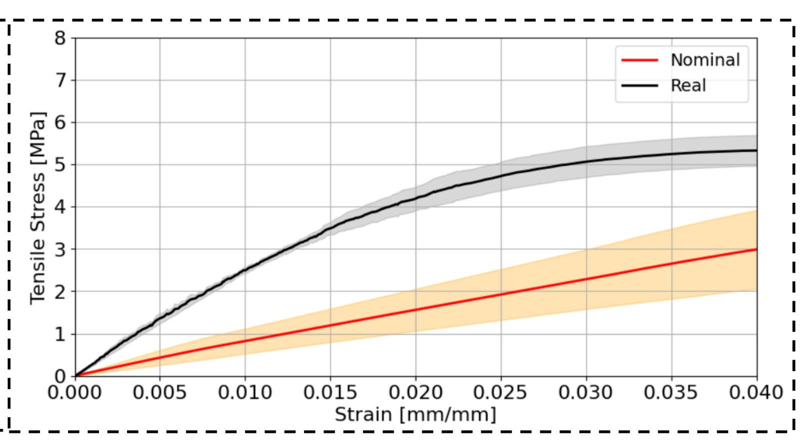
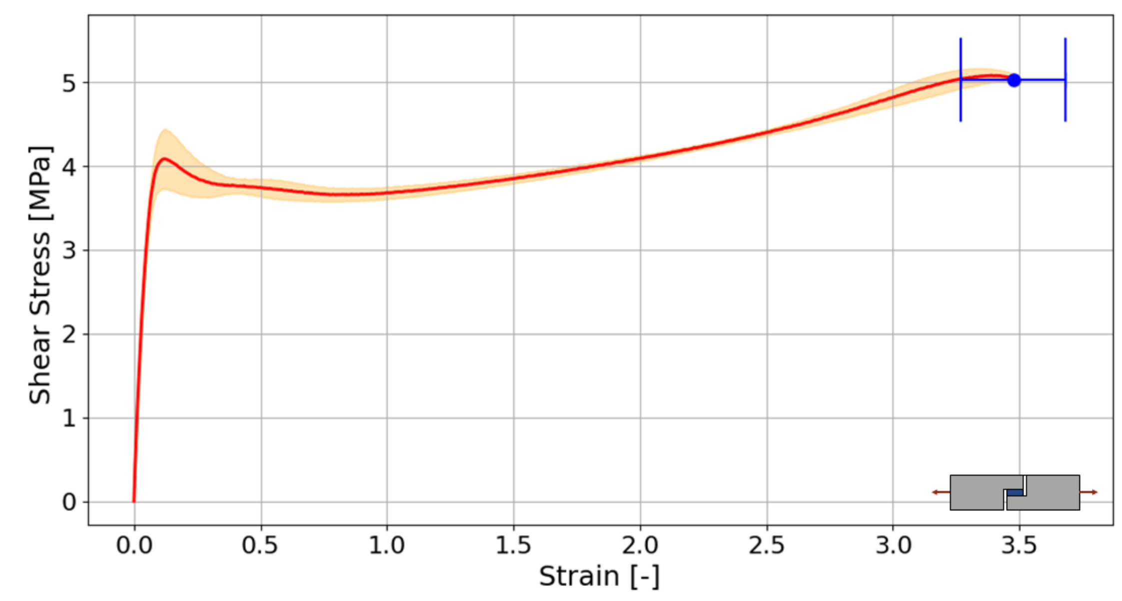


Figure 4. Bulk test results (left) and failure mode (right).

3.2 TAST

All specimens failed adhesively. TAST provide information about the shear modulus, maximum shear strength and elongation to failure (fig 5).



Property	LS-XU
G [MPa]	76.67 ± 2.52
τ_f [MPa]	5.09 ± 0.08
γ [-]	3.54 ± 0.19

Figure 5. TAST results.

3.3 DCB

DCB tests revealed adhesive stretching, characteristic of highly deformable materials like LS-XU. The measured fracture energy includes two components: intrinsic fracture energy and bulk dissipation energy. Consequently, the resulting value is an apparent, geometry-dependent fracture energy (Fig. 6).

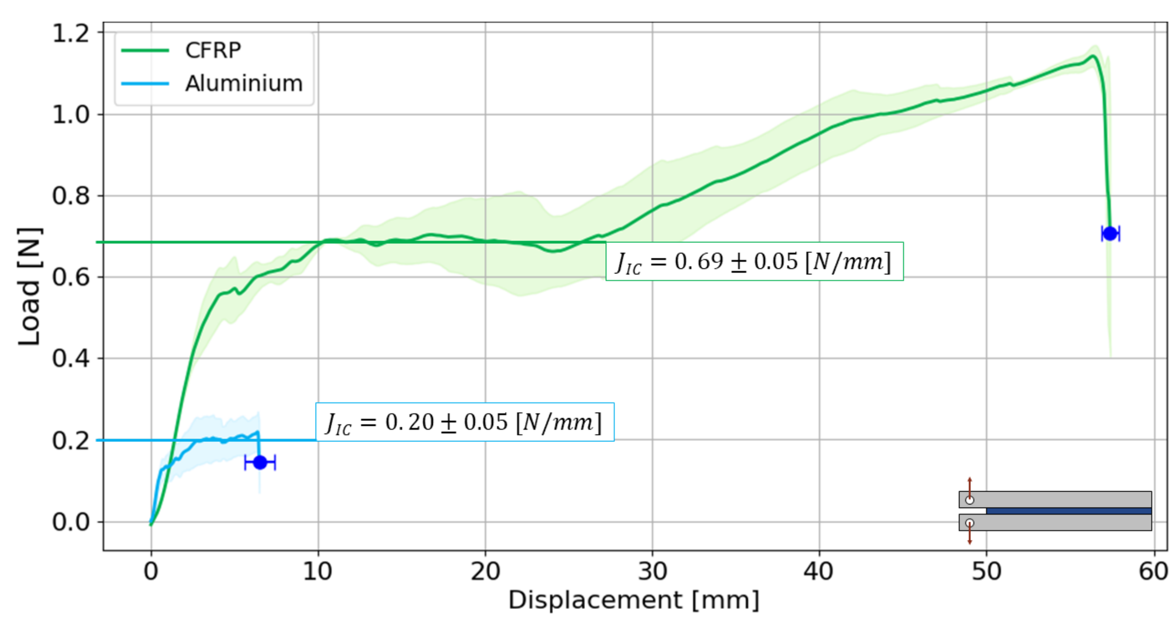
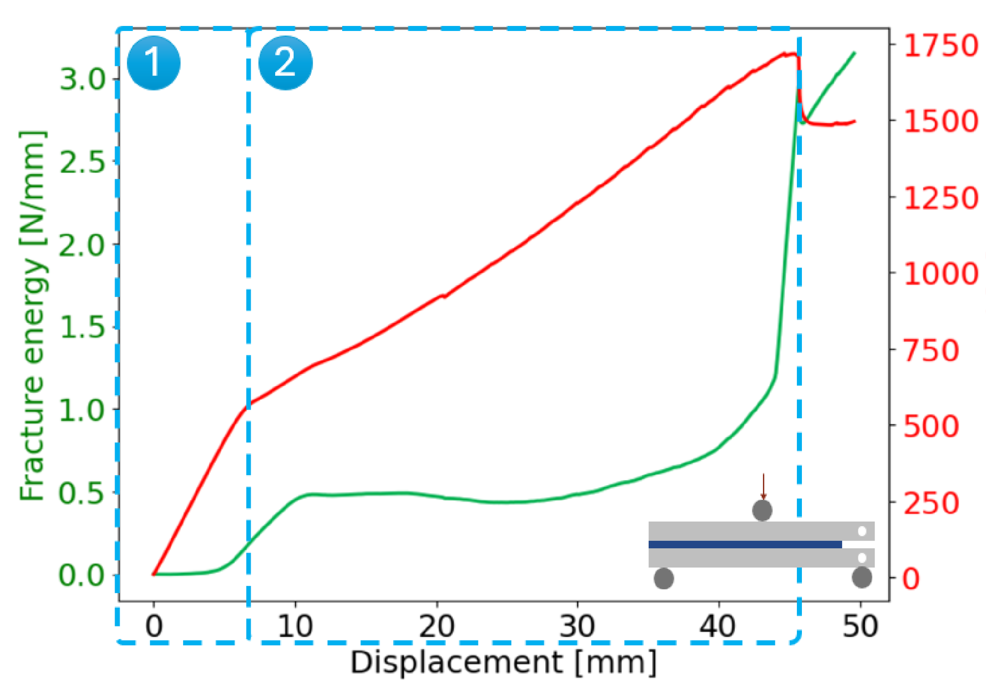
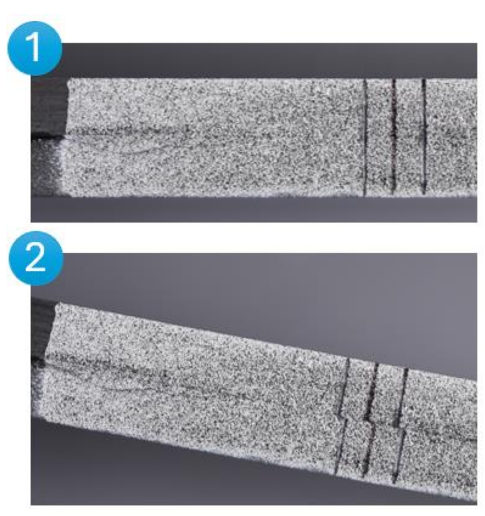


Figure 6. DCB apparent fracture energy results (left) and stretching phenomena (right).

3.4 ENF

ENF tests showed that the adhesive undergoes elastic and plastic deformation prior to detachment from the substrates, which occurs instantaneously when the load drop occurs. DIC analysis enhanced the relative displacement of the substrates along the crack direction (fig 7).





Property	LS-XU
J_{IIc} [N/mm]	2.66 ± 0.19

Figure 7. ENF results.

4. Conclusion

- Tensile properties are comparable with similar materials and shear properties highlight the plastic deformation of LS-XU;
- Fracture tests provided an apparent fracture energy, influenced by bulk energy dissipation. In mode I, the interfacial failure leads to different energies for different materials. Mode II revealed elastic and plastic behavior of the LS-XU until it detaches from the substrates;
- Peel adhesion tests are recommended for future works.

References

[1] J Anthony and Paul C Paris. Instantaneous evaluation of j and c. Int. J. Fract,38(1):R19–R20, 1988.

[2] Ulf Stigh, Svante Alfredsson, and Anders Biel. Measurement of cohesive lawsand related problems. ASME International Mechanical Engineering Congressand Exposition, Proceedings, 11, 01 2009.

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