Exploring Mechanical and Fracture Properties of an acrylic PSA: An Experimental Investigation of Influential Parameters

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Introduction

Pressure-sensitive adhesives (PSAs) bond instantly to substrates with light pressure, without chemical reactions. Adhesion is influenced by factors such as viscoelastic, mechanical, and fracture properties. This study evaluated the viscoelastic behaviour and tensile strength of an acrylic PSA, positioning it in the viscoelastic window. Tensile tests were performed with various stacked layers, while fracture tests using the J-integral method measured fracture energy, considering the effects of substrate roughness, layer count, and PSA thickness.

Experimental details

Adhesive

The adhesive used in the study was an acrylic PSA with long-term strength and temperature stability.

Substrate

For the DCB tests, acrylic (PMMA) substrates were used, in order to enable the evaluation of damage propagation during testing.

Joint geometry

The specimens' geometry that were used to perform the tests can be observed in Figure 1.

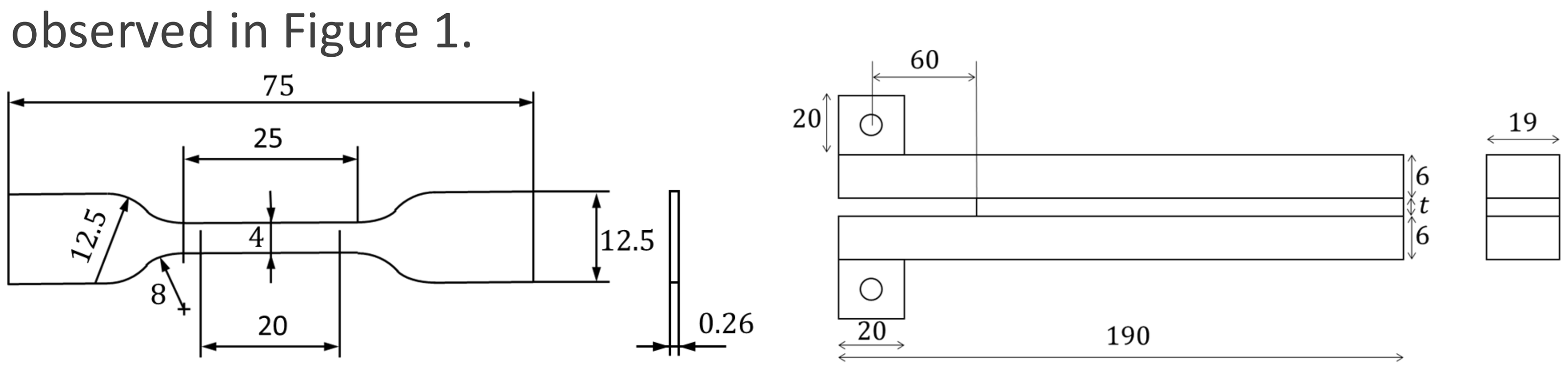

Figure 1– Specimens' geometry, in mm: bulk (left) and DCB (right).

Results

Rheological properties

Figure 2 (left) shows G' exceeding G'' at most frequencies, indicating elastic behaviour, while G'' increases above 10^2 Hz, enhancing adhesion. The viscoelastic window (Figure 2 - right) places the acrylic PSA mainly in the high shear quadrant, with some presence in the non-PSA region.

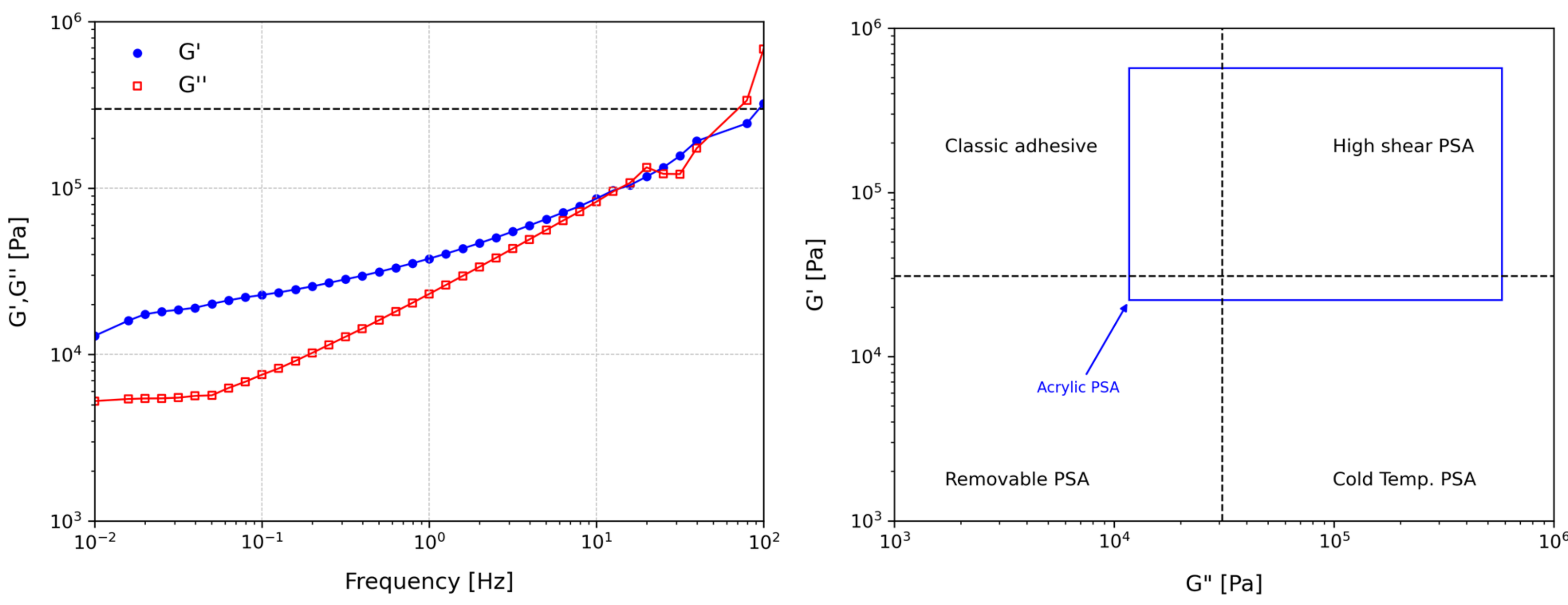

Figure 2– G' and G'' curves as a function of the frequency (left) and viscoelastic window (VW) (right) for the PSA adhesive.

Bulk tensile testing

Figure 3 depicts the characteristic stress-strain curves for 15 mm/min, when comparing different number of stacked layers. The comparison between the engineering and true tensile stress until failure can be observed on the left, while the same comparison until 100% strain is showed on the right.

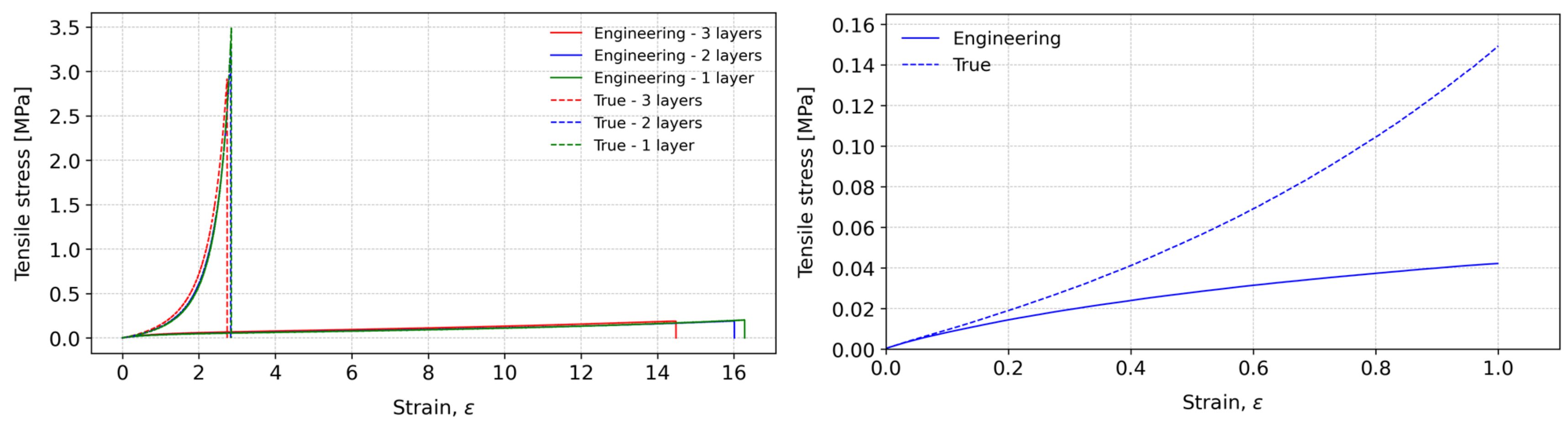

Figure 3– Characteristic stress-strain curves for engineering values (solid lines) and true values (dashed lines) at 15 mm/min: full curves (left) and curves until 100% strain (right).

For the bulk tensile tests, some conclusions could be reached:

- Adding more layers reduced joint strength.
- Beyond a single layer, the number of layers had little effect on engineering and true strength.
- Lower layer counts showed higher engineering strain to failure.
- Engineering and true stress values matched closely for strains up to 2% and differed by less than 10% at 10% strain.

DCB tests

DCB fracture tests assessed the impact of surface energy, surface roughness, adhesive thickness, and layer count on fracture energy, as shown in the load-displacement and fracture energy curves in Figure 4.

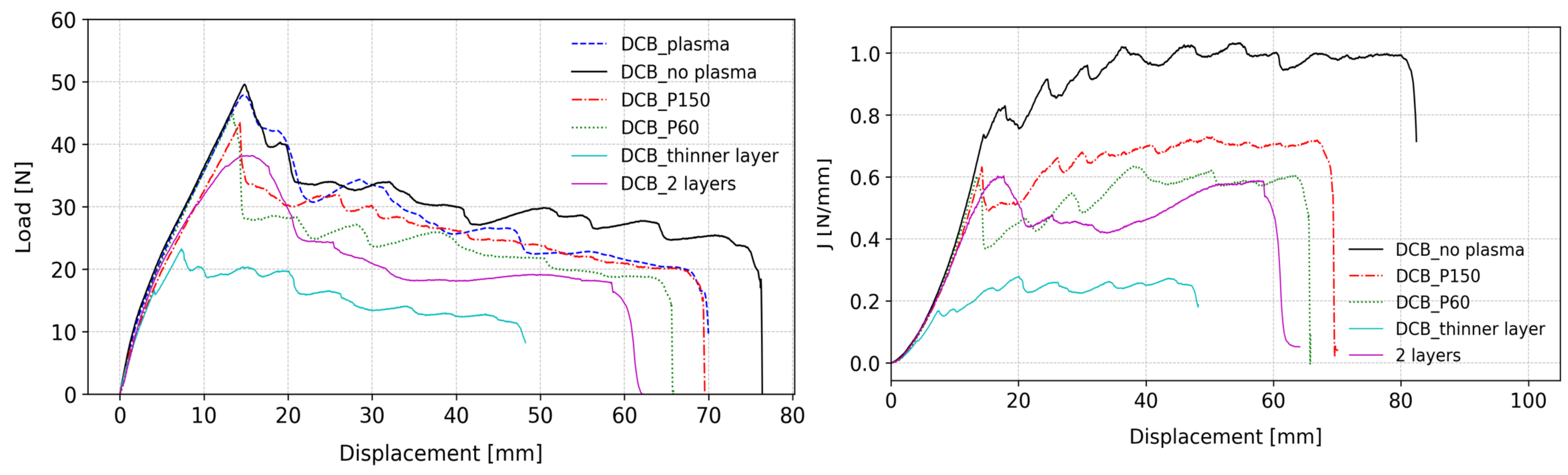

Figure 4 – Load vs displacement (left) and J vs loading point displacement (right) curves obtained in DCB tests for the different tested conditions.

Plasma treatment showed no difference from the reference condition. High and intermediate roughness (P60, P150) and two-layer samples had similar failure loads, while the thinner sample showed lower values. The reference condition had the highest fracture energy (~ 1 N/mm), with differences observed in propagation for the other conditions.

Conclusions

Rheological tests positioned the PSA in the viscoelastic window, providing insight into its properties. Bulk tensile tests showed that more layers reduced tensile strength, especially true strength. In fracture tests, greater roughness, thinner adhesive, and stacked layers negatively affected joint performance.

Acknowledgements

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