Characterization of rheological, mechanical and fracture properties of an acrylic PSA

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Introduction

Pressure sensitive adhesives (PSAs) are defined by the capacity to form an immediate bond with the substrate without the need for a chemical reaction and with only light pressure[1]. Adhesion in these materials is a complex phenomena that may be understood by analyzing multiple variables such as viscoelastic, mechanical, and fracture properties[2]. The purpose of this work was to evaluate the viscoelastic behavior of an acrylic PSA and position it in the viscoelastic window, as well as to calculate the material's tensile strength. In addition, varied numbers of stacked adhesive layers and two crosshead speeds were used to assess the adhesive's tensile strength under various situations. DCB fracture tests were carried out, and the J-integral method was applied to determine the fracture energy throughout the testing. The impact of the substrate roughness, number of stacked layers, and PSA thickness was also evaluated.

Experimental details

Adhesive

The adhesive used in the study was an acrylic PSA with long-term strength and temperature stability. This material allows for the joining of different materials in several adverse environments, which make it eligible to industrial applications.

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.

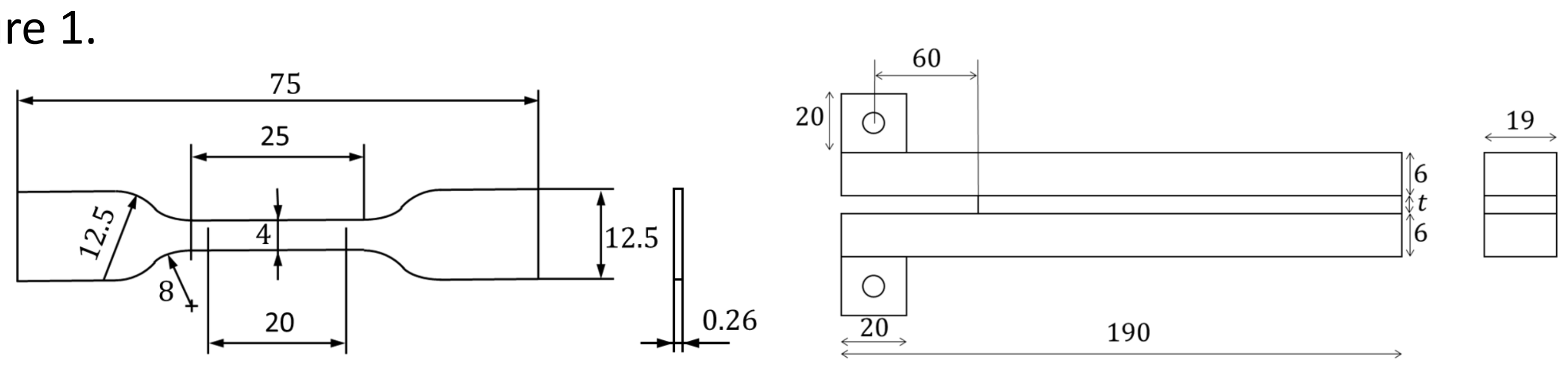

Figure 1 – Specimens' geometry, in mm: bulk (left) and DCB (right).

Results

Rheological properties

The curves of the storage modulus G' and loss modulus G'', as a function of frequency, are depicted in Figure 2, on the left. For the most part of the curves G' presents values higher than G'', which indicates a predominant elastic behaviour. For the frequencies corresponding to the debonding of the PSA (>10^2 Hz), G'' presents high values, corresponding to a high dissipation of energy, which promotes the adhesive strength.

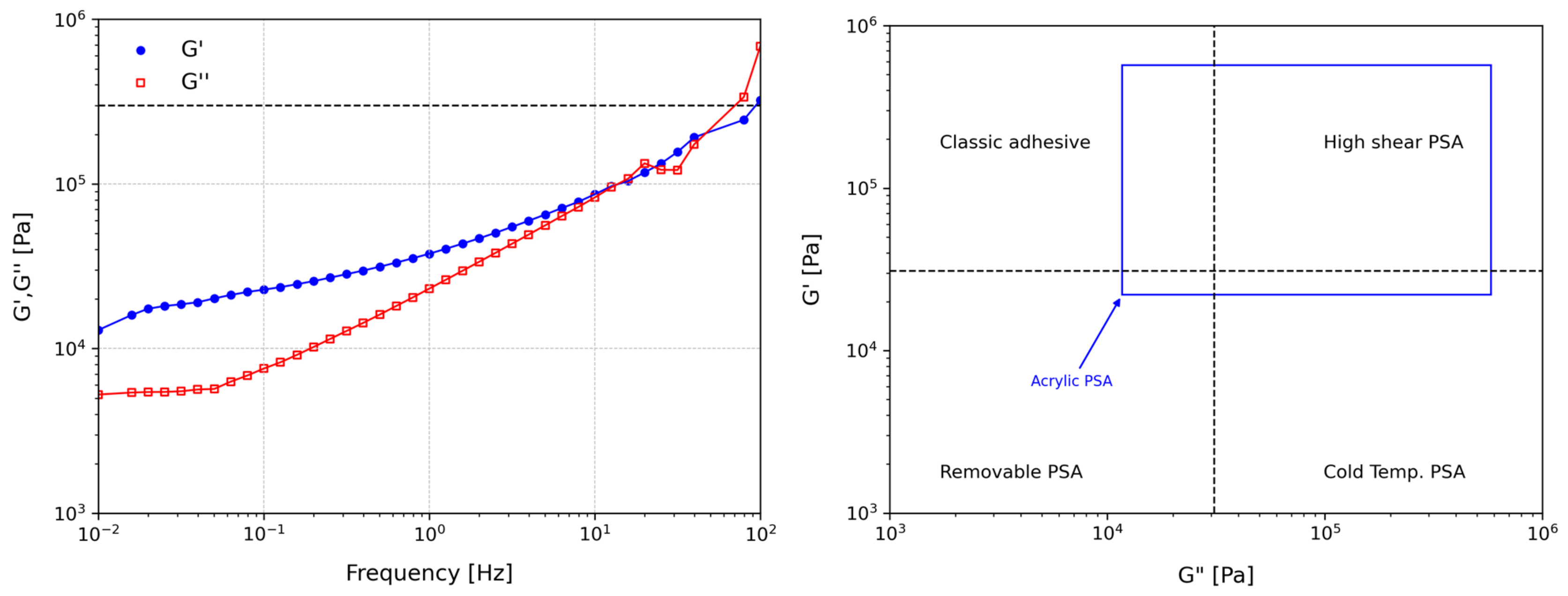

Figure 2 – G' and G'' curves as a function of the frequency (left) and viscoelastic window (VW) (right) for the PSA adhesive.

The acrylic PSA position in the viscoelastic window (VW) can be observed in Figure 2, on the right. The material was placed mostly in the high shear quadrant, that is characterized be high shear and moderate peel resistance. However, the PSA also presents a region in the non-PSA quadrant, where materials have high elasticity, reduced adhesion and easy debonding.

Bulk tensile tests

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.

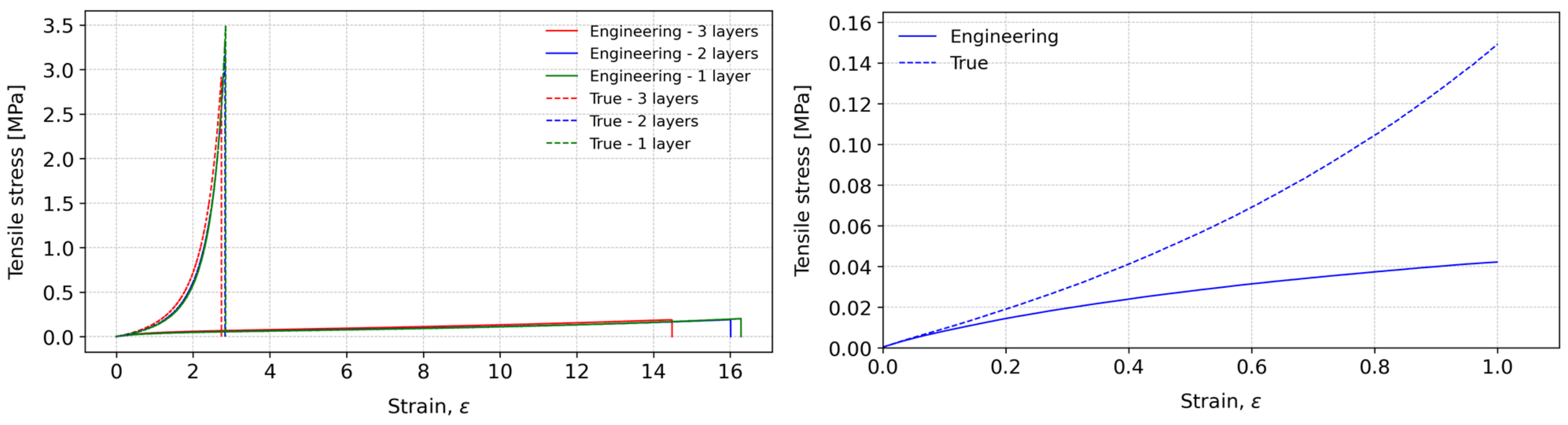

Figure 3 – Characteristic stress-strain curves for engineering values (solid lines) and true values (dashed lines) at 15 mm/min: full curves (left) and curves until 100% strain (right).

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

- The introduction of a new interface, by stacking new layers, implied a decrease in the joint strength.
- The number of layers, when there is more than 1 layer, appeared to have a minor influence on both engineering and true strength.
- The engineering strain to failure is higher for the lower number of layers.
- Both engineering and true stress values are coincident for very small strains, until 2%, and present less than 10% difference up until 10% of strain.

Figure 4 depicts the characteristic stress-strain curves for 225 mm/min, where the same trends as the 15 mm/min crosshead speed were observed. Increasing the crosshead-speed, and consequently the strain rate, resulted in a more brittle behaviour of the PSA and therefore resulted in higher values for the tensile strength.

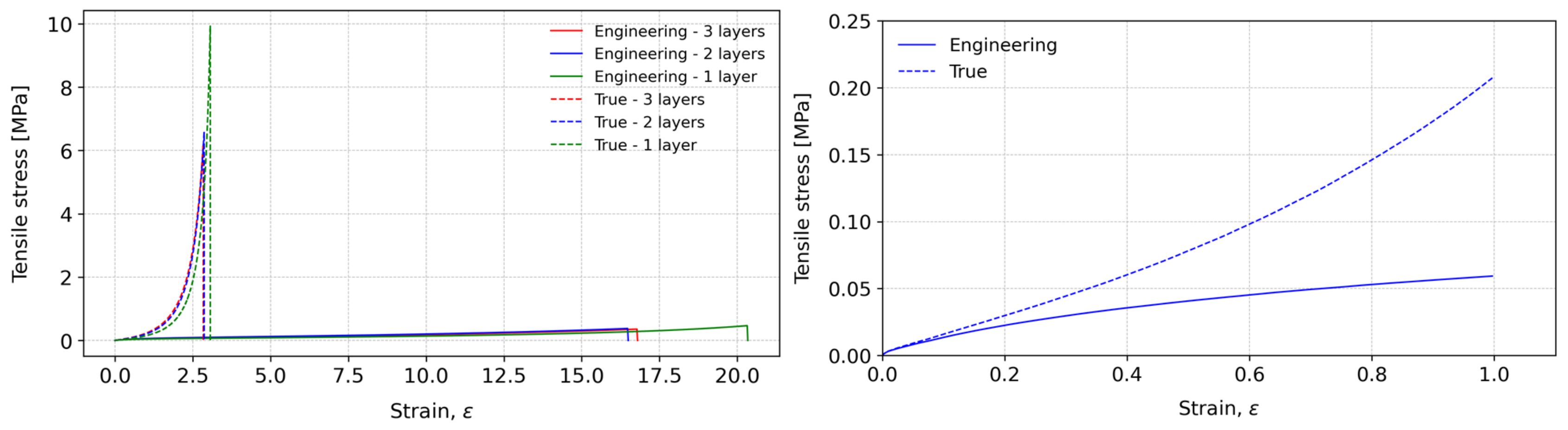

Figure 4 – Characteristic stress-strain curves for engineering values (solid lines) and true values (dashed lines) at 225 mm/min: full curves (left) and curves until 100% strain (right).

DCB tests

The influence on the fracture energy of the surface energy, surface roughness, adhesive thickness and number of stacked layers was evaluated resorting to DCB fracture tests. The comparison between the load-displacement curves and the fracture energy curves can be observed in Figure 5 left and right, respectively.

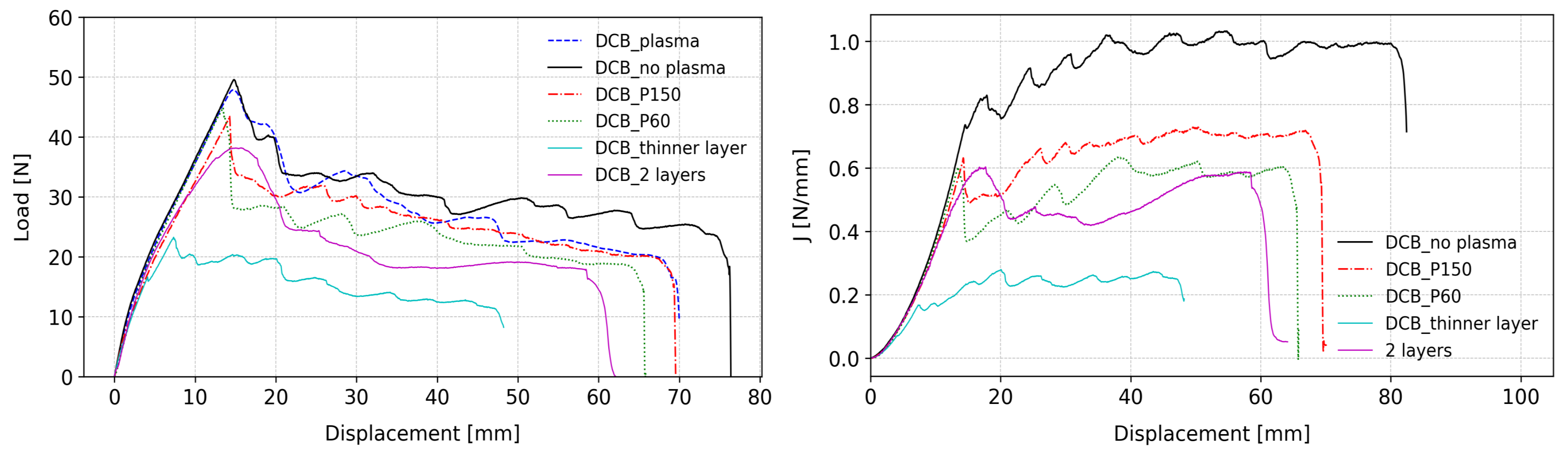

Figure 5 – Load vs displacement (left) and J vs loading point displacement (right) curves obtained in DCB tests for the different tested conditions.

- The use of plasma treatment presented no differences when compared to the reference condition (no plasma).
- High roughness (P60), intermediate roughness (P150) and 2 layers, yielded similar failure loads, with some differences in the propagation of the damage part of the curves, while the thinner load presented the lower values.
- For the fracture energy curves, the reference condition proved to have the best performance, with a propagation value of about 1N/mm.
- Although the high and intermediate roughness and the 2 layers conditions attained similar failure loads , the fracture energy during propagation presented differences.

Conclusions

The rheological tests allowed to position the PSA in the VW, which can determine material properties that enable a better understanding of the material behaviour. The bulk tensile tests showed the influence of the stacked layers and the cross head speed test, where an increase of the number of layers implied a decrease in the tensile strength, especially for the true tensile strength value. The higher test speed implied a big increase in the tensile strength of the PSA. Regarding the fracture tests, the higher values of the roughness, smaller thickness of the adhesive and stacked layers negatively impacted the joint performance.

Acknowledgements

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References

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