# Experimental testing and numerical simulation of joints bonded with a new silylated polyurethane based flexible adhesive

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Advanced Joining Processes Unit

## 1. Introduction

Silylated polyurethane adhesives are hybrid formulations which promote adhesion, possess an elastomeric behaviour and vibration damping capabilities, being suitable for the automotive and sealant industry. The performance of a new SPU based adhesive was assessed in single lap joints using aluminium adherends with two overlap lengths. A numerical model was established to simulate the joint behaviour, using CZM. The model was validated by comparison of the mechanical characterization tests performed and the numerical outputs.

## 2. Adhesive properties

The 2k adhesive was mechanically characterized following the standardize Bulk and TAST. The DCB and a mixed-mode apparatus were used to determine the $G_{Ic}$ and estimate the $G_{IIc}$ values [1,2].

Table 1 – Mechanical properties

| Property | Units | 2k SPU |
|---|---|---|
| Young's modulus, $E$ | [MPa] | 10.17 ± 0.96 |
| Poisson's ratio, $\nu$ | [-] | 0.418 ± 0.009 |
| Tensile failure strength, $\sigma_f$ | [MPa] | 4.16 ± 0.21 |
| Tensile failure strain, $\varepsilon_f$ | [%] | 41.1 ± 5.8 |
| Shear modulus, $G$ | [MPa] | 7.07 ± 1.53 |
| Shear failure strength, $\tau_f$ | [MPa] | 5.47 ± 0.74 |
| Shear failure strain, $\gamma_f$ | [%] | 84.7 ± 11.5 |
| Toughness in mode I, $G_{Ic}$ | [N/mm] | 1.191 ± 0.055 |
| Toughness in mode II, $G_{IIc}$ | [N/mm] | 4 |

## 3. Experimental results

SLJ of 25 and 50 [mm] overlap length were manufactured with anodized aluminium adherends. A cohesive failure was reported for both overlap lengths, exhibiting a similar lap shear strength.

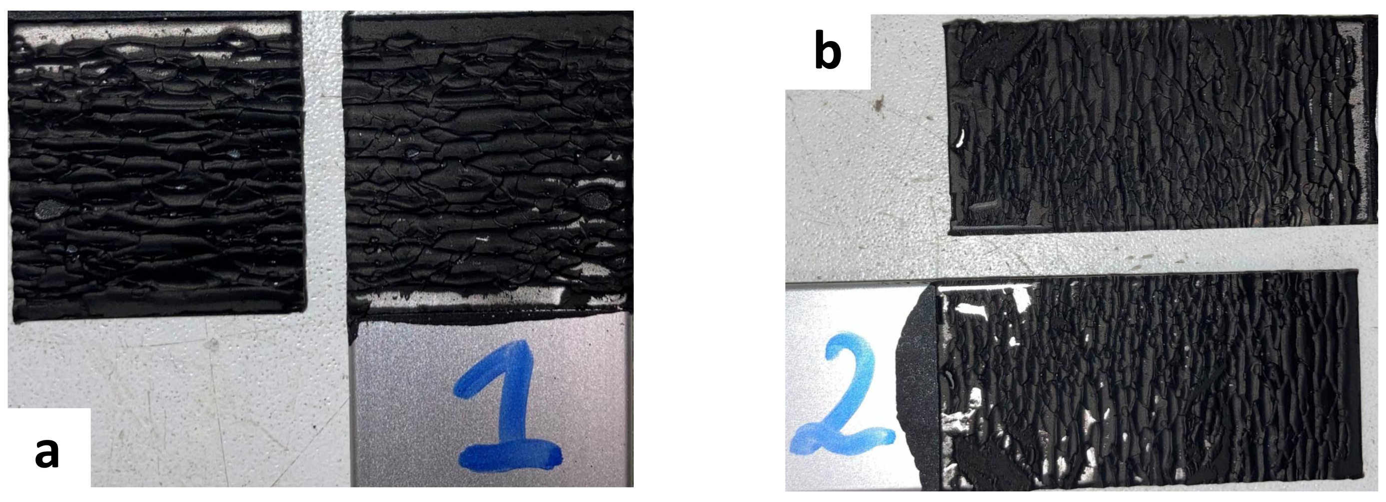


Figure 2 – Modes of failure: a) Al 25 [mm]; b) Al 50 [mm]

Table 2 – Lap shear strength for the SLJs tested

| Adherend | Lap shear strength [MPa] | |
|---|---|---|
| | **25** [mm] | **50** [mm] |
| Aluminium | 6.47 ± 0.23 | 5.70 ± 0.57 |

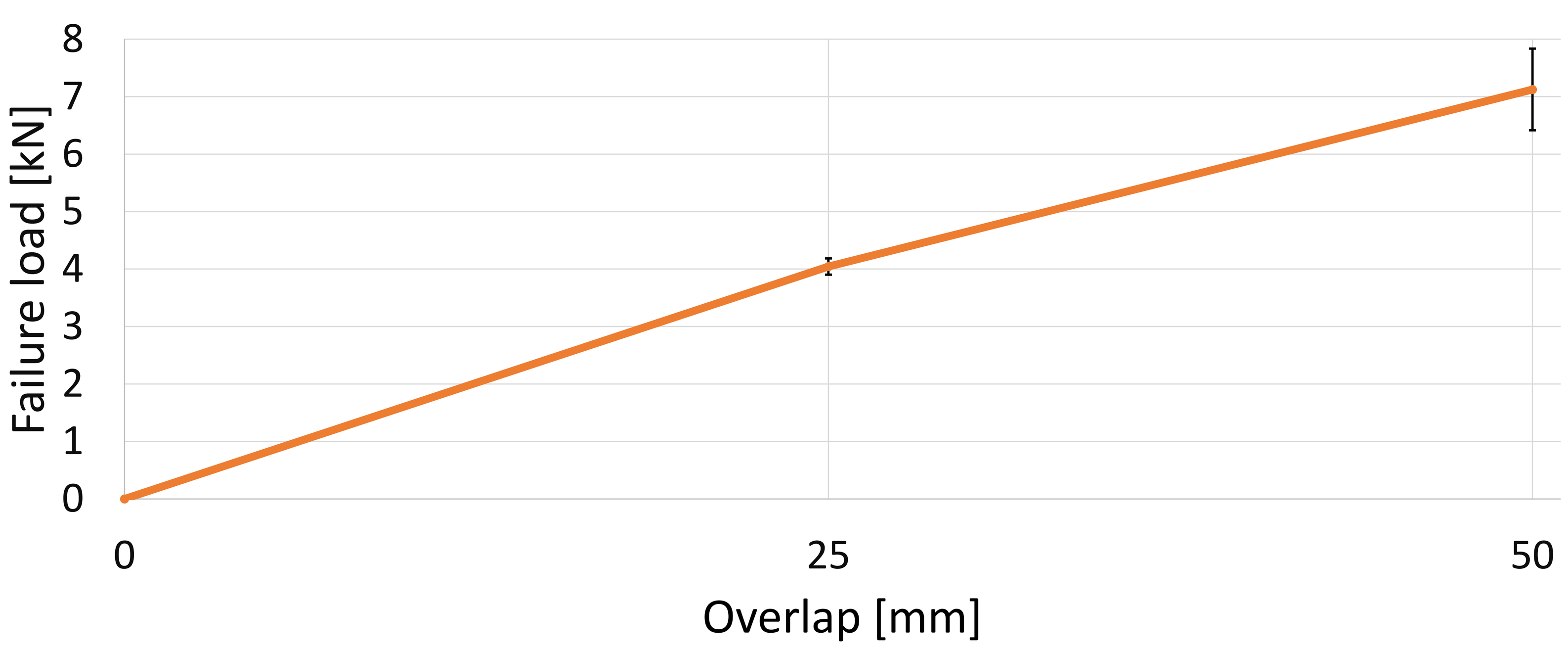


Figure 3 – Failure load *vs* overlap length for the aluminium SLJs

## 4. Numerical modelling

A CZM triangular shape law presented adequate results, provided the elastomeric behaviour of the material absent of any yielding point. The traction-separation law exhibits an initial elastic response followed by a linear degradation. For the initiation of damage, a quadratic nominal stress criterion was selected. A linear power-law was employed to predict the separation.

Quadratic nominal stress

$$\left\{\frac{\langle t_I\rangle}{t_I^0}\right\}^2 + \left\{\frac{t_{II}}{t_{II}^0}\right\}^2 = 1$$

Linear power-law

$$\frac{G_I}{G_I^0} + \frac{G_{II}}{G_{II}^0} = 1$$

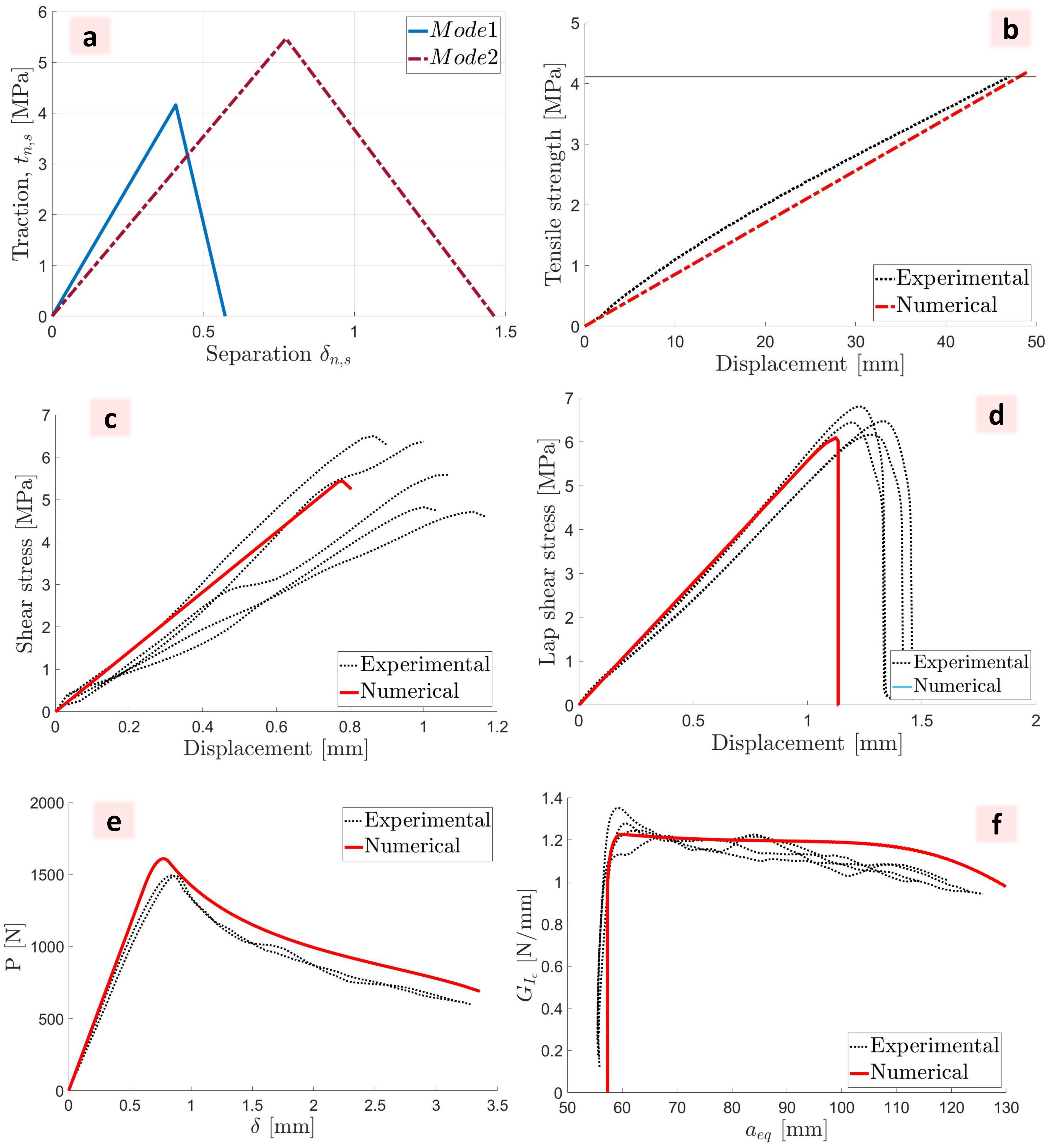


Figure 4 – Experimental versus numerical output data for the tested models: a) triangular shape cohesive law applied; b) tensile test; c) shear test; d) Aluminium SLJ 25 [mm] overlap; e) P-δ curve for DCB in mode I test; f) R-curve following CBBM

## 5. Conclusions

- The failure mode for the SLJs with different overlap lengths was cohesive, exhibiting an excellent bond when joining anodized aluminum substrates.
- The new SPU based adhesive behaved elastically and had no yield point. A CZM triangular shaped law was found to adequately model the in-joint behaviour of the adhesive under quasi-static conditions.

## References

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