Development and study of a new silane based polyurethane hybrid flexible adhesive - Mechanical characterization, joint testing and numerical modelling

V.C.M.B. Rodrigues (INEGI, Portugal), E.A.S. Marques, R.J.C. Carbas, M. Youngberg, A. Dussaud (Momentive Performance Materials Inc., Tarrytown, USA), B. Reza, L.F.M. da Silva

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 mechanically characterized under quasi-static conditions and assessed in single lap joints using aluminium. A numerical model was established to simulate the joint behaviour, using cohesive zone modelling (CZM). The model was validated by comparison of the mechanical characterization tests performed and the numerical outputs. This work has outputted two papers [1,2].

2. Adhesive properties

The 2k adhesive was mechanically characterized following the standardized Bulk (NFT 76-142) and TAST (ISSO 11003-2). The DCB (ISO 25217) and a mixed-mode apparatus were used to determine the GIc and estimated GIIc values [3-5].

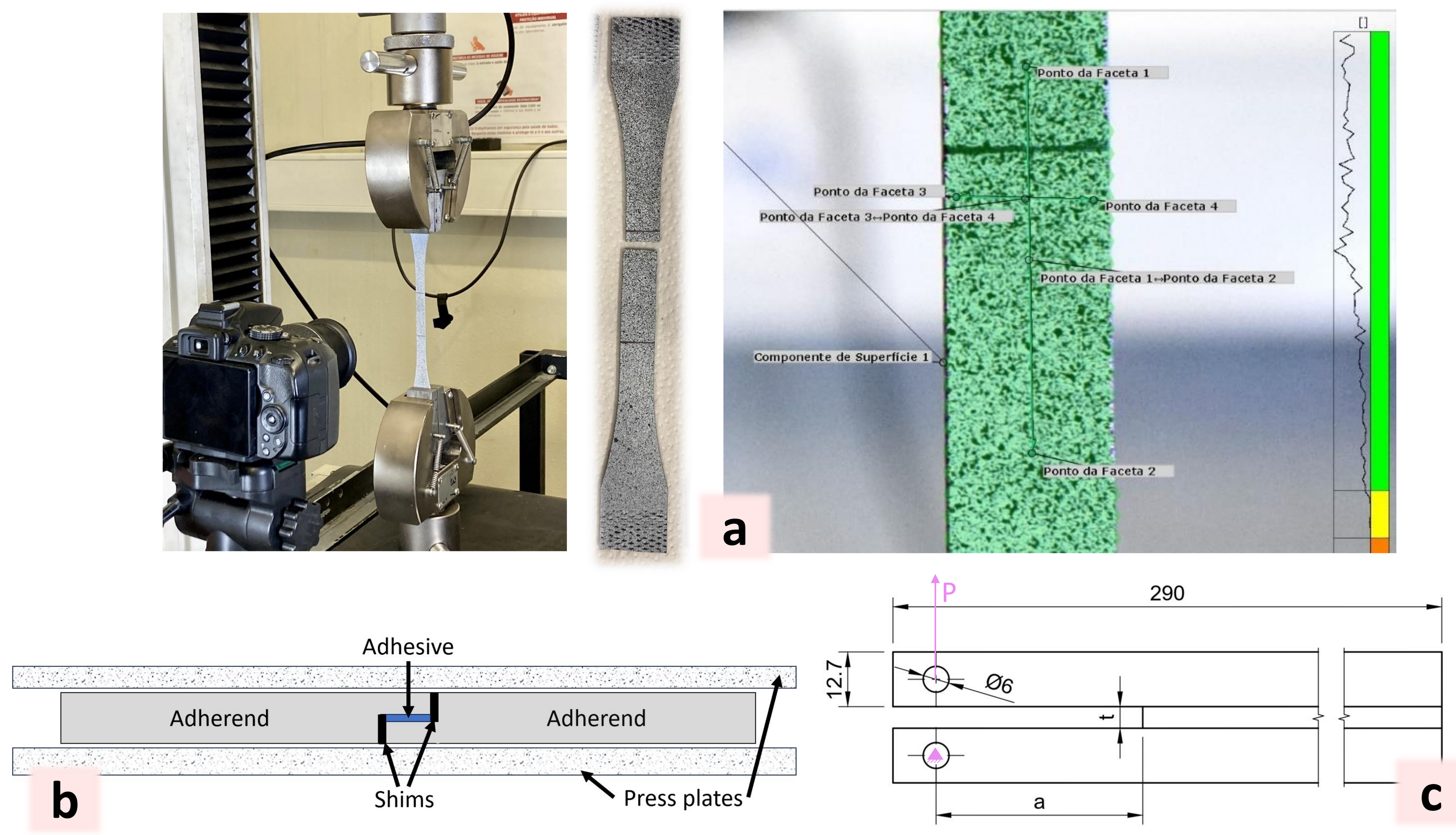

Figure 1 – Mechanical characterization tests: a) bulk tensile specimens with and strain field obtained by DIC; b) manufacture of TAST specimens; c) manufacture of DCB specimens for fracture tests

Table 1 – Mechanical properties

Property	Units	2k SPU
Young's modulus, E	[MPa]	10.17 ± 0.96
Poisson's ratio, ν	[-]	0.418 ± 0.009
Tensile failure strength, σ_f	[MPa]	4.16 ± 0.21
Tensile failure strain, ε_f	[%]	41.1 ± 5.8
Shear modulus, G	[MPa]	7.07 ± 1.53
Shear failure strength, τ_f	[MPa]	5.47 ± 0.74
Shear failure strain, γ_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

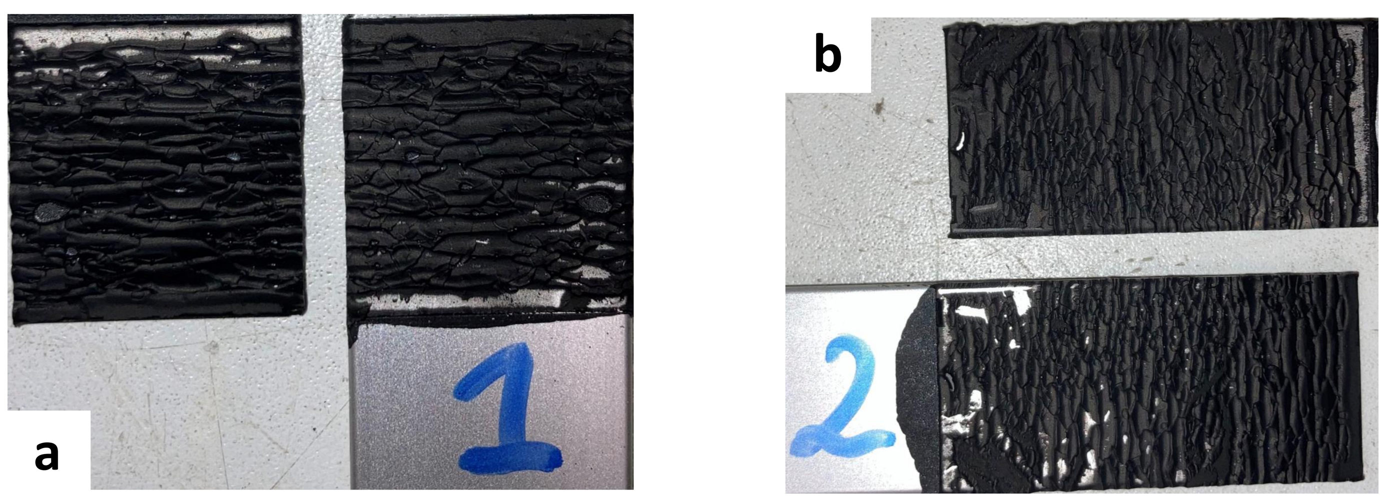

Figure 2 – Modes of failure: a) Al 25 [mm]; b) Al 50 [mm]

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

3. 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

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

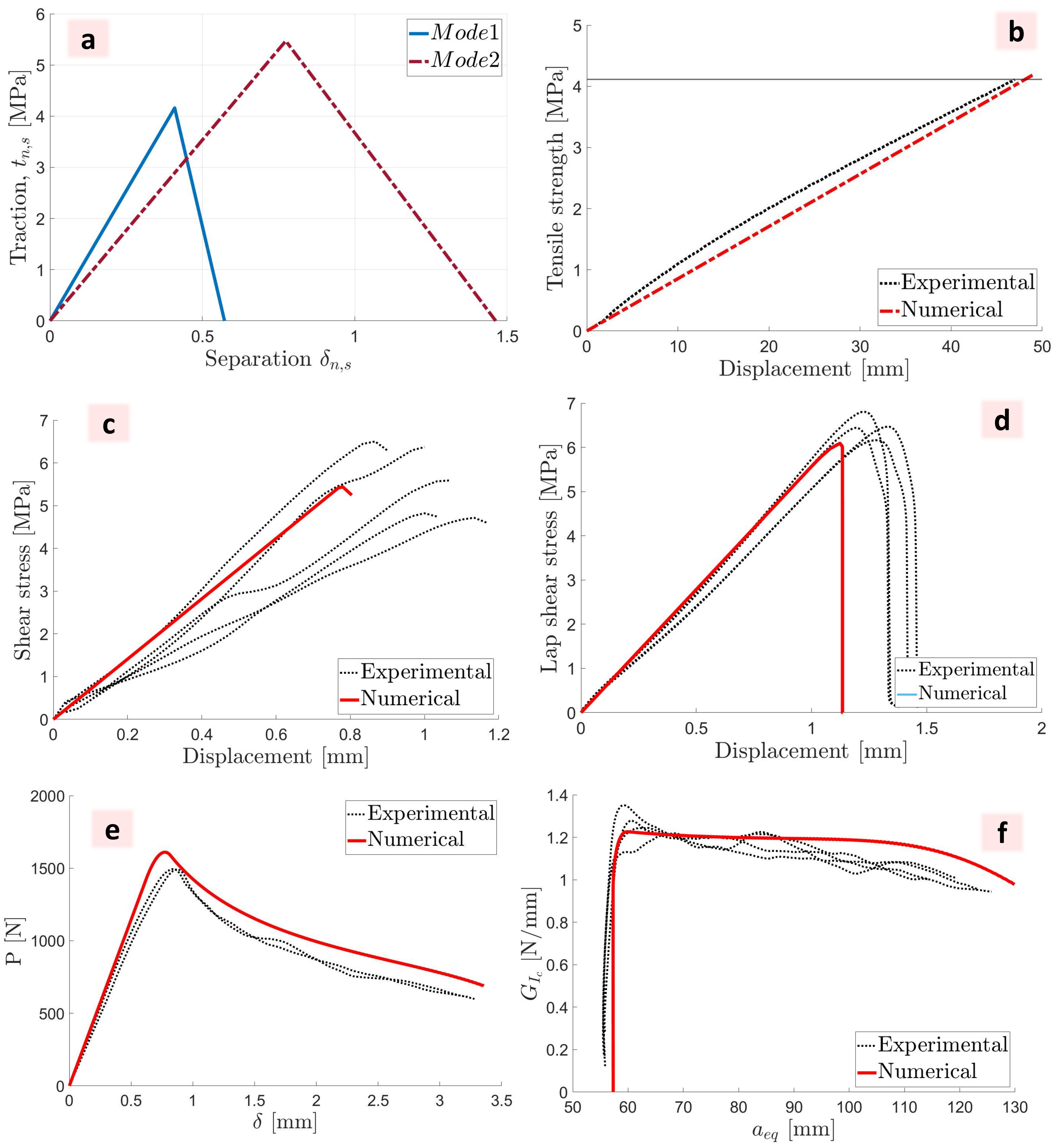

Figure 3 – Experimental versus numerical output data for the tested models: a) triangular shape cohesive law applied; b) tensile test; c) shear test; d) Aluminum SLJ 25 [mm] overlap; e) P-δ curve for DCB in mode I test; f) R-curve following CBBM

4. Conclusions

- The SPU novel adhesive showed mechanical properties in-between benchmarked values of commercialized silicones and 2k polyurethanes.
- A CZM triangular shaped law was found to adequately model the in-joint behaviour of the adhesive under quasi-static conditions.

References

[1] Rodrigues, Vasco CMB, et al. "Development and Study of a New Silane Based Polyurethane Hybrid Flexible Adhesive—Part 1: Mechanical Characterization." Materials 16.23 (2023): 7299.
[2} Rodrigues, Vasco CMB, et al. "The Development and Study of a New Silylated Polyurethane-Based Flexible Adhesive—Part 2: Joint Testing and Numerical Modelling." Materials 16.21 (2023): 7022.
[3] M. Costa, R. Carbas, E. Marques, G. Viana, L.F.M. da Silva, An apparatus for mixed-mode fracture characterization of adhesive joints, Theoretical and Applied Fracture Mechanics, Volume 91, 2017, Pages 94-102, ISSN 0167-8442.
[4] Banea, M. & Silva, L.F.M. & Campilho, Raul. (2011). Mechanical characterization of a high temperature epoxy adhesive. Welding Equipment and Technology. 22. 58-62.
[5] Campilho, Raul & Banea, M. & Neto, J. & Silva, L.F.M.. (2012). Modelling of Single-Lap Joints Using Cohesive Zone Models: Effect of the Cohesive Parameters on the Output of the Simulations. The Journal of Adhesion. 88. 513-533. 10.1080/00218464.2012.660834.

Acknowledgements

The authors express their sincere gratitude for the funding and support provided by *Fundação para a Ciência e Tecnologia* (FCT), Portugal.

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

inegi driving science & innovation

FCT Fundação para a Ciência e a Tecnologia

3RD INTERNATIONAL CONFERENCE ON INDUSTRIAL APPLICATIONS OF ADHESIVES 2024