Effects of strain rate and temperature on mixed mode fracture behaviour of polyurethane adhesives

M Ribas (FEUP, Portugal), A Akhavan-Safar, EAS Marques, RJC Carbas, S Wenig, LFM da Silva

ADVANCED JOINING PROCESSES UNIT

Introduction

Understanding the behaviour of adhesive joints under high strain rates is fundamental since it is a key factor in the design of vehicles structures. By incorporating adhesives with high fracture energy into joint designs, engineers can enhance the overall durability and reliability of structures, specially if those are under mixed mode conditions. The aim of this work is to bridge the research gap and gain a comprehensive understanding of the fracture behaviour of polyurethane adhesives under diverse loading rates and temperatures.

Experimental Methodology

A ductile polyurethane-based adhesive with mechanical characteristics adapted for industrial purposes was employed throughout this study. The adhesive's glass transition temperature is -5 ºC.

Table 1 – Summary of test conditions

		Temperature		
		Low Temperature -30 ºC	**Room Temperature 23 ºC**	**High Temperature 60 ºC**
Loading Rate	**Quasi-static 0.2 mm/min**	Mixed mode test (45º)	Mixed mode test (45º/60º)	Mixed mode test (45 º)
	Intermediate Speed 200 mm/min	Mixed mode test (45 º)	Mixed mode test (45º)	Mixed mode test (45 º)
	High Speed 6000 mm/min	Mixed mode test (45 º)	Mixed mode test (45º)	Mixed mode test (45 º)

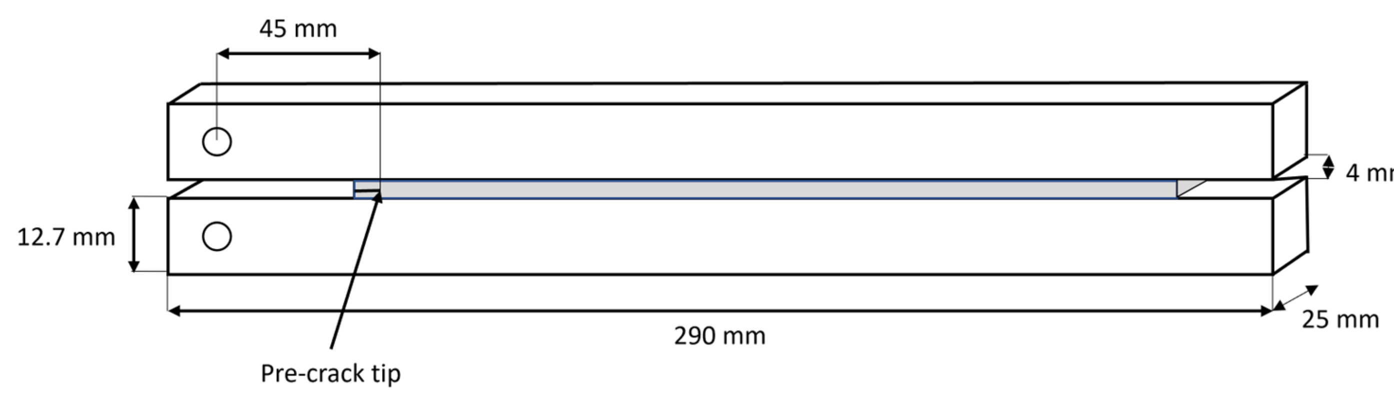

Figure 1 – DCB specimen.

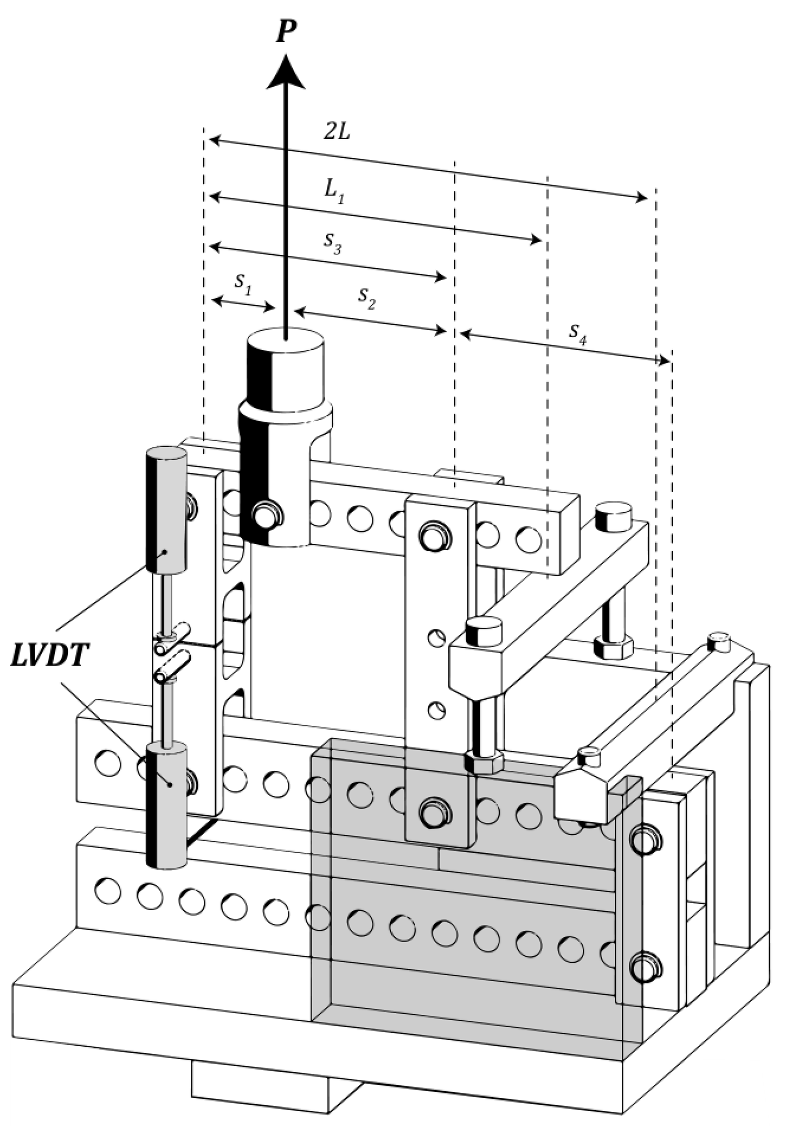

Figure 2 – Apparatus used for the mixed-mode conditions [1].

Results and Discussion

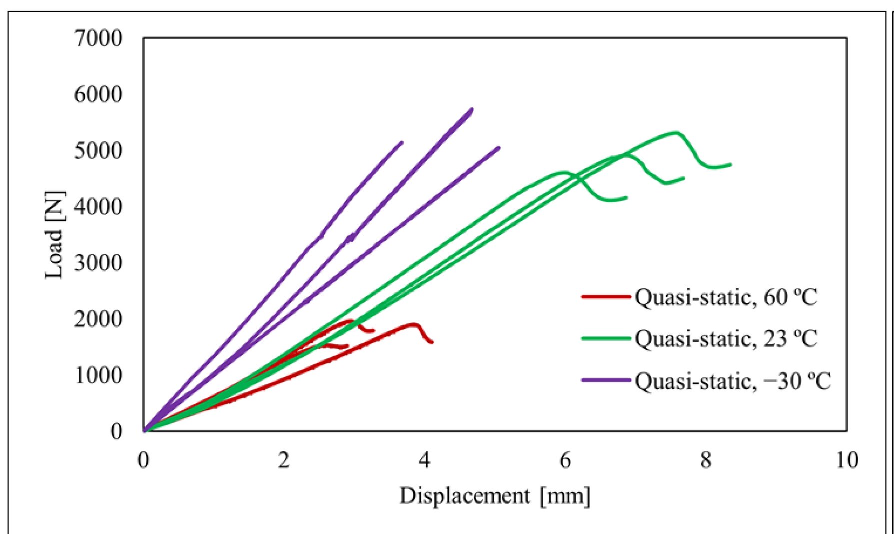

Figure 3 – Load-displacement of the machine for test submitted to quasi-static conditions for a mixed mode apparatus set up at 45º.

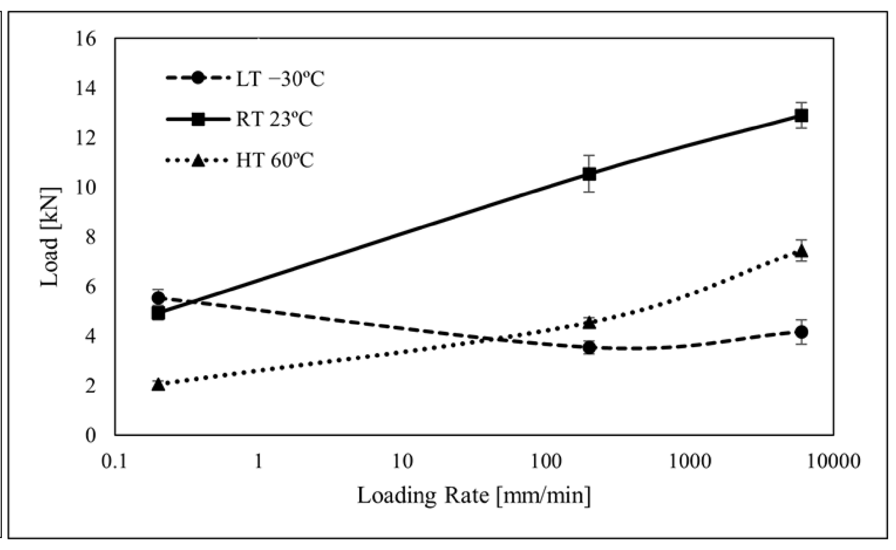

Figure 4 – Maximum load of the machine as function of loading rate and temperature for a mixed mode apparatus set up at 45º.

When the test speed is increased from quasi-static to high strain rate, the adhesive can tolerate higher loads, especially at temperatures above its glass transition point. At temperatures below T_g, the adhesive becomes more brittle and stiff, making it more prone to cracking under stress and strain. Because of the lower ability to dissipate energy through deformation, the adhesive is more vulnerable to manufacturing faults and voids.

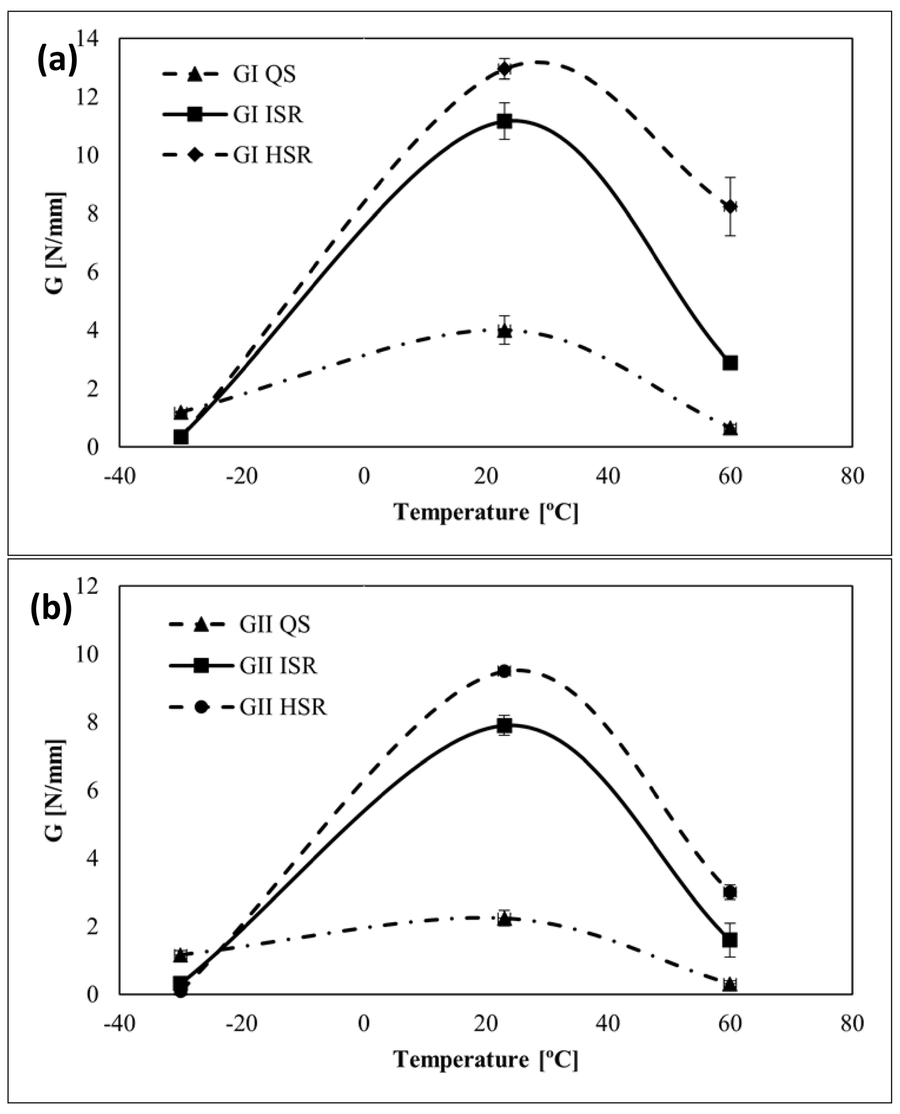

Figure 5 – Fracture energy modes as a function of temperature: (a) Mode I part (b) Mode II part.

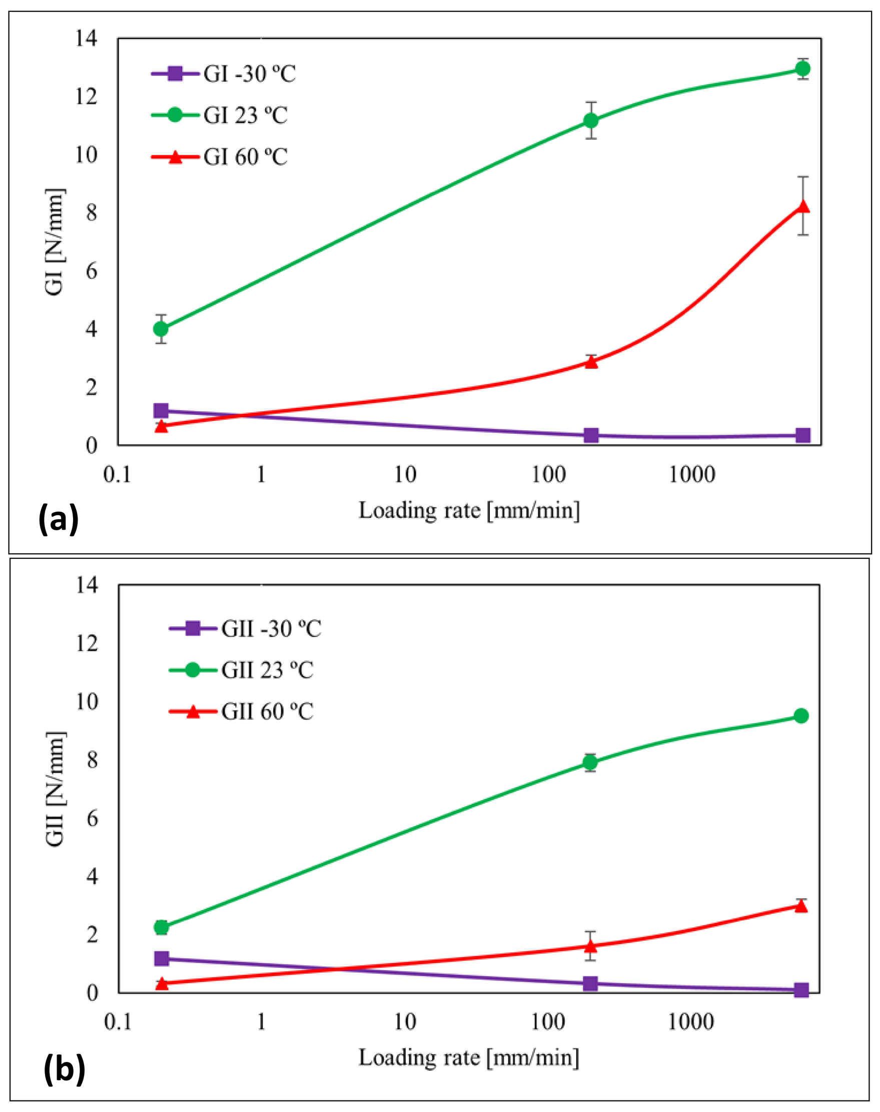

Figure 6 – Effect of temperature on fracture energy as function of loading rate for different temperatures: (a) Mode I part (b) Mode II part.

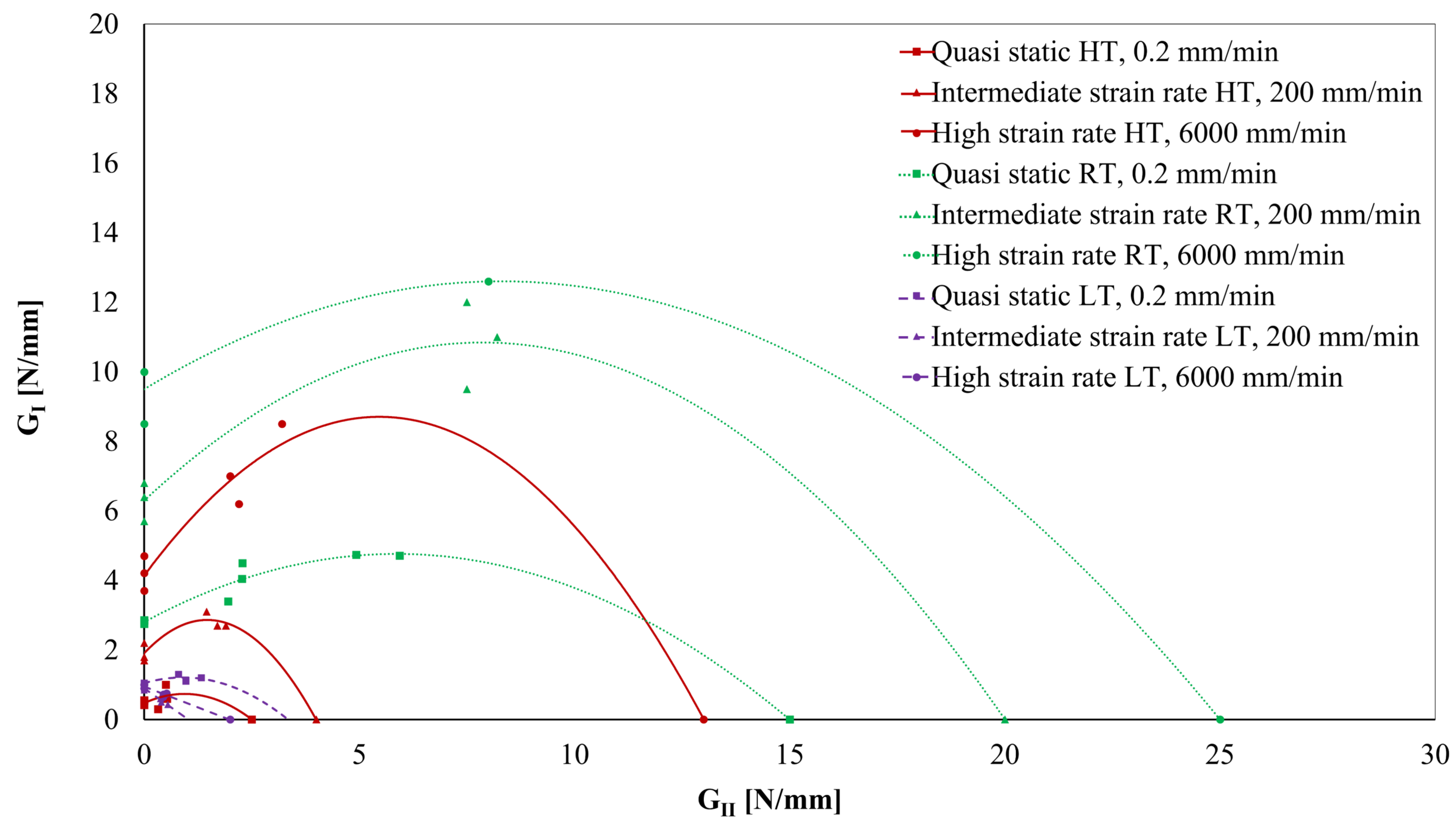

Figure 7 – Fracture envelope.

Conclusions

The critical strain energy release rate is highly dependent on the service temperature, and the loading rate also plays a significant role, depending on the specimen's temperature. For temperatures above Tg, the maximum load supported by the specimen increases as the loading rate increases. Moreover, the influence of temperature is particularly significant for intermediate and high strain rates, with G_I increasing by a factor of 35 for intermediate strain rate and 38 for high strain rate from low temperature to room temperature. G_{II} also increased significantly, with factors of 25 and 95 times, respectively. Overall, both strain rate and temperature affect both mode I and mode II of the mixed mode, but mode I appears to be more sensitive to these effects. Finally, the best adhesive performance was observed at higher loading rates and room temperature, with a G_I of approximately 13 N/mm and GII around 7 N/mm.

References

[1] M. Costa, R. Carbas, E. Marques, G. Viana, L.F.M. da Silva, "An apparatus for mixedmode fracture characterization of adhesive joints," Theoretical and Applied Fracture Mechanics, 2017.

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

inegi driving science & innovation

AB2023
7TH INTERNATIONAL CONFERENCE ON ADHESIVE BONDING 2023