Exploring mixed mode fatigue and fracture of polyurethane adhesives: Strain rate and temperature effects

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Introduction

Understanding the behaviour of adhesive joints under different conditions 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 and fatigue behaviour of polyurethane adhesives under diverse loading rates and temperatures.

Experimental Procedure

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)

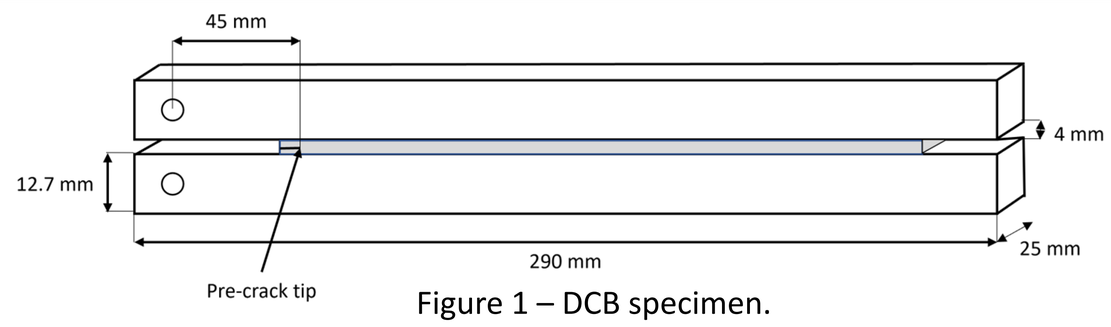


Figure 1 – DCB specimen.

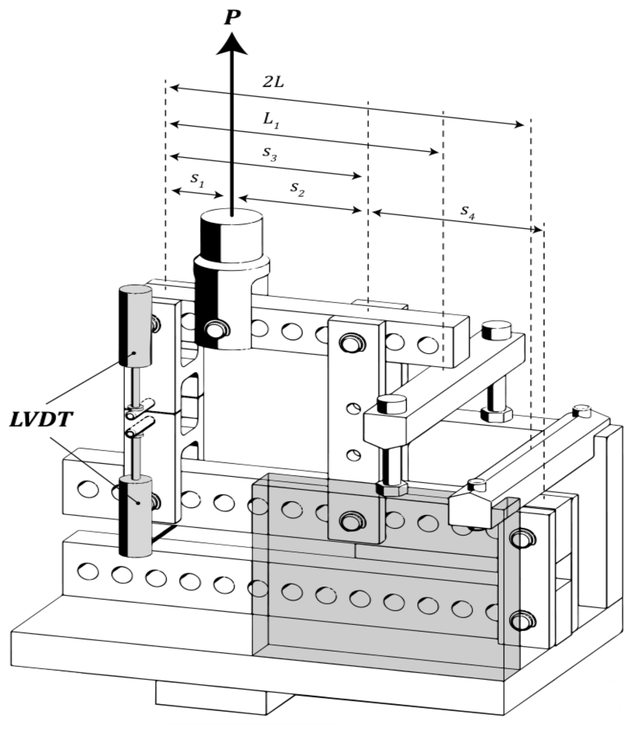


Figure 2 – Apparatus used for the mixed-mode loading conditions [1].

Results and Discussion

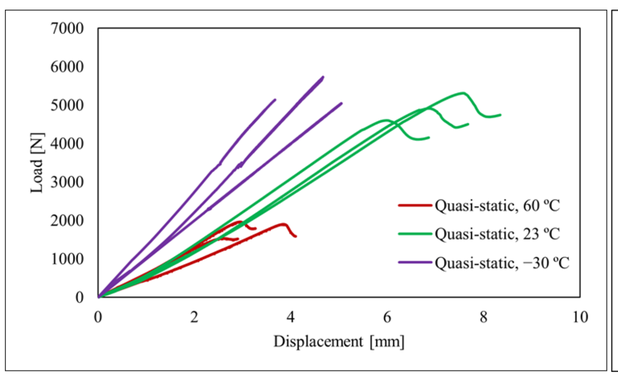


Figure 3 – Load-displacement of the machine for test submitted to quasi-static conditions for a mixed mode apparatus set up at 45º.

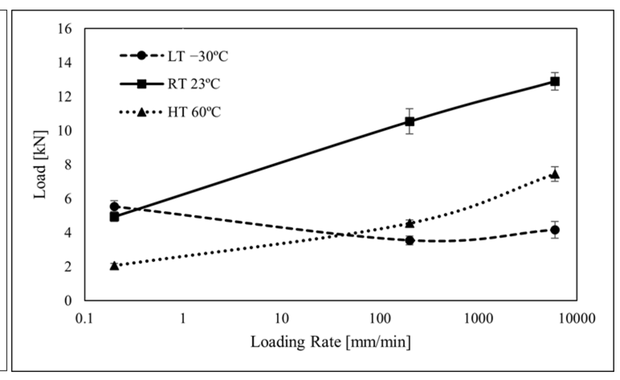
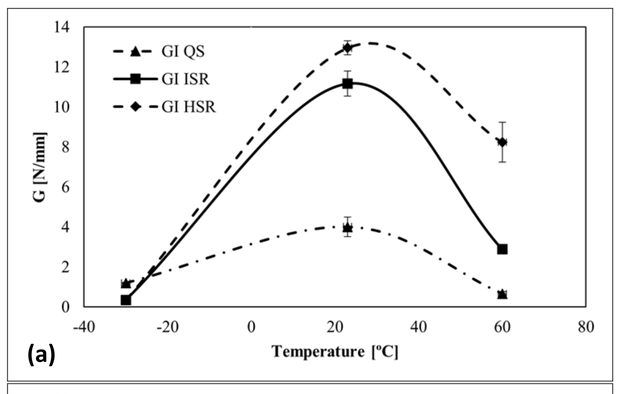


Figure 4 – Maximum load of the machine as function of loading rate and temperature for a mixed mode apparatus set up at 45º.



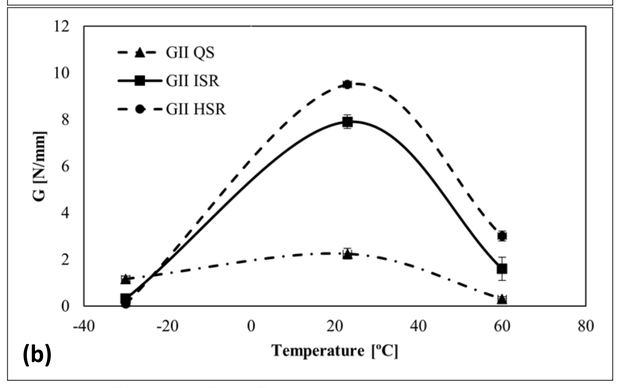
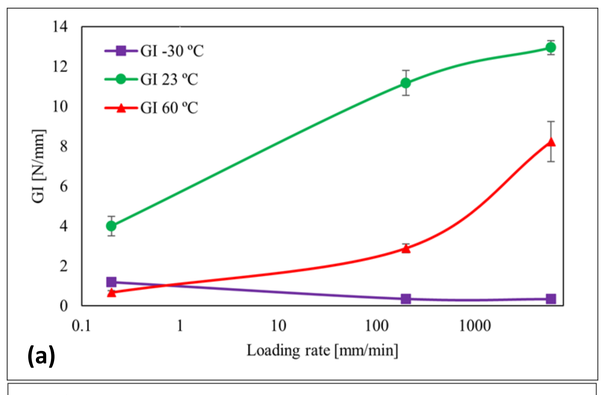


Figure 5 – Fracture energy as a function of temperature: (a) Mode I part (b) Mode II part.



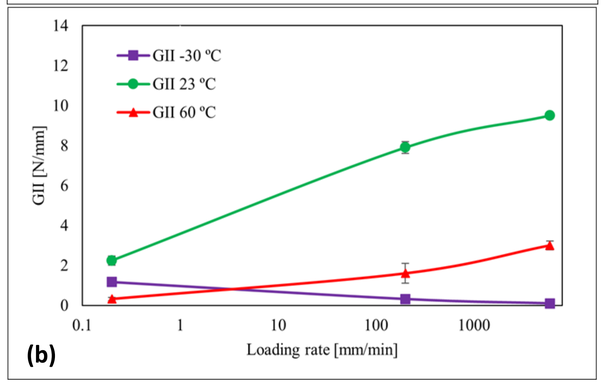


Figure 6 – Fracture energy as a function of loading rate: (a) Mode I part (b) Mode II part.

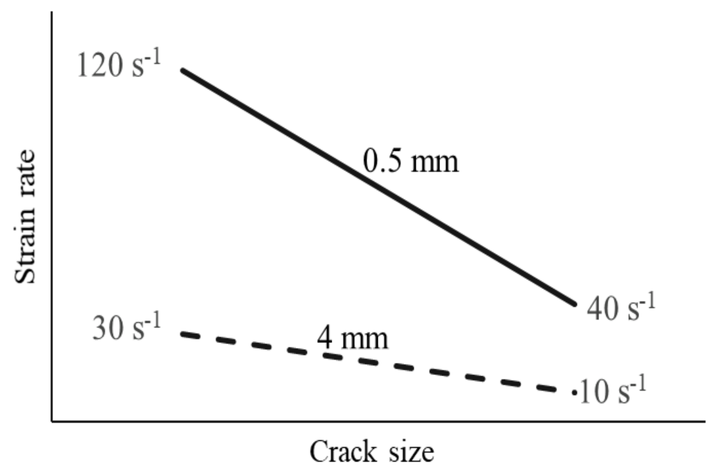


Figure 7 – True strain rate as a function of crack size for both adhesive thicknesses.

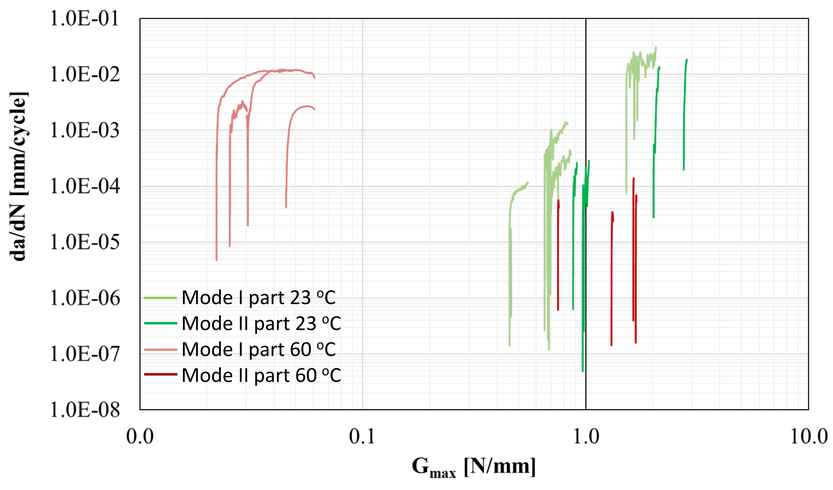


Figure 8 – Paris-law curves.

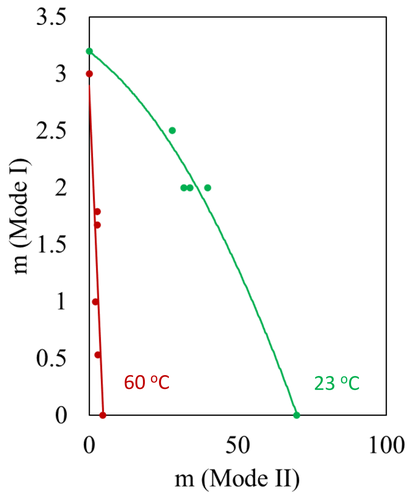


Figure 9 – Paris-law curve's slopes.

Conclusions

The critical strain energy release rate is highly dependent on service temperature and loading rate, especially above the Tg of adhesive. Temperature has a substantial impact on intermediate and high strain rates, with G_I and G_{II} increasing significantly. While both strain rate and temperature affect mode I and mode II part of the mixed mode, however, it was revealed that mode I is more sensitive to these parameters. The best adhesive performance was obtained at higher loading rates and at room temperature. Similar to the fracture tests, in mixed-mode fatigue, it was also observed that the mode I component is more sensitive to temperature than mode II. However, in both modes, temperature has a negative effect on the fatigue threshold energy.

Reference

[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.