Effects of loading conditions and strain rates on mechanical properties of polyurethane adhesives in cold environments

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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 behaviour of polyurethane adhesives under diverse loading conditions and strain rates.

Experimental Methodology

A ductile polyurethane-based adhesive was employed throughout this study. The adhesive's glass transition temperature is -5 °C. The polyurethane adhesives was tested under different loading modes (mode I and mixed mode I+II), loading rates (0.2 mm/min, 200 mm/min, 6000 mm/min) and temperatures (-30 °C, 23 °C and 60 °C).

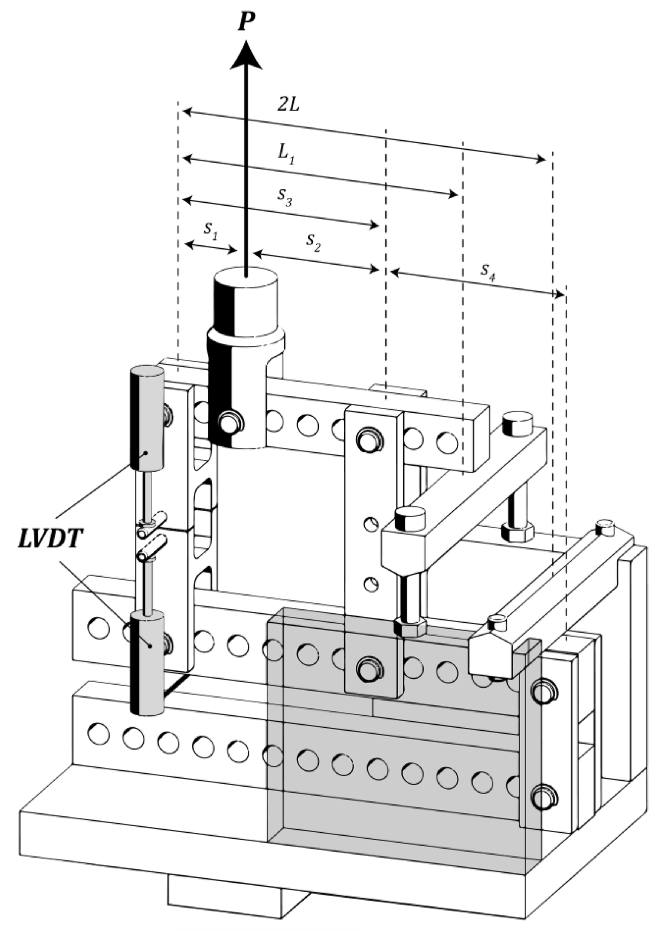

Figure 1 – Apparatus used for the mixed-mode conditions [1].

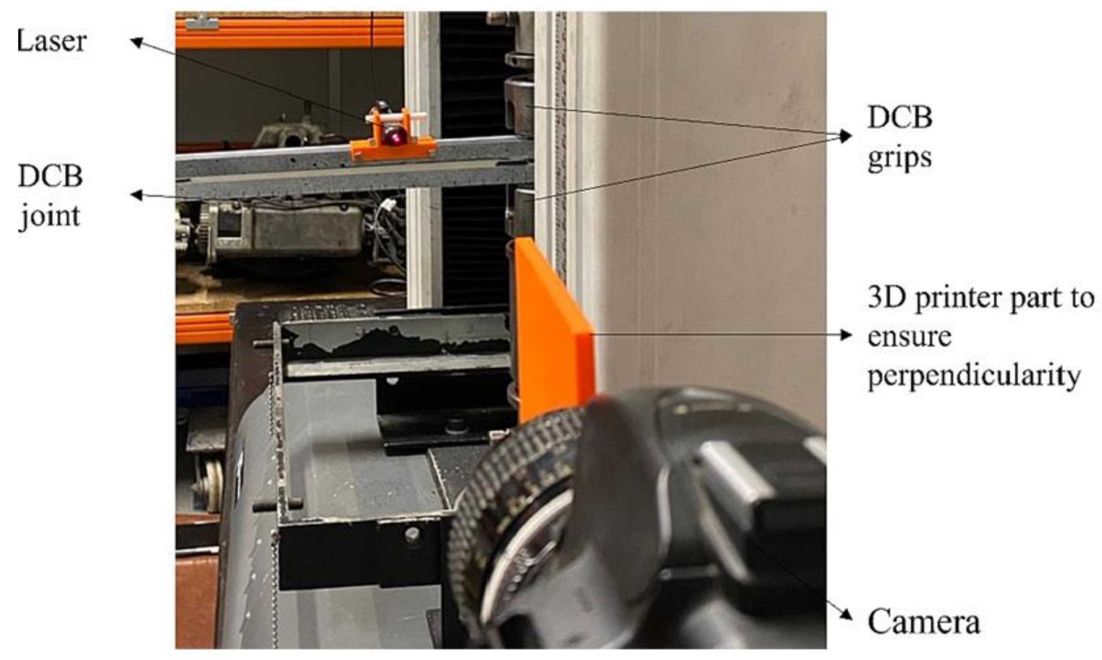

Figure 2 – DCB setup to monitor strain along the overlap and ensure perpendicularity.

Results and Discussion

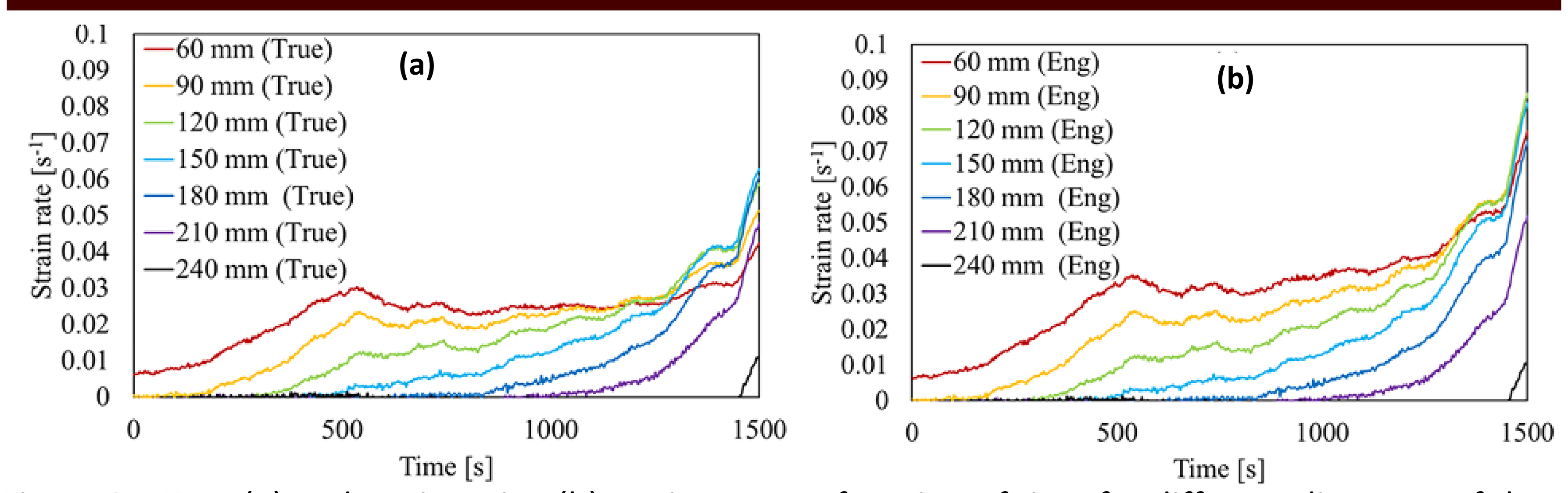

Figure 3 – True (a) and engineering (b) strain rates as function of time for different distances of the DCB edge (0.2 mm/min, 23 °C)

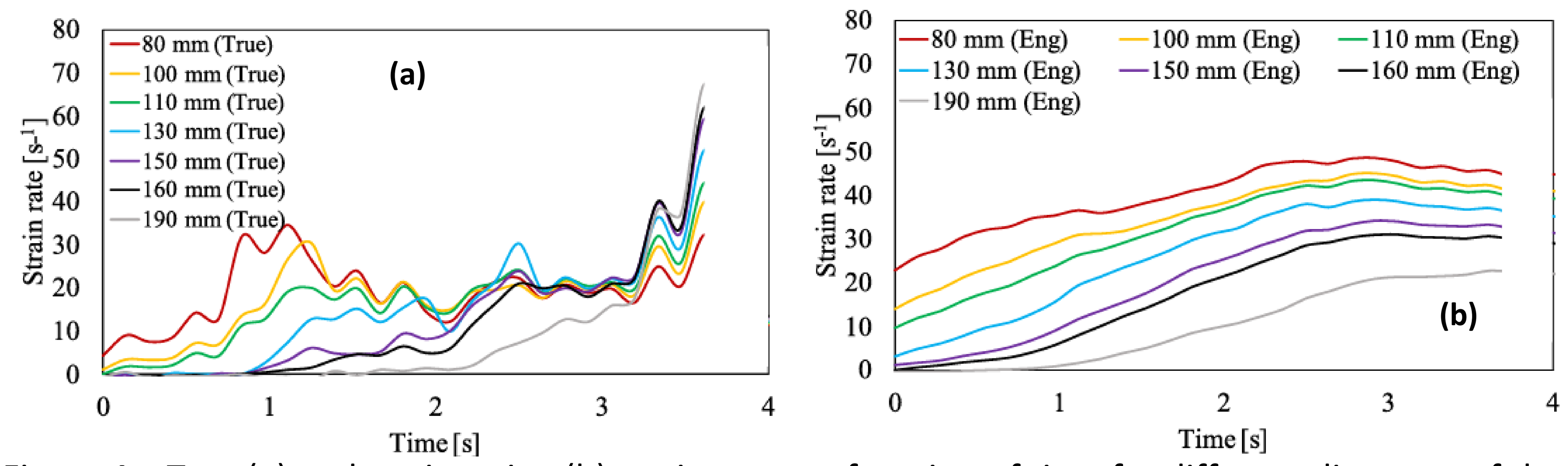

Figure 4 – True (a) and engineering (b) strain rates as function of time for different distances of the DCB edge (200 mm/min, 23 °C)

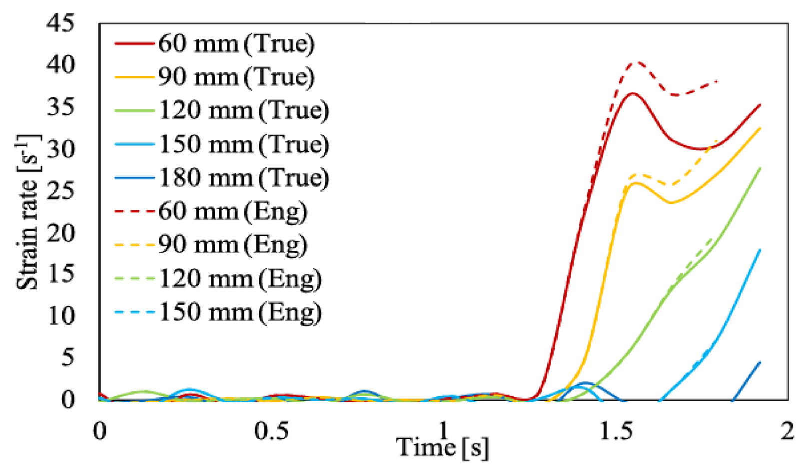

Figure 4 – True and engineering strain rates as function of time for different distances of the DCB edge (200 mm/min, -30 °C)

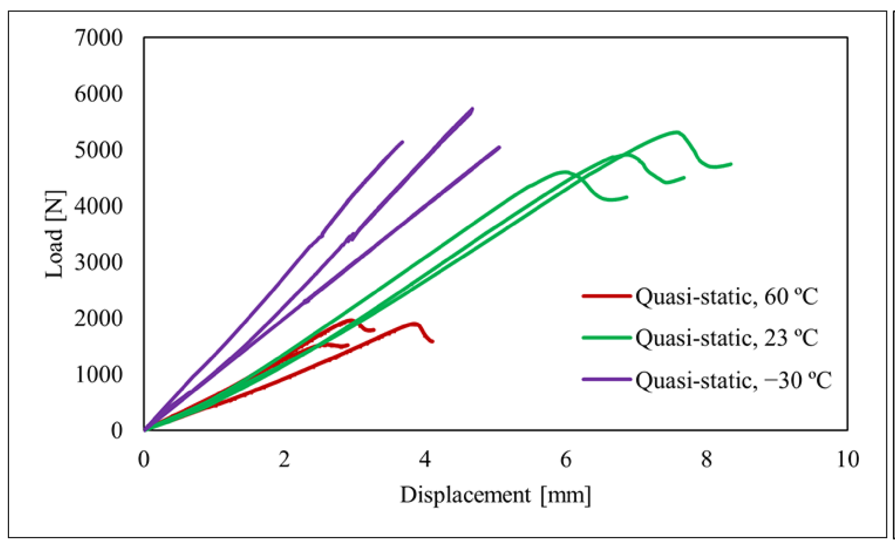

Figure 5 – Load-displacement of the machine for test submitted to quasi-static conditions for a mixed mode apparatus set up at 45°.

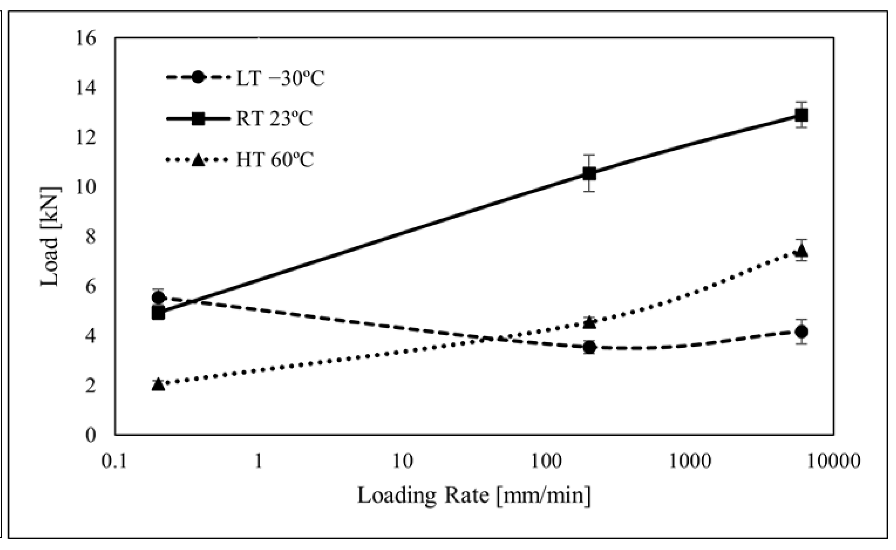

Figure 6 – Maximum load of the machine as function of loading rate and temperature for a mixed mode apparatus set up at 45°.

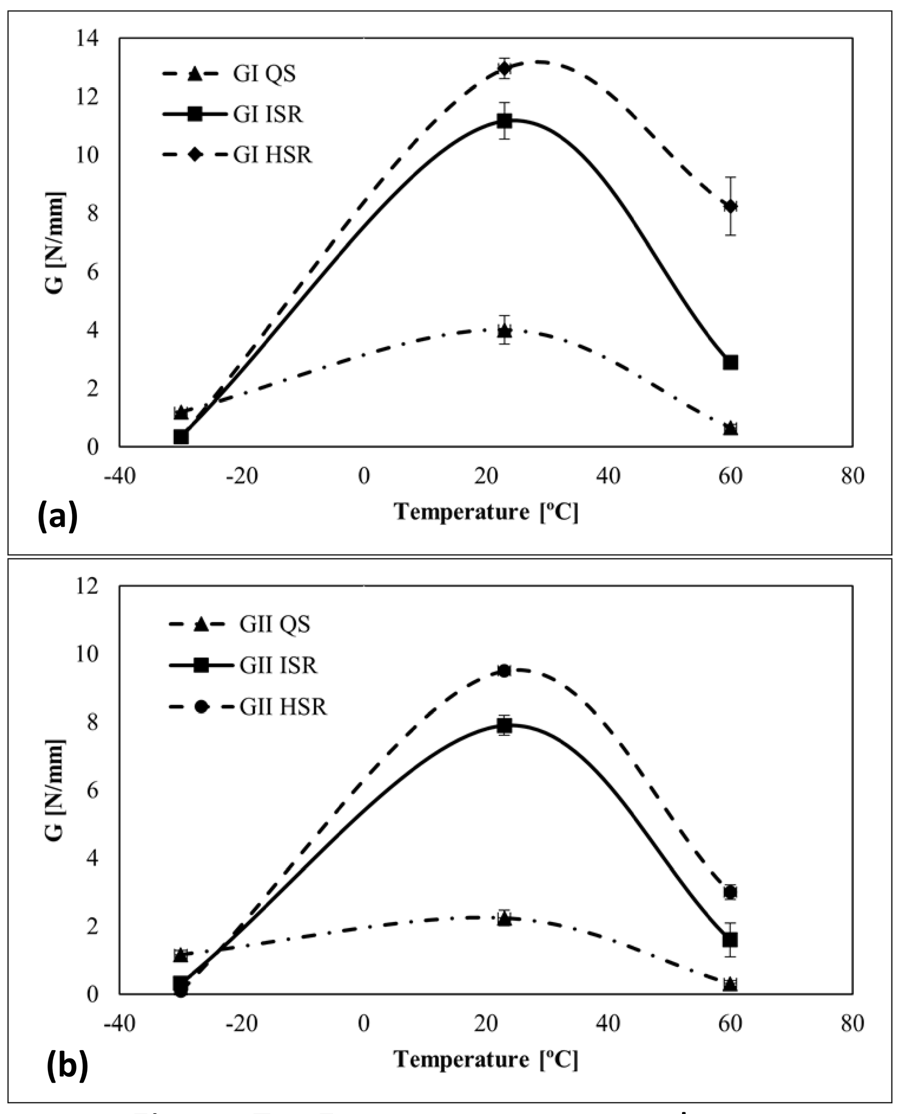

Figure 7 – Fracture energy modes as a function of temperature: (a) Mode I part (b) Mode II part.

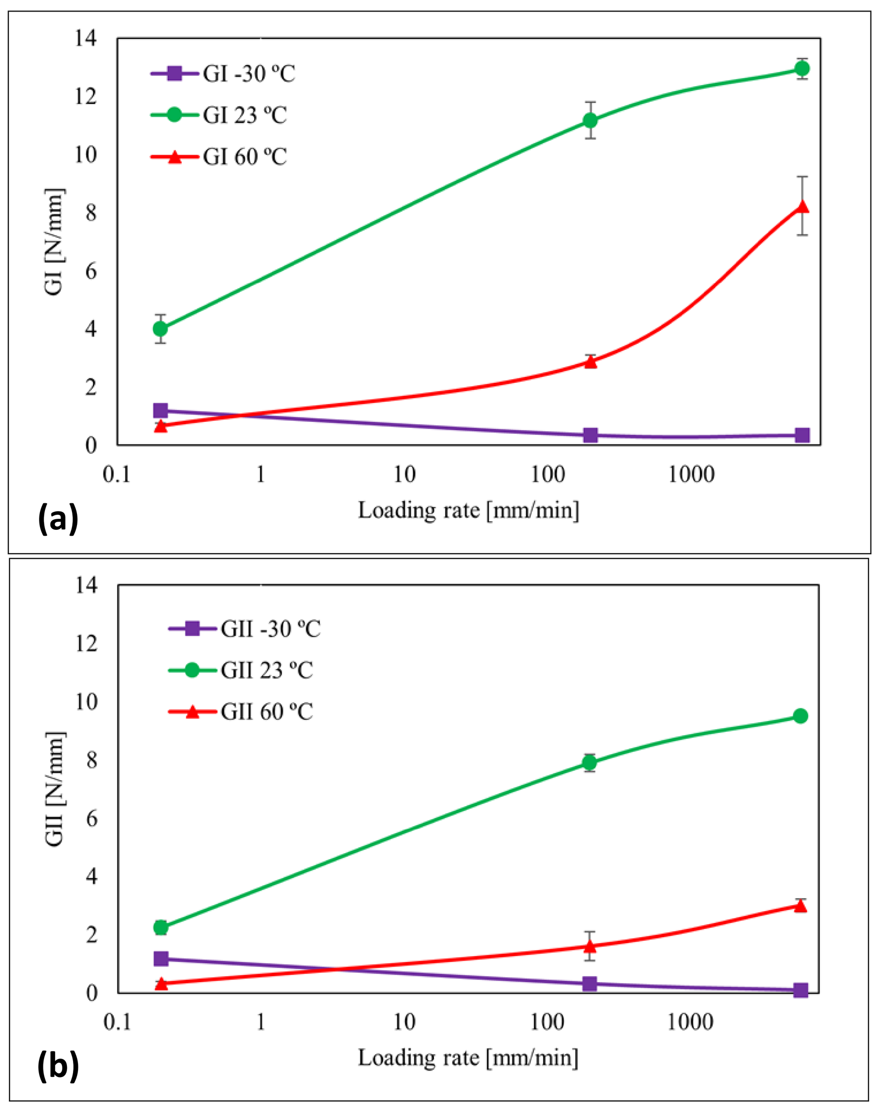

Figure 8 – Effect of temperature on fracture energy as function of loading rate for different temperatures: (a) Mode I part (b) Mode II part.

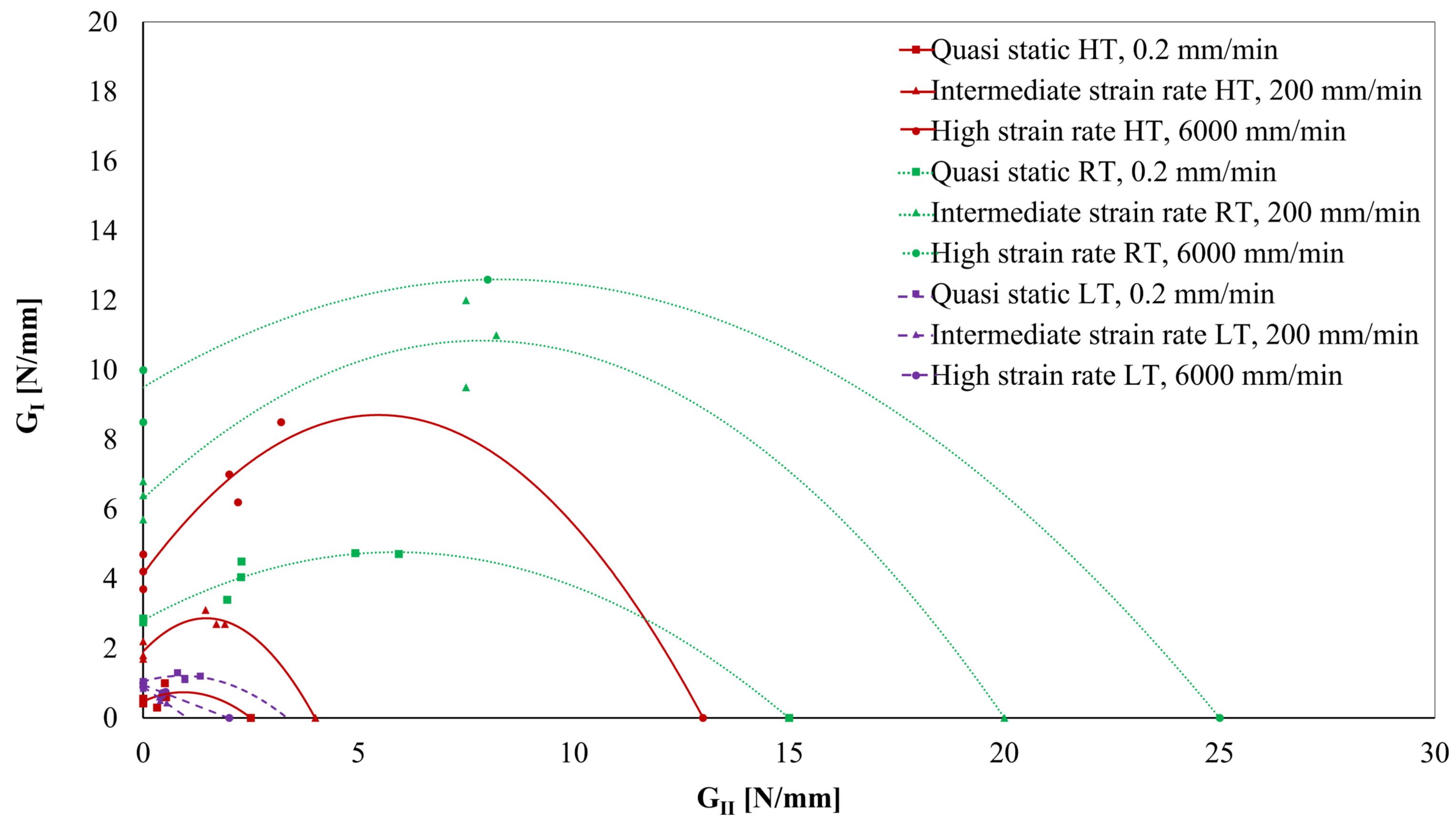

Figure 9 – Fracture envelope.

Conclusions

The study revealed that altering test speeds between two tests does not lead to significant variations in strain rate values, even when maintaining a constant loading rate, indicating fluctuations in strain rate throughout testing. Consistent strain rate control is crucial during testing, especially at higher strain rates, as the variation in strain rate increases with loading rate. Low temperatures do not significantly impact strain rate fluctuations. The critical strain energy release rate is heavily influenced by service temperature and loading rate, particularly above T_g, where higher loading rates increase maximum load support. Temperature significantly affects G_I and G_{II} at intermediate and high loading rates, with mode I being more sensitive.

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.

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