Fracture Characterization of a Structural Polyurethane Adhesive as a Function of Adhesive Thickness

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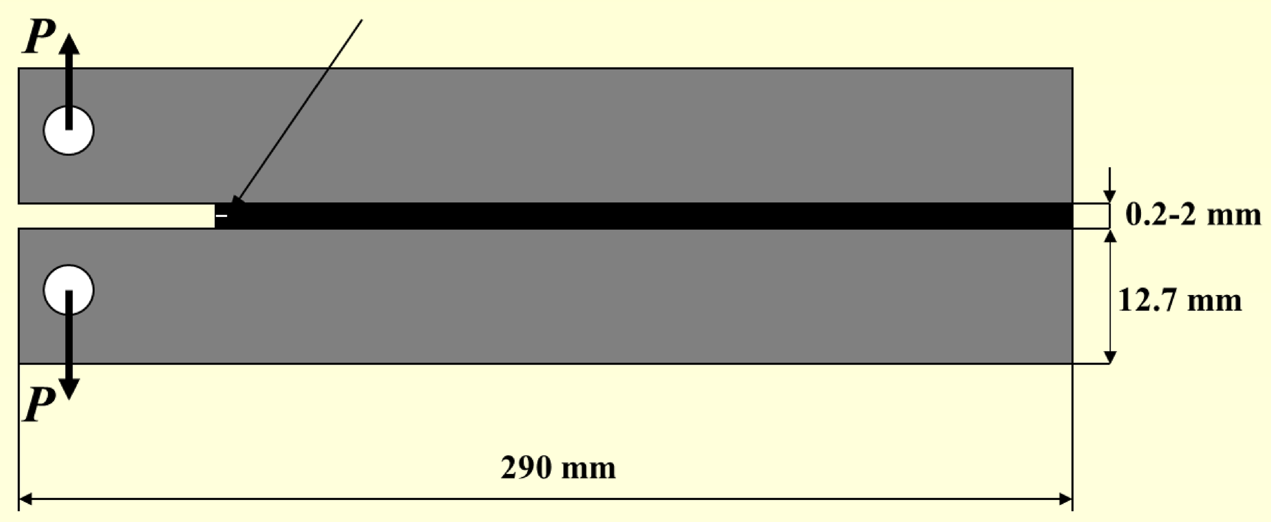
Abstract

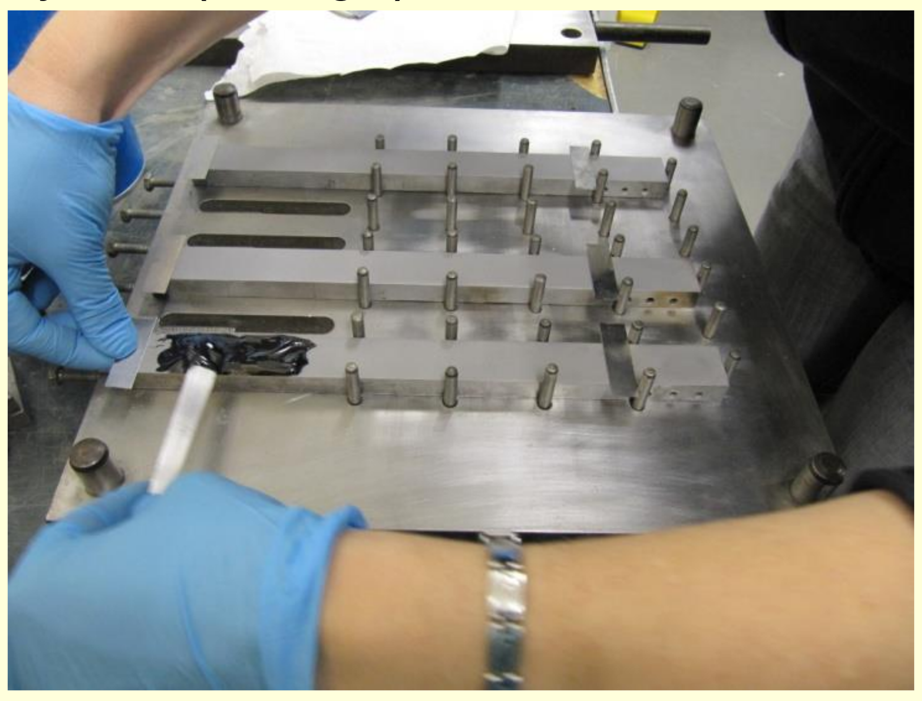
In order to predict the strength of adhesive joints accurately, correct material data of adhesives are essential. Hence, the accurate and efficient determination of the fracture toughness and the associated fracture mechanisms of adhesives are of fundamental importance. It is known that the fracture toughness depends on the thickness of the adhesive layer. However, most of the results from literature are for typical structural epoxy adhesives which are generally formulated to perform in thin sections. Nevertheless, new crash-resistant structural adhesives are designed to perform in thicker sections and might have a different behaviour as a function of adhesive thickness. In this study, the fracture behavior of adhesively bonded joints with a structural polyurethane adhesive was investigated experimentally. The mode I fracture toughness of the adhesive was measured using double-cantilever beam (DCB) test with various thicknesses of the adhesive layer ranging from 0.2 mm to 2 mm. The Compliance-Based Beam Method (CBBM) was used to evaluate the fracture toughness in mode I.

Experimental details

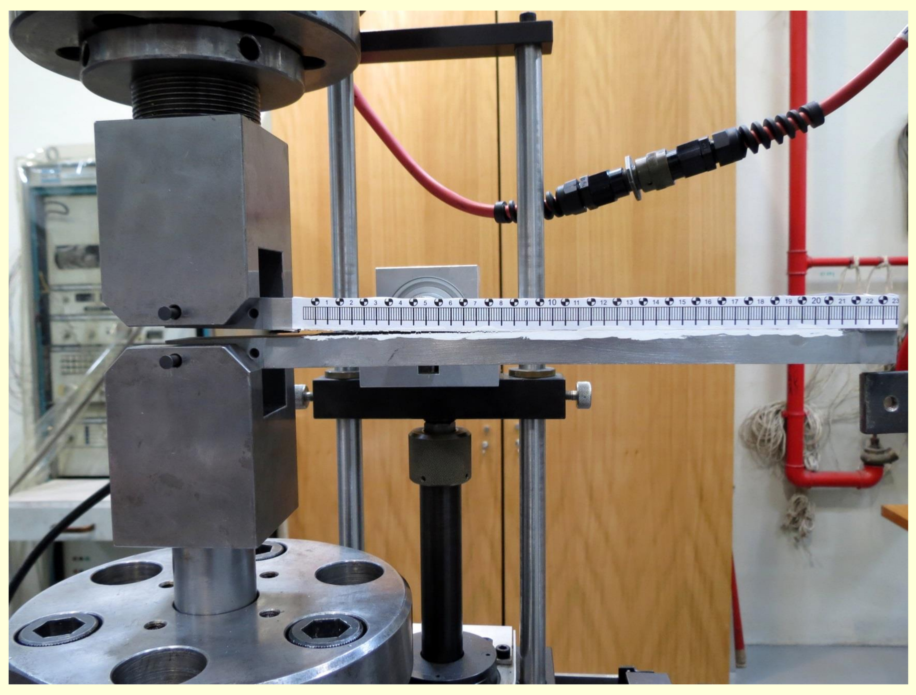
DCB - specimen geometry



SikaForce 7888 - a two-component structural polyurethane adhesive, supplied by Sika (Portugal).



- MTS 312.31 tensile testing machine;
- Similar strain rate in the adhesive layer;
- 0.2, 0.4, 0.6, 0.8, 1 and 2 mm adhesive thickness.



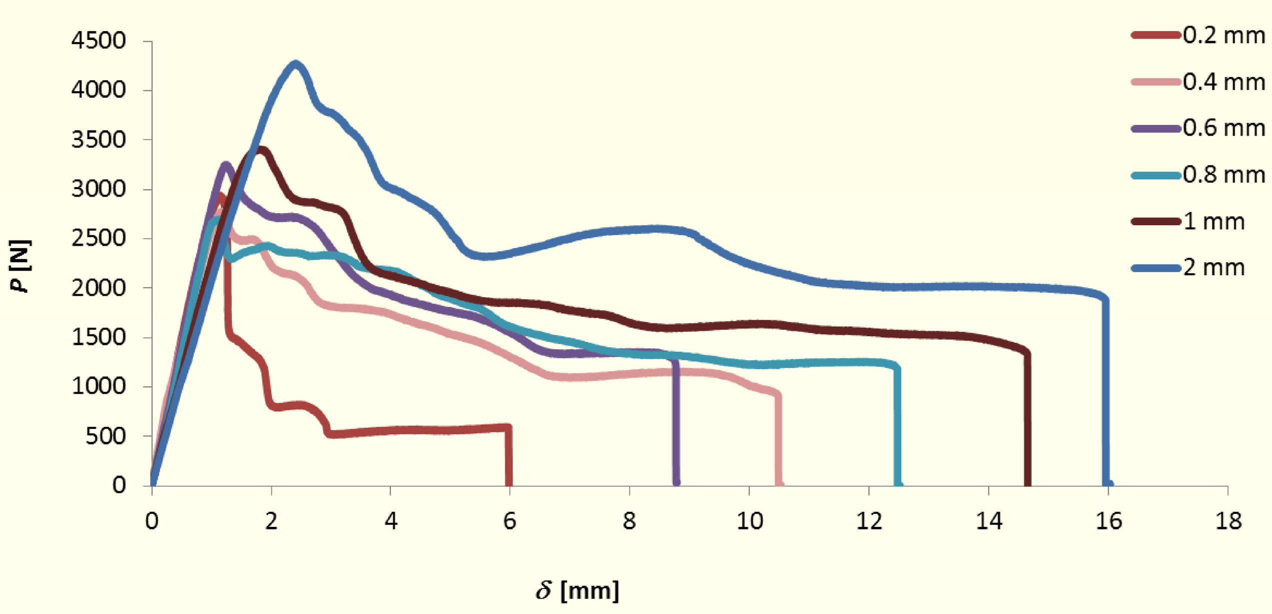
Results

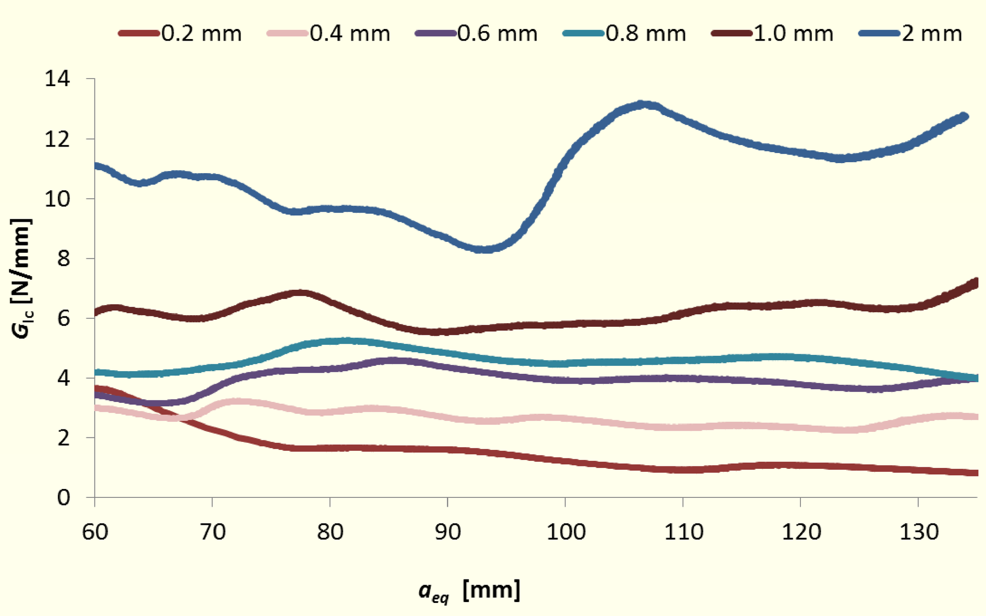
The Compliance-Based Beam Method (CBBM), (de Moura et al., 2008):

$$G_{Ic}=\frac{6P^2}{b^2h}\left(\frac{2a_{eq}^2}{h^2E_f}+\frac{1}{5G}\right)$$

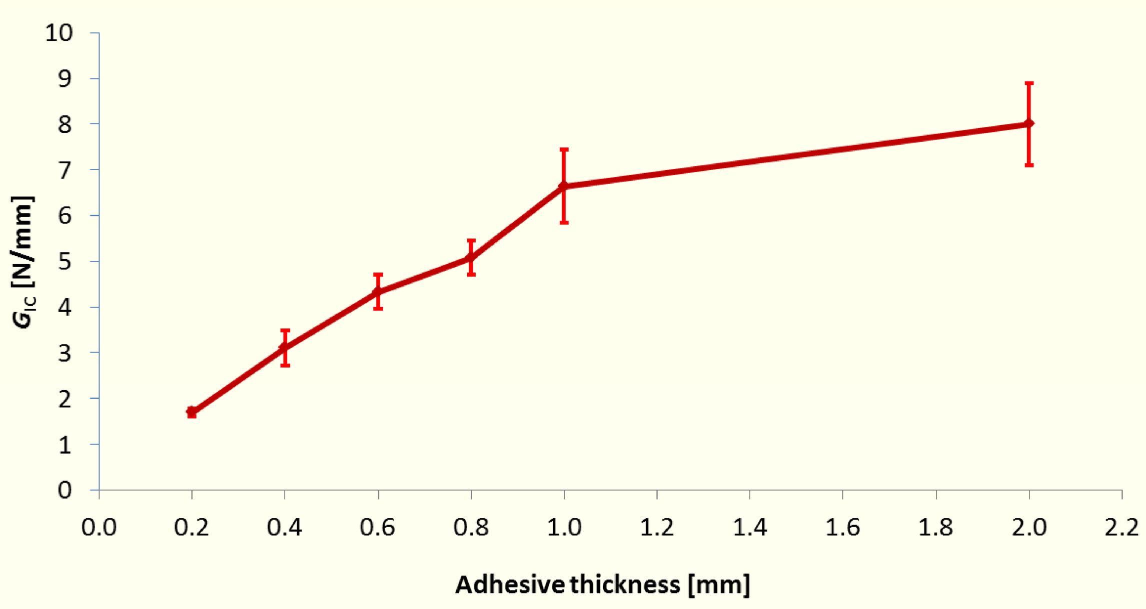
a_{eq} is an equivalent crack length obtained from the experimental compliance and accounting for the fracture process zone (FPZ) at the crack tip, E_f is a corrected flexural modulus to account for all phenomena affecting the *P*-*δ* curve, such as stress concentrations at the crack tip and stiffness variability between specimens, and *G* is the shear modulus of the adherends.

Representative experimental *P*–*δ* and *R*-curves of the DCB specimens as a function of adhesive thickness

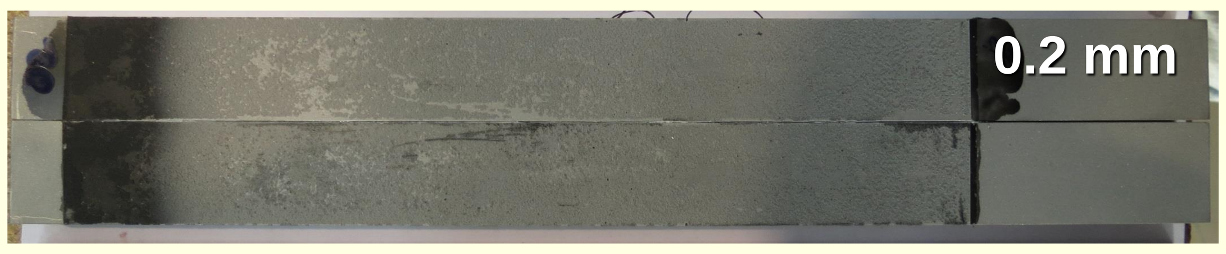


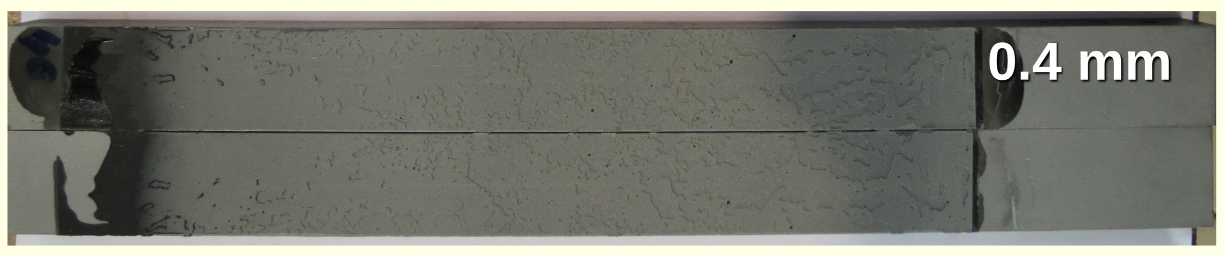


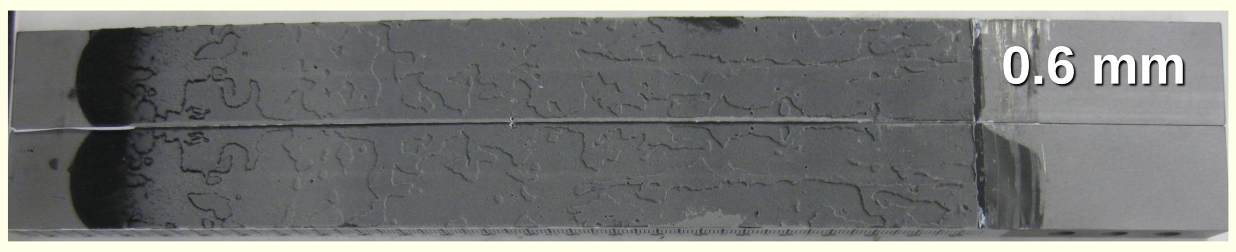
Fracture toughness G_{Ic} as a function of adhesive thickness

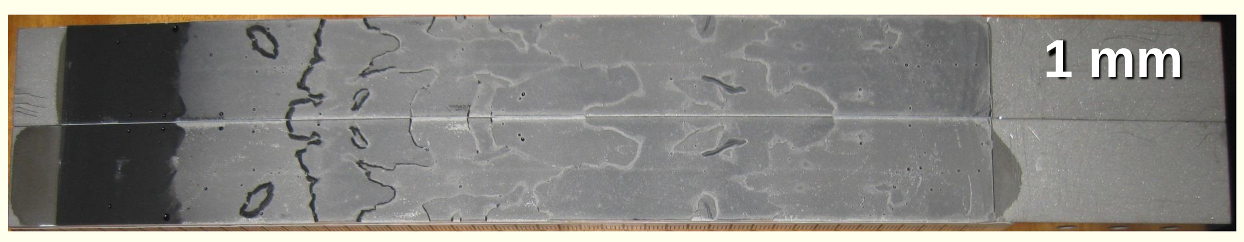


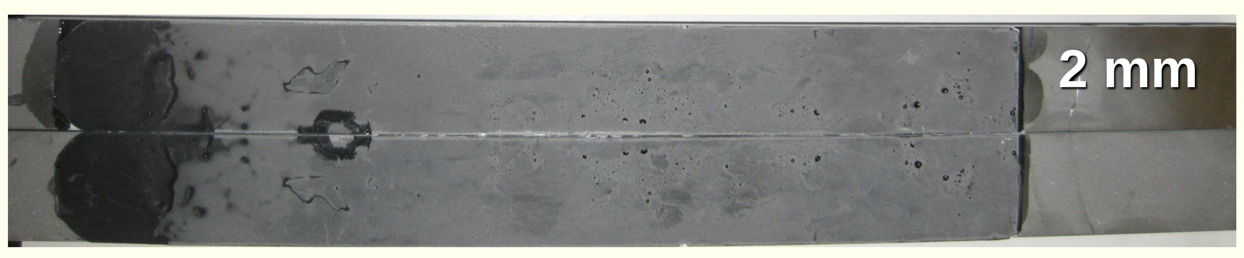
Failure modes











Conclusions

In this study the pure mode I fracture toughness of a structural polyurethane adhesive for automotive industry as a function of adhesive thickness was determined. The fracture toughness, G_{Ic}, was found to depend strongly on the thickness of the adhesive layer. G_{Ic} increased nearly linearly up to 1 mm adhesive thickness, while from 1 mm to 2 mm increased only by approximately 20%. This can be explained by the fact that the amounts of defects such as micro-voids and micro-cracks are larger in thicker adhesive layers. However, 2 mm bondline thickness might not be the thickness where G_{Ic} reach its maximum value. Anyway, defect free joints with thicknesses higher than 2 mm are difficult to manufacture.

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