Curing state effects on the tensile cohesive response of an epoxy based adhesive

A. Akhavan-Safar, P. Teixeira (INEGI, Portugal), R. Carbas, L.F.M. da Silva

ADVANCED JOINING PROCESSES UNIT

Introduction

Heat curing epoxy based adhesives are extensively used in primary bonded structures. Mechanical response of bonded joints is significantly influenced by the curing state of adhesives. Incomplete curing can lead to a poor joint performance and premature failure of bonded structures. [1]. In this work double cantilever beam (DCB) joints tests at different curing states was conducted to demonstrate the influence of incomplete curing on mode I fracture energy of a one component epoxy based adhesive.

Experimental methodology

The adhesive characterization requires different calorimetry tests to obtain the specific heat, reaction enthalpies, and the time-temperature dependence of the curing process [1]. The one component epoxy adhesive Teroson EP5089 was used for this study. The curing kinetics model proposed by Kamal that describes the evolution of the curing state in function of time and temperature was calibrated to simulate the curing process [2]. The model parameters were obtained by fitting the model with experimental from DSC tests.

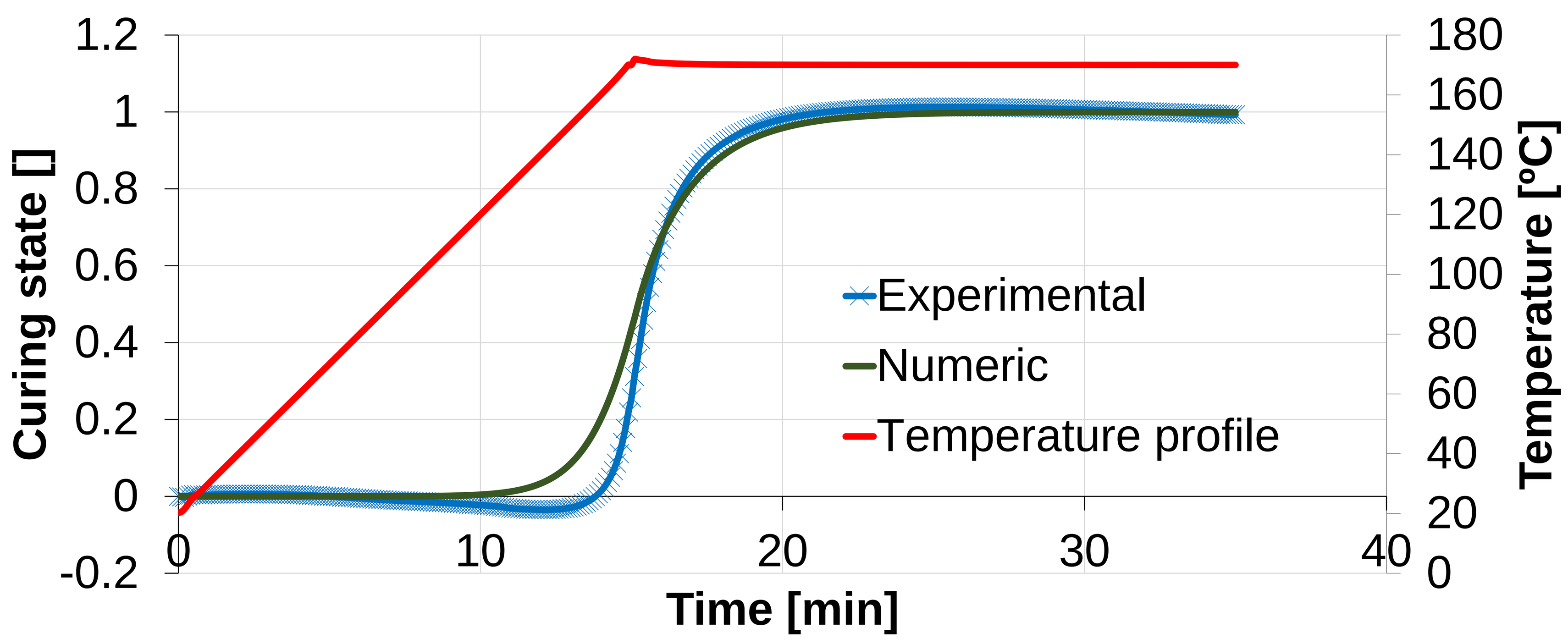

Figure 1 – Calibrated curing model.

To examine the curing level influence in the mode I fracture energy, three different curing levels were defined (50%, 70%, 100%) and the manufacturing process was adjusted to produce a (3) three DCB specimens set as shown in Fig. 1. The curing temperature was set to be 140 °C to ensure a low curing rate and facilitate the production

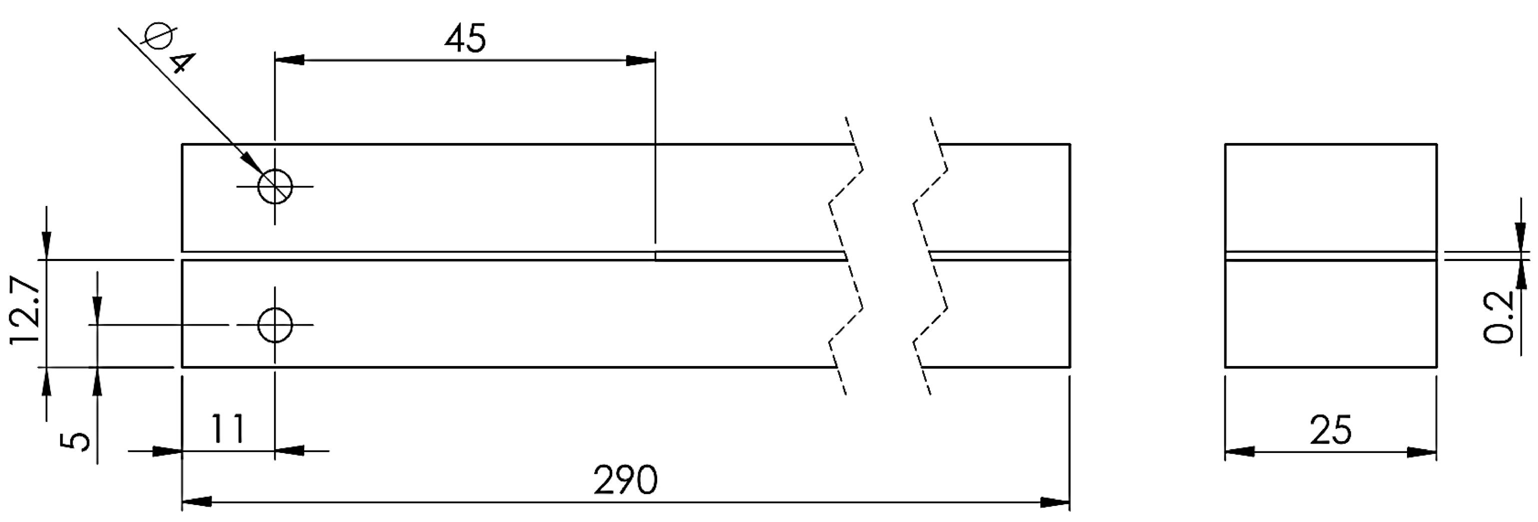

Figure 2 – DCB specimen.

Discussion

Figure 3 shows the load displacement of the DCB joints, only one curve per set is shown for simplicity. The initial stiffness of the adhesive joint is reduced by 43% and 78% for 70% and 50% cured specimens respectively, similarly the peak load is also reduced by 34% and 87%. This behavior is expected because incomplete curing means that all crosslinking chains in the polymer were not achieved making the adhesive softer and weaker. The crack resistance curves shows a similar shape for 100% and 70% with a reduction of 30% in the fracture toughness G_{IC}. The fracture toughness for the 50% cured sample is very low, it has only the 5% of the toughness corresponding to the full cured sample.

Experimental results

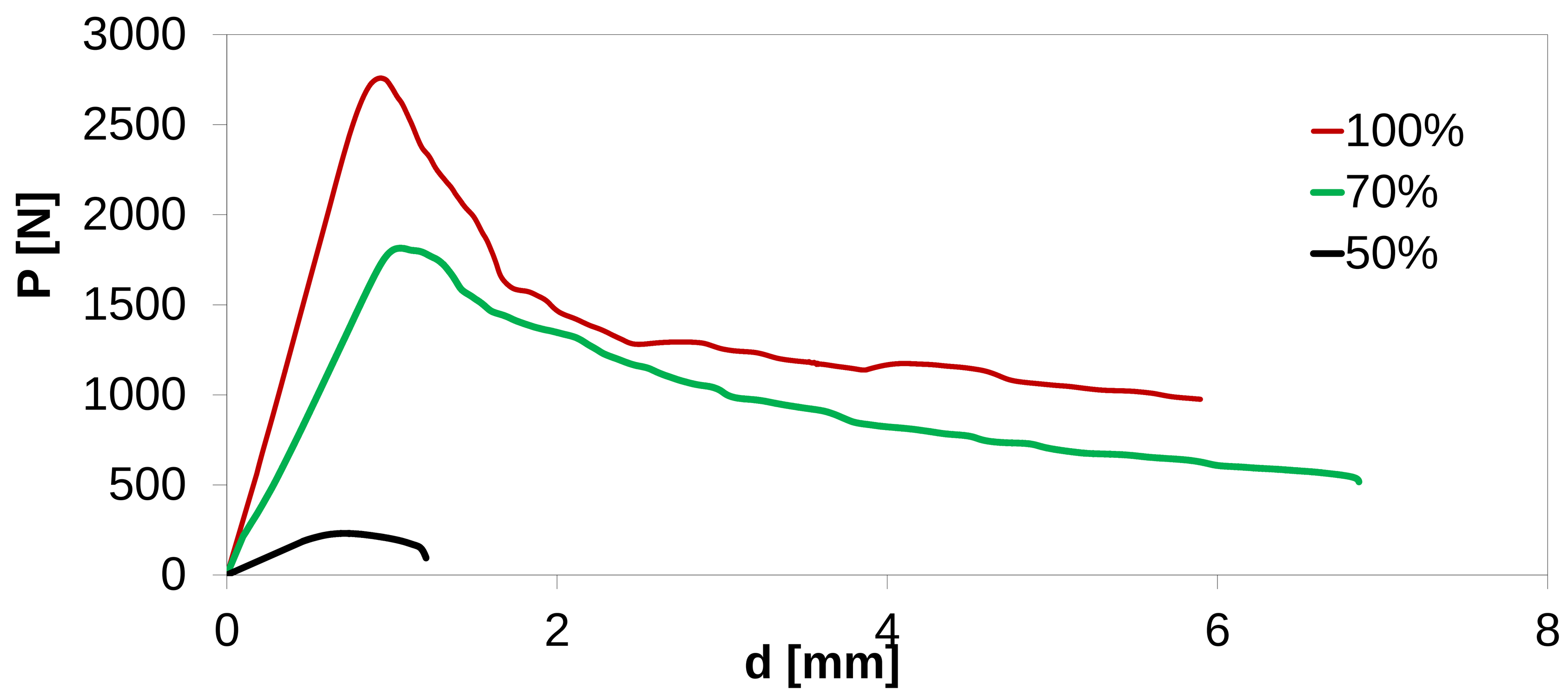

Figure 3 – Load displacement curves

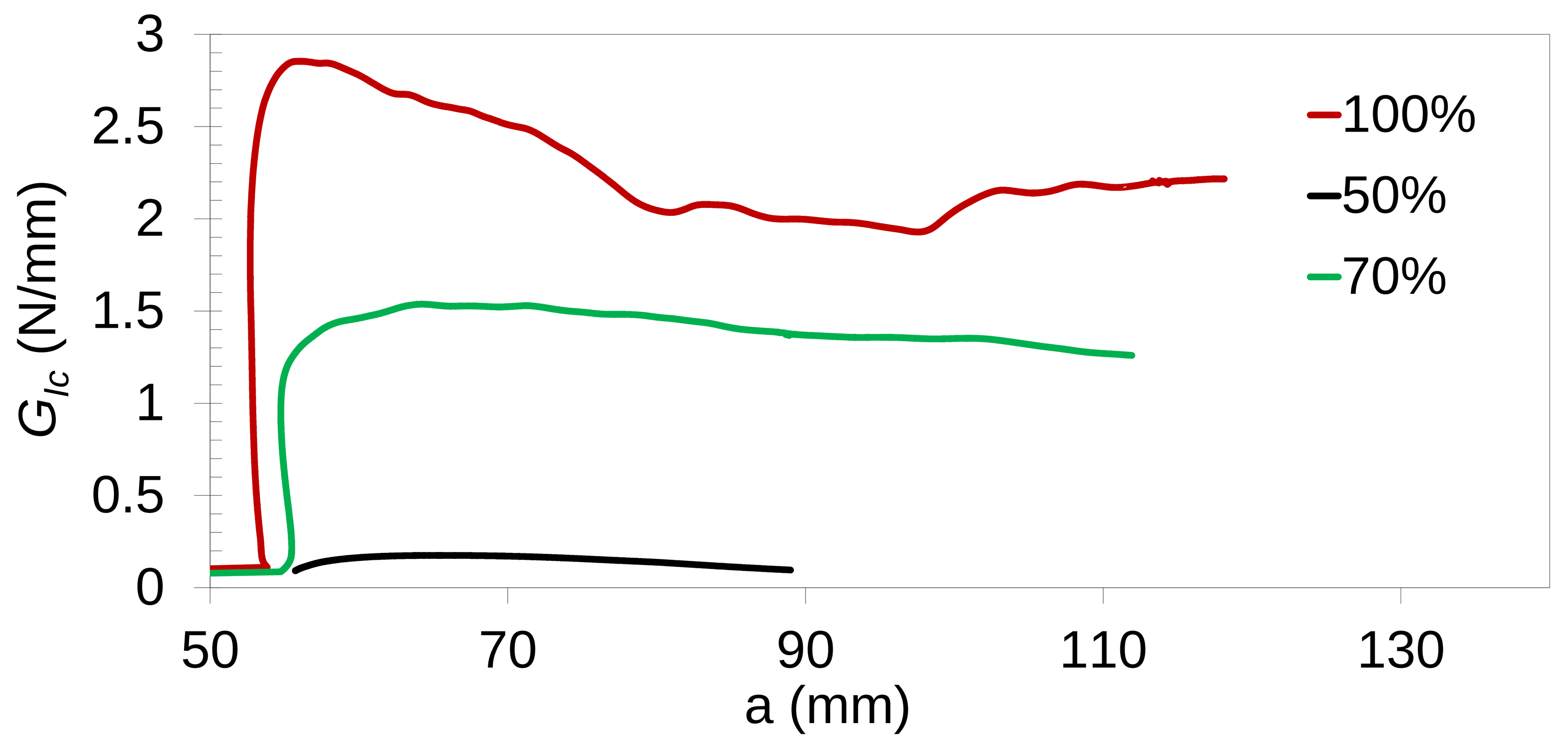

Figure 4 – Crack growth resistance R-curves.

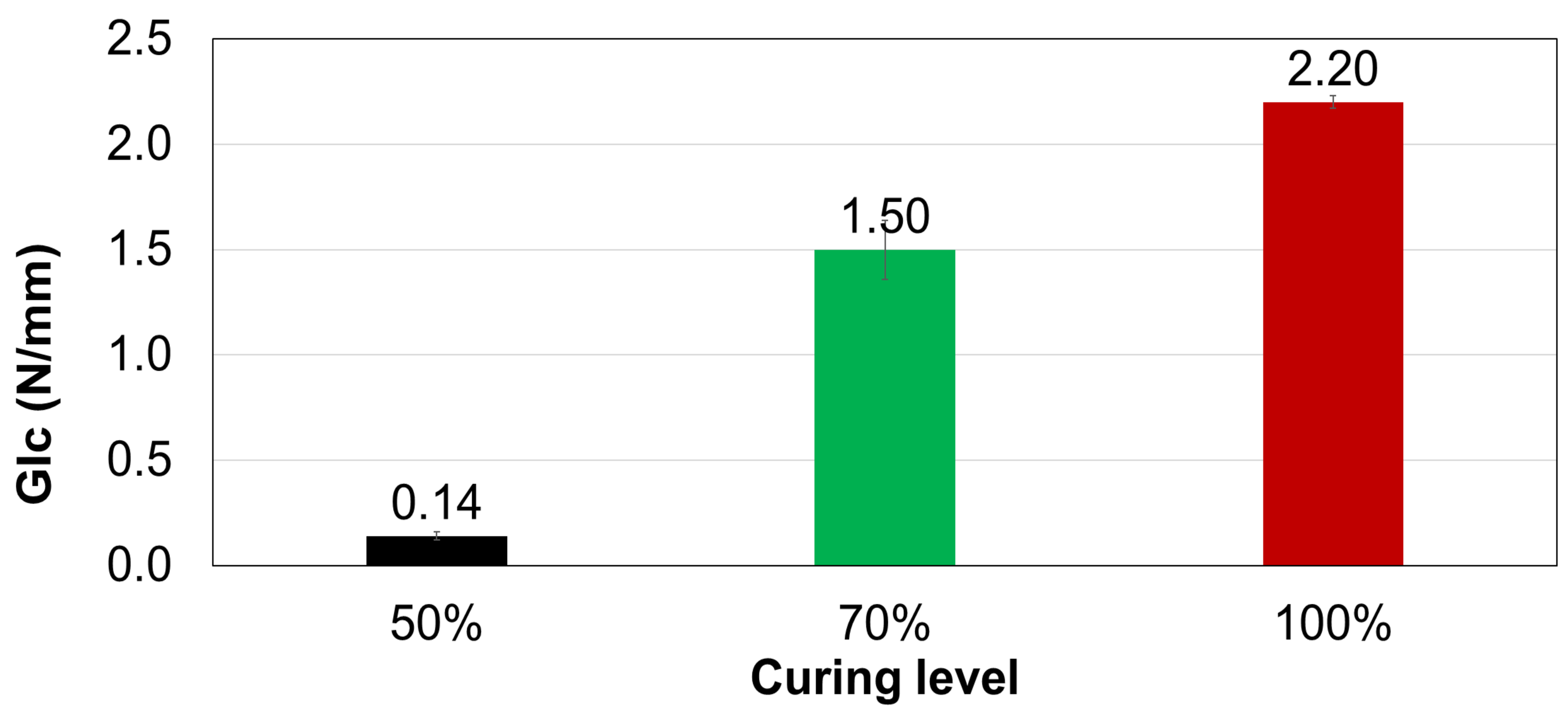

Figure 5 – Fracture toughness G_{IC}

Conclusions

The curing level has a direct influence in the mechanical performance of an adhesive joint. For the 70% cured adhesive the fracture toughness G_{IC} was reduced almost 30% while for the 50%of curing, the toughness was reduced to almost 90%. Further studies are required to obtain the complete dependence to curing level.

References

[1] Schiel, M., Kahrs, J., Stammen, E., & Dilger, K. (2016). Determination of cure-dependent properties of adhesives by thermal analysis using reaction kinetics and a novel experimental apparatus. International Journal of Adhesion and Adhesives, 68, 411–417. https://doi.org/10.1016/j.ijadhadh.2015.12.015

[2] Kamal, M. R. (1974). Thermoset characterization for moldability analysis. Polymer Engineering and Science, 14(3), 231–239. https://doi.org/10.1002/pen.760140312

[3] Agha, A., & Abu-Farha, F. (2021). Experimental methods to capture curing induced effects in adhesive bonded joints. International Journal of Adhesion and Adhesives, 104(September 2020), 102735. https://doi.org/10.1016/j.ijadhadh.2020.102735