On the mode I interfacial toughness of adhesive bonds accounting for strain-softening

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Adhesive bonding consists in the joining of two adherents by an adhesive, typically made of glassy thermoset or thermoplastic polymer. This technology offers many advantages over traditional joining techniques, such as a more uniform stress distribution across the bond and the possibility to join different materials. A key-factor for the design of joints lies in the determination of the toughness of the interface which can be used for structural integrity assessment. While extensive research has been performed on the effect of several material and geometrical parameters on the bond line toughness, the effect of the strain-softening arising in the polymer adhesive has not been systematically addressed yet. The question of interest is to what extent a bond line model must account for the intrinsic softening of the adhesive to provide a fair representation of the crack tip plasticity and dissipation of energy. An important side effect is that if plastic softening plays a key role on setting the toughness, then ageing of the adhesive with time, which is known to modify the magnitude of the softening, could contribute to a significant evolution of the joint toughness with time.

The mode I toughness of an interface between an adhesive material subject to strain-softening and an elastic substrate was investigated by finite element calculations. An asymptotic K-field model with cohesive zone elements simulating the fracture mechanism was used. Phenomenological hardening laws reproducing the plastic response behavior of amorphous glassy polymer involving first hardening, softening and re-hardening were used. For the sake of simplicity, rate sensitivity was not addressed. The effect of the peak hardening stress and of the softening stress on the joint toughness was investigated for different elastic mismatch values and critical stresses at the interface.

It is found that the joint toughness significantly increases with decreasing peak hardening stress and increasing amplitude of the softening. This is related to larger plastic zone sizes and higher plastic strains, hence to more energy dissipation. Increasing the interface work of fracture magnifies this effect. There is an interesting coupling between the elastic mismatch and softening, related to their influence in the fracture process zone length.

Keywords: Finite element calculations, strain softening, toughness, amorphous glassy polymer

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