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MICROMECHANICAL MODELIG OF DELAMINATION WITH THE THICK LEVEL SET MODEL

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In this work, the thick level set model developed by Moës et al. [1, 2] is applied to micromechanical analysis of interfacial failure. Failure of adhesive bonds or delamination in composite laminates is often modeled with the assumption of zero thickness of the interface. However, the adhesive layer in bonded structures and the resin-rich region between the plies of laminates do have a thickness; there is a so-called 'interphase'. The nature of the failure process does not always justify neglecting the variations inside the interphase. Particularly for shear failure, a complex failure process occurs within the interphase, which increases the effective fracture toughness of the interface with respect to normal failure. In order to be able to predict the fracture toughness of delamination or bond failure under general load conditions, this study aims at modeling the processes within the interphase.

Simulating the failure mechanism of the interphase under shear loading in a robust manner is challenging. In our experience, conventional approaches that involve nonlinear finite elements with damage in the constitutive law are not functioning for this case because of convergence problems when multiple microcracks appear and merge. However, such difficulties can be circumvented by using the thick level set model which removes the development of damage from the iterative search for equilibrium.

In the thick level set model, damage is described as a function of distance to a level set. The nonlinear problem of crack growth is solved in a staggered manner. Firstly, stress and strain are computed for a given damage distribution by means of a standard mechanics problem. The only nonlinearity that is present in this mechanics problem is due to the distinction between compressive and tensile behavior of the damaged material. Secondly, the damage field is updated based on the latest stress and strain fields. In a weak form that is defined only on the damaged subdomain, configurational forces are computed along the front, which are used for an explicit update of the level set field.

Figure 1: Shear failure mechanism for adhesive bond: final damage profile from a simulation with randomly located predefined defects

In this contribution, it is demonstrated that the level set approach is very suitable for the complex failure mechanism in an interphase under shear loading, which involves the merging of multiple cracks (see Fig. 1). Several extensions of the existing formulation from [2] that are relevant for the case at hand are investigated, such as the introduction of hardening plasticity and the possibility of free sliding deformations in developed cracks.

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