A computational model for analysis of interface damage in fibrous composites

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Various scales are needed to be analysed for understanding damage and fracture of composite laminates. An initial onset of damage is usually considered between a fibre and matrix of the weakest lamina, i.e. at a micro-mechanical level. Nevertheless, in practical calculations it is also required to analyse crack that appears between the laminas. Both of these partial problems can be solved by a general model for interface rupture proposed in [5] which may take into account anisotropic character of laminas, various orientations of fibres in adjacent laminas and also different physical phenomena to influence the behaviour of a structure made of laminated materials.

The present model of interface damage and fracture is based on quasi-static evolution of energies in a system which includes the concept of scalar damage variable [1], a cohesive zone model for describing the interface relations between displacements and stresses [4], crack mode sensitivity to consider the fact that opening cracks dissipate smaller amount of energy than shearing ones [3], and that the dissipation in the shear mode can include friction even in an anisotropic sense due to the anisotropy of laminas and the general orientation of their fibres [5].

Using such a model, micro-mechanical debonding of fibres from the matrix was analysed as shown in Fig. 1. Also delamination in a layered structure was obtained by the same computational model, see Fig. 2.

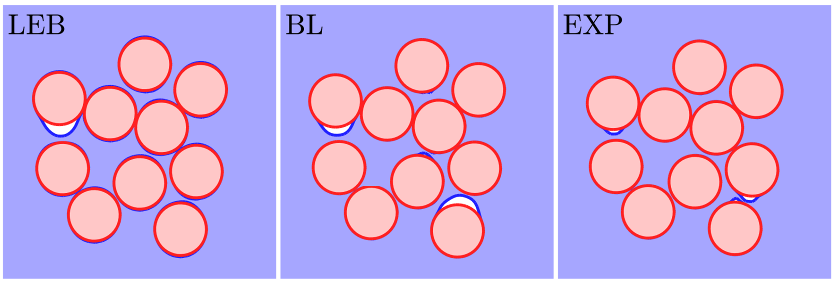

Figure 1: Crack initiation at fibre-matrix interfaces of a fibre bundle. The matrix is large with respect to the size of the bundle and a tension load is applied sufficiently far at vertical direction. The differences are caused by various stress-displacement relations supposed in the interface: LEB – linear elastic-brittle interface, BL – elastic linear-softening model, EXP – exponential (Ortiz-Pandolfi) cohesive zone model

The parameters of the model which include fracture energy at various fracture modes, the form of the interface stress-displacement relation and its parameters, friction coefficients and also other parameters can be appropriately set for each particular engineering calculation. E.g., we may observe the differences of the results obtained by various cohesive zone models in Fig. 1.

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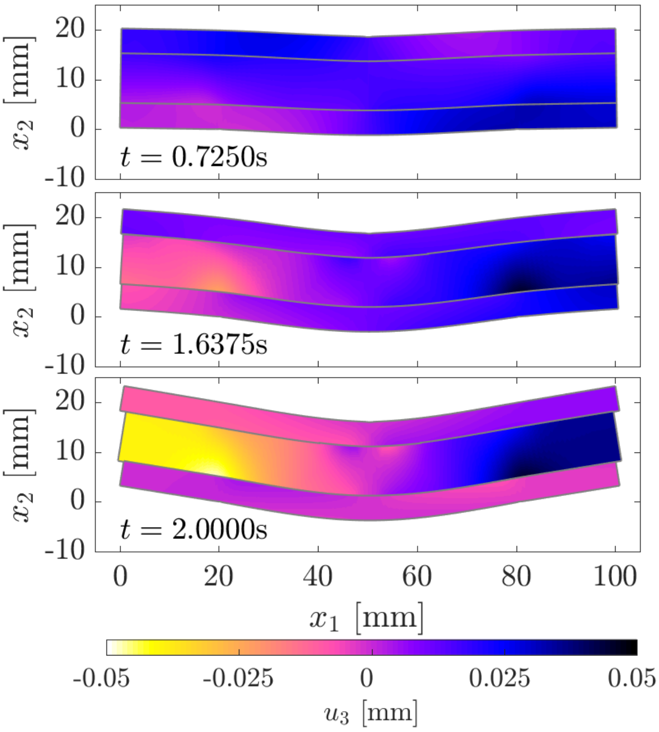

Figure 2: Deformations at various instants of a three-layer tree-point-bended beam: top and bottom layers — homogenised fibrous lamina with a skew orientation of fibres (45°); central layer — anisotropic material with a cubic symmetry. The colour scheme corresponds to the displacement in the out-of-plane direction, it clearly documents shearing type of rupture between the layers and presence of friction.

References

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