Microstructure based translaminar fracture modelling of plain weave composite laminates using lattice springs network model

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ABSTRACT

Fracture process in composite materials is a complex phenomenon due to its heterogeneous composition as well as the intricate architecture in which the constituents are organised at the microscopic scale. The process involves several failure mechanisms that control the nucleation and growth of micro-cracks which can simultaneously occur at multiple locations. For better design and safe use of composite materials, increasingly being used in structural applications, there is a pressing need for development of predictive models that are able to account for the complex nature of the fracture process in these material systems.

In the present work, square-lattice spring network model (LSNM) with nearest and next-nearest neighbour interaction is used to simulate translaminar fracture of plain weave laminates. To incorporate the effect of micro-structural patterns, first, a region from the cross-section of a six-layered representative glass-epoxy plain weave composite laminate [1] is approximated with idealised geometric patterns [2]. The patterns are then used to generate the 3-dimensional spatial distribution of longitudinal and transverse for the laminate. The volume fraction is averaged through thickness and mean of transverse fibre volume fraction is used as cut-off volume fraction to distinguish between hard bonds and soft bonds in the 2-dimensional spring-network representation of the laminate. The elastic modulus of hard bonds and soft bonds is calculated using a combination of numerical FE based homogenisation and rule of mixture.

For validation of the fracture model, mode-I crack growth in a modified compact test specimen is simulated and compared with the fracture test data [1]. The failure properties of the hard and soft bonds are estimated from a parametric study. The model is able to reproduce the macroscopic force-displacement response accurately in the elastic regime as well as in the post-peak regime. Also, the fracture path observed in the simulations has similar characteristic features as those seen in the fracture experiments. As a consequence of the pattern in the elastic heterogeneity incorporated in the present model, the high stresses are distributed over a wider region around the crack tip than in a randomly allocated elastic heterogeneity in an earlier model [1]. In the simulations, the growth of the macroscopic mode-I crack is seen to occur largely as a result of the breakage of the softer bonds where the near crack-tip strains tend to localise.

REFERENCES

[1] Dhatreyi Boyina, T. Kirubakaran, Anuradha Banerjee, and R. Velmurugan. Mixed-mode translaminar fracture of woven composites using a heterogeneous spring network. *Mechanics of Materials*, 91:64 – 75, 2015.

[2] Adi Adumitroaie and Ever J. Barbero. Beyond plain weave fabrics – i. geometrical model. *Composite Structures*, 93(5):1424–1432, 2011.