

An adaptive anisotropic gradient-enhanced damage framework for progressive failure in fiber-reinforced composites

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Abstract

This work presents an adaptive gradient-enhanced damage framework for modelling progressive intra-laminar failure in transversely isotropic fiber-reinforced composites, with an emphasis on anisotropic damage localization at the mesoscale. A stress-based fourth order tensor is introduced to regularize the anisotropic nonlocal interactions within the fracture process zone. Unlike conventional gradient damage models, the approach employs an improved spatial nonlocal description with a single internal length scale. The proposed framework uses independent internal damage variables for fiber tension/compression, matrix cracking, and shear failure. The computational efficiency is enhanced by employing a multi-level based adaptive mesh refinement strategy. Active-inactive error indicators are introduced to sufficiently refine the discrete crack-tip prior to damage onset and to capture the complete fracture domain post nucleation. The Newest vertex and Maubach's refinement routines are integrated as the element level based hierarchical refinement strategies to inherently address the conformity and reflectivity of discretized domain efficiently. A robust staggered solution algorithm is employed to solve the decoupled system of equations using lower order finite elements in the analysis, without compromising with the accuracy. The robustness of the

framework is verified against several benchmark problems, and the obtained results are found consistent with the experimental/literature observations at reduced computational costs.

Keywords:

Adaptive mesh refinement Localized gradient damage model Composites Anisotropic interactions