A nonlocal finite element model for progressive failure analysis of composite laminates

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A nonlocal finite element model for progressive failure analysis of composite laminates

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Abstract Localized damage and failure of composites often lead to spurious mesh dependence and zero energy dissipation due to the lack of a length scale by using finite element analysis. Based on the variational form of the stress boundary value problem with an interface discontinuity, this paper originally proposed a finite element model on the nonlocal intralaminar damage and interlaminar delamination of composite laminates. First, strain-based initial failure criteria and damage evolution criteria are used for the fiber and matrix, and the delamination is modeled by bilinear cohesive model. It is shown two length scales are introduced into the damage evolution behaviors of the fiber and matrix to solve the localization problem of composites. Second, the global nonlocal stiffness equation is derived including the nonlocal intralaminar consistent tangent stiffness and the cohesive interface stiffness, and the node forces for bulk and interface elements. Third, numerical algorithm and finite element codes are developed by combining ABAQUS-UMAT, UEL, USDFLD subroutines and UEXTERNALDB utility subroutine to implement the proposed model, where nonlocal averaging is performed on the derivatives of the equivalent strains with respect to the strain components during each load increment which are included in the nonlocal consistent tangent stiffness. Finally, damage evolution behaviors and load responses for two $[0°/90°]_{4s}$ T700/8911 composite specimens with different central hole sizes are studied by nonlocal FEA. Numerical results demonstrate the ability of the proposed model to address localized deformation, strain softening and strength prediction of composites effectively.

Keywords A. Laminate, Polymer-matrix composites (PMCs) ; B. Strength, Mechanical properties, Delamination; C. Finite element analysis (FEA)

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