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Micromechanical progressive failure analysis of fiber-reinforced composite using refined beam models

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An efficient and novel micromechanical computational platform for progressive failure analysis of fiber reinforced composites is presented. The numerical framework is based on a class of refined beam models called Carrera Unified Formulations (CUF), a generalized hierarchical formulations which yields a refined structural theory via variable kinematic description. The crack band theory is implemented in the framework to capture the damage propagation within the constituents of composite materials. The initiation and orientation of the crack band in the matrix is determined using the maximum principal stress state and the traction-separation law governing the crack band growth is related to the fracture toughness of the matrix. Crack growth in pure mode I condition is assumed when the maximum principal stress is tensile in nature. Mode II cracks are formed with the crack band oriented along the plane of maximum shear stress when the maximum principal stress is compressive. A representative volume element (RVE) containing randomly distributed fibers is modeled using the Component-Wise approach (CW), an extension of CUF beam model based on Lagrange type polynomials. The mesh objectivity of the post-peak strain softening behavior is achieved through judicious scaling of fracture toughness of the material. RVE is subjected to combination of transverse tension, transverse compression and transverse shear loading. The numerical results are compared against experimental data available in literature and an analogous 3D finite element model with the same constitutive crack band model. The efficiency of the proposed numerical framework is achieved through the ability of the CUF models to provide accurate three-dimensional displacement and stress fields at a reduced computational cost (approximately one order of magnitude of degrees of freedom less as compared to standard 3D brick elements). The applicability of CUF beam models as an efficient micromechanical platform for progressive failure analysis is highlighted.

Keywords: Progressive failure analysis, Crack band, Refined beam models, Multiscale modeling.