NONLINEAR CONTINUUM DAMAGE MODELS FOR CERAMIC MATRIX COMPOSITES WITH SIGNIFICANT IN PLANE PLY ANISOTROPY

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Continuous ceramic fiber reinforced ceramic matrix composites (CMCs) components have recently appeared in several new gas-turbine engines for aero propulsion. However, current models for damage prognosis of CMCs to support the design, certification and sustainment of safety critical CMC components are limited. Here a formulation for a two-dimensional (2D) continuum damage model derived via a thermodynamics-based approach based called openDM is introduced. The model is formulated both with two scalar damage parameters that account for damage as a result of matrix cracking in both the fiber and transverse directions and four scalar damage parameters that includes the previously described matrix cracking as well as matrix damage due to shear in the ±45° directions. The applicability of these models are considered for a balanced 2D woven based SiC fiber reinforced composites and a 2D unidirectional ply based SiC fiber reinforced composite with predominately SiC matrix produced that exhibits significant anisotropy in the fiber and transverse directions. While the response of the 2D woven composite was captured well with the two parameter model, the more anisotropic unidirectional ply based CMC required more damage parameters to account for a more complex damage response as was observed experimentally. The process of model calibration, verification and validation is discussed for both materials that were considered. Implemented of the models was accomplished using nonlinear classical laminate theory in python and the resulting code is generally applicable for the analysis of 2D ply-based CMCs with a wide range of stacking sequences.