

# A CONSTITUTIVE MODEL FOR FIBER REINFORCED POLYMER PLIES – COUPLING OF PLASTIC AND ELASTO–DAMAGE MECHANISMS

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The constitutive model for unidirectional fiber reinforced polymer plies developed in [1, 2] is extended. The existing model predicts plastic strain accumulation and uses continuum damage mechanics to model the stiffness degradation accompanied by strain hardening as well as strain softening behavior. Due to the characteristics of such materials the damage criterion, the damage evolution, and the stiffness degradation as well as the plasticity are formulated in an anisotropic manner.

In this work the existing model is reformulated with focus on thermodynamic consistency and to maintain simple calibration by commonly established experiments, particularly for the coupling of plasticity and damage. The proposed model is set up within the framework of thermodynamics of irreversible processes and uses internal damage and plasticity variables to consistently describe the evolution process. The internal damage and plasticity variables evolve according to mutually independent nominal and effective stress–strain curves, respectively. This enables the model to be calibrated to a wide range of coupling scenarios. The rate constitutive equations implemented in a material subroutine for ABAQUS/Standard (SIMULIA, Providence, RI, USA) are integrated numerically using an implicit scheme, which ensures that the damage and yield conditions are satisfied throughout the deformation process.

The capabilities of the proposed constitutive model are demonstrated on multiple angle–ply laminates with respect to the coupling of plasticity and damage. The coupling is studied by using laminates with different ply–angles to intentionally induce different partitions of the inelastic behavior into plasticity and damage.

- [1] Th. Flatscher, H. E. Pettermann, A constitutive model for fiber-reinforced polymer plies accounting for plasticity and brittle damage including softening-implementation for implicit FEM, *Composite Structures* 93.9 (2011): 2241–2249.
- [2] Th. Flatscher, C. Schuecker, H. E. Pettermann, A constitutive ply model for stiffness degradation and plastic strain accumulation: Its application to the Third World Wide Failure Exercise (Part A), *Journal of Composite Mat.* 47.20-21 (2013): 2575–2593.