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# LAMINATE DAMAGE MODEL FOR CFRP STRUCTURES

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**Summary:** For the prediction of the maximum bearable load of a composite structure, damage models are necessary, since the first damage event often occurs much earlier than the ultimate failure of the laminate. Current continuum damage models for CFRP require very fine FE meshes, where each ply is represented by one layer of elements. Between the plies cohesive elements are used to model delamination [1]. For structural analyses often layered shell elements are used to minimize the numerical effort. The presented material model is developed in particular for this kind of discretization. The main difference to current models is that the strength and thus the transition from the hardening to the softening regime is defined on laminate level and not on ply level. In the hardening regime the laminate can show nonlinear material behavior, but the load can be further increased. Especially under in-plane shear load CFRP shows essential nonlinear behavior. An additional reason for the nonlinear response of a laminate can be damage in certain plies. For the correct prediction of the non-linearity also the deformation induced fiber orientation change has to be considered. Otherwise, incorrect stress states are determined, leading to misinterpretation of locus and time of damage initiation and progression. Once damage initiation is detected by a criterion, it has to be verified if the load can be further increased and damage accumulation in the corresponding plies begins or the strength of the laminate is reached. If the laminate strength is reached, the softening of the material starts to represent the total separation of the laminate. Therefore, the current laminate stiffness is reduced controlled by the fracture toughness of the laminate. The model is validated against various tension and open-hole tension tests fabricated of the same carbon/epoxy IM7-8552 material. The excellent correlation with different angle-ply tension specimens demonstrates the applicability of the model to represent large nonlinear deformations. The additional verification with open-hole tension tests shows mesh-size independency and good accuracy of the presented material model.

References:
[1] B.Y. Chen (2013) Numerical analysis of size effects on open-hole tensile composite laminates. Composites: Part A, 47, 52-62