A 3D Continuum Damage Model for Tough Fibre Reinforced Polymer Composites Using Cuntze's Failure Mode Concept

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ABSTRACT

Fibre Reinforced Plastics with tough epoxy and thermoplastic matrices showing inherent non-linear behaviour are spreading increasingly. Conventional design approaches, which assume linear elastic material behaviour and laminate failure at First Ply Failure, are very conservative [1]. For an efficient and reliable design of structures the mechanical behaviour considering various failure modes under complex loading and damage progression has to be estimated in the design phase with numerical simulations. For this purpose continuum damage models are available [2]. However, most state-of-the-art continuum damage models do not consider the inherent non-linear behaviour of the matrix material or are not suited for 3D solid finite elements [3]. This work proposes a 3D continuum damage model. It uses a single-parameter flow criterion from Sun and Chen [4] in combination with Cuntze's Failure Mode Concept [5] for intra laminar failure. As the Failure Mode Concept by Cuntze is based on invariants, no computational expensive iterative fracture angle search for inter-fibre failure is needed. In addition, the model features a strain-based gradual degradation model adopted from Donadon et al. [6]. This work describes details of the developed model like the coupling of the Failure Mode Concept with the degradation model as well as the implementation of the model into Abaqus / Standard as a user-defined material model (UMAT). The model is verified with single element models using periodic boundary conditions. Furthermore, the model is validated against tests on coupon level from literature. Both tough epoxy and thermoplastic carbon fibre composite specimens are considered. It can be shown that the model is able to capture the failure behaviour of the specimens and accurately predict failure loads.

REFERENCES

[1] Schuecker, C., & Pettermann, H. E. (2008). Fiber reinforced laminates: progressive damage modeling based on failure mechanisms. *Archives of Computational Methods in Engineering*, 15(2), 163-184.

[2] Liu, P. F., & Zheng, J. Y. (2010). Recent developments on damage modeling and finite element analysis for composite laminates: A review. *Materials & Design*, 31(8), 3825-3834.

[3] Din, I. U., Hao, P., Franz, G., & Panier, S. (2018). Elastoplastic CDM model based on Pucks theory for the prediction of mechanical behavior of Fiber Reinforced Polymer (FRP) composites. *Composite Structures*, 201, 291-302.

[4] Sun, C. T., & Chen, J. L. (1989). A simple flow rule for characterizing nonlinear behavior of fiber composites. *Journal of Composite Materials*, 23(10), 1009-1020.

[5] Petersen, E., Cuntze, R. G., & Hühne, C. (2016). Experimental determination of material parameters in Cuntze's Failure-Mode-Concept-based UD strength failure conditions. *Composites Science and Technology*, 134, 12-25.

[6] Donadon, M. V., Iannucci, L., Falzon, B. G., Hodgkinson, J. M., & de Almeida, S. F. (2008). A progressive failure model for composite laminates subjected to low velocity impact damage. *Computers & Structures*, 86(11-12), 1232-1252.