11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

Hybrid Micro Meso Modeling Approach to Predict Compressive Failure of Composites

Majeed Bishara* and Raimund Rolfes

Leibniz Universität Hannover, Institute of Structural Analysis
Appelstr. 9A, 30167 Hannover, Germany, www.isd.uni-hannover.de
* Corresponding author: m.bishara@isd.uni-hannover.de

Key Words: *Fiber kinking, Composite, Multiscale analysis, Compressive failure.*

A Hybrid Micro Meso modeling approach (HMiMe) is presented to simulate the compressive failure of multidirectional laminates and woven composites. Compressive failure of carbon-epoxy composite materials can be seen as an interaction of three failure mechanisms: Fiber kinking, matrix cracking and delamination. This interaction is responsible for the final failure of the structure at the meso- and macroscale. The experimental results are able to show the failure mechanisms inside the composites [1, 2], but the sequence of events of the mechanisms is still not fully understood. The need for a deeper understanding of these interactions is important for a better prediction of the failure behaviour, to be able to develop predictive analytical models, and to improve the mechanical properties of composite materials under compression.

A thorough understanding of fiber kinking is essential for the prediction of stiffness and strength of long fiber reinforced composites under compression. The initiation and propagation of kink bands are very complex problems, where different phenomena such as local (material and geometrical) nonlinearities and local instabilities interact and have to be taken into account. Although the peak load of unidirectional laminates can be determined with a simple 1D-micromodel, the full (2D and 3D) micromodeling is essential to simulate the propagation of kink bands and their interactions with the other failure mechanisms.

The high effort (cost and time) related to experimental tests demands the use of finite element multiscale analysis to determine the stiffness and strength of composite structures. Based on a 3D-micromodel, a new Hybrid Micro Meso modeling strategy is developed to establish stiffness and strength of multidirectional laminates and woven composites under compressive loading, including the effect of fiber kinking. The HMiMe approach is based on a micromechanical model in the kinking-relevant areas (axial loading with respect to the fiber direction) and mesomodeling in all other areas where fiber kinking is not expected to occur (transverse loading and off-axis compression areas). A nonlinear constitutive model for the matrix is used at the microscale to describe the fully nonlinear mechanical behaviour of the material, while a homogenized transversally isotropic constitutive low [3] is applied for the in the regions where fiber kinking is not relevant. The initiation and propagation of kink bands are in this way appropriated represented, so that the interaction during the kinking process can be simulated and the complete nonlinear stress-strain response can be determined.

The simulation results of the HMiMe model for specific composite specimens show localized high stress concentrations in the regions with fiber misalignment. Matrix yielding is taking place in these areas and results in kink bands for the fibers parallel to the loading direction. Delamination and matrix cracking are initiated around the kink bands and propagate inside the material. The progressive failure under pure compression is predicted using this HMiMe modelling approach.

REFERENCES

[1] C. Soutis, Measurement of the static compressive strength of carbon-fibre/epoxy laminates. *Composites science and technology*, pp. 373-392, 1991.

[2] R. Joffe, D. Mattsson, J. Modniks, and J. Varna, Compressive failure analysis of non-crimp fabric composites with large out-of-plane misalignment of fiber bundles. *Composites Part A: Applied Science and Manufacturing*, Vol. **36(8)**, pp. 1030–1046, 2005.

[3] M. Vogler, R. Rolfes, P.P. Camanho, Modeling the inelastic deformation and fracture of polymer composites – Part I: Plasticity model. *Mechanics of Materials*, Vol. **59**, pp. 50–64, 2013.