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MULTISCALE MODELING OF THE COMPRESSIVE BEHAVIOUR OF CFRP STRUCTURES

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The intensive use of Carbon Fibers Reinforced Plastics in aeronautics applications implies to master the prediction of any behaviour up to final failure. The so-called virtual testing approach supports this goal and relies on the use of robust models for key physical mechanisms. Among them, the kinking phenomenon in compression along the fibers direction is a major one since it is involved either in static or dynamic complex test cases such as energy absorbers for crashs. It can lead to a large amount of dissipated energy thanks to the fragmentation of the whole structure in the strongly nonlinear regime. While the physics of kinking are relatively well known at the scale of the fibers, its modeling at the mesoscale and its interaction with delamination is still a challenging issue [2].
Preliminary studies focus on quasi-static loadings of relatively small samples. A micro model of a representative unit cell incorporating carbon fibers in an epoxy matrix has been developed and is able to represent the main degradation mechanisms associated to kinking. It is based on Fleck & Budiansky's kinking theory [1]. This micro model has been used to extract the most important characteristics (strength, dissipated energy, kink band size) and the associated scattering mainly due to the statistical waviness of the fibers. From that point on, a ply-scale model has been improved to account for compressive loadings. The chosen representative volume element relies on the fragment size at the micro scale. An approximate potential form, in which the associated state and evolution laws are identified using an energy equivalence principle between the scales, has been proposed. The kink band size, which is a representative material length, plays the role of a localization limiter. This constitutive law is parameterized by the fiber waviness angle and is able to represent material and geometrical nonlinearities under multi-axial loadings. This work can be divided in three parts. The first one describes the kinking micro model and the main associated results [3]. The second part focuses on the construction of

a homogenized constitutive law at the mesoscale [5], compatible with previous meso-scale models developed by Ladevèze and co-authors. The third part features an application of the strategy to the modeling of the degradation of holed plates in compression. For this purpose, the mesoscale model has been implemented in the virtual material model developed in [4]. This hybrid description strategy allows the interaction between the micro buckling mechanism (kinking) and other classical degradation mechanisms, such as splitting, delamination and transverse cracking, to take place for any configuration. The different crack networks and degradation features obtained by simulation are compared to the experimental ones [6]. A rather good agreement on the cracking pattern is shown. The degradation scenario and the competition between the different cracking patterns is also better understood.

REFERENCES

[1] B. Budiansky and N. A. Fleck, N. Compressive failure of fibre composites. Journal of the Mechanics and Physics of Solids, 41(1):183-211, 1993.

[2] J.M. Guimard, O. Allix, N. Pechnik, and P. Thevenet. Energetic analysis of fragmentation mechanisms and dynamic delamination modelling in CFRP composites. Computers and Structures, 87(15):1022-1032, 2009.

[3] N. Feld, O. Allix, E. Baranger, and J.M. Guimard. Micro-mechanical prediction of UD laminates behavior under combined compression up to failure: influence of matrix degradation. Journal of Composite Materials, 45(22):2317-2333, 2011.

[4] P. Ladevèze, G. Lubineau, and D. Violeau. A computational damage micromodel of laminated composites. International Journal of Fracture, 137(1):139-150, 2006.

[5] N. Feld, O. Allix, E. Baranger, and J. M. Guimard. A micromechanics-based mesomodel for unidirectional laminates in compression up to failure. Journal of Composite Materials, 46(23):2893-2909, 2012.

[6] C. S. Yerramalli and A. M. Waas. A failure criterion for fiber reinforced polymer composites under combined compression-torsion loading. International journal of solids and structures, 40(5):1139-1164, 2003.