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A multiscale damage model for analysis of laminated composites at the micro scale

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ABSTRACT

An increasing number of high-performance applications use composite materials such as laminates. This interest has motivated many research works at different scales, leading to a better understanding and modelisation of degradations. But predicting the evolution of damage up to fracture remains a crucial research topic in the mechanics of composite materials and structures. In the aerospace industry, the use of laminates leads to complex characterization procedures, involving, nowadays, a huge amount of experimental tests. A current challenge is now to substitute these experimental investigations with numerical tools, called ”virtual testing”.
In this context, it becomes essential to increase the confidence in damage prediction. That’s why an hybrid approach named ”A computational damage micromodel for laminated composites” was proposed in [1]. This semi-discrete approach use both micromechanics [2,3] and mesomechanics [4] points of view and then a synergy between them. In this paper, an enhancement of the previous model is proposed, where inelastic behaviours are added. Numerical illustrations obtained with a high-performance computational method is then following, in order to show capabilities of the model.

The proposed damage micromodel requires to define a representative elementary volume called the ”fibre/matrix material”, where a homogenized behaviour is described through a continuum mechanic model. Diffuse damage is introduced thanks to the ”Damage Mesomodel for laminated” [5]. Description of this material is now enriched with viscoelastic and plastic mechanisms. A particularity is the use of effective quantities, in order to get comprehensive but simple models. Therefore, viscosity effects are simply described through a linear Schapery model [6], which takes into account the observed nonlinearity with respect to the stress’ level.
The second part of the model describes the behaviour of minimal cracking surfaces, which are defined between elementary fibre/matrix material volumes. For that purpose, a discrete part is introduced according to the finite fracture mechanics [7]. Thus, microcracking and microdelamination propagation are driven by energy release rate criteria.

The integration of this new micromodel in conventional codes leads to prohibitive numerical

costs. Since every potential crack needs to be represented, an important number of degrees of freedom have to be defined. In this context, a dedicated method, based on a multiscale strategy with space homogenization developed in [6], has been applied. Such a method is suitable for parallel computing and allows to simulate several stacking sequences and shapes, showing a good agreement with observed micro and macrophenomena, from diffuse damage up to localization leading to final failure.

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