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AN ANALYSIS OF DAMAGE ACCUMULATION IN COMPOSITE MATERIALS USING COMPUTATIONAL MICROMECHANICS

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ABSTRACT

The development of accurate tools to simulate the mechanical behaviour until fracture of composite laminates is of obvious practical interest because it helps to reduce dramatically design time, facilitates optimization and cuts down the cost of certification. Simple failure criteria can predict the onset of damage in laminates but they are not enough to predict the maximum strength in laminates which can accumulate damage prior to fracture or which are subjected to very complex stress states (e.g. impact). In these cases, laminate behaviour has been addressed through numerical simulations in which the mechanical behaviour of material points in each ply is controlled by a continuum damage model [1-2]. Damage accumulation is taken into account by reducing progressively the elastic constants at each point according to a set of internal damage variables which depend on the various failure mechanisms.

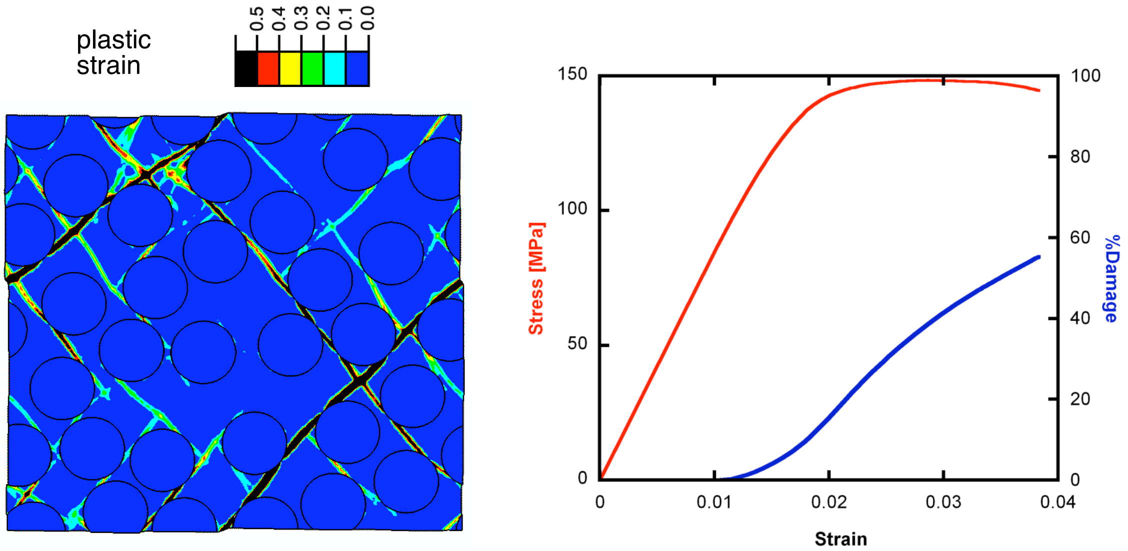
One key ingredient of these damage models is the evolution of the damage variables with the applied load. This parameter is very difficult to estimate experimentally because fiber-reinforced composite lamina usually fails catastrophically under the maximum load and has to be estimated from phenomenological observations or indirect evidence. Nevertheless, it is obvious that the accuracy of the predictions depend on this choice.

Another approach to determine the accumulation of damage during deformation is based on computational micromechanics [3-5]. The mechanical behaviour until fracture of a composite lamina is computed from the finite element simulation of a three-dimensional representative volume element (RVE) of the composite microstructure, which explicitly takes into account the fibers, matrix and interfaces. The actual deformation mechanisms experimentally observed in the matrix and fibers were included in the simulations through the appropriate constitutive equations, while cohesive elements were inserted at the fiber-matrix interface to account for the effect of interface decohesion.

The contour plot of the accumulated plastic strain in the RVE of the composite lamina subjected to transverse compression is in Fig. 1a, showing fracture by the formation of plastic shear bands in the matrix which link up interface cracks. The corresponding stress-strain curve and the evolution of the damage parameter with the applied strain are

plotted in Fig. 1b.

This technique is applied in this paper to determine the evolution of the damage parameter in a composite lamina uniaxially reinforced with 50 vol. % C fibers subjected to different lading conditions which include transverse compression, in-plane and out-of-plane shear. In particular the effect of the matrix and interface behaviour and of the loading mode and lading path are assessed through the use of computational micromechanics.



(a) (b)

Figure1: (a) Contour plot of the accumulated plastic strains in the composite material subjected to transverse compression. (b) Stress-strain curve together with the evolution of damage for the material depicted in (a).

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