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VIRTUAL TESTING OF COMPOSITE LAMINATE COUPONS

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ABSTRACT

Aeronautical certification requires the mechanical characterization of composite materials by means of numerous standard coupons tests such us plain tension, compression, shear, CAI, etc. A large amount of the total time and cost spent for certification is related to mechanical testing and this is particularly the case when material aging under hot/wet conditions should be taken into account. Nowadays, the timeframe for material certification can be reduced through computer-assisted virtual experiments. Computational mesomechanics based on the finite element method has emerged as accurate and robust tools to investigate the mechanical behaviour of structural materials due to its capability to include realistic constitutive equations and damage models and to the increasing power of digital computers [1]. Success in virtual simulation of the mechanical properties of composite materials should be based on an adequate representation of the mesostructure of the composite materials (laminate sequence) and should take into account the main damage mechanisms observed experimentally: intralaminar -lamina failure- and interlaminar failure –delamination- [2].

An example of this methodology is presented in this paper, which presents a simulation of the mechanical behaviour until failure of laminate coupons with different lay-up configurations subjected to uniaxial tension. Each lamina in the laminate is included and discretized explicitly in the model using standard solid brick elements. The lamina behavior is represented by a transversally isotropic linear elastic material in which failure is included using a continuum damage approach [3]. The onset and growth of damage in each lamina is obtained using the LaRC03-04 failure criteria [4] and the relevant parameters –strength and fracture energy- can obtained either by physical testing at the lamina level or/and by means of computational micromechanical models [5]. Interlaminar failure was also taken into account by inserting cohesive elements at the interface between each lamina to include failure by delamination. Simulations were carried out using Abaqus and the intralaminar failure was implemented by means of a user subroutine.

The contour plot of the shear damage variable in a typical multiangular laminate with configuration $[0,\pm45,0,90]_s$ subjected to uniaxial tension is presented in Figure 1a. This plot demonstrates the ability of this methodology to show damage patterns individually

in each lamina and to study the interaction among them during the deformation process. The corresponding stress-strain curve is also plotted in Fig. 1b. The curve is bilinear in shape and a smooth knee at a stress of 600 MPa observed corresponding to the onset of damage at the 90º and 45º plies. After damage is saturated, the response is again linear up to the final fracture due to the failure of the 0º layers. Final failure is due to the localization of damage (fiber breakage and matrix failure) at a certain section of the composite coupon.

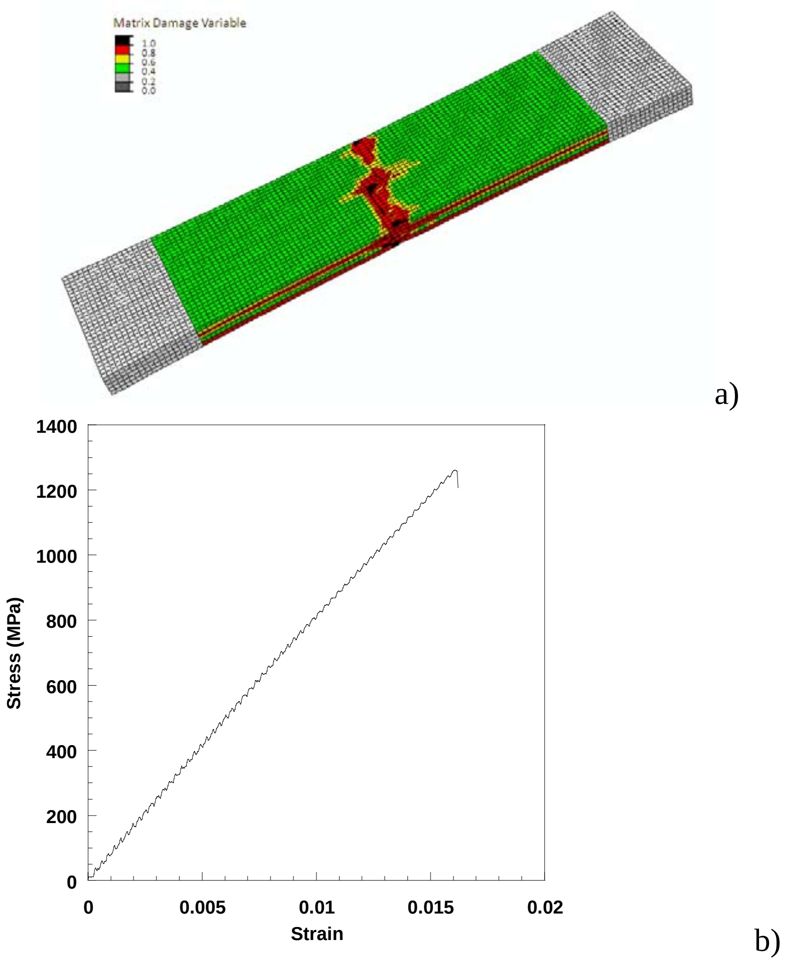

Figure 1: (a) Contour plot of the shear damage variable at the composite coupon subjected to uniaxial tension. (b) Stress-strain corresponding to the model depicted if Figure 1(a).

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