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INTERLAMINAR DECOHESION AND INNER-LAYER DAMAGE IN COMPOSITE STRUCTURES

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ABSTRACT

Laminate composites are widely recognized as mechanically high performance structural components. The number of applications of composite structures is constantly increasing due to low weight and relative high strength, combined with the possibility of tailoring specific mechanical performances choosing number and thickness of each lamina, density and orientation of the fibres, and other design variables.

Beside the unquestionable positive features of laminate composite elements, some concerns could be revealed by the failure modes displayed. In fact, if traditional metallic components show a rather safe ductile failure mode, laminate elements usually display a brittle or quasi-brittle collapse mode. It is then of paramount relevance to understand and model the post elastic behaviour of laminate composite elements.

Experimental observations show that delamination is the dominant failure mechanism of composite elements and, according to [1] two main mechanical nonlinear deformation modes drive delamination. The two aspects which are involved in the delamination process are the interlaminar interfacial deterioration and the diffuse or localized inner-layer damage phenomena.

The paper deals with the finite element modelling of these two competing and coupled nonlinear deformation modes.

The inner-layer effects are modelled by a continuum elastic-damage material model which takes into account the diffused and localized transversal microcracks, fibre breakage and other degradation phenomena taking place inside the lamina layer. The elastic-damage model employed in the analysis is a variation of the model proposed by the authors in [2]. In order to maintain a well posed problem and avoid mesh sensitive results an integral nonlocal approach is adopted with a specific intrinsic internal length parameter.

The interlaminar deterioration is instead modelled by an elastic-damage with frictional residual strength interface model. The interface model, proposed by the authors in a general setting in [3], is able to describe the localized decohesion process which develops along a surface connecting adjacent layers. On the contrary of the most diffused interface models, the one adopted is able to describe the smooth transaction from cohesive to frictional behaviour. The interface model is similar to the one

proposed in [4] but with some refinements which make the interface model fully thermodynamically consistent.

A single academic example is reported, simulating a four-layers composite beam subjected to a four point bending test, schematically represented in figure 1. In figure 2 the load displacement curve, carried out be the numerical simulation, is reported. Figure 3a plots the damage patters at the maximum load condition and it shows two damage localization bands crossing the first two laminas. The macrocracks represented by the damage bands stops on the second lamina and do not propagate over it. In fact, an interlaminar decohesion phenomena begins between the second and the third laminas and, subsequently, it also begins between the third and the fourth laminas. The mechanical process develops with two damage localization bands, crossing the third and the fourth laminas, as shown in figure 3b.

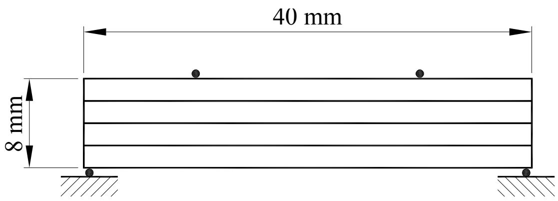

Figure 1: Four point bending test of laminate composite.

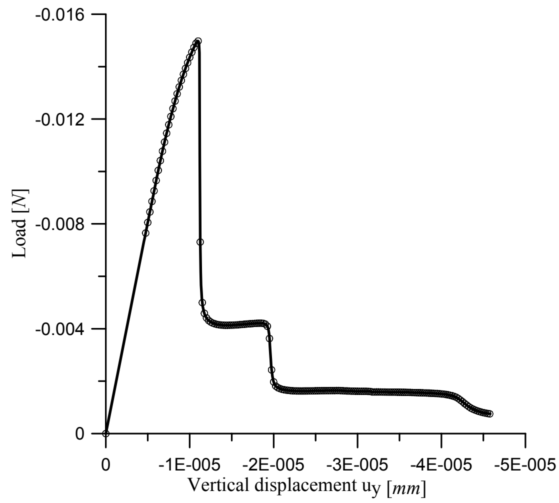

Figure 2: Load displacement curve

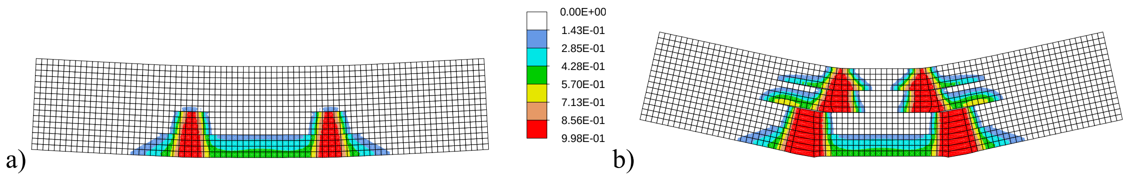

Figure 2: Damage patters, a) maximum loading condition, b) failure loading condition.

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