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An enhanced beam model of the Asymmetric Double Cantilever Beam (ADCB) test for composite laminates

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The Asymmetric Double Cantilever Beam (ADCB) test is a generalisation of the standard DCB test, where the two arms of the specimen are made of different materials and/or have different thicknesses. The test is suitable for assessing the mixed-mode delamination toughness of laminated composites, as well as the mixed-mode fracture toughness of adhesively bonded joints [1,2].

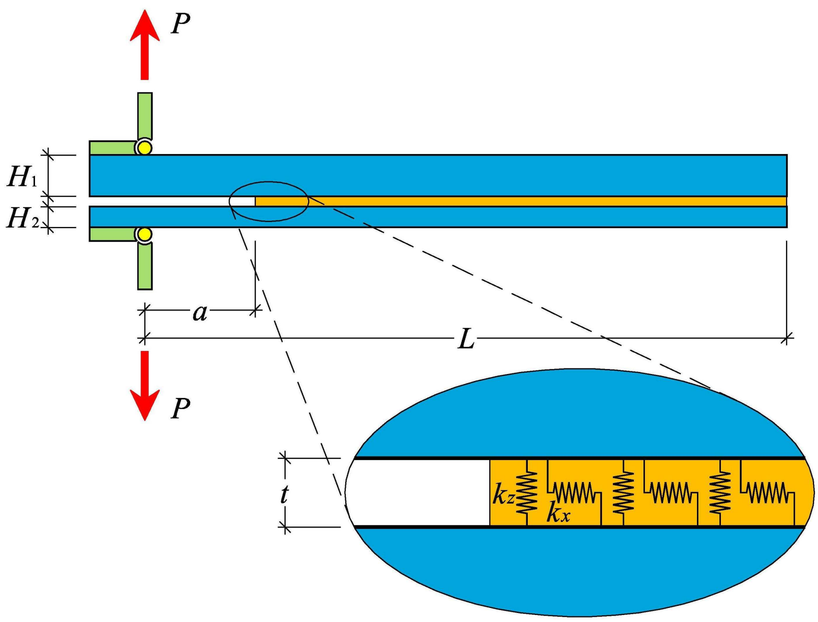

Fig. 1 : The mechanical model of the ADCB test.

The present paper introduces a mechanical model of the ADCB test (fig. 1) for composite laminates. The specimen is considered as an assemblage of two sublaminates partly bonded together by an elastic interface, thus generalising an idea originally suggested by Kanninen [3]. Although the proposed model is based on a beam theory approach, however a number of enhancements are introduced with respect to simpler models available in the literature [4,5] and in previous works by the authors themselves [6]. The sublaminates are modelled as elastic orthotropic beams whose bending, extension and shear deformability are taken into account. In particular, shear deformability is relevant since the mechanical behaviour of composite materials is to be described. The interface consists of a continuous distribution of linear elastic springs, acting along both the normal and tangential directions with respect to the laminate plane. The elastic reactions are proportional to the relative displacements evaluated between the internal surfaces of the bonded portions, and represent the interlaminar stresses exchanged between the two sublaminates. Consequently, the sublaminates

are subjected to distributed loads, and also to distributed couples due to the eccentricity of the reactions of the tangential springs with respect to the axes of the sublaminates.
A set of six differential equilibrium equations based on Timoshenko's beam theory, endowed with suitable boundary conditions, governs the problem for the internal forces of the two bonded sublaminates. By introducing the constitutive laws and by carrying out some analytical manipulations, we arrive at a set of two differential equations where the unknown functions are the normal and tangential interlaminar stresses, σ and τ, respectively. These two equations can be transformed into a single differential equation of higher order for the normal stress σ only. This equation can be solved by standard methods, so analytical expressions for σ and τ are determined. Consequently, the Mode I and Mode II contributions to the energy release rate, G, are deduced. Finally, also explicit expressions for the internal forces and the compliance, C, are obtained.
As far as the integration constants are concerned, although they could be deduced analytically, we find more convenient to calculate their values by solving numerically a set of algebraic equations, which represents the boundary conditions for the ADCB test. In this way, through our model we are able to calculate all the quantities having a mechanical interest, for any ratio of thicknesses and stiffnesses of the bonded sublaminates. For the sake of illustration, Fig. 2 shows the normal and tangential interlaminar stresses as functions of the distance from the delamination front, x, for three ratios of the number of plies of the two sublaminates (16:24, 16:32, and 16:64).
A very good agreement is found between the theoretical predictions of the model and the results of numerical models and experiments reported in the literature.

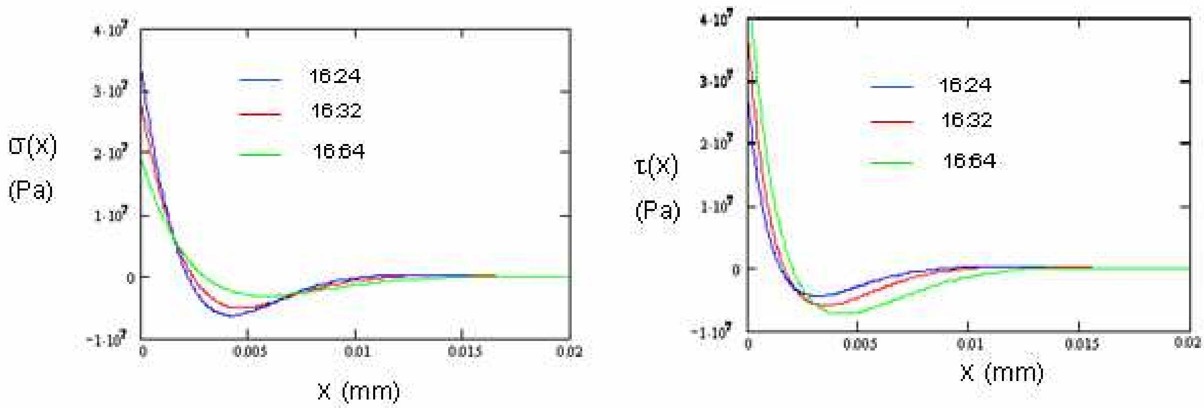

Fig. 2 : Normal and tangential interlaminar stresses.

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