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SIMULATIONS OF DAMAGE IN CROSS-PLY LAMINATES UNDER TENSILE FATIGUE: EFFECT OF MICROSTRUCTURAL RANDOMNESS

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ABSTRACT

Damage accumulation in composite materials is a progressive, multi-mechanism process [1-4]. Cross-ply laminates, subjected to mechanical loading, demonstrate different failure modes: transverse matrix cracking in 90º plies, delamination between 0º and 90º plies, longitudinal matrix cracking, which develops along the fibre direction of 0º plies, and fibre fracture in 0º plies. The most important damage mechanisms that usually develop first in such laminates are transverse matrix cracking and delamination failure.

Transverse matrix cracking reduces the effective strength and stiffness of laminates and is mostly experienced at any early stages of loading. Matrix cracks serve as initiation points for a cascade of events that lead to failure, so understanding of transverse cracking is necessary for predicting long-term durability of laminates. Transverse cracks induce local stress concentration at their tips and can initiate interlaminar delamination between 0^{o} and 90^{o} plies due to the mismatch of the Poisson's ratios and in-plane shear stiffness between differently oriented plies.

Finite-element simulations are carried out to model the interaction between these damage mechanisms in CFRP composites in order to evaluate its effect on the overall behaviour of laminates subjected to tensile fatigue loading. The microstructural randomness exhibited by these laminates is accounted for since it is responsible for non-uniform distributions of stresses in them even under uniform loading conditions. This is achieved by using random fracture properties within the layer of cohesive elements, used to model damage in laminates. A three-dimensional finite element model is developed incorporating anisotropic material properties of the laminate. Input parameters required for the implementation of cohesive zone (CZ) modelling approach are obtained from the tests on double cantilever beam (DCB) specimens for mode I and

mixed-mode flexure tests for combined modes I & II. Several sensitivity studies are performed with a view to analyse the effects of mesh density, the number of CZ layers, and of parameters of the cohesive law on the damage propagation in the laminates.

In order to highlight the effect of microstructure randomness in carbon fibre-reinforced laminates, a DCB specimen is simulated (Fig. 1) by varying the cohesive properties such as tripping traction and initial stiffness of the cohesive law within the cohesive layer. This results in the variation in the level of damage within the cohesive layer.

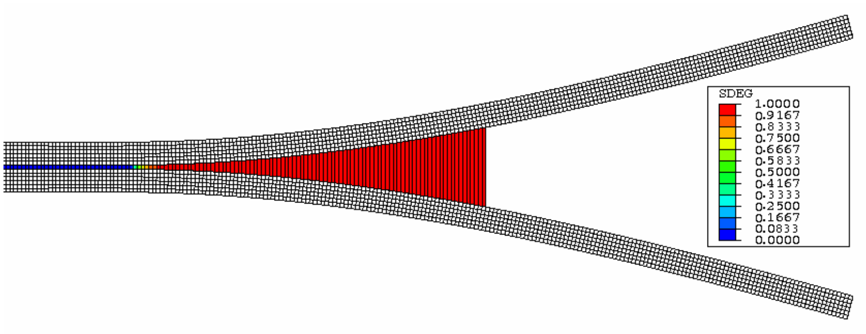

Figure 1. Finite-element analysis of damage evolution in DCB specimen

The results of computational analysis are compared with experimental results and an analytical solution of the problem.

REFERENCES

[1] V.V. Silberschmidt, "Crack propagation in random materials: computational analysis", *Comput. Mater. Sci.*, Vol. **26**, No. 1, pp. 159-166, (2003).

[2] V.V. Silberschmidt, "Matrix cracking in cross-ply laminates: effect of randomness", *Compos. A*, Vol. **36**, pp. 129–135, (2005).

[3] V.V. Silberschmidt, "Multiscale modelling of cracking in cross-ply laminates". *Multiscale Modelling of Composite Material Systems: The Art of Predictive Damage Modelling*. C. Soutis, P.W.R. Beaumont (eds.). Cambridge, Woodhead Publishing, pp.196-216, (2005).

[4] V.V. Silberschmidt, "Effect of micro-randomness on macroscopic properties and fracture of laminates", *J. Mater. Sci.*, Vol. **41**, pp. 6768–6776, (2006).