FINITE ELEMENT MODELLING OF CRACK GROWTH IN COMPOSITES

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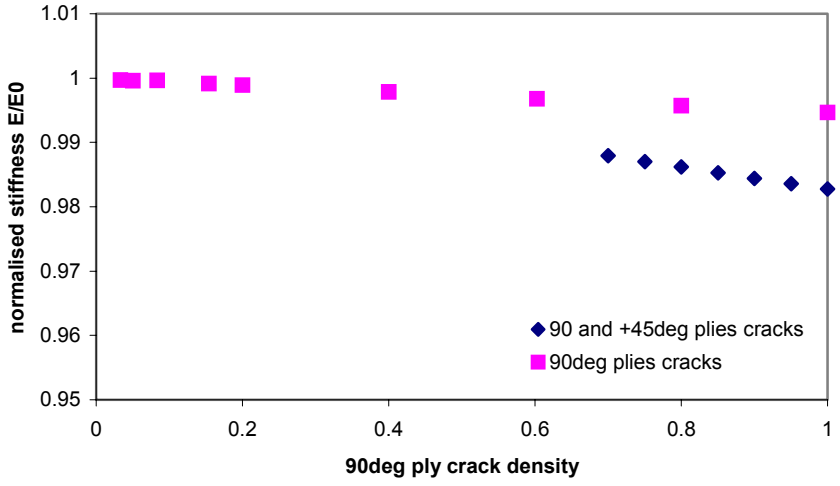
Composite materials are very attractive in terms of stiffness to weight and strength to weight ratios. Barriers to the wider use of these materials include the lack of appropriate physically-based design methodologies allowing for the progressive damage occurring under service conditions. Catastrophic failure in continuous fibre reinforced composite laminates is typically preceded by the initiation and growth of intralaminar transverse matrix cracks, leading to more severe damage like delamination. Matrix cracking degrades mechanical properties under quasi-static or cyclic loading.

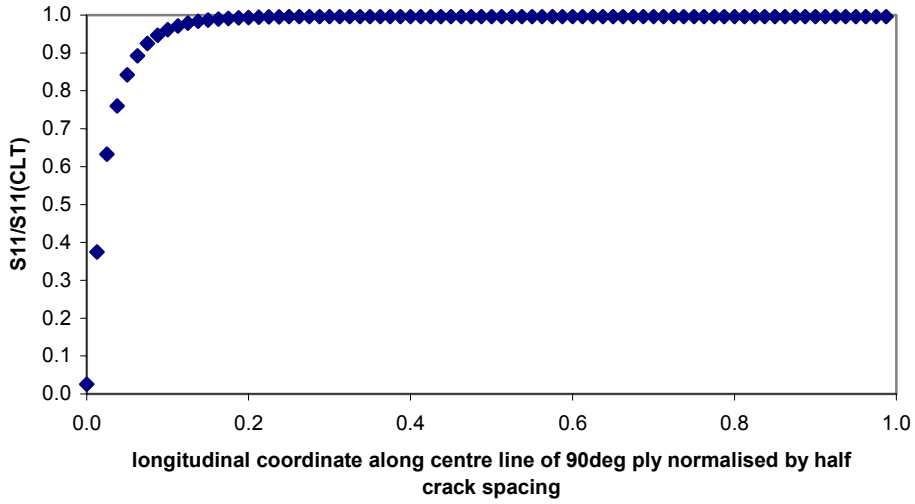
Simulations of cracked laminates involve the analysis of a "unit cell" of the specimen after experimental observations of the crack densities and their geometries. Submodelling techniques around cracks are used. The overall properties (stiffness and Poisson's ratio) are extracted from uncracked models and compared with results expected from Classical Lamination Theory (CLT).

Overall laminate properties as well as stress distributions at locations of interest are then extracted from the cracked models. The following figure shows the stiffness loss occurring in a CFRP laminate of ply thickness 0.125 mm.



1. Stiffness loss normalized by stiffness of intact laminate in quasi-isotropic CFRP laminate after quasi-static loading.

The longitudinal stress as a function of longitudinal distance along the middle of the cracked layer is shown in the figure below. The stress profile corresponds to a crack spacing of 5mm and indicates that the value of S_{11} for a non cracked laminate is reached within 1% at a normalised distance of 0.175, which means that the stress is recovered for a ratio of crack spacing over ply thickness (0.125mm) above 14. For a crack spacing below 1.75 mm, stress shielding occurs and the stress value for a non-cracked laminate is not recovered between cracks.



2. Profile of normalised longitudinal stress along the centre line of the 90° ply for a crack spacing of 5 mm.

Comparison is made with experimental measurements. The effect of thermal strains is also looked at and the crack opening displacement measured experimentally compared with the value given by the simulation.

Matrix crack growth is also investigated via the technique of virtual crack growth that gives the strain energy release rate components from local forces and displacements at the crack tip.

Finally, delaminations are added around cracks and their growth simulated.

References

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