FEM implementation of the minimization of the total energy subjected to a stress condition to predict delaminations in ILTS tests

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Inter-Laminar Tensile Strength (ILTS) test uses L-shaped composite coupons with laminas having different orientations. In the present investigation, this mechanism is modelled using a quite general formulation of the Coupled Criterion of Finite Fracture Mechanics (CCFFM) [1] applied to the Lineal Elastic Brittle Interface Model [2] (CCFFM + LEBIM) [3] based on the Principle of Minimum Total Energy subjected to a Stress Condition (PMTE-SC) [4].

The PMTE-SC, employing a load-stepping procedure, minimizes the total energy functional, the sum of the potential and dissipated energies, in the feasible region of all possible new crack configurations given by the stress criterion, in each load step. A great advantage of PMTE-SC is that the total energy is separately convex in displacements and damage variable. This feature allows solving convex optimization problems separately in terms of displacements and damage variable in each load step, which makes this procedure very robust and efficient especially if a suitable staggered scheme of minimization is applied. In the literature similar staggered schemes are also referred to as Alternate Minimization Algorithm (AMA) [5]. The PMTE-SC with a suitably modified AMA has been implemented in a Python script using the commercial FEM code Abaqus.

In the ILTS test, a four-point bending test tool applies a purely bending load to the curved part of the specimen. For this purpose, the test includes four freely rotating rollers in contact with the specimen.

In these tests, microcracks appear first, which after their coalescence produce intralaminar failure. This failure propagates in an instable manner in the form of delaminations, this type of instability is known as snapback. In fact, almost instantaneous delaminations occur at the remaining interfaces, so it is not trivial to determine the point or points at which failure initiates. To capture this unstable appearance of the damage, the experimental test should allow the simultaneous reduction of the load and the displacement. In classical numerical simulations, this behavior manifests itself in the form of convergence problems due to sources of model nonlinearities, thus the use of a robust numerical tool is needed.

Preliminary calculations carried out by means of the code implementing PMTE-SC with the modified AMA have shown that this code is an adequate tool to predict onset of multiple delaminations in the ILTS specimens.

References

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