Cohesive modelling of mixed-mode delamination with internal friction

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Abstract This work is devoted to the formulation of a new cohesive law for the modelling of mixed mode delamination. The proposed model is based on the physical observation that the failure of many interfaces is characterized by the competition between different mechanisms under dominant shear or tensile stresses, which is not usually taken explicitly into account in damage cohesive models (see e.g. [1-4]). A notable exception is e.g. the work in [5], where a multiscale frictional model is proposed, accounting for friction under normal tensile tractions and shear at the microscale.
In the proposed cohesive model, internal friction is accounted for at the macroscale with a phenomenological approach, based on the definition of two damage modes. A three-surface activation criterion, characterized by an internal friction angle (figure 1), is defined in the normal and shear tractions plane: each one of the three normals to the domain defines a distinct damage mode. A decomposition of the strain energy release rate in terms of the three damage modes is achieved in a natural way by projecting the cohesive tractions onto the three normals. The mixed-mode fracture energy is the result of the interaction among modes, without the need to define an empirical law for its evolution with mode mixity.
Several numerical examples are simulated in order to validate the proposed interface law in both pure mode and mixed-mode delamination problems. In particular, the comparison between the numerical results and the experimental data of Mixed-Mode Bending (MMB) tests [6] is shown.

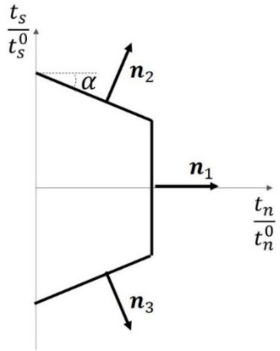

Fig 1 Three-surfaces activation domain in tractions compenents space.

REFERENCES

[1] **O. Allix, A. Corigliano,** *Modeling and simulation of crack propagation in mixed-modes interlaminar fracture specimens,* International Journal of Fracture, **77**, 111-140, 1996.
[2] **M.J. Van den Bosch, P. J. G. Schreurs, M. G. D. Geers,** *An improved description of the exponential Xu and Needleman cohesive zone law for mixed-mode decohesion,* Engineering Fracture Mechanics, **73**, 1220-1234, 2006.
[3] **P. P. Camanho, C. G. Dàvila, M. F. de Moura**, *Numerical Simulation of Mixed-mode Progressive Delamination in Composite Materials,* Journal of Composite Materials, **37**, 1415-1438, 2003.
[4] **K. Park, G. H. Paulino, J. R. Roesler**, *A unified potential-based cohesive model of mixed-mode fracture,* Journal of the Mechanics and Physics of Solids, **57**, 891-908, 2009.

[5] **R. Serpieri, E. Sacco, G. Alfano**, *A thermodynamically consistent derivation of a frictional-damage cohesive-zone model with different mode I and mode II fracture energies,* European Journal of Mechanics - A/Solids, **49**, 13-25, 2015.
[6] **M.L. Benzeggagh, M. Kenane**, *Measurement of mixed-mode delamination fracture toughness of unidirectional glass/epoxy composites with mixed-mode bending apparatus*, Composites science and technology, **56**, 439-449, 1996.