ESMC 2018 BOLOGNA
UNIVERSITÀ DI TRENTO
ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA
BOLOGNA July 2-6, 2018 | Palazzo dei Congressi
EUROPEAN MECHANICS SOCIETY
ESMC 2018
10th European Solid Mechanics Conference

MS: 3-8 - Recent advances in damage mechanics

An isotropic damage cohesive formulation for mixed-mode delamination

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Keywords: mixed-mode delamination, cohesive model, isotropic damage

The concurrent presence of normal and shear interlaminar stresses often characterizes the delamination growth, leading to mixed-mode loading conditions. In this work, an isotropic damage cohesive law is formulated for the numerical simulation of mixed-mode delamination problems with variable mode ratio. The proposed model is based on the identification of three main damage modes, defined by three directions in the tractions $t_n - t_s$ plane, one associated to mode I opening, and the other two symmetrically inclined with respect to the normal direction, with an angle of inclination that plays a role similar to a parameter of internal friction and governs the interaction between the modes. The projection of the interface tractions and openings onto the three damage modes allows in a straightforward way for an additive decomposition of the strain energy release rate into the three driving forces individually acting on each one of the damage modes.

A number of experimental works on composite materials (see, e.g., [1]) show that the fracture energy significantly grows in passing from pure Mode I to pure Mode II, as a result of different micromechanical mechanisms involved in the delamination process. The proposed cohesive model does not require any assumptions on the evolution of the fracture energy with the mode-mixity and is able to capture the non-monotonic increase of fracture energy for increasing mode ratio without the need of introducing any empirical laws [2], in contrast to what is currently done in most models [4]. The formulation has been developed in a thermodynamically consistent framework, so that the model does not require any assumptions on the loading path [3]. The numerical simulation of several mixed-mode delamination tests is presented, mainly focusing on the results of Mixed-Mode Bending (MMB) tests [4].

References

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