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A Mixed-Mode Delamination Model Accounting for Large Openings and Fiber-Bridging

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ABSTRACT

When large openings or extensive fiber- bridging phenomena are involved, classical cohesive models formulated under the assumption of small relative displacements often fail to predict the delamination growth. In the presence of large openings, the rotational equilibrium of the cohesive element is not satisfied [1], while the development of large scale fiber-bridging sensibly enhances fracture energy [2]. This effect, mainly governed by the normal opening, has been experimentally observed in several DCB tests performed on fiber-reinforced composites and is described in terms of R-curves, expressing the progressive growth of the toughness up to a steady-state value. In this work the isotropic damage cohesive model formulated in [3] under the assumption of small openings is extended to properly model both the cases of small and large openings and the presence of large-scale bridging or interfacial fibrillation. The considered cohesive model is specifically conceived for the case of mixed-mode delamination with variable mode ratios. Since the fiber bridging is mainly induced by mode I loading conditions, two distinct traction-separations laws are introduced for Mode I and II. A classical bilinear traction-separation law is adopted in pure Mode II, while the traction separation law in pure Mode I is, instead, characterized by a trilinear softening branch, consisting of an initial linear branch, followed by a plateau and by a second linear branch up to complete decohesion. Assuming that the fiber bridging occurs when the plateau is reached allows formulating a simple activation criterion that can be generalized also to mixed-mode conditions. To account for the transition from small to large openings, the classical interface element is substituted with a fibril element, whose constitutive behaviour is defined such that no discontinuity in the dissipated energy or in the transmitted cohesive tractions is introduced. As shown in [2], this kind of elements is able to account for large openings in a consistent way, since the interface tractions and openings are colinear. [1] Vossen, Schreurs, van der Sluis, Geers, On the lack of rotational equilibrium in cohesive zone elements, Computer Methods in Applied Mechanics and Engineering, 254, 146-153 (2013) [2] Dàvila, Rose, Camanho, A procedure for superposing linear cohesive laws to represent multiple damage mechanisms in the fracture of composites, International Journal of Fracture, 158, 211-223 (2009) [3] Confalonieri, Perego, A mixed-mode cohesive model for delamination with isotropic damage and internal friction, Proceedings of the sixth ECCOMAS Thematic Conference on the Mechanical Response of Composites (2017)