Mode decoupling versus mode partitioning to determine pure-mode fractures in unconventional specimens

Panayiotis Tsokanas [1], Paolo Fisicaro [2], Paolo S. Valvo [2], Lucas F. M. da Silva [3]

[1] Department of Mechanical Engineering and Aeronautics, University of Patras, Greece
[2] Department of Civil and Industrial Engineering, University of Pisa, Italy
[3] Department of Mechanical Engineering, Faculty of Engineering, University of Porto, Portugal

panayiotis.tsokanas@gmail.com

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Abstract: There is a growing research and industrial interest in determining the interfacial fracture toughness of non-traditional material systems such as dissimilar adhesive joints, asymmetrically stacked composite laminates (possibly with an elastically coupled behavior), fiber metal laminates, and thin laminates with adhesively bonded backing beams. To determine the interfacial toughness of such material systems, laboratory coupons are extracted that inherently feature a material asymmetry w.r.t. the crack plane. Because of this asymmetry, which introduces mode mixity even if the specimen is loaded in pure mode, we here call those specimens *unconventional*.

To characterize the pure-mode fracture toughnesses of unconventional specimens, researchers attempt to decouple fracture modes I and II (and III, if present) through an appropriate design of the specimens. Emphasis has been given to the case of a bi-material adhesive joint under pure-mode I loading, where two decoupling conditions have been proposed in the literature: (a) mode decoupling is achieved when the differential equation of the mode I (mode II) fracture is only governed by the interfacial normal (shear) stress and relative transverse (axial) displacement [1]; (b) mode decoupling is achieved when the bending rigidities of the two adherents are equal [2]. Those two conditions are translated into the design formulae $E_1h_1^2 = E_2h_2^2$ and $E_1h_1^3 = E_2h_2^3$, respectively, where E_i and h_i are the Young's modulus and thickness of adherent i, $i \in \{1,2\}$, respectively. Our presentation will review the existing decoupling conditions and discuss their correctness.

Mode decoupling is impossible for a coupon with pre-defined material properties and thicknesses that cannot be tailored using the above design formulae. In addition, in the presence of residual thermal stresses, common for layered material systems, decoupling conditions are not available in the literature. An appropriate mode partitioning scheme can be selected in such cases to determine the modal contributions to the energy release rate. During the last three decades, several mode partitioning methods have been proposed, which could be classified into four families [3]: methods based on a rigid interface and the beam theory; methods based on linear elastic fracture mechanics; elastic-interface methods; and miscellaneous methods. In our presentation, we will review those methods and emphasize two models we have proposed [4,5] that can consider the effects of bending–extension coupling and residual hygrothermal stresses.

References:

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