Scale transition methodologies for effective cracks in composite materials

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ABSTRACT

In a hierarchical multiscale approach for fracture, the macroscopic representation of a large collection of micro-cracks requires fulfillment of the Hill-Mandel scale transition relation such that the total amount of energy dissipated is the same whether it is described in detail with micro quantities or in terms of an effective crack. To satisfy this relation, various scale transition approaches have been proposed in the literature. In particular, it was shown in [1, 2] that a combination of crack surface-based and volume-based averaging schemes provide a suitable representation of the effective crack. Nonetheless, in composite materials with a strong contrast in fracture properties (e.g., matrix and fibers), the scheme may fail to guarantee a proper scale transition when multiple fracture mechanisms are interacting.

In the present work, alternative scale transition methodologies are proposed and compared. In the first kinematics-based approach the macroscopic crack opening is obtained as a surface average of microcrack openings while the traction is computed from the scale transition requirement. Conversely, in the second kinetics-based approach, the macroscopic traction is determined as a surface average of microcrack tractions while the effective crack opening is set by the scale transition requirement. Though both methods satisfy the Hill-Mandel condition, they provide distinct effective traction-separation relations.

Several representative cross-sections are analyzed, corresponding to cracks at mid-ply locations as well as ply interfaces of a fiber-reinforced composite. Through post-processing of the results, it is shown that the kinematics-based averaging (first method) provides a macroscopic traction that it is prone to rapid fluctuations while the kinetics-based averaging (second method) shows a more smooth response but with openings that can deviate significantly from the surface average of the microscale openings. The suitability of each method is discussed in light of these findings.

REFERENCES

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