The Prediction of the Crack Propagation Direction According to the Criterion of Maximum Energy Dissipation

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An efficient tool is presented to predict the behavior of cracks in all kinds of multi-phase or composite materials where the material properties exhibit a spatial variation. Based on the material (or configurational) force approach, this tool accurately computes the crack driving force and the crack growth direction in inhomogeneous elastic or elastic-plastic materials.

The local crack driving force vector $\mathbf{J_{tip}}$ is evaluated as a vector sum of the far-field J-integral vector $\mathbf{J_{far}}$ and the so-called material inhomogeneity term vector, $\mathbf{C_{inh}}$. The latter term quantifies the crack tip shielding or anti-shielding effect of the material inhomogeneities. For example, an increase of the elastic modulus or the yield stress in the direction of crack extension induces a negative material inhomogeneity term which provides a shielding effect [1,2]. The components of the vector $\mathbf{J_{far}}$ are evaluated using a conventional J-integral evaluation procedure by assuming virtual crack extensions in two different directions, e.g., along and perpendicular to the direction of a pre-existing crack. The components of $\mathbf{C_{inh}}$ are evaluated by a post-processing procedure after the conventional finite element stress analysis [1,2]. In accordance with the criterion of maximum energy dissipation [3,4], the crack extension follows the direction of the local crack driving force vector $\mathbf{J_{tip}}$.

The procedure allows us to take into account smooth material property variations as they occur, e.g., in functionally gradient materials, as well as jumps of the material properties at sharp interfaces between two different components. The effect of residual stresses can be also accounted for. To demonstrate the ability of the procedure, it is applied to specimens containing sharp bimaterial interfaces with different orientations with respect to the crack. Elastic and elastic-plastic bimaterials are considered, as well as a variation of only the Young's modulus, of only the yield stress, and the simultaneous variation of both material parameters. The results of the model are compared to the results of different other criteria known from literature, such as the maximum tangential stress criterion or the minimum strain energy density criterion. It is shown that in some cases large discrepancies between the different criteria appear.

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