Quantifying the interplay amongst fracture, heterogeneities, plasticity and process zone

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Abstract

The physics of fracture in heterogeneous or composite materials is often linked with how cracks interact with the constituent phases (or inclusions). A matrix crack approaching a stiffer inclusion will experience a shielding effect (a reduction in the crack driving force), whereas an anti-shielding effect is experienced if the inclusion is softer (lower elastic modulus) than the matrix. Despite a long history of research into crack-inclusion interactions, there appears to be a very limited study on the interplay amongst physical processes and parameters such as plastic yielding, stiffness mismatch, and the evolution of fracture process zone in a composite material. The current research will address the gap by explicitly quantifying such interactions on the crack driving force. For this purpose, crack propagation in a simplified inclusion-matrix system is modeled using the eXtended Finite Element Method (XFEM) in the context of the cohesive zone approach. The crack driving force parameters associated with the elastic mismatch and the plastic yielding in inclusions are quantified using configurational force integrals. While the crack growth is governed by maximum principal stress, the crack direction is controlled using maximum energy dissipation criteria. Specific emphasis is placed on revealing the competing/synergistic effects of plasticity and stiffness mismatch in the presence of varied fracture process zone lengths. The results are qualitatively correlated with the strengthening and toughening mechanisms in composite materials, which, in turn, guide fracture-resistant microstructure design. The study provides insights into the gaps in understanding one of the fundamental interaction problems in fracture mechanics.

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