Microstructural Effects in Brittle Fracture with the Extended Finite Element Method

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Abstract

A two-dimensional numerical model of microstructural effects in brittle fracture is presented, with an aim towards the understanding of fracture in materials with an arbitrary distribution of phases and microstructure. The eXtended Finite Element Method (X-FEM) [1] in conjunction with a grain growth microstructural evolution model (Pott's model framework) is used in the simulations to predict the mechanical response and fracture behavior of materials. In the X-FEM, a discontinuous function and the two-dimensional asymptotic crack-tip displacement fields are added to the finite element approximation to account for the crack using the notion of partition of unity. This enables the domain to be modeled by finite elements with no explicit meshing of the crack surfaces. The microstructural calculations are carried out on a regular lattice and mapped onto the finite elements; the grain boundaries of the microstructure do not coincide with the edges of the finite element. The critical fracture energy (G_c) of the grain boundary is assumed to be different from that of the bulk material. The crack growth criterion in the bulk is governed by the maximum hoop stress criterion, whereas along the grain boundary, the growth direction is determined by testing the maximum hoop stress direction to that along the grain boundary and selecting the one that has a greater G/G_c. Uniaxial strain loading conditions in the x_1-direction is used. The upper and lower-surfaces are assumed to be traction-free, and an initial defect (crack) is introduced in the specimen. Brittle fracture is investigated by carrying out computer simulations for varying bulk and grain boundary fracture energies, and the inter-play between intergranular and transgranular modes of crack growth is studied. The ease and capability of modeling the propagation of arbitrary defects through a microstructure is realized, which opens-up many exciting avenues for future research in the realm of fracture in functionally-graded materials.

References

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