The Effect of Material Inhomogeneity at Mesoscale on Macroscopic Dynamic Fracture Response

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Abstract

We consider two different material models to study the effect of inhomogeneity at the mesoscale on macroscopic fracture response. First, we assume the material is homogeneous. Second, we use a Voronoi-tessellation partition to form *Statistical Volume Elements* (SVEs). We analyse these SVEs under three loading conditions to determine the normal and shear fracture strengths of the SVEs. After deriving the statistical properties of the SVEs, such as their probability distributions of fracture strength and two-point correlation functions, we use the Karhunen-Loeve method to derive statistically consistent fracture strength fields at the mesoscale.

We compare the fracture response of the two models under uniform tensile loading. We show that the concept of dynamic fragmentation of homogeneous materials is not physical in that fractures would form instantaneously across the entire domain when the load reaches the material strength. In contrast, cracks nucleate at discrete weak points in inhomogeneous material models. The propagation of these initial cracks would generate a highly nonuniform stress field that, along with the inhomogeneous fracture strength field, would produce more realistic fracture patterns. We obtain commonly observed features of dynamic fracture, such as crack-path oscillation, microcracking, and crack bifurcation, in simulations based on the inhomogeneous model.

We study the effects of certain loading and material parameters on macroscopic fracture patterns using an interfacial damage model [2]. For loading, we consider parameters related to loading rate and load biaxiality. We also study the influence of a mesoscopic fracture-energy parameter that depends on a relaxation time in the interfacial damage model. We obtain distinct fracture patterns and homogenized macroscopic stress–strain responses for different loading and material combinations.

Finally, we explore the influence of the finite element discretization on fracture response. We demonstrate that the degree of mesh refinement, the mesh type (structured versus unstructured), and whether the mesh is fixed or adaptive affects the macroscopic fracture pattern, ultimate load, and dissipated energy. One of our interesting findings is that macroscopic dissipated fracture energy is relatively insensitive to increasing mesh refinement beyond a certain level of refinement.

References:

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