Effect of the spatial inhomogeneity of fracture strength on fracture pattern for quasi-brittle materials

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The response of brittle and quasi-brittle materials is greatly influenced by their microstructural architecture. Models that assume material properties, particularly fracture strength, are spatially uniform fail to capture two important aspects of fracture in quasi-brittle materials. First, spatial variability in material properties greatly influence developed fracture patterns as weaker points act as seeds for crack nucleation. The cracks that initially propagate induce stress concentration and shield neighboring regions, resulting in a highly nonuniform stress field and types of fracture pattern observed experimentally. On the other hand, a model with spatially uniform strength can predict very nonphysical responses, for example simultaneous failure of all points under spatially uniform and temporally increasing stress field. Second, the influence of microscale defects on fracture response and their variability from sample to sample explain the scatter in macroscopic measures such as ultimate load and absorbed energy upon complete failure of a sample.

In this work, we assume fracture strength to be a random field. We use the Karhunen-Loeve method to realize random fields that are in turn obtained by some assumed first and second moments for the underlying fracture strength. We derive these moments by obtaining fracture strength of stochastic volume elements (SVEs) and using the moving window approach for a material with randomly distributed microcracks. Next, we study the effect of microscale randomness on induced fracture patterns. We investigate how certain features of the random field, including its point-wise probability distribution function, the spatial correlation length scale, and the size of SVE used for homogenization, affect the predicted fracture patterns. We use the asynchronous spacetime discontinuous Galerkin (aSDG) finite element method for our dynamic fracture simulations for domains where fracture strength is realized based on the aforementioned statistical approaches. We use initial and boundary conditions that correspond to a spatially uniform and temporally increasing stress field. This loading most clearly demonstrates the effect of material inhomogeneities on fracture patterns; unlike crack propagation from existing sources of stress concentration, e.g. crack tips, crack nucleation locations and to some extend crack propagation directions are highly affected by the underlying realized random fields.