Fracture analysis of a quasi-brittle material based on a random field representation of micro-cracked domain

Reza Abedi, Philip L. Clarke, Omid Omidi, Pavan Kumar

Mechanical, Aerospace & Biomedical Engineering, University of Tennessee Knoxville (UTK) / Space Institute (UTSI), 411 B. H. Goethert Parkway, Tullahoma, TN 37388

The material failure and post-instability response is greatly influenced by the microstructural architecture and energy absorption mechanisms; for ductile materials large inelastic deformations re-balance microscale stress field and retard fracture while for brittle and quasi-brittle materials–e.g., bone, concrete, rocks, high explosives, beryllium alloys, ceramics, and many composites–even the same geometry and loading condition can give quite different fracture patterns. The high dependence of their fracture progress on microstructural defects results in wide scatter in their ultimate strength and the so-called size effect.

Our approach for incorporating randomness in quasi-brittle materials is based on the modeling of stochastic volume elements (SVEs). Representative volume elements (RVEs) are commonly used in practice to homogenize the properties of materials with different constituents at microstructure. However, the sizes of RVEs are intentionally chosen large enough so that the homogenized values such as elastic moduli are spatially uniform for a statistically homogeneous material. The use of SVEs in this work ensures that the material randomness is maintained upon “averaging” of microscale features. To create the random field we generate several realization of a material, for example by having a certain overall crack density. By choosing the center of SVEs at a given spatial position on these random realizations and using the moving window approach, where the center of SVE translates in these random realizations, we obtain first and second moments of the target random field. We employ the created random field for the fracture simulation of brittle materials. We use the spacetime discontinuous Galerkin finite element method for our dynamic simulations. Cracks can nucleate from any spatial position based on the corresponding fracture strength, which in turn is obtained from the SVE analyses of microcracked domains.