Fracture modeling of rocks based on random field generation and simulation of inhomogeneous domains

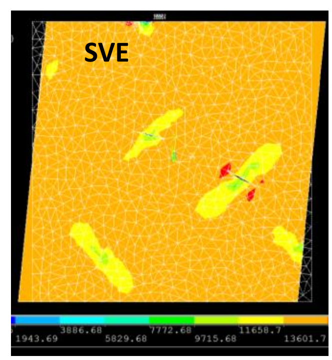
Philip L. Clarke, Reza Abedi

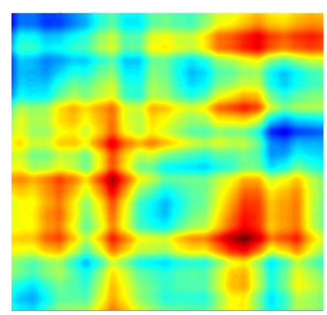
Mechanical, Aerospace & Biomedical Engineering, University of Tennessee Knoxville (UTK) / Space Institute (UTSI), 411 B. H. Goethert Parkway, Tullahoma, TN 37388

Abstract

Realistic fracture simulations in rock as a heterogeneous brittle material with significant inherent randomness, require the use of models that incorporate its inhomogeneities and statistical variability. In ductile materials inelastic deformations re-balance microscale stress field and retard fracture propagation, but for rocks microscale distribution and strength of defects have a very important role in their fracture response. As a result, 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 rocks 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 realizations 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. Subsequently, the point-wise probability distribution function and spatial covariance function are used to generate consistent realizations of random fields based on Karhunen-Loeve (KL) method. Figures below show sample RVEs and a random field generated by KL method. Finally, such realizations will be subjected to mechanical loads, such as those observed in hydraulic fracturing and blast loading on rocks. A powerful and mesh adaptive spacetime discontinuous Galerkin finite element method is used for dynamic fracture simulations. The effect of statistical parameters of the random field on fracture response will be discussed.





Keywords: Stochastic Volume Element (SVE); Random field; Karhunen-Loeve; Dynamic fracture; brittle material.