Homogenization and simulation of solids with random microstructure

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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. Specifically, point-wise mean value and standard deviation and two-point spatial correlation function of elasticity tensor for solid domains with different sampling window sizes and microcrack densities will be presented. We will also present numerical results obtained by Spacetime Discontinuous Galerkin (SDG) method for the fracture simulation of quasi-brittle materials. To incorporate randomness in material microstructure a stochastic model for crack nucleation and propagation is employed. Finally, we discuss the simulation of random fields obtained by SVEs in the context of stochastic fracture model presented.