Discrete Element Modelling of Rupture Cascades During Compressive Failure of Heterogeneous Solids

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ABSTRACT

We present a discrete element model of porous rocks and investigate the uniaxial compression of cylindrical specimens. In order to capture the heterogeneous micro-structure of materials the sample is generated by sedimenting randomly sized spherical particles inside a cylindrical container. The cohesive interaction of particles is represented by beam elements which can break when they get overstressed. The breaking rule takes into account the stretching and shear of particle contacts. The time evolution of the system is generated by molecular dynamics simulations [1,2].

Computer simulations revealed that under strain controlled uniaxial loading of the system first micro-cracks nucleate in an uncorrelated way all over the sample. As loading proceeds localization occurs, i.e. the damage concentrates into a narrow damage band. Inside the damage band the material is crushed, into a poorly sorted mixture of fine powder and larger fragments with a power-law mass distribution, as observed in fault wear products (gouge) in natural and laboratory faults [1,2,3]. Dynamic bursts of radiated energy, analogous to acoustic emissions observed in laboratory experiments, are identified as correlated trails of local fracture emerging as the consequence of stress redistribution. Characteristic quantities of burst such as size/rupture area, released elastic energy, and duration proved to have power law probability-size distributions over a broad range. The energy and duration of bursts have power law dependence on the rupture area created [1,2,3].

As the system approaches macroscopic failure consecutive bursts become progressively more correlated: The size distribution of bursts proved to have a power law behavior with an exponent which decreases systematically towards macroscopic failure, also as observed in laboratory experiments [3,4,5]. The formation of the damage band is marked by a decrease in the average distance between consecutive bursts. The correlation integral of burst locations exhibits power law behavior in the vicinity of the failure point. The simulation results are in reasonable agreement with the experimental findings on porous materials [3,4,5].

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