Geophysical Research Abstracts
Vol. 18, EGU2016-14850, 2016
EGU General Assembly 2016

Wave generation by fracture initiation and propagation in geomaterials with internal rotations

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Crack or fracture initiation and propagation in geomaterials are sources of waves and is important in both stability and fracture (e.g. hydraulic fracture) monitoring. Many geomaterials consist of particles or other constituents capable of rotating with respect to each other, either due to the absence of the binder phase (fragmented materials) or due to extensive damage of the cement between the constituents inflicted by previous loading. In investigating the wave generated in fracturing it is important to distinguish between the cases when the fracture is instantaneously initiated to its full length or propagates from a smaller initial crack. We show by direct physical experiments and discrete element modelling of 2D arrangements of unbonded disks that under compressive load fractures are initiated instantaneously as a result of the material instability and localisation. Such fractures generate waves as a single impulse impact.

When the fractures propagate, they produce a sequence of impulses associated with the propagation steps. This manifests itself as acoustic (microseismic) emission whose temporal pattern contains the information of the fracture geometry, such as fractal dimension of the fracture. The description of this process requires formulating criteria of crack growth capable of taking into account the internal rotations. We developed an analytical solution based on the Cosserat continuum where each point of body has three translational and three rotational degrees of freedom. When the Cosserat characteristic lengths are comparable with the grain sizes, the simplified equations of small-scale Cosserat continuum can be used. We established that the order of singularity of the main asymptotic term for moment stress is higher than the order of singularity for conventional stress. Therefore, the mutual rotation of particles and related bending and/or twisting of the bonds between the particles represent an unconventional mechanism of crack propagation.