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DEM Simulations of Fault Gouge Processes - where we stand, where we'll go

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Most active faults contain a granular material called 'fault gouge', largely consisting of ground up wall rock. The fault gouge is generally thought to have a significant influence on the mechanical behaviour of the fault. It is therefore of major importance to understand the processes which govern the mechanics of the fault gouge. Numerical simulations of sheared granular materials are an excellent complementary tool to be used alongside traditional field and laboratory based methods. Due to the inherently discrete nature of the granular fault gouge , the discrete element method (DEM) is particularly well suited for this task.

One particular advantage of the numerical models is that all grain scale processes and developing structures within the simulated fault gouge can be observed directly at all times. This is rarely possible in laboratory experiments and even harder in the field. It should, however, be pointed out that a comparison between the numerical models and observations of real fault gouge or laboratory experiments is essential in order to validate to numerical models.

During recent years, the increase in available computing power has enabled the implementation of increasingly complex and hence more realistic models of fault gouge. A major contribution to our ability to harness this computing power has been the development of fully parallel DEM simulation software such as the open source package ESyS-Particle.

The main improvements introduced into the numerical models of fault gouge in recent years include the transition from 2D to 3D models, the implementation of realistic breakage of aggregate grains, allowing gouge evolution and changing the smallest grain fragments from single spherical particles to pseudo-angular aggregates.

With the inclusion of those improvements, the numerical models exhibit evolving grains size distributions and development of strain localisation textures with increasing shear strain and frictional behaviour which matches very well the observation from laboratory experiments (at least to a first order). However, the models still have limitations. In particular the restricted geometrical resolution of the models does introduce noise into the friction measurements and therefore limits the ability to recognise small variations in friction.

Among the behaviours of fault gouge which are not modelled yet are therefore higher order aspects of fault friction, such as velocity dependence or rate- and state-dependent behaviour. Further advances in computing technology in the coming years will enable an improvement of the geometrical resolution of the gouge models. Equally important will be the inclusion of additional physical processes into the numerical models such as contact healing.