



Modeling of brittle-viscous flow using discrete particles

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Many geological processes involve both viscous flow and brittle fractures, e.g. boudinage, folding and magmatic intrusions. Numerical modeling of such viscous-brittle materials poses challenges: one has to account for the discrete fracturing, the continuous viscous flow, the coupling between them, and potential pressure dependence of the flow. The Discrete Element Method (DEM) is a numerical technique, widely used for studying fracture of geomaterials. However, the implementation of viscous fluid flow in discrete element models is not trivial. In this study, we model quasi-viscous fluid flow behavior using Esys-Particle software (Abe et al., 2004). We build on the methodology of Abe and Urai (2012) where a combination of elastic repulsion and dashpot interactions between the discrete particles is implemented. Several benchmarks are presented to illustrate the material properties.

Here, we present extensive, systematic material tests to characterize the rheology of quasi-viscous DEM particle packing. We present two tests: a simple shear test and a channel flow test, both in 2D and 3D. In the simple shear tests, simulations were performed in a box, where the upper wall is moved with a constant velocity in the x-direction, causing shear deformation of the particle assemblage. Here, the boundary conditions are periodic on the sides, with constant forces on the upper and lower walls. In the channel flow tests, a piston pushes a sample through a channel by Poiseuille flow. For both setups, we present the resulting stress-strain relationships over a range of material parameters, confining stress and strain rate.

Results show power-law dependence between stress and strain rate, with a non-linear dependence on confining force. The material is strain softening under some conditions (which). Additionally, volumetric strain can be dilatant or compactant, depending on porosity, confining pressure and strain rate.

Constitutive relations are implemented in a way that limits the range of viscosities. For identical pressure and strain rate, an order of magnitude range in viscosity can be investigated.

The extensive material testing indicates that DEM particles interacting by a combination of elastic repulsion and dashpots can be used to model viscous flows. This allows us to exploit the fracturing capabilities of the discrete element methods and study systems that involve both viscous flow and brittle fracturing. However, the small viscosity range achievable using this approach does constraint the applicability for systems where larger viscosity ranges are required, such as folding of viscous layers of contrasting viscosities.

References:

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