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Numerical investigation of fault zone roughness: Interplay between fault geometry and friction

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The influence of roughness is central in understanding the behavior of various types of shear zones including faults, landslides and deformation in glacial till. All of these zones contain a non-planar wall, which interacts with either a gouge zone, or another wall. Laboratory friction experiments have traditionally attempted to isolate the role of boundary roughness focusing on shear within the gouge. We use the 3D Discrete Element Method (DEM) and the ESyS-Particle code to investigate both the effect of boundary roughness and friction. The DEM allows us to investigate the micromechanics of the shear zone by directly visualizing force chain magnitude and orientation, and also the distributed or localized nature of shear in the numerical experiment. We use two end-member shear zones: 1) fault gouge is sandwiched between two rough walls and 2) fault gouge is contained inside of two smooth walls. For rough fault models, grooves are 0.8mm in height and have a regular spacing of 1mm, equivalent to standard laboratory friction experiments. In all models the gouge particles range from 100 to 200 micron in diameter in a 3 mm thick layer, the normal stress is held constant at 15 MPa with a constant shear velocity applied to one wall while the other is held stationary. We vary the coefficient of friction between the particles and wall and monitor the shear strength, distribution of forces between particles, force chain orientation, localization of shear, and porosity distribution in the shear zone. We find that when wall friction is equal to gouge friction, large values of interparticle friction promote localization near the shear zone boundary due to the inefficiency of shearing many high friction contacts in the granular zone. A rough fault zone balances this effect by necessitating that shear occurs within the gouge zone and not strictly at the gouge-wall interface; however, variations in the shearing layer are still observed depending on the particle friction. For rough faults the contrast between the friction of the wall and gouge is negligible. Smooth faults exhibit a large dependence on wall friction versus and gouge friction when gouge friction exceeds 0.1. Smooth faults decrease the average force of particle-particle contacts, exponential slope of the probability distribution function, and anisotropy of force chain orientation. From our numeric experiments we conclude that rough naturals faults will have a higher overall strength and transfer more force to frictional grains activating grain scale processes than smooth mature faults