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Mechanism of fault friction variations associated with rolling of non-spherical particles

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Friction resisting the fault sliding is known to be rate and path-dependent, which is often related to the movement of the gouge particles. This movement includes particle rotation which can be modelled either using the Cosserat-type models or by direct computer simulation using a discrete element method. These models are however based on the notion that the gouge particles are spherical (circular in 2D) tacitly assuming that the real non-spherical shapes of the particles create quantities effects, which can be accounted for by introducing proper correction factors. We show that non-spherical particles behave qualitatively different. This is a result of the fact that the normal force applied to the non-spherical particle can create a moment whose resistance to the particle rolling changes with the angle – a phenomenon not possible in a spherical (circular) particle due to symmetry. If rolling of a particle is caused by macroscopic shear stress, the normal stress will resist or assist the rolling depending on the angle. As a result the effective friction coefficient associated with a single particle can be reduced to zero in the process of its rolling and then restore its initial value. This leads to the oscillatory behaviour of the friction coefficient as a function of displacement.

When sliding involves the rolling of (very) many particles the random variations in their sizes and initial positions cause the friction coefficient to oscillate with decreasing amplitude; the characteristic displacement of this decrease can be an order of magnitude greater than the average particle size.

If the gouge layer is sufficiently thick, the friction variations can be associated with rotating clusters of particles. The size of the clusters exceeds the particle size by a factor of the order of the ratio of the effective modulus of the particulate material to the acting shear stress. Thus the clusters may be significantly larger than the original particles and hence the variations in the friction coefficient can happen over considerable displacements.