Fluid lubrication of faults during earthquakes: Evidence from high velocity experiments on fluid-saturated gouge

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Earthquakes involve a wide range of slip velocities ranging from low strain-rate aseismic creep to high strain-rate dynamic sliding. Understanding the frictional behavior of clay-rich gouge that found commonly in mature natural faults, especially at seismic slip velocities, is essential in helping to understand rupture propagation processes during great earthquakes. Previous high-velocity (HV) friction experiments on gouges showed characteristic slip-weakening behavior and drastic drop in fault strength at slip velocity more than ˜0.1 m/s (i.e., Mizoguchi et al. 2007). Various mechanisms have been proposed to elucidate the observed dynamic weakening last several years: including the moisture-related processes (Mizoguchi et al. 2006), thermal-decomposition-related weakening (Han et al. 2007) and thermal pressurization (Brantut et al. 2008, De Paola et al. 2008). In the presentation, we will review the previous results of HV experiments, and then compare with our new results on water-saturated gouge sheared at coseismic slip velocities.

We have performed HV friction experiments on illite-smectite clay-rich powder using rotary-shear friction apparatuses at slip velocities, V, of 0.02-1.3 m/s, normal stresses of 0.6-1.8 MPa and displacements of over 3 m under dry and wet (water-saturated) conditions. In both dry and wet cases, typical slip weakening behaviors were observed at V more than 0.17 m/s. However, overall shear strength during the slip weakening is always lower in the wet case: the frictional coefficient at steady state is 0.2-0.6 and 0.05-0.1 for dry and wet conditions, respectively. Specific feature of the wet case is that shear strength of the wet clay at the steady state is almost independent of normal stress at V=1.3 m/s (the slope of shear stress versus normal stress curve is nearly zero). Measured temperature close to sliding surface by thermocouples increased to ˜110oC during slip weakening. These imply that the wet clay could behave as viscous fluid during coseismic sliding partly due to the fluid pressurization by frictional heat, leading to very low shear strength. The results suggest that earthquake ruptures could energetically easily propagate through wet, clay-rich gouge zones.