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Frictional properties of Nojima fault gouge at low, intermediate and high velocities

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The 1995 Kobe earthquake stimulated detailed studies on Nojima fault, one of the faults that caused the earthquake. After 15 years, more work still needs to be done for full understanding of the mechanical and transport properties of the fault zone. We address three problems in this study; (1) comparison of our results from high-velocity friction experiments on Nojima fault gouge using our rotary-shear low-to-high-velocity friction apparatus (the 2nd HV machine) with those in Mizoguchi et al. (2007, GRL) using the 1st HV machine now at Kochi Core Research Institute, JAMSTEC, (2) high-velocity friction experiments with a variety of slip histories, (3) friction experiments at intermediate to low velocities. We worked on a new outcrop of Nojima Branch fault in Funaki. Fault zone consists of dark gray clayey fault gouge (0.05-0.2 m in width), fault breccia of the Cretaceous granodiorite (3-3.5 m wide) and fault breccia of Plio-Pleistocene Osaka Group (a few meters wide).

(1) Comparison of the 1st and 2nd high-velocity machines
Experiments were conducted on clayey fault gouge and fine fault breccia next to fault gouge of about 1.2 mm in thickness sandwiched between a pair of solid cylinders of gabbro with an outer diameter of 25 mm, at room temperature and room humidity conditions. Overall our results agree very well with those of Mizoguchi et al. (2007, GRL) even though samples were collected from different outcrops; that is, the steady-state friction markedly decreases as slip rate increases from 0.009 to 1.3 m/s, and slip weakening distance decreases with an increase in the normal stress from 1 to 3.68 MPa. The fracture energy of (1-3) x 10^6N/m from the two studies is of the same order as that for Kobe earthquake, (0.5-1.0) x 10^6N/m.

(2) High-velocity frictional behaviors with variable slip histories
Sone and Shimamoto (2009, Nature Geoscience) used the same acceleration and deceleration rates which is not the case for most earthquakes. We changed the acceleration and deceleration rates, to see if their simple slip/velocity weakening law can describe the observed frictional behaviors with variable slip histories. Our results are consistent with those of Sone and Shimamoto, in that fault gouge undergoes initially strengthening, subsequent dramatic slip-weakening and final strength recovery upon decelerating fault motion. Experiments with different rates of acceleration produces similar slip-weakening, but a slower deceleration rate yields a more pronounced strength recovery. Their empirical slip/velocity weakening law describes observed behaviors reasonably well although the law tends to slightly overestimate the strength recovery. The law will be useful for modeling dynamic fault motion during earthquakes.

(3) Frictional behaviors at intermediate and low velocities
Our machine is capable of producing 3 mm/year to nearly 10 m/s in slip rate, so we extended our friction experiments down to 0.86 x 10^{-3}mm/s at room temperature and at a normal stress of 1.2 MPa. Experiments are still preliminary, but results show velocity weakening at low velocities, velocity strengthening at intermediate velocities and dramatic slip-weakening with increasing slip

rate at high-velocities above several tens of mm/s. Velocity-weakening to velocity-strengthening transition with increasing slip rate was recognized previously for halite (e.g., Shimamoto, 1986, Science). Earthquake rupture has to overcome this velocity-strengthening barrier in the intermediate regime to develop into a large earthquake. More results will be reported on this topics at the meeting.

Keywords: High-velocity friction, Fault gouge, Variable slip rate, Nojima fault, Low-velocity, intermediate-velocity