Dramatic velocity weakening of dry quartz friction at relatively slow slip velocities

*Akito Tsutsumi[1], Hirotaka Iida[2], Yuko Onoe[1]

1. Graduate School of Science, Kyoto University, 2. Geothermal Engineering. Co. Ltd.

Understanding the frictional properties of subduction-zone fault materials is crucial to understanding subduction-zone seismogenesis. Previous experimental studies have demonstrated that fault weakening in siliceous rocks occurred at relatively low slip velocities ($V > 0.01$ mm/s) [Goldsby and Tullis, 2002; Di Toro et al., 2004; Hayashi and Tsutsumi, 2010], under which conditions transformation reactions are unable to proceed because of low temperatures. Formation of a silica gel layer has been suggested as a possible cause of the weakening behavior [Goldsby and Tullis, 2002]. However, there exists only limited information on the frictionally generated material and little is known about the weakening mechanism. To study the effect of moisture on the fault zone process in siliceous material, we have performed friction experiments on a synthetic quartz sample under two different humidity conditions: in room humidity (relative humidity RH = 20 to 75%) and in dry (RH < 3%) conditions. to

Three types of friction experiments were performed using a rotary-type testing machine on a pair of hollow-cylindrical specimens of quartz with outer and inner diameter of 25 and 5 mm, respectively, at a constant normal stress of 1.5 MPa. Constant velocity tests and velocity stepping tests were conducted under a range of slip velocities from 0.005 to 105 mm/s. In slide-hold-slide (SHS) tests, samples were first slid at $v = 105$ mm/s, by which sliding friction coefficient f decreases to attain a steady-state value of about $f = 0.2$. Then, rotation of the sample was stopped for periods of 1 to 10000s, after which rotation of the sample at the same rate was restarted.

In room humidity conditions, steady state friction shows velocity weakening at $v > 0.01$ mm/s, which is consistent to the previous studies. We find that steady-state friction values measured at the dry condition are almost constant at $f = 0.2$ for slip velocities v from 0.1 to 100 mm/s. SHS tests show that time-dependent frictional healing is observed for hold time duration $t > 10$s in room humidity condition. On the contrary, the time-dependent frictional healing is negligible when tested in the dry condition.

Our results imply that the moisture-absorption strengthening, which has been proposed to be an effective mechanism for time-dependent healing of high-velocity friction of gabbro (Mizoguchi et al. 2006) is an important underlying mechanism of the frictional weakening of quartz rocks observed in ambient humidity conditions.

Keywords: high-velicity friction, velocity weakening, gel lubrication

