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Stick-slip experiments using a rotating viscometer

Naoya Higashi[1]; Ikuro Sumita[2]

[1] Earth Sci. Kanazawa Univ; [2] Earth Sci., Kanazawa Univ.

Faults are known to slip irregularly in the form of stick-slip motions. Some of the parameters which govern the statistical behavior of stick-slip motions are; mechanical properties and the thickness of the fault gouge, presence of water, if any, in the fault zone, and the slip velocity of the fault. Combination of these parameters give rise to the complexity and unpredictability of stick-slip motions. In order to better understand the physics of stick-slip motions, it is important to study these effects separately. Recently, Anthony and Marone (2005) used glass beads to study such parameter dependence of stick-slip motions. However, analysis of long-term statistical behavior has not been made yet. In this study, we conducted a series of simple experiments to study such parameter dependence, with particular emphasis on their long term statistical behavior.

Experimental method: We used a Couette-type viscometer and a vane spindle (diameter 1.267cm). Glass beads were poured into a beaker of a diameter of 6.5 cm and the spindle was inserted at the center of the beaker to a depth of 9mm. The motor inside the viscometer rotates at a constant rate and the spindle rotates in a stick-slip manner when it shears the layer of glass beads. We measured the torque at the shaft of the spindle and analyzed the time-series data. The rotation rate of the spindle is 0.05 rpm and we obtained a time-series data for a time span of 10 rotations. As a parameter we changed the particle diameter of the glass beads from 0.2 to 1 mm.

Results: When the static friction inhibits the spindle from rotating, the torque increases linearly with time. As the stress exerted at the spindle increases, it starts to slip slowly, and the slope of the torque versus time becomes smaller. Eventually, the spindle makes a large slip and the torque decreases in a step wise manner. This process represents one cycle of the stick-slip motion. As we increase the particle diameter, we find that the amplitude of the fluctuations of the torque increases. From visual observation, we find that the glass beads are only mobile upto 1 cm from the edge of the spindle. We analyzed the statistics of the stick slip motion, and find that the average time interval of the slip, and the stress drop of the slip, increases with the particle diameter. We also find that the tendency of preslip prior to the large slip, is more significant for smaller particle size.

Discussion: Our experimental results can be interpreted using the concept of force chain. For a given diameter of the beaker, a glass beads with larger particle diameter has less points of contact, so the force chain is more stable against shear. As a consequence, the time interval between the slips become longer and the stress drop for each event becomes larger as the particle size increases.

Reference: Anthony, J. L. and C. Marone, 2005, J. Geophys. Res., 110, 10.1029/2004JB003399.