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Numerical study of mechanics of earthquakes and faulting

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Stick-slip phenomena observed in laboratory friction experiments seems to be analogous to earthquakes. A large amount of experimental works has been done to know the nature of these phenomena and conditions when they occur. Two modes of the slip phenomenon are observed in experiments. One mode is unstable slip, or stick-slip phenomenon, with sudden stress drop from critical value. Another mode is stable slip without accompanying stress drop. These modes are influenced by temperature, confining pressure, gouge layers, rock types, slip rate (strain rate), stiffness of apparatus and so on. If mechanism of transition from stable to unstable slip is clarified, our understanding of earthquake will advance. However, as the temporal and spatial scalability of the slip phenomena is still difficult to understand and the most features concerning to slip phenomena are empirical, the mechanics of fault has not yet been resolved. On the basis of understanding of slip phenomena, in this study we investigate the effect of gouge layers between slip surfaces by numerical simulations using the distinct element method (DEM) extended by Matsuda and Iwase (2002).

We use simplified models of fault system including gouge to focus on macroscopic interaction between fault and gouge. In our study, 71 columnar elements with the same radius, 0.2 (m), are packed in the model fault that consists of a pair of parallel walls which have the width of 15 times of the diameter of an elements. The columnar elements and walls are assumed to be both the Voigt-Kelvin material and the friction among them are taken into account. Boundary conditions of side of the walls are cyclic. The bottom wall is fixed in space. The upper wall is moving parallel to the wall surface at a constant rate (0.06-0.6 m/s). Vertical displacement of the upper wall is also allowed to maintain a constant confining pressure (1000 Pa). Shear stress on lower wall is measured during 300 sec.

When the upper wall moves slowly (0.06 m/s), elastic strain energy due to shear stress given by the upper wall is dissolved for the opposite directional rotation of the adjoining elements. This situation is confirmed by a fact that total of rotation energy of elements is about one-half of that of kinetic energy. As the change of shear stress with time is small, this situation is interpreted as the stable slip. While the upper wall moves fast (0.6 m/s), the stress-strain relationship shows the characteristic saw-toothed shape which is seemed to be stick-slip phenomenon observed in laboratory friction experiments. As the shear forces given by rotation of neighboring elements are balanced, translation is dominant in movement of elements. In fact, the ratio of kinetic to rotation energy is small. In the intermediate wall velocity, two modes of slips appear alternatively, and the ratio of energy is varying in response to slip mode.

As a result, in spite of simplification of slip system, the model seems to provide significant insights of slip phenomena: stable, unstable and the intermediate slips. The results also suggest that the intermediate slip may be caused by combination of rotation with translation. The effect of gouge layers will be clarified by numerical study of mechanics of fault in detail.