Growth of dynamic earthquake ruptures and slip processes in a thermo-poroelastic medium

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We study thermo-hydraulic effects on dynamic earthquake rupture in numerical simulations. Numerical simulations are carried out on the basis of the system of governing equations derived in this study. Non-linear feedbacks among changes in temperature, fluid pressure and other physical quantities are shown to play crucial roles in the emergence of diversity in dynamic earthquake ruptures such as slip-weakening behavior and long slip duration.

We observed a slip-weakening behavior although we did not explicitly assume such behavior. We found theoretically that the slip-weakening distance Dsw is characterized by a single parameter. If we approximate the heated zone width as 0.1 m, which is the same order as fault gouge zones, Dsw is shown to be about 0.5 m, , which is comparable to seismological estimate that is about 0.5~1 m (e.g., Ide and Takeo, 1997; Mikumo et al., 2003). We then investigated effects of fluid diffusion by varying the tortuosity. The slip-weakening behavior is observed in this case, too, but the Dsw is longer when diffusion is larger.

When dynamic crack growth is arrested artificially, slip duration is longer in our model than that expected from the classical Griffith crack model. This is due to time dependent stress drop in our model. The rate of slip overshoot depends on when the crack is arrested. This may cause static stress distribution on the crack surface different from the Griffith model and affect consequent ruptures.

The temperature rise is found to be relatively low in our model if the fluid does not flow out of the heated fault zone. In this case the normal Terzaghi effective stress acting on the crack surface Tn is reduced to nearly zero and the heat source term vanishes. This leads to temperature stabilization. The field observation that few pseudotachylytes exist may be consequences of low permeability over the whole region in a porous fault zone. However, if we consider microcrack generation accompanying crack propagation, the situation is drastically changed. The microcracks raise permeability locally, which induces fluid flow out of the heated zone and therefore suppresses fluid pressure increase. Here Tn remains large and temperature continues to rise, which may cause local melting.