Effects of thermal weakening processes at high slip rates on dynamic rupture propagation characteristics

Hiroyuki Noda[1]; Eric M. Dunham[2]; James R. Rice[3]

[1] Earth and Planetary Sci., Kyoto Univ; [2] EPS, Harvard; [3] Div. Engnr. and Appl. Sci., and Dep. Earth Planetary Sci., Harvard University

We have conducted rupture propagation simulations incorporating the combined effects of thermal pressurization of pore fluid, and flash heating of microscopic contacts to see when a rupture propagates in a pulse-like (vs. crack-like) manner. These mechanisms are probably primarily important at high coseismic slip rates. For flash heating, we use a rate- and state-dependent friction law in the slip law formulation, accounting for extreme velocity weakening above a weakening slip rate, V_w around 0.1 m/s that depends on the background temperature, and a very short state evolution distance, L, of 20 microns, which is comparable to the asperity length. We have also conducted a series of calculations with neglecting evolving change in macroscopic temperature, T, and pore pressure, p, and compared the results.

For mode III rupture propagation, given that the shear stress on the planer fault is expressed as a function of slip rate, $tau_{ss}(V)$, Zheng and Rice [1998] derived a sufficient condition for the impossibility of expanding crack-like solution where the central region of the rupture keeps slipping. A critical shear stress, tau^{pulse} is defined as a intercept of a radiation damping line (tau = - $mu/(2c_s) * V$ + *const.*) which fit tangentially to $tau_{ss}(V)$ at V^{pulse}. Here, mu is the rigidity and c_s is the shear wave speed. If the background shear stress, tau^b is lower than tau^{pulse}, an expanding crack-like rupture is impossible. This condition holds without evolving changes in T and p, but breaks with them if we define tau^{pulse} using initial value of T and p. A thin shear zone and low hydraulic diffusivities favors crack-like solution.

All ruptures are initially crack-like in a sense that the central region is slipping, and in the pulse-like cases there is a transition of the type of the rupture. The transition to pulse-like solution takes place at V^{pulse} similarly to the previous work by Cochard and Madariaga [1994]. Without evolving T and p we derive a necessary and sufficient condition for a pulse-like rupture by considering singular crack model [Kostrov, 1964] and defining a critical stress drop: $F(V_r/c_s) * dtau\ V_r\ /\ mu\ V^{pulse}$ .lt. 1 where