SECOND EUROPEAN CONFERENCE ON EARTHQUAKE ENGINEERING
AND SEISMOLOGY, ISTANBUL AUG. 25-29, 2014

SYSTEMATIC UNDERSTANDING OF SPONTANEOUS ACCELERATION AND SLIP CESSATION AND ITS SEISMOLOGICAL INTERPRETATION

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We theoretically study the diversity of dynamic fault slip assuming a fault in a fluid-saturated 1D thermoporoelastic medium. Fault slip evolution interacts with fluid pressure change through the Coulomb frictional stress. We specifically investigate the interactions among fault slip, shear heating, fluid pressure change and slip-induced dilatancy (inelastic pore creation). Our mathematical analysis indicates that two qualitatively different slips, acceleration and spontaneous slip cessation, are generated by two nondimensional parameters, S_u and T_a. The parameter S_u denotes the relative dominance of the effect of dilatancy on the fluid pressure change over that of heating, while the parameter T_a represents the ratio of inelastic porosity due to the characteristic slip based on thermal pressurization to an upper limit of the porosity. Physical interpretation of the two slip behaviors is given as follows. Though deceleration of slip appears owing to fluid pressure reduction due to the dilatancy in the initial stage of slip evolution, the dilatancy effect decreases significantly with time because the porosity gets close to the upper limit. The acceleration rate of the slip eventually becomes zero for some parameter values of S_u and T_a, and after that the thermal pressurization becomes predominant, which induces positive acceleration rate of slip; that is, temperature increases with increasing time, which raises the fluid pressure and reduces the residual frictional stress and high-speed slip. On the other hand, for some parameter values of S_u and T_a, the slip acceleration does not occur and the slip ceases spontaneously. It is a remarkable feature of our model that qualitatively different dynamic slip behaviors appear in a single model: the acceleration case and spontaneous slip cessation case. We also clarified that the whole parameter space (S_u, T_a) is divided into the acceleration domain and spontaneous slip cessation domain, and the mathematical expression about the location of boundary between these two domains is obtained analytically; we found the function $G(S_u, T_a, v_0^*)$, where $G=0$ describes the boundary and v_0^* is the initial value of v^*.

For the acceleration case, if periods of seismic waves to be employed for the investigation of temporal evolution of slip are much shorter than the time interval between the slip onset and the acceleration, we may be able to detect the gradual acceleration phase (GAP) preceding the dynamic fast slip. Moreover, if sufficiently high-frequency seismic waves are used, local peak of slip velocity near $t^*=0$ may be detected as a dynamic event preceding the main shock (preceding event (PE)). Our analysis shows that time intervals between PE and GAP are longer for parameter values nearer the boundary. It is a remarkable feature here that both GAP and PE can be modeled comprehensively from a viewpoint of interaction among the effects of heat, fluid pressure and dilatancy.

For the spontaneous slip cessation case, maximum slip velocity and duration of slips are found to

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be the orders of 1 [m/s] and 0.1 [s], respectively, if the parameter values in Suzuki and Yamashita (2014) are assumed. Slip in this case corresponds to ordinary earthquakes ceasing spontaneously on natural faults as suggested in Suzuki and Yamashita (2010). We also find that we can assume slightly larger values for S_u (about 3) than assumed in Suzuki and Yamashita (2010) to simulate ordinary earthquakes having the above feature. Note that the assumption of upper limit for porosity evolution tends to keep inelastic porosity increase rate lower than that without the limit, which makes slip velocity higher than that without it if the value of S_u is fixed.

We have shown that many aspects of dynamic earthquake slip can be simulated in our model: high-speed slips with GAP or PE, and spontaneous slip cessation. These slip behaviors have been understood in terms of only the two nondimensional parameters S_u and T_a; those behaviors differ only in the parameter values. Categorizing those behaviors analytically (that is, obtaining the function G) is an important outcome. About such slip behaviors, some implications can be given here. For example, if we assume 2-D or 3-D fault model, the acceleration case will correspond to crack-like slip, while the spontaneous cessation will generate pulse-like slip. This is because for the former case, complete stress drop is achieved over a whole fault plane, whereas for the latter case it is almost zero except for the region near fault tips. Origins of crack-like and pulse-like fault slips have been widely discussed (e.g., Festa and Vilotte, 2006; Gabriel et al., 2012) and the present study gives a new insight.

REFERENCES

Festa, G., and Vilotte, J.-P. (2006) “Influence of the rupture initiation on the intersonic transition: Crack-like versus pulse-like modes”, *Geophys. Res. Lett.*, 33, L15320, doi:10.1029/2006GL026378

Gabriel, A.-A., Ampuero J.-P., Dalguer L. A., Mai P. M. (2012) “The transition of dynamic rupture styles in elastic media under velocity-weakening friction”, *J. Geophys. Res.*, 117, B09311, doi:10.1029/2012JB009468

Suzuki, T. and Yamashita, T. (2010) “Nondimensional control parameters governing the behavior of one-dimensional fault slip: Effects of shear heating, inelastic pore creation, and fluid flow”, *J. Geophys. Res.*, 115, B02303, doi:10.1029/2009JB006557

Suzuki, T. and Yamashita, T. (2014) “Effects of Shear Heating, Slip-Induced Dilatancy and Fluid Flow on Diversity of 1-D Dynamic Earthquake Slip”, in press in *J. Geophys. Res.*, doi:10.1002/2013JB010871