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Systematic Understanding of Dynamic Earthquake Slip Process in the System without Fluid Flow

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We have explained many aspects of dynamic earthquake slip process by constructing the framework associated with the interaction among heat, fluid pressure and inelastic pore creation. We found three nondimensional parameters, Su, Su' and Ta, in the framework. In particular, Su describes the relative dominance of the effect of inelastic pore creation on the fluid pressure change over that of shear heating. In our previous studies, we analyzed the parameter range $Su>1-v_0^*$, where v_0^* is the initial value of the normalized slip velocity v^*. For this parameter range, we found the acceleration case and the spontaneous slip cessation case for the slip process. The acceleration case shows the transition from deceleration to acceleration with high-speed final slip, while the spontaneous slip cessation case shows the slip arrest with final zero stress drop. The former case corresponds to gradual acceleration phase (GAP) or a dynamic event preceding the main shock, while the latter indicates pulse-like slip for 2-D fault models. They are quantitatively distinguished by the value of the function G; if $G>0$, the acceleration case is observed, while if $G<0$, the spontaneous slip cessation case appears. We assume the parameter range $Su<1-v_0^*$ in the present study.

First, we found that the steady state value of the normalized slip velocity is zero or unity over a whole range of Su. In addition, deceleration at the initial stage of the slip is required to attain the steady state value zero. In the case $Su<1-v_0^*$, we found analytically that temporal differentiation of slip velocity is always positive, which leads to the conclusion that only acceleration occurs (the steady state value unity is realized) during the slip.

In this case, thermal pressurization is predominant over the pore creation, so that high-speed slip and complete stress drop are observed. Moreover, temperature increase is kept below the fault rock melting point. We found that these natures describe slip for the ordinary earthquakes with GAP and the high-speed slip and without the fault rock melting, which is the same behavior as those of $Su>1-v_0^*$ and $G>0$. It is also important here that, since the final porosity is less than the upper value, we can reproduce (i) non-negligible porosity generation, and (ii) temperature under the fault rock melting point, both of which have been seismologically fundamental requirements, as done in the case $Su>1-v_0^*$. The behavior in the system without the fluid flow is understood in a unified way for all values of Su.

Keywords: theory, heat, fluid pressure, pore creation, nonlinear, interaction