Systematic understanding of the slip-front-propagation velocity in terms of Linear Marginal Stability Hypothesis

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Slip-front-propagation on an interface between two media has attracted interests of many researchers in scientific and industrial fields. In particular, the slip-front-propagation velocity has been obtained using some friction laws such as the slip-velocity-dependent law. Notably, to obtain the propagation velocity, Linear Marginal Stability Hypothesis (LMSH) has been widely employed. First, LMSH assumes the plane wave solution for the slip profile near the slip front, i.e., u~exp(i (k x-omega t)), where u is the slip and k and omega are the complex wave number and frequency, respectively. The imaginary parts of k and omega are written as k_i and $omega_i$, respectively, and the slip-front-propagation velocity is given by $v=omega_i/k_i$. We consider the friction law depending on both the slip and slip velocity, leading to two model parameters in the governing equation. We therefore assume that the terms C_1 u and C_2 \dot{u}, where C_1 and C_2 are the constants, emerge in the governing equation for u. We have obtained the cubic equation for $omega_i$ using LMSH, and found that the numbers of the solutions for $omega_i$ can be categorized into 12 regions on the C_1-C_2 phase space. Here, we aim to categorize the slip-front-propagation velocity on the C_1-C_2 phase space, and give some implications associated with slow earthquakes.

We should emphasize that the slip front has two forms: the intruding and extruding fronts (see details in Suzuki and Matsukawa, 2019). Actually, we have obtained the analytical solutions for $omega_i$, and they are called $omega^{in}_1$, $omega^{in}_2$, and $omega^{in}_3$ for the intruding front, and $omega^{ex}_1$, $omega^{ex}_2$, and $omega^{ex}_3$ for the extruding front. Using these values and the relationship between k_i and $omega_i$, we have also obtained the analytical forms of k_i, which are called k^{in}_1, k^{in}_2, and k^{in}_3 for the intruding front, and k^{ex}_1, k^{ex}_2, and k^{ex}_3 for the extruding front. Therefore, we can write analytical forms for the intruding and extruding slip-front-propagation velocities, $v^{in}_j=omega^{in}_j/k^{in}_j$ and $v^{ex}_j=omega^{ex}_j/k^{ex}_j$ (j=1,2,3), respectively.

In terms of the solutions of v^{in}_j and v^{ex}_j, the C_1-C_2 phase space is divided into 7 regions. They are the regions with (A) v^{in}_1, (B) v^{ex}_1, (C) v^{in}_1 and v^{ex}_2, (D) v^{ex}_1 and v^{ex}_3, (E) v^{in}_1, v^{ex}_2, and v^{in}_3, (F) v^{in}_1, v^{ex}_2, and v^{ex}_3, and (G) no propagation velocity. In particular, we emphasize that there exists the region where v^{in}_j or v^{ex}_j does not exist. This region cannot generate the steady slip-front-propagation, and may imply the generation of slow earthquakes from seismological viewpoint.

Keywords: slip-front-propagation velocity, friction law, Linear Marginal Stability Hypothesis