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On the selection of active fault planes

T. Putelat and J. R. Willis

ITG & DAMTP, University of Cambridge (tp244@damtp.cam.ac.uk / [+44] 01223 765 900)

The stability of the frictional sliding of a multislip system is studied. This is a model problem illustrating how active faults are selected and how their slip rates are determined. The system consists of a homogeneous elastic medium of shear modulus μ and thickness H in mechanical equilibrium and divided by a finite number N of horizontal interfaces, along which a rate-and-state dependent friction acts. This system is driven by a constant velocity V_H at its upper boundary whereas the lower one is fixed. A constant pressure is applied on the upper boundary. Assuming the displacement horizontal and free of horizontal variation, it is found from the boundary value problem, the stress continuity on each interface and Hooke's law that the shear stress τ depends only on the time and obeys the equation $\dot{\tau} = k\big(V_H - \sum_{i=1}^{N} \dot{\delta u_i}\big)$. The constant $k = \mu/H$ is a stiffness parameter and $\dot{\delta u_i}$ are the slip rates. In a steady state, the previous equation relates the N steady-state slip rates V_i according to $\sum_{i=1}^{N} V_i = V_H$. Furthermore, as τ is constant, the V_i are also related by $N-1$ equations coming from the steady-state friction law $\tau = F^{ss}(V_i)$. Thus, the slips V_i are obtained by solving this system of nonlinear equations. We emphasize that, depending on the properties of F^{ss}, the interfaces can be active and slip with different slip rates. We expect a unique slip rate V_H/N if F^{ss} is a monotonic function and two slip rates, V_1 and V_2, if F^{ss} has an extremum. In addition, the stability of these steady-state slidings is shown to depend strongly on the nature of the steady-state friction law. A purely velocity-weakening law implies that the multislip is unstable and only one slipping interface is selected. On the other hand, if the steady-state law has a minimum, there is a critical driving velocity $V_H^c = NV_m$ (*i.e.* a critical number of interfaces $N_c = \lfloor V_H/V_m \rfloor$) above which (*i.e.* such that $N \leq N_c$) the multislip system is stable, all interfaces sliding at V_H/N. Below V_H^c, a stable multislip system with 1 slow interface and $N-1$ faster ones could exist if the velocity-strengthening part of the friction law is steeper than the weakening part. Thus, for this multislip system, the nature of the instabilities is different from the stick-slip oscillations involved in the single interface problem and it could lead to

interesting experimental investigations in order to constrain the friction law around its minimum and obtain a better understanding of what happens when $V \to 0$. Furthermore, the richness of behaviours of this system should give new insights concerning earthquake dynamics and the localisation of deformation in brittle media.