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Sliding interactions between frictional interfaces

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We are interested in developing homogenized constitutive models whose microstructure consists of a network of frictional interfaces. In relation with this motivation, having in mind the complex structure of a fault zone, we are concerned with understanding the sliding interactions between faults. We report a preliminary approach to describe the evolution of a model microstructure and tackle the question of how active fault planes are selected in a network of faults.

Precisely, we study the stability of the steady-state sliding of N parallel frictional interfaces which divide an elastic body sheared at a constant velocity V_H applied at one edge of the medium. In the framework of rate-and-state friction, we first summarise a complete description of the nonlinear dynamics of the frictional sliding of two parallel interfaces. Competing symmetric (*i.e.* the two interfaces slide at $V_H/2$) and asymmetric (*i.e.* fast and slow interfaces coexist) steady states can exist only if the steady-state friction law is a non-monotonic function of the slip velocity. A rate-and-state law that delivers such behaviour and agrees with the experimental results of Heslot et al. (1994) is proposed. Analytical results combined with numerical investigations by continuation techniques and direct time integration are used to detect and characterise the various bifurcations of the different sliding states of the system as the two control parameters which are the driving velocity and the stiffness of the medium are varied. We show that the geometrical details of the steady-state friction law determine the occurence and nature of bifurcations: pitchfork bifurcations from the symmetric to asymmetric steady states correspond to the extrema of the friction law and Hopf bifurcations arise in the velocity weakening regime. Torus and period-doubling bifurcations of periodic orbits also happen and can lead to complicated dynamics in a narrow region of the phase diagram defined by the two control parameters.

When $N > 2$ interfaces are considered, we show that the symmetric steady state (*i.e.* sliding at V_H/N) bifurcates to an asymmetric state for which slow and fast interfaces are equally distributed if N is even. Otherwise, the pitchfork bifurcation changes its nature, becoming transcritical. Bifurcation and phase diagrams for 3 and 4 interfaces exemplify the multiple sliding states which appear, disappear and coexist as the driving velocity changes for a given stiffness. Finally, possible geophysical consequences of such a system are discussed in terms of earthquake mechanics and fault dynamics by comparison with the Burridge-Knopoff model.