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DYNAMIC FAULT WEAKENING CAUSED BY THERMAL PRESSURIZATION IN AN EARTHQUAKE MODEL GOVERNED BY RATE - AND STATE - DEPENDENT FRICTION

We model the traction evolution during the dynamic propagation of an earthquake rupture governed by rate - and state - dependent friction with thermal pressurization of pore fluids. The adopted numerical procedure allows us to perform 3 - D simulations in which the heat generated during sliding raises the pore pressure and reduces fault friction. The goals are to investigate how dynamic traction varies with slip or time and to understand the physical mechanisms controlling dynamic weakening during slip episodes. These features have important implications on the estimate of fracture energy as well as on the size of the characteristic slip-weakening distance.

We have performed different numerical experiments varying the thickness of the slip zone as well as the hydraulic diffusivity value. The variations of diffusivity are associated to changes in permeability comprised between 10^{-20} and 10^{-16} m^2. Porosity can be constant or it can evolve with time according to a specified analytical law. Our results show that the thickness of the slip zone and the hydraulic diffusivity value modify the shape of the traction versus slip curves. Numerical simulations performed with different constitutive formulations reveal that the evolution law strongly affects the traction dependence on slip or time. For particular configurations (for instance, when the effective normal stress changes are not accounted in the evolution of the state variable or when porosity evolves with time), the traction evolution shows a gradual and continuum weakening with increasing slip; for these behaviors the definition of D_c might become rather meaningless.

Our results confirm that the breakdown stress drop is inversely proportional to the fault thickness and to the hydraulic diffusivity. A similar relation has been found for the characteristic slip-weakening distance D_c. The increase of D_c caused by thermal pressurization is relevant: in a set of simulations we have found that values larger than 0.6 m are measured for a hydrated fault zone, while the resulting value for a dry fault is equal to 0.04 m. Thermal pressurization yields large peak slip velocity values, exceeding 1 m/s. We observe that, if diffusivity is comparable or slightly larger than laboratory values, the breakdown stress drop (i.e., the difference between the minimum and the yield stress values) is very large. This suggests that earthquake stress drop might be nearly complete. The estimated fracture energy values are consistent with those inferred seismically.