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Rupture dynamics along bimaterial interfaces: a parametric study of the coupling between interfacial sliding and normal traction perturbation

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Earthquake ruptures often develop along faults separating materials with dissimilar elastic properties. Due to the broken symmetry, the propagation of the rupture along the bimaterial interface is driven by the coupling between interfacial sliding and normal traction perturbations.

We numerically investigate in-plane rupture growth along a planar interface, under slip weakening friction, separating two dissimilar isotropic linearly elastic half-spaces. We perform a parametric study of the classical Prakash-Clifton regularisation for different material contrasts. In particular mesh-dependence and regularisation-dependence of the numerical solutions are analysed in this parameter space.

When regularisation involves a slip-rate dependent relaxation time, a characteristic sliding distance is identified below which numerical solutions no longer depend on the regularisation parameter, i.e. they are consistent solutions of the same physical problem. Such regularisation provides an adaptive high-frequency filter of the slip-induced normal traction perturbations, following the dynamic shrinking of the dissipation zone during the acceleration phase. In contrast, regularisation involving a constant relaxation time leads to numerical solutions that always depend on the regularisation parameter since it fails adapting to the shrinking of the process zone. Dynamic regularisation is further investigated using a non-local regularisation based on a relaxation time that depends on the dynamic length of the dissipation zone. Such reformulation is shown to provide similar results as the dynamic time scale regularisation proposed by Prakash-Clifton when slip rate is replaced by the maximum slip rate along the sliding interface. This leads to the identification of a dissipative length scale associated with the coupling between interfacial sliding and normal traction perturbations, together with a scaling law between the maximum slip rate and the dynamic size of the process zone during the rupture propagation.

Dynamic time scale regularisation is show to provide mesh-independent and physically well-posed numerical solutions during the acceleration phase toward an asymptotic speed.

When generalised Rayleigh wave does not exist, numerical solutions are shown to tend toward an asymptotic velocity higher than the slowest shear wave speed. When generalised Rayleigh wave speed exists, as numerical solutions tend toward this velocity, increasing spurious oscillations develop and solutions become unstable. In this regime regularisation dependent and unstable finite-size pulses may be generated. This instability is associated with the singular behaviour of the slip-induced normal traction perturbations, and of the slip rate at the rupture front, in relation with complete shrinking of the dissipation zone. This phase requires to be modelled either by more complex interface constitutive laws involving velocity-strengthening effects that may stabilize short wavelength interfacial propagating modes or by considering non-ideal interfaces that introduce a new length scale in the problem that may promote selection and stabilization of the slip pulses.