EQUATION OF MOTION FOR DYNAMIC RUPTURE PULSES

Dmitry GARAGASH [1], ***Nicolas BRANTUT*** [2], ***Hiroyuki NODA*** [3]

[1] Dalhousie University, Halifax, Canada
[2] University College, London
[3] Kyoto University, Japan

Seismological observations tend to indicate that major earthquake ruptures propagate along seismogenic faults pulse-like [Heaton PEPI 1990], such that any given point of the ruptured fault accumulates slip over duration much shorter than the overall fault rupture time. Numerical simulations of elastodynamic rupture on strongly dynamically weakening faults [Gabriel et al JGR 2012, Noda et al JGR 2009] have shown that slip pulses do arise spontaneously, but generally are inherently transient even on uniformly-stressed, homogeneous faults - either arresting or accelerating to the limiting speed, prompting transition to crack-like and/or supershear mode.

In this work, we have developed an equation of motion (EoM) for transient pulse motion based on the analysis of the fault field perturbation around a steadily propagating pulse solution. The latter can be readily obtained and fully parametrically characterized for a given fault rheology (see, e.g., Garagash [JGR 2012] for steady pulses driven by thermal pressurization). We validate the pulse EoM by full elastodynamics rupture simulations in the case of a fault dynamically weakened by thermal pressurization (TP).

The rate of pulse slip in the EoM is proportional to the difference between the actual background shear stress resolved on the fault plane and the “steady-state pulse value” of the background stress corresponding to the instantaneous value of pulse slip. This allows for a simple prediction that steadily propagating pulses are unstable when the corresponding pulse slip is a decreasing function of the background stress. This is the case for TP pulses (rendering them unstable), and, likely more generally, for fault rheologies characterized by strong weakening with accrued slip and/or slip rate.

EoM also quantifies how a transient pulse responds to heterogeneity in fault stress and strength (step up/down in stress leads to pulse deceleration/acceleration) allowing, for example, for a sustained, nearly-steady propagation on rough-stress faults.