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Dynamic rupture along interfaces including damage and friction: initiation, propagation and radiation

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Seismic rupture of large earthquakes initiates and propagates along pre-existing faults that have a complex internal structure (fault zone). The mechanical and numerical modeling of dynamic earthquake rupture is of great importance for seismic engineering and seismic risk management.

The propagation and the radiation of a seismic rupture has long been considered in seismology as a friction dominated process, and formulated as a propagating shear crack problem under the assumption of a Barenblatt-type surface energy. Slip weakening and rate-and-state friction laws are today commonly used. Both contain intrinsic length scales leading to a finite fracture energy, and a characteristic cohesive length-scale, insuring finite stress and slip velocity. As the quality and the density of the seismological and geodetic observations are continuously improving, new mechanical and numerical models are developed to study realistic dynamic rupture propagation in heterogeneous faults and extract new information from the recorded radiated waves and energy.

We first provide a short description of recent development of numerical methods based on non smooth contact mechanics and high-order variational approximation together with interface constitutive laws that include the interactions between volumetric damage breakdown processes and frictional dissipation.

Important scaling issues remain in the modeling of rupture dynamics and radiation. We first investigate the radiation and directivity of simple rupture dynamical models along complex fault geometries, including rupture initiation, rupture propagation and rupture arrest phases, comparing classical slip-weakening and interface laws including damage and friction. We then investigate effects related to off-fault dissipation in terms of volumetric dynamical damage, and its potential implication for the scaling of the radiative energy, for different fault geometries.

Finally, we discuss some open issues regarding the multi-scale modelling of earthquake rupture dynamics, and high frequency generation, when keeping a formulation based on surface energy.