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Kinetics and thermal evolution of a crack front in disordered papers or polymers

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During the propagation of a crack in an elastic medium, some of the system's energy brought by the external load is reversibly stored as elastic energy adapting to the crack morphology, while the rest gets irreversibly dissipated by three main processes: the creation of new fracture surfaces and defects/dislocations, the emission of mechanical waves transmitted to the far field and the Joule heating due to some friction in a damaged zone around the fracture front. Since this heat can in return have a significant impact on the physics of the propagation, establishing the energy balance in different fracturing scenarios is of great importance.

Notably, fracture's propagation has been shown to be strongly affected by thermally activated rupture, even when the heterogeneity of the material properties determines strongly the fracture geometry and the intermittency of its propagation. A natural parameter of interest to understand the kinetics of such propagation is the temperature field around the fracture. This question is notably central in earth science, where a lot of attention has been recently set on thermal effects, with the possibility of thermo-pressurization of faults due the expansion of in situ fluids. Independently of thermo-pressurization, the local rise of temperature at the zone enduring damage could significantly affect the creep in this zone, as understood by statistical physics and the Arrhenius law, and thus the global fracturing process.

We are interested in quantifying these different effects with both experimental set-ups and numerical simulations. We present two sets of results. The first set is based on the infrared and optical imaging of a crack propagating in a sheet of paper. The temperature field in the sheet shows local increases of several degrees during the propagation, related to the deformation rate at the tip of the crack. We present some numerical simulations that relate the increase of temperature to the speed at which the crack advances. The second set is based on the imaging of a fracture in a heterogeneous interface inside an acrylic glass body. We show that modeling the crack kinetics based on the material disorder, the elastic interactions at the crack front, as well as on an Arrhenius law - hence temperature dependent - shows good agreement with all the experimental observations – i.e. the scaling laws in the morphology of the crack front, and the distribution of the local rupture velocity.