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Temperature evolution and heat dissipation during crack propagation

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During a crack propagation, energy is dissipated in mainly three ways: creation of new fracture surface (possibly at microscopic scale in a process zone), emission of elastic waves that get dissipated in the far field, and local Joule heating during friction in a process zone. There is in addition some reversible elastic energy change associated to the crack advance.Since the temperature variations can have an important impact on the physics of the crack propagation, establishing properly this balance in different crack propagation scenarios is of great importance.

Notably, the physics of fracture propagation has been shown to be strongly affected by thermally activated rupture, even when the heterogeneity of material properties determines strongly the microscopic fracture geometry and the intermittency in the fracture propagation. A natural question, in such kinetic crack propagation, is the temperature field during the cracks propagation. This question is also central in earth science, where a lot of attention has been set recently on thermal effects, with the possibility of thermo-pressurization of faults due to thermal expansion of fluids present in faults. Independently of thermo pressurization, the rise of temperature locally, at the zone enduring damage, could significantly affect the creep in this zone, as understood by statistical physics and Arrhenius law, and thus the crack propagation.

We are interested in quantifying directly these different effects in an experimental situation. We present results based on infrared and optical imaging of the propagation of a crack in a sheet of paper. The temperature field shows local increases of the temperature of several degrees during the crack propagation. Optical images acquired with a fast video camera are correlated in order to extract the deformation field at each time step. We show how the temperature in our paper sample varies with the deformation rate at the tip of the crack. We also present some numerical simulations that relate the increase of temperature with the propagation speed of the crack.