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On the energy balance behind frictional ruptures

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Earthquake ruptures are driven by the dynamic weakening of frictional strength along faults. This drop of frictional stress toward a residual level is at the origin of the slip-weakening model, which became a well-established framework to study seismic ruptures and their energy budget. In this framework, the part of frictional energy associated to the rupture propagation (i.e. the fracture energy) corresponds to the excess of frictional dissipation on top of the residual stress, also referred as the breakdown work.

In this study, we test this energy partition for friction models that do not impose the magnitude of the residual stress. For example, rate-and-state models are a class of generic friction laws for which the residual stress after the rupture emerges from the interplay with the bulk elastodynamics. In this context, we simulate a frictional rupture at the interface between two linearly elastic solids and study the energy balance driving its propagation. Using dynamic fracture mechanics, we independently measure throughout the rupture the energy release rate from the bulk elastic fields and the frictional dissipation along the interface. From the comparison between these two quantities, we identify the part of interface dissipation corresponding to the fracture energy and show how the latter can be significantly smaller than the total breakdown work.

In a second phase, we test the generality of these results along another type of interface representative of mature fault zones filled with gouge.

This study shines new light on the energy budget of frictional ruptures and finds implications in the estimation of the fracture energy during earthquakes.