EGU22-6939
https://doi.org/10.5194/egusphere-egu22-6939
EGU General Assembly 2022

Contribution of thermal weakening in the frictional rupture dynamics

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The analogy between earthquakes (i.e. frictional ruptures) and shear crack motions is commonly used to investigate and understand the mechanics and occurrence of such natural phenomena. However, if on one side experimental works showed how shear cracks (obeying to a square root singularity, in the framework of Linear Elastic Fracture Mechanics) describe the onset of frictional ruptures, on the other side recent models suggested that frictional ruptures can be controlled by unconventional singularities (i.e., singularity orders that deviated from the square root singularity) if weakening occurs behind the rupture tip.

To study this, we performed stick-slip experiments with a biaxial apparatus working in a direct shear configuration. The tested samples consist of two polymethylmethacrylate (PMMA) blocks generating, once put into contact, an artificial fault interface. Normal load (1 to 5 MPa) and an increasing shear load were applied, leading to spontaneous ruptures nucleation. Rupture was captured through a strain gauge rosettes array along the fault, allowing the measurement of local strain and stress fields at high recording frequency (2 MHz).

Different events occurring at different rupture speeds (100 to 900 m/s) were studied. At the strain gauge location, a dual strength weakening is observed, reflected in a scale dependent evolution of breakdown work with fault' slip, contrarily to fracture energy which is, by definition, scale independent. This behavior, probably caused by thermal weakening (i.e. flash heating) activated during slip, is well described by the recently developed unconventional theory of frictional ruptures (i.e. rupture driven by a non-square root singularity). We demonstrate that such unconventional singularity emerges from velocity strengthening behavior, related to heat diffusion far from the rupture tip. Moreover, these experiments suggest that an analysis of the propagating rupture in the framework of Linear Elastic Fracture Mechanics, which assumes a square root singularity, could prove to be not always sufficiently exhaustive when frictional weakening occurs far from the rupture tip.