

THE ROLE OF GRAIN FRAGMENTATION IN UNDERSTANDING SHEAR LOCALIZATION VIA DEM SIMULATION

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ABSTRACT

Mature fault zones are formed by abrasive wear products, such as gouge, which results from the frictional sliding occurring in successive slip events. Shear localization in fault gouge is strongly dependent on, among others, fault mineralogical composition and grain size distribution, originating from a wide variety of microstructural textures that may be related to different types of fault motion from aseismic creep, slow earthquakes to fast slip events. Within a quartz fault zone, one can encounter different stages of maturity, ranging from an incipient and poorly developed fault zone (i.e. discontinuous and thin gouge layer) to a mature fault zone that has experienced a lot of wear from previous sliding events (i.e. well-developed gouge layer). The localization of deformation within a mature gouge layer has been identified as possibly responsible for mechanical weakening and as an indicator of a change in stability within the fault.

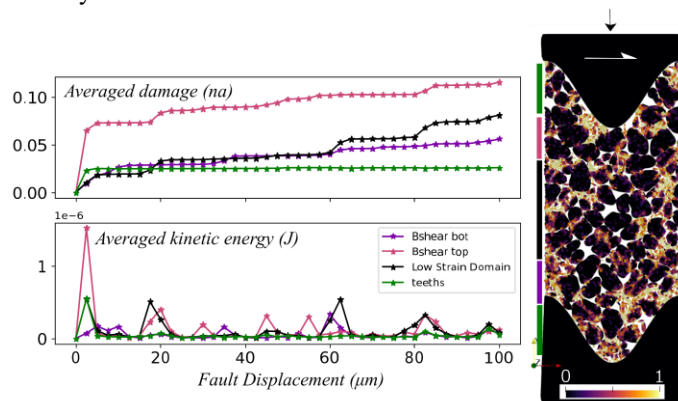


Fig.1 Averaged damage (na) and kinetic energy (J) within the different fault zones as a function of the fault displacement (μm).

However, to upscale the physics of shear deformation, we need to unveil the physical parameters and micro-mechanisms that govern shear localization. To gain insights into the role of dynamic changes in grain size (i.e. fragmentation), slip behavior, and fault rheology, we performed 2D numerical simulations of quartz fault gouges in a direct shear configuration using the

Discrete Element Method (code MELODY [1]), Fig. 1. We can reproduce angular particles that can fragment during the simulation as the fault gouge accumulates strain. These experiments were performed to understand the micro-mechanical processes happening during fragmentation and shearing at a constant normal stress. Three mixtures of quartz were sheared to reproduce different initial grain size distributions within the fault (average grain sizes $300\ \mu\text{m}$, Fig. 1, $100\ \mu\text{m}$, and a 50% mixture of both). All these particles are subdivided into smaller ones (size $20\text{-}30\ \mu\text{m}$) that can fragment during the experiment.

Thanks to visual and data outputs, we can observe how particles behave during the compaction and shearing of the gouge. We use four main parameters to describe fault gouge evolution: the damage of coarse particles, the force chains, the change of porosity, and the kinetic energy linked to each particle breakage, fig.1. Moreover, these numerical experiments were designed to reproduce and be directly compared with shear experiments realized on a double direct shear apparatus in the Laboratory [2, 3]. The fragmentation algorithm in the code can reproduce the shear localization observed within the real quartz microstructures and the progressive formation of Riedel bands. The connection between numerical and laboratory experiments gives important information on the connection between grain size distribution, shear localization, Acoustic Emissions, and the resulting fault slip behavior. In this context, the proportion between small/coarse particles within the fault plays an important role in controlling fault rheology.

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