Single-asperity friction and wear in seismic faults

Adriane Clerc*[1], Guilhem Mollon[1], Amandine Ferrieux[1], Lionel Lafarge[1], and Aurélien Saulot[2]

[1]Laboratoire de Mécanique des Contacts et des Structures (LaMCoS) – Institut National des Sciences Appliquées de Lyon, Centre National de la Recherche Scientifique – France

[2]Laboratoire de Mécanique des Contacts et des Structures (LaMCoS) – Institut National des Sciences Appliquées de Lyon, Centre National de la Recherche Scientifique – France

Abstract

Understanding earthquakes mechanisms still represents a challenge, motivated by the large consequences of the numerous earthquakes occurring each year. A number of uncertainties remain concerning the complexity of the fault structure, the constitutive properties of materials and the fault rheology. To address those points, different models coexist to conceptualize a fault. We choose to model a seismic fault as two rough surfaces in contact through a series of asperities, in the presence of wear particles (called granular gouge in geophysics or third body in tribology). In other words, we borrow from the tribological approach the pin-on-disk experiment so that the fault concept previously described is downscaled to a single asperity sliding on a rough surface. The single asperity response to shearing induced by sliding and the evolution of friction are studied closely to understand the different stages undergoing by the asperity and the consequences on the fault behaviour during co-seismic events.

The original experimental apparatus consists in a centimetric pin with a hemispherical extremity representing the fault asperity while a large flat rotating disk stands for the opposite surface of the experimental fault. Both pieces are made in the same rock with controlled roughness. The experimental downscaled fault is submitted to co-seismic conditions: contact size of 0.1-5 mm, contact normal stress of 10-200 MPa, sliding velocity of 0.01-1 m/s. The originality of the experiment device compared to usually used geophysical triaxial or rotational devices is the length of imposed sliding distance (up to 100 m in our experiments so far). A number of high-sampling-rate sensors are used to constrain the observation of the asperity contact during the simulated seismic events. Complete post-mortem analyses of the pin and the wear tracks with optical microscopy, SEM and roughness images allow to quantify the regime features, from centimetric to submicron clues. Thanks to this fine analysis, friction scenarios can be reconstructed in accordance with the time-series acquired during tests.

For tests conducted on Carrara marble, with a low velocity (linear velocity $<$ 0.1 m s-1.), we observe that, independently of the normal load applied, the friction coefficient exhibits a clear transition between an idealized lab conditions regime and a mature interface with the formation of granular gouge, as a function of the sliding distance. The longer the sliding distance, the more the track becomes uniformly rough and the more the pin is abraded and

*Speaker

cover of granular particles. Surprisingly, the wear rate increases while the pin's contact surface increases while abrading, so that the apparent normal stress decreases. The post mortem analyses of the pin's contact surface allow to understand the evolution of the microstructures as displacement increases, especially how the wear changes in relation of the circulation of the third body with in the contact. The granular gouge is analysed independently in order to determine the specific surface and to build an energetical balance of the shear induced by sliding.

For high velocity test (linear velocity > 1m.s-1) on Carrara marble, the dynamic weakening observed is supported by mirror like surfaces on the contact interface created by frictional heating. Those surfaces mark a sharp contrast between the granular gouge or the intact minerals found in other tests. Thus, a close attention to the post mortem surfaces and their nanometric features inform us of the abrasion and deposition modes of the third body created during sliding.