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Observation of the evolution of fault gauge under micro-CT

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Rock weakening and friction instability, during fault slip, is believed to play an important role in earthquakes. The study of such aspects rely on laboratory shear tests conducted on rocks, among which the direct shear and the rotary shear are the most common types. Rotary shear tests have two distinct advantages over direct shear: (1) unlimited shearing distance, and (2) constant contact area. Therefore, rotary shear is more suitable to study, for instance, the formation of gauge and its influences on earthquake fault instability.

During the past 15 years, rotary shear tests have been conducted on a large range of rock types, velocities, sliding distances, and temperature conditions. These experiments indicated that faults are lubricated during slipping, and that the friction decreases dramatically while approaching seismic slip rates. Many mechanisms have been proposed to explain such weakening behaviour, including flash weakening, melt lubrication, powder lubrication and thermal pressurization. Researchers also pointed out that the dynamic formation of a fault gouge (i.e. powder lubrication), which forms and accumulates between the fault surfaces as the result of rock wearing, plays an important role in lubricating the faults. Nevertheless, this claim has never been demonstrated.

In fact, the gauge layer produced during such tests, and its properties, continuously change as a function of slip distance, but also velocity, aging, applied stresses, and temperature. Additionally, during a test conducted with a conventional rotary shear apparatus it is extremely difficult to depict such variations. The study of the gauge layer geometry and its properties can hardly be conducted without the perturbation, for instance, of the grain arrangement, or the temperature and pressure conditions. Therefore, in order to understand the role of the gauge in decreasing the friction coefficient, it might be extremely meaningful to observe, without disturbance and continuously, how fractures develop, and gauge particles form, roll, translate, collide, comminute.

In this contribution, we present a new X-ray transparent vessel which can perform rotary shear tests inside the X-ray computed tomography apparatus (μCT) installed at the University of Toronto. This setup can perform rotary shear tests on 12 mm diameter samples and image the slipping surfaces and the forming gauge without disturbing the specimens. We conduct rotary shear tests at sub-seismic slip rates (i.e. from 0.15 to 6 mm/s) and for incremental short slip distances (e.g. 60 steps of 0.3 mm for one revolution cycle) in order to reconstruct the 4D evolution of the slipping surfaces and the gauge layer. While rotating the specimen, normal stress, displacement, and torque information are acquired with a sampling rate of 2 kHz. The samples can be confined up to 10 MPa and saturated with liquids by means of a hydraulic circuit.

These work may lead to a much more detailed observation of the physical interaction on the earthquake fault. Together with the other laboratory and field observations, we can enrich the understanding of the powder lubrication mechanism.