Onset of frictional sliding: the effect of interfacial heterogeneities

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The transition from static to sliding friction is mediated by the propagation of interfacial shear cracks. These cracks break the solid contacts that form rough frictional interfaces and are quantitatively described in term of fracture mechanics. In this study, we show that the introduction of heterogeneities at the interface, such as a localized patch of lubricant, leads to unexpected dynamics at the onset of sliding motion. Lubricant facilitates rupture nucleation but can also act as a barrier for rupture propagation.

Keywords (from 3 to 5 max): interface dynamics, multi-contact interfaces, onset of sliding, lubrication

1. Introduction

The onset of sliding motion is conditional on the propagation of rupture fronts that detach the contacting asperities forming a frictional interface. The transition from static to sliding friction takes place when a rupture traverses the entire interface. But ruptures can also arrest before reaching the end of the interface. Propagating ruptures have been shown to be true shear cracks, driven by singular fields at their tip and fracture mechanics have been successfully used to describe rupture arrest along homogeneous frictional interfaces [1]. Here we show that interfacial heterogeneities lead to unexpected rupture dynamics at the onset of sliding motion [2].

2. Methods

We introduce lubricant patches at the interface between two frictional solids to locally change the interfacial properties (Fig. 2a). Solid blocks made of PMMA are pressed and sheared until a sliding event occurs.

2.1. Measurements methods

We perform high-temporal-resolution measurements of the real contact area, using an optical method based on total internal reflection of light, and strain fields measurements, using strain-gauges located near the interface (Fig. 1).

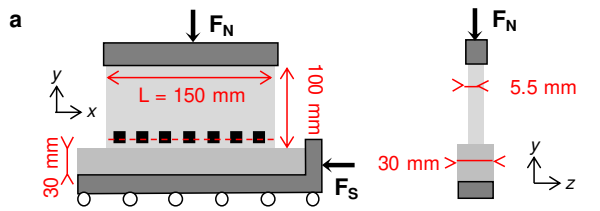

Figure 1: Experimental setup. Blocks of PMMA are pressed and sheared. Black squares denote strain gauges.

2.2. Results

The strain-field measurements performed as the rupture propagates lead to the determination of the fracture energy of the frictional interface. We first show that, surprisingly, a thin layer of lubricant increases the interfacial fracture energy.

A crack arrest criterion is a balance between the available elastic energy, via the applied stress, and the fracture energy. We highlight two roles of the lubricant patch, (i) to facilitate rupture nucleation, by decreasing the required applied stress, and (ii) to act as a barrier for rupture nucleation, by increasing the fracture energy (Fig. 2b).

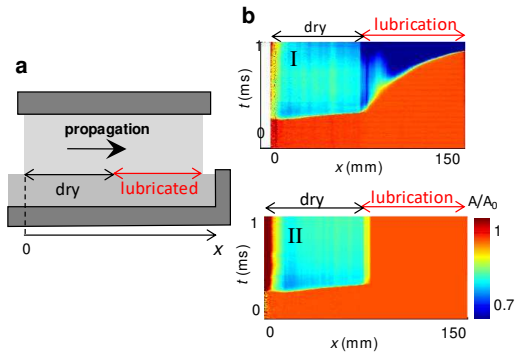

Figure 2: (a) Heterogeneous interfacial properties due to the introduction of a lubricant patch. (b) Spatiotemporal evolution of contact area for (top) a propagating and (bottom) an arrested rupture.

3. Discussion

The lubrication of solid surfaces is generally thought to reduce frictional resistance to sliding motion and to prevent material wear. Here we show that it strongly modifies the fracture properties of a frictional interface, by increasing the fracture energy, and therefore can act as a barrier for rupture propagation. Fracture mechanics provide a new way to view the otherwise hidden complex dynamics of micro-contacts forming the interface. It can be used as a tool to characterize the interfacial properties of a frictional system.

4. References

[1] Svetlizky, I. et al., "Brittle Fracture Theory Describes the Onset of Frictional Motion," Annu. Rev. Condens. Matter Phys. 10, 253-273 (2019).

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