Friction weakening by mechanical vibrations

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We investigate experimentally friction weakening by mechanical vibrations for both granular and solid friction. We show that in both cases, the quantity governing the friction weakening is the vibration velocity, $(A\omega)$, where A is the vibration amplitude and ω its frequency. The grains rearrangements under vibrations is therefore not the mechanism at stake. The critical velocity $(A\omega)_c$ at which the transition between stick-slip and continuous sliding is observed is of the same order of magnitude, a hundred microns per second, and is directly linked to the roughness of the surfaces in contact.

Keywords (from 3 to 5 max): friction weakening, vibrations, roughness, asperities

1. Introduction

During catastrophic events such as landslides, earthquakes or pyroclastic flows, puzzling phenomena of frictional weakening have been reported. Many works have focused on quantifying the effect of endogenous or external mechanical vibrations on frictional properties. They have shown that mechanical disturbances reduce or even suppress friction. However, the mechanism at stake is still under debate: instabilities generation and self-fluidization, material softening, contact opening, etc... In addition, the critical parameter controlling the transition also remains controversial. In systems with a low confinement pressure, Lastakowski et al. [1] have shown that the vibration velocity, and not its acceleration, is the key parameter controlling the frictional weakening in granular assemblies, with a surprisingly low value of the critical vibration velocity leading to the transition between stick-slip and continuous sliding. However, is the grains mobility mandatory to trigger this transition ? Is the key parameter identical for granular and solid friction ?

2. Methods

2.1. Experimental setup

A plexiglas slider (length 9cm, width 6cm) of mass m is pulled across a fixed substrate by a cantilever spring (metallic blade, stiffness k) moved at constant speed V (Fig. 1a). The parameters (m, k, V) are chosen such that without vibration, the system is in the stick-slip regime. For granular friction, a monolayer of the same beads is glued under the slider. For solid friction, we fix identical paper samples both on the substrate and under the slider. We investigate smooth (Inapa) and rough (Canson) paper samples. Horizontal vibrations are imposed to the whole setup by a mini-shaker (Bruël & Kjaer) clamped on the substrate. Their amplitude and frequency are measured in-situ by accelerometers (Dytran).

2.2. Results

For both granular and solid friction, we report a frictional weakening when the vibration amplitude and/or frequency increase. Although the vibration velocity $(A\omega)$ is always the governing parameter for the decrease of the stick-slip amplitude, its decay and transition to continuous sliding exhibit different shapes.

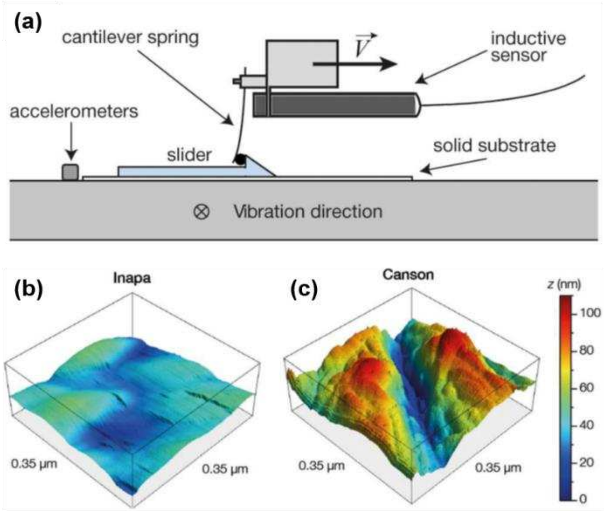

Figure 1: (a) Experimental setup. (b,c) AFM maps of rough (Canson) and smooth (Inapa) paper samples.

3. Discussion

AFM measurements on both paper samples reveal that the topography at small scale is clearly different between the smooth (Fig.1b) and rough (Fig.1c) paper samples. Additional measurements for granular beads (glass spheres) are taken from the litterature [2]. We propose that the radius of curvature R of the asperities is a good candidate for the relevant lengthscale that controls the frictional properties [3]. For small R, the asperities are sharper and the critical vibration velocity should be larger to undergo the transition between stick-slip and continuous sliding.

4. References

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