Numerical Modelling of the Dynamics of the Onset of Sliding

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Résumé :

Nous utilisons un modèle multi-échelles de la transition entre frottement statique et frottement dynamique, pour étudier la vitesse des fronts de rupture le long d'interfaces multi-contact étendues. Nous montrons que la vitesse des fronts est directement contrôlée par la vitesse de glissement associée, pour toute la gamme de vitesses explorée. Nous proposons ensuite un classement, basé sur les mécanismes en jeu, pour les différents types de fronts observés. Nous montrons finalement comment le coefficient de frottement statique local est contrôlé par l'histoire du glissement, au même endroit, mais lors de la rupture précédente de l'interface.

Abstract :

We use a multi-scale model for the transition from static to dynamic friction to investigate the speed of rupture fronts along extended multi-contact interfaces. We show that front speed is directly controlled by slip speed across the full speed range explored. We then propose a mechanism-based classification of the various front types. We finally show how the local static friction coefficient is controlled by the slip history of the previous rupture of the interface.

Mots clefs: Multicontact interfaces, onset of sliding, rupture front, front speed, static friction, multi-scale model

1 Introduction

The transition from stick to slip at a dry frictional interface occurs through the breaking of the junctions between the two contacting surfaces. Typically, interactions between the junctions through the bulk lead to rupture fronts propagating from weak and/or highly stressed regions, whose junctions break first. Experiments find rupture fronts ranging from quasi-static fronts with speeds proportional to the external loading rates [1], to fronts that travel faster than the shear wave speed [2], via fronts much slower than the Rayleigh wave speed [3], and fronts that propagate near the Rayleigh wave speed. The mechanisms behind and selection between these fronts are still imperfectly understood.

2 Methods

Here we perform simulations in an elastic 2D spring-block model where the frictional interaction between each interfacial block and the substrate arises from a set of junctions modeled explicitly [4]. The full model is identical to the one first described in [5].

3 Results

We find that the following proportionality between material slip speed v_{slip} and rupture front speed v_c, previously reported for slow fronts [5], actually holds across the full range of observed front speeds:

$$v_c \propto v_{slip} \frac{k_i l_0}{\tau_{thres} - \tau_0},$$

with k_i, the shear stiffness of the connection between one block and the track, τ_{thres} the threshold stress for the block to start slipping, τ_0 the initial shear stress and l_0 the characteristic length of the shear stress decay along the interface.

We revisit a mechanism for slow slip in the model and demonstrate that fast slip and fast fronts have a different, inertial origin. Indeed, both fast slip and fast front speed scale with $\rho^{-1/2}$, with ρ the mass density of the material, just like bulk wave speeds.

We highlight the long transients in front speed even in homogeneous interfaces, which suggests that fronts observed experimentally may also be transient. In any case, both the local shear to normal stress ratio and the local strength are involved in the selection of front type and front speed. In particular, the relevant stress parameter is:

$$\bar{\tau} = \frac{\tau_0 - \tau_{slip}}{\tau_{thres} - \tau_{slip}},$$

with τ_{slip} the kinematic friction stress of a block.

Lastly, we introduce an experimentally accessible integrated measure of block slip history, the Gini coefficient, which is a known estimator of inequality, used for instance to quantify wealth inequalities within a population [6]. We demonstrate that in the model it is a good predictor of the history-dependent local static friction coefficient of the interface.

All these results [7] will contribute both to building a physically-based classification of the various types of fronts and to identifying the important mechanisms involved in the selection of their propagation speed.

Références

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