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ELASTODYNAMIC SLIDING OF A LAYER ON A FLAT UNDER COULOMB'S FRICTION: VELOCITY DEPENDENCE, OPENING WAVES AND SUPERSONIC SLIP PULSES

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ABSTRACT

Constitutive frictional laws, which are assumed to control interface behavior are deduced from macroscopic tests. At the same time, a numerical simulation of the same macroscopic test, with the deduced frictional law assumed to govern the interfacial behavior, may notproduce the macroscopic behaviorobserved in the experiment. This interesting effect is strongly related to the elastodynamic behavior of the macroscopic system [1]. For example, assuming in the interface the simplest Coulomb's friction law with a single coefficient of friction, may result in a velocity-dependent macroscopic friction law [2]. In this talk we will present recent theoretical results highlighting the difference between local and globalfrictional behavior.

We consider the following set-up: an infinite elastically isotropic layer is pressed against a rigid flat and is slid over it at a constant speed; the frictional behavior of the interface is governed by Coulomb law. This problem was addressed using the finite element method using periodic boundary conditions imposed on a finite-length elastic layer; the solution is integrated in time using HHT implicit integration. A parametric study was carried out, in which we controlled the Poisson's ratio, sliding speed and the coefficient of friction.

The particularity of this set-up is that the initial stress state of the interface is homogeneous along the sliding direction, which can be reproduced in circular contact systems, like ring-on-flat or cylinder-in-hole. Thus, in shear, all the points reach the frictional limit simultaneously and they all start to slide. However, this uniform sliding appears to be unstable independently of the friction coefficient [3], thus leading to localization of the sliding within slip pulses, propagating in the direction of motion at supersonic celerity, or within slip events resembling standing waves. This steady-state non-uniform sliding at local scale results in a velocity-dependent friction at global scale and thus naturally obey velocity-weakening friction law with a static and dynamic friction coefficients. In addition, the global friction was shown to dependent non-monotonically on Poisson's ratio.

This stationary regime persists if the coefficient of friction does not exceed the critical value of one [4], otherwise the sliding mechanism changes drastically. The frictional slip localizes within a single zone, which transforms into an opening wave. Since in opening no energy is dissipated, the global frictional force rapidly decreases and can even turn negative, i.e. can be inversed. This peculiar behavior is studied theoretically within a wave-guide theory and an intensive parametric finite element study is also carried out [4]. In Fig. 1 several snapshots of a finite element simulation demonstrating the formation of localized slip and an opening wave are depicted.

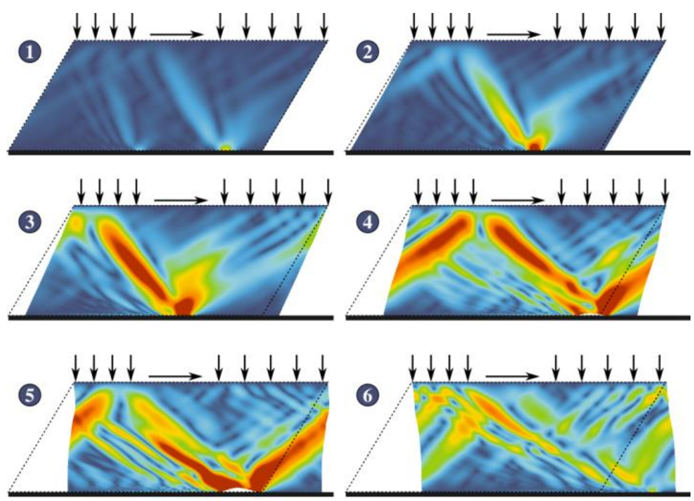

Fig. 1.Localization of slip and formation of opening waves in sliding of an elastic layer over a rigid flat under Coulomb's friction (the color represents material-point speed).

REFERENCES

[1] Ben-David, O., Fineberg, J. Static friction coefficient is not a material constant. Phys Rev Lett, 106:254301, 2011.

[2] Adams, G.G. Radiation of Body Waves Induced by the Sliding of an Elastic Half-Space Against a Rigid Surface. ASME J Appl Mech 67:1-5, 1999.

[3] Brener, E.A, Weikamp, M., Spatschek, R., Bar-Sinai, Y., Bouchbinder E., Dynamic instabilities of frictional sliding at bimaterial interface. J Mech Phys Solids 89:149, 2016.

[4] Martins, J.A.C., Guimaraes, J., Faria, L.O. Dynamic surface solutions in linear elasticity and viscoelasticity with frictional boundary conditions. J Vib Acoust, 117:445-451, 1995.

[5] Yastrebov, V. A. 2016, Sliding Without Slipping Under Coulomb Friction: Opening Waves and Inversion of Frictional Force. Tribology Letters 62:1-8.