ON THE DEPENDENCY OF FRICTION ON LOAD: THEORY AND EXPERIMENT

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KEYWORDS
interface structure; roughness

ABSTRACT
In rubber friction studies it is often observed that the kinetic friction coefficient depends on the nominal contact pressure. This is usually due to frictional heating, which softens the rubber, increases the area of contact, and (in most cases) reduces the viscoelastic contribution to the friction. We present experimental results showing that the rubber friction also depends on the nominal contact pressure at such low sliding speed that frictional heating is negligible. We attribute this effect to the viscoelastic coupling between the macroasperity contact regions (see Fig. 1), and present a simple earthquakelike model and numerical simulations supporting this picture.

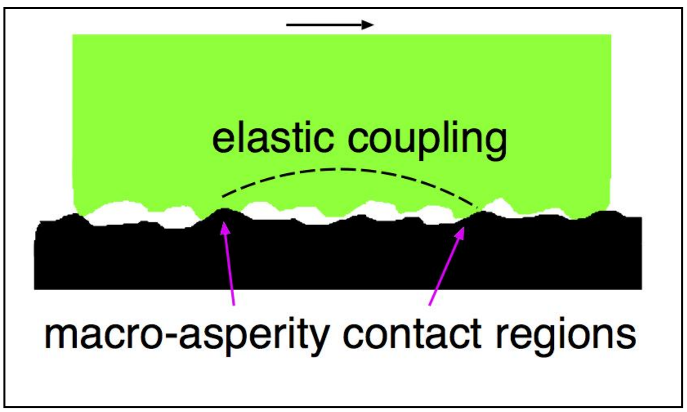

Fig.1 An elastic block (e.g., rubber) sliding on a substrate. For a randomly rough surface the concentration of macro-asperity contact regions increases proportional to the normal force. This will affect the lateral elastic coupling between the macro-asperity contact regions, and results in a friction force which depends non-linearly on the load.

Experiment. We have studied rubber friction for tread rubber compounds sliding against concrete and asphalt road surfaces. The measurements were performed using the Leonardo da Vinci set-up [1]. The slider consists of two rubber blocks glued to a wood plate. We have found that close to the first maximum (as a function of increasing sliding speed v) of the $\mu(v)$ friction curve (the first maximum is due to the adhesive interaction between the rubber and the road surface in the area of real contact), the friction coefficient decreases slightly with increasing nominal contact pressure. At the same time the friction coefficient for lower velocities is the same in all cases within the accuracy of the measurements.

Simulation. The experimental results were explained qualitative with the help of a quasi-1D model in Ref. [1]. Now we present a full 3D-model. Our model is similar to the Burridge and Knopoff spring-block model. In the model the top block (the slider) is coupled with the bottom block (the substrate), assumed to be rigid and fixed, by a set of frictional contacts. The sliding block is decomposed (or discretized) into N mass points, which are connected by viscoelastic springs. A fraction θ of the mass points at the bottom surface of the sliding block are connected by frictional coupling to the substrate. The upper surface of the sliding block is connected to a rigid surface with viscoelastic springs, and the rigid surface moves with a velocity v parallel to the substrate. The parameter θ is proportional to the normal load.

The model shows that the lateral coupling between the macroasperity contact regions can enhance the stick-slip of the contact regions. This effect has important implications for rubber sliding dynamics, e.g., in the context of the tire-road grip.

ACKNOWLEDGMENTS
The research work was performed within a Reinhart-Koselleck project funded by the Deutsche Forschungs-gemeinschaft (DFG). We would like to thank DFG for the project support under the reference German Research Foundation DFG-Grant: MU 1225/36-1. The research work was also supported by the DFG-grant: PE 807/10-1.

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