Comment on "Friction Between a Viscoelastic Body and a Rigid Surface with Random Self-Affine Roughness"

In their Letter, Li *et al.* [1] present a calculation of the friction between a viscoelastic body and a rigid surface with self-affine fractal roughness. The calculation presented is for a 1D array of springs with damper in contact with a 1D rigid line profile. It is based on the "method of reduction of dimensionality" (MRD). The authors have claimed in the past that this method is exact (or nearly exact [2]), and their discussion and the fact that all quantities are reported in SI units suggest that their model is applicable to real-world realizations of elastomers, such as rubber. However, we have recently shown that the MRD fails even qualitatively for randomly rough surfaces [3]. To demonstrate this we compare the predictions of the MRD with numerically exact results for the full 3D problem (with 2D surfaces), obtained as described in Refs. [3,4].

In Fig. 1 we show the calculated fractional contact area A/A_0 as a function of the squeezing pressure for elastic solids. We present results for two surfaces with the same root-mean-square slope. The red and blue squares are the result of a numerical exact study. The red and blue solid lines are the predictions using the MRD. Note that $A(p)$ approaches A_0 much faster in the MRD than in the numerically exact theory. We attribute this failure to describe the contact mechanics correctly to the incorrect treatment of the elastic coupling between the asperity contact regions.

The authors focus on the high-load case where the contact area approaches complete contact [1]. However, for this limiting case the 1D mapping approach is particularly inaccurate (see Fig. 1). There are several other points where the authors of Ref. [1] make unphysical assumptions. First, rubber friction for sliding velocities above ≈ 1 mm/s is strongly influenced by the flash temperature. That is, the local energy dissipation in asperity contact regions results in local temperature increase. Since the rubber viscoelastic modulus is extremely temperature dependent (a 5 K increase in temperature can shift the viscoelastic spectrum by one decade in frequency) this has a crucial influence on the rubber friction as discussed in detail in Ref. [5]. In Figs. 2–4 in Ref. [1] the friction is calculated in the range 1 cm/s–100 m/s, and in this velocity range the flash temperature, not included in the treatment in Ref. [1], will dominate the frictional behavior. Frictional heating is also the reason for why Amonton's friction law is often not valid for rubber friction: increasing the load increases the frictional heating which tends to reduce the rubber friction. Indeed, experiments performed at very low sliding velocity, where frictional heating is not important, usually exhibit (for rough surfaces) a load-independent kinetic friction coefficient [6]. The fact that the friction coefficient $\mu = F/F_N$ becomes dependent on load F_N when the contact area approaches complete contact is trivial since F must saturate. This holds for all materials.

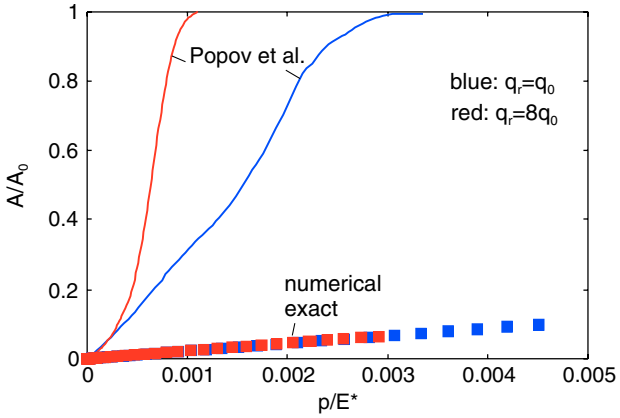

FIG. 1 (color online). The area of real contact A in units of the nominal contact area A_0 as a function of the squeezing pressure p in units of the effective elastic modulus E^*. For self-affine fractal surfaces with $H = 0.7$ and rms slope 0.1. The surfaces have the small and large wave vector cutoff $q_0 = 1$ and $q_1 = 4096$, respectively, and the roll-off wave vector $q_r = 1$ (blue curves) and $q_r = 8$ (red curves).

Other points not addressed by the authors are the magnitude and origin of the short-wavelength cutoff [5], and also the contribution from the area of real contact, which in fact dominates the friction at very low sliding speeds [7,8]. In conclusion, the Letter by Li *et al.* [1] does not incorporate the relevant effects for the friction between a viscoelastic body and a rigid surface with random self-affine fractal roughness.

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