MACROSCOPIC FRICTION OF MICROSCOPICALLY ROUGH SOFT CONTACTS

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1. Introduction

One can distinguish a number of possible mechanisms and sources of dissipation at different length- and time scales, which can contribute to what manifests itself as the macroscopic frictional response. As such, rough contacts in sliding usually exhibit complex behavior, and their satisfactory description is still viewed as one of the frontiers of modeling in tribology [1]. In this work, we follow the multiscale approach to modeling, which provides us with methods allowing to gain deeper understanding of the analyzed contact systems and to effectively model friction.

We focus on a specific class of contact systems in which one or both bodies are soft and thus may undergo large deformations. These can be, for instance, rubber-like materials like elastomeric seals or biological tissues like the skin. For such systems, the viscoelastic dissipation induced by the moving contact roughness and the accompanying non-homogeneous fluctuation of contact forces is usually viewed as a dominant effect that is responsible for differences in frictional characteristics between the micro- and the macro scale [2, 3]. However, it turns out that one can also observe non-trivial frictional effects at the macro scale even if only purely elastic contacts and the simple Amonton-Coulomb friction model are considered at the micro scale [4–6]. The latter (purely-elastic) case is more deeply analyzed and discussed in this work.

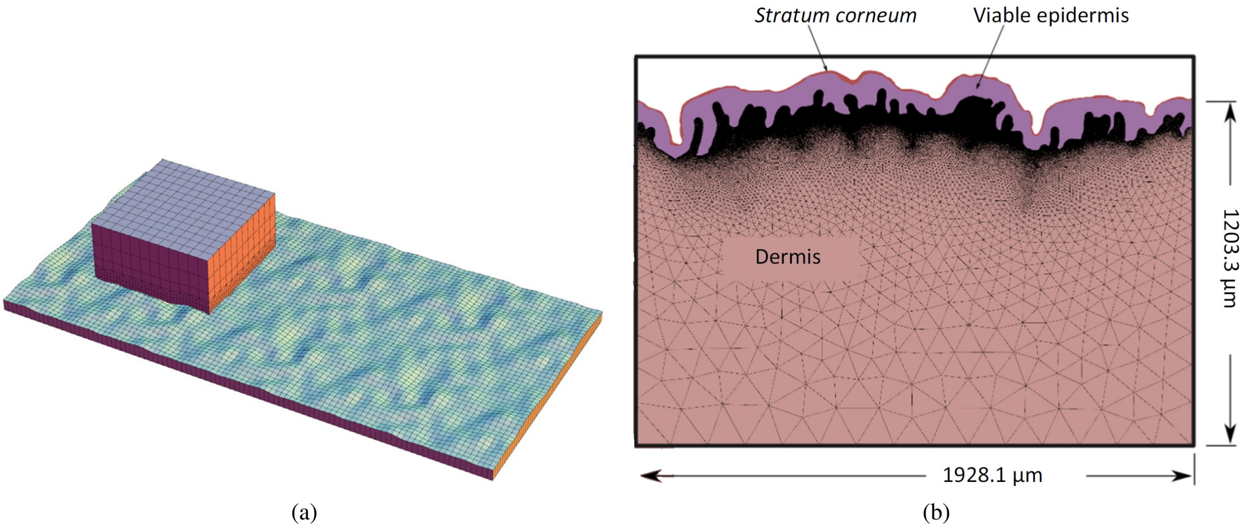
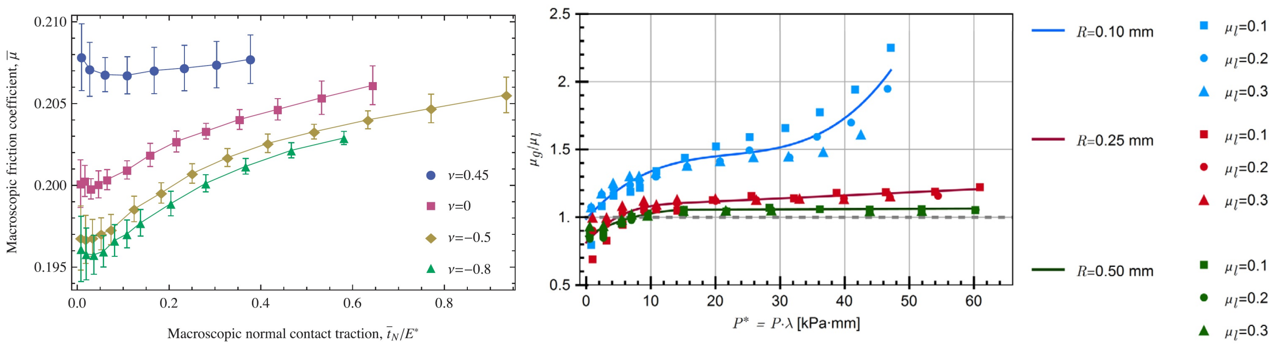


Figure 1: Two microscopically-rough contact systems: (a) randomly rough periodic surfaces, (b) 2D anatomically-based FE model of the skin to be in sliding contact with a rigid indenter.

2. Frictional response of microscopically rough soft elastic contacts

Two families of contact systems have been analyzed. The first family (further referred to as Case 1) is based on randomly generated rough periodic surfaces [4], see Figure 1a, and is characterized by relatively low asperities' heights and slopes' angles. The second family (Case 2) uses the geometry and material properties which correspond to a real anatomy of skin section. It features a complicated surface topography at the microscopic scale and a layered structure [5, 6], see Figure 1b. In Case 2, a simplified counter-surface has been considered, represented by isolated rigid cylinders (not shown in Figure 1b).

In both cases, FEM-based contact homogenization procedures have been used (different for each case) to analyze the frictional response. As expected, it was shown that the macroscopic friction coefficient can be in general different from the microscopic one. But it was also observed that it can substantially depend on the normal contact pressure. A further study of how the friction-pressure relationship depends on various problem parameters has been performed in both analyzed cases. In Case 1, for the Poisson's ratio $\nu \leq 0$, a counter-intuitive effect has been observed, in which the macroscopic friction coefficient drops below the microscopic one, see Figure 2a. In Case 2, the global-to-local friction coefficient ratio is higher than in the Case 1, and it possibly depends on asperities' radii on the counter-surface, see Figure 2b.



(a) (b)

Figure 2: Friction-pressure relationship in macro scale: (a) in Case 1, [4], for different values of the Poisson's ratio ν and for the micro-scale friction coefficient $\mu_l = 0.2$, (b) in Case 2, [6], for different cylindrical indenter radii R and different micro-scale friction coefficients μ_l.

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