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A 2-D model for friction of complex anisotropic surfaces

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ABSTRACT

The friction force observed at macroscale is the result of interactions at various lower length scales that are difficult to model in a combined manner. For this reason, simplified approaches are required, depending on the specific aspect to be investigated. In particular, the dimensionality of the system is often reduced, especially in models designed to provide a qualitative description of frictional properties of elastic materials, e.g. the spring-block model. In this paper, we implement for the first time a two dimensional extension of the spring-block model, applying it to structured surfaces and investigating by means of numerical simulations the frictional behaviour of a surface in the presence of features like cavities, pillars or complex anisotropic structures. We show how friction can be effectively tuned by appropriate design of such surface features.

1. Introduction

The frictional behavior of macroscopic bodies arises from various types of interactions occurring at different length scales between contact surfaces in relative motion. While it is clear that their ultimate origin lies in inter-atomic forces, it is difficult to scale these up to the macroscopic level and to include other aspects such as dependence on surface roughness, elasticity or plasticity, wear and specific surface structures (Nosonovsky and Bhushan, 2007; Persson, 2000). Moreover, the dependence on "external parameters", e.g. relative sliding velocity of the surfaces and normal pressure, is neglected in approximate models such as the fundamental Amontons–Coulomb law, and violations of the latter have been observed (Deng et al., 2012; Katano et al., 2014).

For these reasons, simplified models are required in theoretical studies and numerical simulations, and friction problems can be addressed in different ways depending on the specific aspects under consideration. In order to improve theoretical knowledge of friction, or to design practical applications, it is not necessary to simulate all phenomena simultaneously, and a reductionist approach can be useful to investigate individual issues. Thus, despite the improvement in computational tools, in most cases it is still preferable to develop simplified models to describe specific aspects, aiming to provide qualitative understanding of the fundamental physical mechanisms involved.

One of the most used approaches to deal with friction of elastic bodies consists in the discretization of a material in springs and masses, as done e.g. in the Frenkel–Kontorova model (Braun and Kivshar, 2004), or the Burridge–Knopoff model

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