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Atomistics of friction

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Abstract

When two solid bodies contact and slide against each other, a frictional phenomenon occurs. There have been two models for the origin of the friction forces: the surface roughness model and Tomlinson's model. The surface roughness model explains the origin of the static friction force; contacting solid surfaces are so rough that surface asperities are mechanically locked against the gravitational force. From an atomistic point of view, Tomlinson explained a mechanism of the energy dissipation for the origin of the dynamic friction force. The atomistic mechanisms are described for the origin of the static and the dynamic friction forces, based on the theoretical conclusion that Tomlinson's mechanism is unlikely to occur in realistic frictional systems. The mechanism for the origin of the static friction force resembles the mechanical locking mechanism in a surface roughness model. The origin of the dynamic friction force is formulated as a problem of how the given translational kinetic energy dissipates into the internal relative motions of constituent atoms of bodies during sliding. From studying the available phase space volume of the translational motion becomes negligibly small for a large system size, compared with that of the internal motions, it is concluded that the energy dissipation occurs irreversibly from the translational motion to the internal motions. The comparison of the atomistic mechanisms with the surface roughness model and Tomlinson's model is discussed. A phenomenon of superlubricity, where two solid bodies move relatively with no resistance, is discussed.

Keywords: Friction; Surface roughness; Tomlinson's model; Superlubricity

Contents

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1. Introduction

When two solid bodies contact each other and one body begins to slide against the other, a frictional phenomenon appears. The friction force is the drag against sliding, appearing along the contacting surfaces. According to whether or not two bodies move relatively, the friction forces are classified into static and dynamic ones. They have different physical origins [1].

The static friction force may be characterized by the maximum force necessary to begin to slide one body against the other. The dynamic friction force is the force applied to continue to slide one body against the other with a finite velocity. The energy must be dissipated during sliding. It is experimentally known that the dynamic friction force depends less on the sliding velocity [2,3]. Thus, the origin of the dynamic friction force is a problem of how the energy can be dissipated. For the sake of simplicity, we hereafter call the static and the dynamic friction forces simply as the friction forces. When any confusion may occur, we add the prefixes term “static” or “dynamic” to the friction force.

Roughly speaking, two pictures (or models) have been advocated for the origin of the friction forces [1–3]. The first is called the surface roughness model. The contacting solid surfaces are so rough that surface asperities are mechanically locked against the gravitational force. It is necessary to apply an external force to slide one body against the other. This mechanical-locking mechanism was conjectured especially by the earlier workers such as da Vinci, Amonton, and Coulomb, and concerns with the origin