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The friction effects in the stick-slip phenomena of the human skin

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ABSTRACT

In tribosystems that include contact with a flexible body, friction-induced vibration may be present. Dimensionless analysis coupled with numerical manipulation was employed to model the discontinuity between the static and kinetic behaviour of the friction. The present paper discusses the nature of stick-slip between a human fingertip and standard printing paper, intending to describe the theoretical stability conditions of movement. The amplitude of the stick-slip phenomenon is analised as a function of the human skin's rheological and tribological properties, the system's rigidity, and the sliding contact velocity.

1. Introduction

The primary goal of this article is to collect and synthesize information about friction, adhesion, lubrication, and wear of biological systems and to apply the resulting knowledge for developing a theoretical model with experimental data input to describe the friction effects of human skin.

Many authors have studied biological friction phenomena with applications for humans [1–9] and artificial skin [10]. The main issue arising from the tests conducted is that there is no standard for testing the tribological aspects of skin.

In general, stick-slip is likely to occur if there is a variation of friction coefficient and relative movement between two surfaces. This phenomenon is more prevalent at low velocities. The stick-slip phenomenon refers to the vibration that occurs when the static coefficient of friction is higher than the kinetic coefficient of friction in the case of the relative movement of two solids in contact, but this is not the only mechanism that drives the stick-slip mechanism. Other mechanisms identified in recently published articles that influence the stick-slip process are velocity and stiffness [11], surface topography [12], damping, torsional stiffness, and angular velocity [13], contact stresses and topology [14], damping [15–17].

The amplitude of the stick-slip movement is determined by the characteristics of rigidity of the two mating surfaces, the relative velocity, and the friction behaviour of the two solids in contact [18,19].

The phenomenon of stick-slip or vibration induced by friction is a phenomenon that occurs at low and very low velocities. The effect is often undesirable, as the vibrations produced can damage the mechanical systems or disturb the sound by high intensity and frequency noises, but it is also desired in the case of bowed musical instruments such as the violin [12]. Furthermore, the phenomenon is present in the case of car brakes [16,17] and clutches [20] and is a generator of positioning errors in the case of machine tools [21].

The stick-slip phenomenon, therefore, occurs if the relative velocity is less than the value of the velocity at which the slip is stable and depends on the rigidity characteristics of the system and the friction behaviour of the two materials in contact. [22,23] The stick-slip motion is conditioned by the ratio between the static friction coefficient and the kinetic friction coefficient and only occurs if the ratio is >1 [24,25]. The coefficient of static friction is dependent on the contact duration. A common feature of materials is the growth of the contact area over time. Experimental observations in this direction have been made, the conclusion being that it is closely related to the plastic relaxation of microcontacts [26] that increases the actual contact area and leads to an increase in the coefficient of static friction.

The stick-slip phenomenon's traditional characteristics are depicted in Fig. 1. The phase of increasing the frictional force is followed by a phase of sudden discharge of the energy stored at the contact level and the transition from the static to the dynamic friction regime.

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