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

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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 static and kinetic behavior of friction. The present paper discusses the nature of stick-slip that occurs between a human fingertip and standard printing paper with the aim of describing the theoretical stability conditions of movement. The amplitude of the stick-slip phenomenon is analyzed as a function of the rheological and tribological properties of the human skin, the rigidity of the system and the velocity of the sliding contact.

Keywords: biotribology, human skin, stick-slip

1. Introduction

If there is a variation of the coefficient of friction, and relative movement occurs between two surfaces, stick-slip is likely to occur. This phenomenon is more prevalent at low speeds and is dependent on the rigidity of the system in the direction of movement. 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 behavior of the two solids in contact [1,2].

2. Methods

2.1. Experiments

To map the mechanical characteristics of the contact between a human finger and paper, a setup was devised involving the CETR UMT-2 (Universal Mechanical Tester) Tribometer. The in-vivo testing method was utilised to capture the stick-slip phenomenon. By employing this type of test, a comprehensive set of data was generated which was used to describe the mechanical behaviour of the fingertips. Four separate velocities (0.05, 0.1, 0.5, and 1 mm/s) and three separate force values (1.5, 3 and 5N) were used. The indenter used was a rigid sphere with a diameter of 28 mm covered with standard printing paper that was held stationary with the use of a clamp.

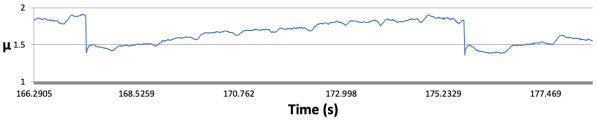

Figure 1: Typical stick-slip episode

One of the more interesting aspects of a stick-slip movement that can easily be seen in Figure 1 is the multitude of microslips (creep) that occur as the contact saturates and enters its critical point where a maximum coefficient of static friction is achieved. These microslips have been observed to be dependent on the velocity and force applied.

2.2. Theory

From a theory standpoint, the homogeneous differential equation for the sliding period was used to analyze the conditions of occurrence of the stick-slip phenomenon as follows:

$$\ddot{\xi} + 2\alpha\dot{\xi} + (\xi - \xi_o) = 0 \qquad (1)$$

Where:

$\xi_o = \frac{pA_c\omega_n\mu_{ko}}{v_o k} = \mu_{ko} w$ is the displacement at the end of slip stage.

The dimensionless parameters controlling the stick-slip are clarified by deriving the dimensionless forms of the governing equations for time, velocity, and acceleration. Thus, equations for both amplitude (A_ξ) and duration (τ_{max}) can be obtained:

$$\tau_{max} = \frac{1}{\sqrt{1-\alpha^2}} \operatorname{atan}\left[\frac{1}{\frac{\alpha}{\sqrt{1-\alpha^2}} + \sqrt{1-\alpha^2(\xi_p-\xi_o)(1+\frac{\alpha^2}{1-\alpha^2})}}\right. \qquad (2)$$

$$A_\xi = \xi_{max} - \xi_o = \xi(\tau_{max}) - \xi_o \qquad (3)$$

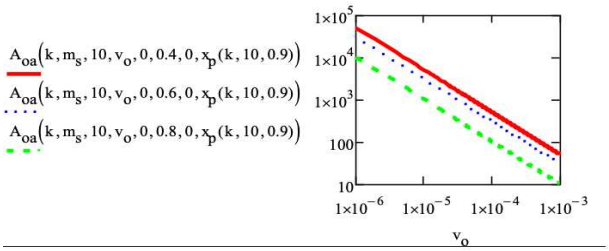

Figure 2: The dimensionless amplitude of the stick-slip movement of human skin.

3. Discussion

The stability of the stick-slip movement is given by a loading (Φ_c) and a damping (α) parameters. The loading parameter, creep time and creep velocity were determined experimentally, and were used to predict the occurrence of the stick-slip movement.

4. References

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