Specific Causes of Friction and Vibration

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ABSTRACT

This article is devoted to spasmodic displacements of surfaces. Practically observed oscillations have a small frequency. The true cause of the friction jumps is determined. It is established that the friction force from a place is a given increasing function. An analysis of the phenomenon of jumps during friction is considered using the example of a slip of a body relative to a rough plane. After the end of the first jump, the body has uniform motion, then the second jump according to the harmonic law again has uniform motion, etc.

Keywords: friction, jump, contacting surfaces, theory of dry friction, the reason for jumps is slip, vibration frequency, elasticity, vibration during metal cutting, contact of rubbing bodies, type of lubricant, rough plane, spring tension, friction force of moving away, harmonic law, displacement, the instant the beginning of a new leap

Introduction

In the literature there are a significant number of articles on the abrupt displacement of contacting surfaces observed at low sliding speeds. This phenomenon formed the basis of the theory of dry friction proposed by Boudena F.P. It is this phenomenon that causes an abrupt movement of surfaces [1-4].

Haykin S.E S.E. pointed out the inadequacy of Boudena F.P, proving that the jumps during friction are mechanical relaxation oscillations. Some researchers have shown that jumps depend on mechanical parameters characterizing the friction force [5-9]. Boudenom F.P. Pointed out that the presence of jumps should depend on the mechanical parameters of the system. The very irregularities of the contacting surfaces, possessing elasticity, are the cause of the jumps.

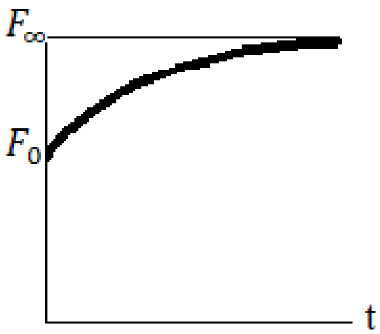

Fig. 1.

The last statement cannot be correct, since in this case the oscillation frequency of such a system must be very high. At the same time, the practically observed oscillations have a low frequency. What is the real reason for jumps during friction, how to explain them, and what are the conditions for their existence. The analysis of the phenomenon of jumps is of practical importance (vibration during metal cutting, the impossibility in some cases of slow smooth mutual movement of parts of mechanisms, etc.)

It is known that: 1) the jumps arising at low speeds of mutual sliding disappear with increasing this speed: 2) the amplitude and frequency of the jumps depend on the sliding speed, the mass of the slide and the rigidity of the system; 3) the first jump is much larger than the subsequent ones [10-15].

Haykin S.E. noted that jumps will inevitably take place if the system has some elasticity, and the friction force, considered as a function of the sliding speed, has the so-called feed characteristic. However, these assumptions do not explain why the amplitude of the jumps decreases with an increase in the sliding velocity, with the first jump being larger than the subsequent ones.

However, the friction force as a function of the sliding speed in the low-speed zone, on the contrary, has an increasing characteristic. This is consistent with the idea of the friction mechanism as a process of viscous destruction of material in the contact area of rubbing bodies. The explanation of the phenomenon of jumps during friction should be based on taking into account the increase in the starting friction force and the dependence on the duration of the stationary contact. Presentation of this theory.

Let us assume that the starting friction force is a given increasing function $F(t)$ of the duration t of contact between two bodies in the absence of slippage between them. The approximate form of the function $F(t)$ is shown in picture 1. Dependency

$$F(t) = F_{\infty} - (F_{\infty} - F_0)e^{at} \quad (1)$$

quite satisfactorily represents this function, here F_0 is the value of the starting friction force with a long duration of the contact of the bodies without mutual sliding; F_0 is the value of the same force with practically no fixed contact time; α - coefficient, depending on the properties of rubbing bodies, the degree of their processing, the type of lubricant, etc. of course,

$$F_{\infty} \succ F_0 \quad (2)$$

Let us assume that the value of the frictional force of motion (i.e., when bodies slide over each other) is also equal to F_0 and does not depend on the sliding speed of one body over another. We will analyze the phenomenon of intermittent motion or jumps during friction using the example of a body sliding relative to a rough plane (picture 2).

Let the body A, which is connected by a spring C of rigidity K with a stationary object, lie on a rough plane B. The plane begins to move, dragging the body along with it and thereby tensioning the spring with force.

$$P = Kx_0, \quad (3)$$

Where, x_0 - the displacement of the body from the position at which the spring is not tensioned.

Body A will move together with plane B until the tension P of spring C reaches the value of the starting friction force $F(t)$, corresponding to the previous time t of contact of the body with the plane. If body A before the beginning of the movement of plane B lay on it for a long enough time, then we can put

$$Kx_0 = F_{\infty}, \quad (4)$$

where x_0 is the value of the displacement x, upon reaching which the sliding (jump) of the body A along the plane B begins. This sliding occurs in the presence of two forces acting on the body F_0 the assumed constant frictional force of motion F_0 directed towards the motion of the plane, and the force of flatness spring P, expressed by formula (3).

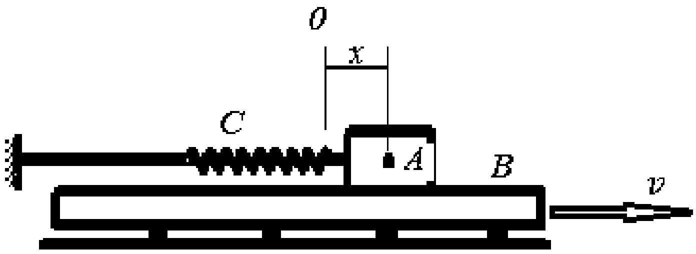

Fig. 2.

Under the action of the above two forces, the further movement of the body will occur according to the harmonic law about the equilibrium position $x = a$ (picture 3), which is determined by the relation

$$K_a = F_0 \quad (5)$$

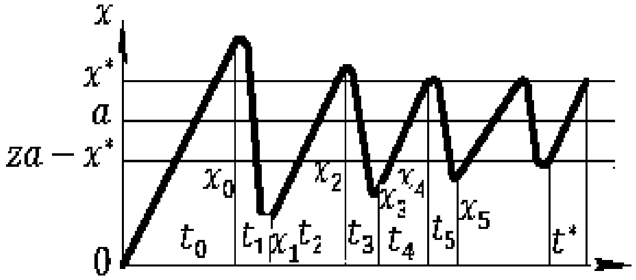

Fig. 3.

At the beginning of sliding, body A had displacement $x = 0$ and velocity. Consequently, body A will first continue to move in the same direction as the points of plane B, gradually decreasing its speed and lagging behind them.

Further, the speed of the body will change its sign and it will begin to move in the opposite direction, first with a speed increasing in absolute value. After the body passes the position corresponding to the displacement $x = a$ at which the friction force is equal to the elastic force of the spring, the velocity of the body in absolute value will again decrease until it changes its sign again, and the body will begin to move with increasing speed in the direction of motion of plane B.

At some displacement $x = x_1$, the velocity of the body A will be equal to the velocity of the plane B, i.e. the value. Since the movement of the body occurs according to a harmonic law, the displacements of the body corresponding to the same value of the velocity v are symmetric about the equilibrium position. Hence,

$$\frac{(x_0 + x_1)}{2} = a \quad (6)$$

Where

$$x_1 = 2a - x_0 \quad (7)$$

After the speed of the body A reaches the value v, it ceases to slide along the plane B and does the next, together with the plane right up to the next leap. Indeed, body A cannot get ahead of plane B, since in this case the friction force would change sign and the body would be acted upon in the direction of motion of the plane

$$-Kx_1 - F_0 = -K(2a - x_0) - F_0 = F_\infty - 3F_0 \quad (8)$$

However, the latter is negative (if F_∞ exceeds F_0 by less than three times) and the body's speed cannot increase.

If we denote by t_2 the time during which the body A after the cessation of sliding will move together with the plane B, and through x_2 - the displacement of the body at the instant of the beginning of a new jump, then, obviously, the equality

$$x_2 = x_1 + vt_2 \quad (9)$$

Fig. 4.

On the other hand, at this instant the tension force of the spring Kx_2 and the starting friction force are equal, the value of which is now determined by the time t_2 of contact without sliding between body A and plane B after the first jump. Therefore, the equality

$$Kx_2 = K(x_1 + vt_2) = F(t_2) \quad (10)$$

allowing to find, knowing the function $F(t)$, the interval t_2 and the offset x_2.

The new jump will also represent a movement according to the harmonic law, which will end in the instant when the speed of the body A again equals the speed of the plane B. The corresponding value of the displacement can be found by the formula

$$x_3 = 2a - x_2 \quad (11)$$

similar to relation (7)

Further, the body A for some time t_4 again uniformly moves with the speed v together with the plane B, until the second jump starts during the displacement. To find the time t_4 one should solve an equation of the same form as (10), i.e.

$$Kx_4 = K(xa + vt_4) = Ft_4 \quad (12)$$

After the end of the second leap, a uniform movement follows again, then a third leap will occur, etc.

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