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PHYSICAL MODELING OF THE EFFECT OF ADHESION ON THE FRICTION PROCESS IN MACHINES AND PARTS

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ABSTRACT

This article investigates the effect of adhesion on the friction process of mechanisms in machines and their components. The research indicates that adhesion has a significant influence on the mechanism of the friction process. It is evident that factors such as the adhesion layer formation mechanism, its strength, dynamic conditions, surface tension, molecular forces, and the surface condition of the adhesion layer all affect the friction process. Furthermore, the work expended on frictional adhesion varies depending on surface tension and the wetting angle. The research shows that if adhesion is diffusive, the primary controlling factor is the energy generated between crystal defects. This energy varies based on the inter-defect distance and inter-defect electrification. If adhesion during friction is of a diffusive nature, the nature of diffusion around any axis and the speed of diffusion can be mathematically described. If adhesion during friction is deformational, deformation occurs in different directions.

1. Introduction

The mechanism of friction in machines and the factors that influence it remain a critical research topic. Finding an optimal solution to this problem requires examining it from nanotribological, microtribological, and macrotribological perspectives [1].

From a nanotribological standpoint, understanding the adhesion mechanism and its effect on friction allows for a more comprehensive analysis of the issue. During friction, one material exerts force on another, and at the points of contact, atomic interactions occur as the atoms attract each other [2]. A key aspect of this phenomenon is the behavior of atoms in frictional contact and the physical modeling of adhesion effects, which can help address the problem.

The impact of adhesion on friction depends on multiple factors. These include the adhesion layer formation mechanism, the strength of the adhesion layer, the influence of dynamic conditions, the interaction between adhesion and cohesion, and the effect of surface tension on the adhesion layer [3]. Additionally, molecular forces, the nature and variation of these forces, the surface condition of the adhesion layer, and the influence of air humidity on adhesion all play a role in determining friction behavior [4].

2. Research methodology

Initially, the study focuses on the work of adhesion during friction, particularly its relationship with surface tension (θ) and wetting.

$$W_{adg} = \theta_{surface\ tension}(1 + cos\theta) + N \quad (1)$$

The wetting angle plays a crucial role in adhesion, and the first challenge is to control the factors that influence it during friction. One of the most intriguing aspects of adhesion is the mechanism by which it occurs during friction.

From a mechanical perspective, adhesion takes place when the adhesive substance fills the pores of the material. If adhesion follows an adsorption mechanism, it occurs at the molecular level through surface contact. In cases where adhesion follows a chemical mechanism, it results from the formation of chemical compounds between two substances. It is also possible that frictional adhesion occurs through an electrification mechanism.

A key area of interest is how these mechanisms interact. Depending on the conditions of friction, they may replace one another, combine to form a more complex adhesion mechanism, or alter the nature of friction. If adhesion occurs via diffusion, the primary concern is the energy generated between defects in the crystal structure.

$$\mathrm{E} = \frac{q^2}{\varepsilon R} \quad (2)$$

It is clear that if the mechanism of adhesion during friction is diffusion, the distance between R-defects and the electrification between q-defects depend on the dielectric permeability of the ε −material.

$$\mathrm{jx} = \frac{vC(x,\tau)}{vx} \quad (3)$$

When there is friction on the surface, we can write the mechanism of diffusion around any axis as follows:

$$\mathrm{V} = \frac{dq}{d\tau} = DS\frac{vC(x,\tau)}{vx} \quad (4)$$

The rate of diffusion in adhesion during friction is:

$$\mathrm{j} = -\mathrm{D}\ \mathrm{grad}\ \mathrm{C}(\mathrm{x,y,z},\tau) = -\mathrm{D}\nabla C(\mathrm{x,y,z},\tau) \quad (5)$$

If diffusion goes in 3 directions in the process of adhesion during friction, then:

$$\mathrm{f} = F_{slide}/F_n = (F_{dif} + F_{ad}/F_n) \quad (6)$$

If the adhesion during friction is of a diffusion nature, then the basic formula that characterizes the friction is as follows:

$$M_{ir} = \int (F_i X_R - F_R X_i) dV \quad (7)$$

If adhesion during friction is deformational, the friction mechanism will behave as follows: The friction in different directions changes depending on the processes occurring within a single volume. However, if one part of the rubbing surface experiences adhesion deformation while another part follows a diffusion mechanism, the overall friction mechanism will differ. Friction progresses more rapidly in the deformation-dominated region.

On the other hand, if adhesion during friction follows an adsorptive mechanism, the friction mechanism will behave differently. The way adhesion changes during friction depends on various factors, especially when adsorption is involved. In this case, key influencing factors include the integral changes in thermodynamic functions, variations in Gibbs energy, and the mechanism of adsorption change based on surface parameters:

$$W_a = K_1(1-\theta)\text{p} \tag{8}$$

If adhesion during friction follows the adsorption mechanism, the main controlling factors are the speed and pressure of W_a −adsorption. Additionally, one of the key factors in this process is the thermal effect of adsorption. If adhesion during friction is governed by adsorption, the variation in thermal effects plays a crucial role in determining the overall mechanism:

$$\Delta H = \Delta G + T\Delta s \tag{9}$$

3. Discussion of results

The thermal effect of adsorption during friction depends on the mechanism of change in surface enthalpy (H), surface free energy (G), and entropy change (S). However, if we were to physically describe the adsorption mechanism of adhesion during friction:

$$D_s = \frac{S}{V} = \frac{K_{sv}}{q} \tag{10}$$

It is clear that the adhesion K_{sv} − during friction depends on the coefficient characterizing the shape of the particles on the surface and the surface-volume coefficient:

$$\text{S} = 4\pi R^2{}_0\, n^{2/3} \tag{11}$$

$$\text{V} = \frac{4}{3}(\pi \text{R}^3{}_0\text{n}) \tag{12}$$

It is clear that the radius of atoms and molecules (R_0) varies depending on the surface-to-volume ratio and the number of molecules and atoms in the particle (N). If adhesion during friction is adsorptive, then the surface energy changes depending on the following parameters:

$$G_s = 4\pi v \left|\frac{3\pi}{4\pi}\right|^{\frac{2}{3}} \cdot n^{\frac{2}{3}} \tag{13}$$

It is clear that the mechanism of adsorption-type adhesion during friction depends on surface tension (v), surface area (s), and the volume of v-atoms and molecules. At the same time, the freedom of the mechanism of adsorption-type adhesion during friction is influenced by:

$$G_V = -nK_B T k \ln\left(\frac{P}{P_s}\right) \tag{14}$$

We can express the effect of energy as follows: If adhesion during friction follows the adsorption mechanism, the free energy (K_B) depends on the Boltzmann constant, the absolute temperature (T), and the vapor pressure (P_1P_s).

If the adhesive deforms during friction, the direction of friction depends on the stresses. It is clear that, in this case, the stresses can change direction depending on various parameters. These stresses are influenced by several factors, including the mechanisms of adhesion and adsorption, as well as the friction mechanism itself.

$$-\oint \theta_{ir} df_R \tag{15}$$

Distribution of the force applied to friction in different directions and coordinates:

$$M_{ir} = \int (F_i X_R - F_R X_i) dV \quad (16)$$

The stress distribution during friction is:

$$M_{stress\ distrib} = \int \left(\frac{\vartheta \emptyset_{ie}}{\vartheta X_e} X_R - \frac{\vartheta \emptyset_{Re}}{\vartheta X_e} \right) dV = \int \frac{\vartheta(\emptyset_{ie} X_H - \emptyset_{Re} X_{i)}}{\vartheta X_L} dV - \int (\emptyset_{ie} \frac{\vartheta X_R}{\vartheta X_L} - \emptyset_{Re} \frac{\vartheta X_i}{\vartheta X_L}) dV \quad (17)$$

During friction, if adhesion is deformational, we can express the change in internal energy (dε) as follows: (Provide the equation or description here)

$$\mathrm{d}\varepsilon = T ds + \emptyset_{in} du_{iR} \quad (18)$$

In general, the processes that occur during friction, the factors that influence them, and the physical modeling of their effects on the mechanism are highly relevant.

4. Conclusion

1. Adhesion has a significant impact on the mechanism of the friction process.

2. The formation mechanism of the adhesion layer during friction directly affects the friction process.

3. The work required for frictional adhesion varies depending on surface tension and the wetting angle.

4. If adhesion is diffusive during friction, the primary controlling factor is the energy generated between crystal defects.

5. If adhesion during friction is deformational, the distribution of deformation and stress changes direction under the influence of various parameters.

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