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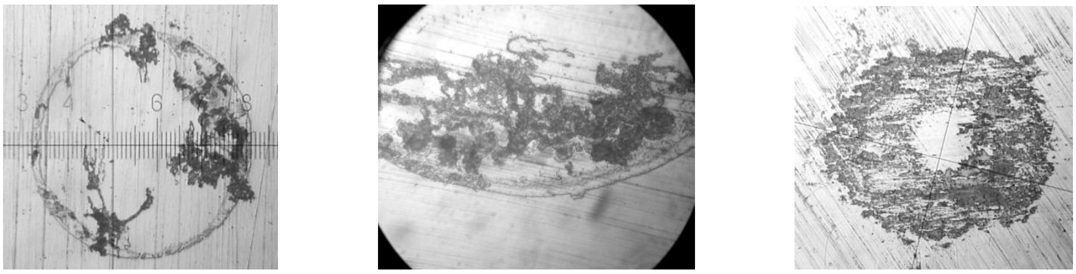
BEHAVIOR OF PARTIAL SLIP IN CONTACT ZONE BALL AND FLAT SURFACE

У статті досліджується поведінка сталевих поверхонь при субмікронних циклічних прослизання. Визначено міра активації поверхонь при динамічному контактуванні
Ключові слова: *субмікронні, активація, контактування*

Introduction

Fretting-processes are determined by a complicated complex of mechanical, natural and chemical processes, which occur into zone of contact of two surfaces at the presence of tangential stress contacts. Recently increasing attention of the researches is given to quasistatic contact in conditions of dynamical loading. It is possible to state, that the given condition of contact is characteristic in most cases for really operate nominal - fixed joints, when there is no visible relative displacement [1–3]. The last statement requires detail discussion with the purpose of definition of parameters small amplitude fretting. The difficulties consist that for certain of state of stress and deformation of surface the amplitude-frequency characteristic of oscillations of two body practically is identical, that, a priori excludes, relative displacement of surfaces. However, for research of the interface of surface are damages characteristic for fretting. It is possible to assume, that the elastic interaction of two bodies in a tangential direction suffices for initiation fretting. In this case configuration of separate spots of contact both in scale of roughness, and in the boundaries of contour area of contact allows occurring to relative microdisplacement which up to a several micron. It is enough of it for intensive evolution of fretting in the boundaries of a preliminary displacement of surfaces (ris. 1).



a ***b*** ***c***

Ris. 1. **Initiation of fretting-processes on an edge of nominal – fixed contact (*a, b*) and further development of process (c) for $N=10^7$ cycle, Ω = 100 Hz, diameter sphere Ø 12 mm**

Depending on kinetics of accumulation of surface damages by fretting the evolution of a spectrum of oscillations occur, behind which there is a modification of amplitude and velocity relative slip, forces of friction, moment installation of an equilibrium roughness. Thus, the operation of tangentional, which do not exceed a limiting force of friction ($Q < \mu P$) is result to much significant to smaller amplitudes of a relative displacement in partial area of contact, on a comparison with that, which traditionally referred to fretting (20 … 100 μm).

Other part of contact is deformed is agreed and is named as a zone of stuck. From the general equation of equilibrium [4]:

$$Q = \mu P\left[1 - \left(\frac{c}{a}\right)^3\right] \quad (1)$$

let's receive ratio for sizes of zones of stick and slip:

$$\frac{c}{a} = \left(1 - \frac{Q}{\mu P}\right)^{1/3} \quad (2)$$

The relative displacement of two bodies for diameter of ring area of contact ***a*** is determined by expression:

$$\Delta = \frac{3\mu P}{16 \cdot a}\left(\frac{2-\nu_1}{G_1} + \frac{2-\nu_2}{G_2}\right)\left[1 - \left(1 - \frac{Q_x}{\mu P}\right)^{2/3}\right] \quad (3)$$

Disregarding slip moment:

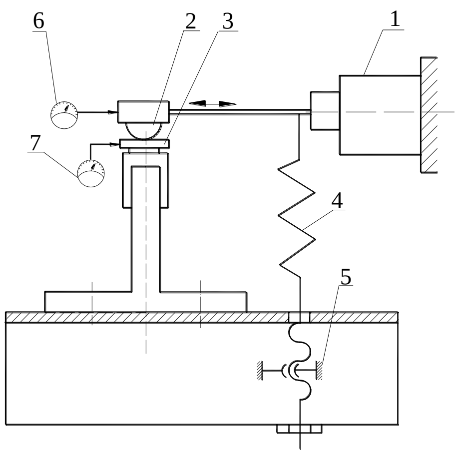
$$\Delta = \frac{Q_x}{8a}\left(\frac{2-\nu_1}{G_1} + \frac{2-\nu_2}{G_2}\right) \quad (4)$$

We investigated geometric performances of spot of contact for sphere and flat with from the point of view of development small amplitude fretting on the boundary of contact.

The equipment

The scheme of plant for a research of frictional contact in conditions of fretting represented in a fig. 2. On an elastic beam with a sufficient rigidity in a tangential direction ($2 \cdot 10^6$ H/m) the flat specimen 3 is placed. The ball 2 is fixed on vibrator 1 electromagnetic type. Frequency of vibration of 100 Hz. The displacement of each element of contact pair is check by through indicators (6, 7) inductive type, which probes are rigidly fixed. It excludes inertia micro impacts between a probe of the gauge and checking body. The normal load in contact was formed by an elastic element 4 with the help of rotations of the screw 5. Visual monitoring for oscillations and the digital information processing was made because of software product, developed by us, Dual ADC [2].

Optic research carry out on microscope MIM-10 and measurements of geometric parameters of contact on tool microscope IMC–10. Counter-specimen is ball-beating steel by a diameter 12 mm.



Ris. 2. ***The scheme of plant for a research of frictional contact in conditions fretting***

Configuration of contact

Let's consider a picture of microdisplacement of points of two bodies, which are characterized as nominally - fixed contact. In the boundaries of a zone of stick all points of a surface test identical tangential displacements and the point K_1 coincides with C_1, K_2 with C_2. Having set transition of the upper body x_1, the body 2 is shifted on x_2. The coordinates x_1 and x_2 are inspected immediately by gauges of displacement (ris. 3, a). The difference $\Delta x = x_1 - x_2$ 2 gives a relative displacement of two bodies (ris. 4).

Since points K_2 and C_2 the ring slip zone for points K_3 and C_3 (fig. 3, b) begins. The points K and C mean points on a surface of contact which coincide before appendix of tangential force. The points A_1 and B_1 are deleted enough from contact, that it would be possible to place the gauge of displacement.

Let's consider a rigidity of a ball absolute. Then displacement Δx coincides with displacement of points of contact of ball $\Delta x = K_1K_2$. And point C tests elastic tangential displacement distinct from Δx.

Significances of slip˙ will be:

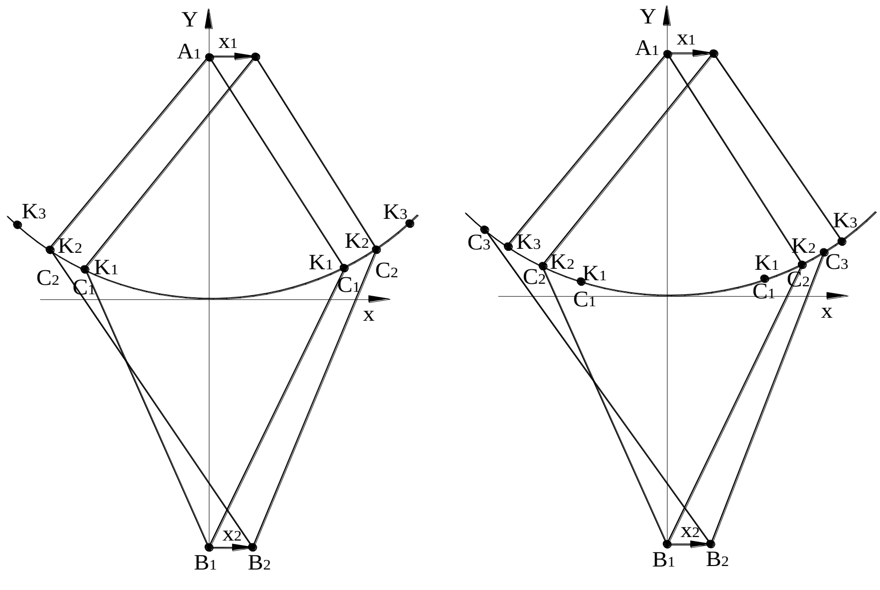
$$\delta_s = x_k - x_c = (\Delta x + x_2) - (x_2 + u_e) = \Delta x - u_c \qquad (5)$$

The conditions of absence slip˙ are equality of displacement in a tangential direction of all points of contact. If the difference of displacement of two bodies Δx, which is inspected by the gauge of displacement, does not exceed an elastic displacement of points of contact, is satisfied condition:

$$\mu\sigma_c < \tau_c \qquad (6)$$

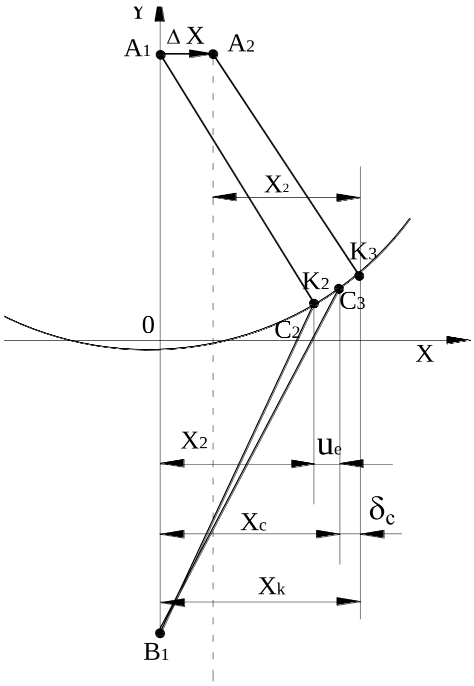
where σ_c – distribution of normal stress in zone of stick, τ_c – distribution, of tangential stress.

The relation of difference of points of contact in directions of axeses *x* and *y* a little also is possible to neglect displacements in a vertical direction $\nu/(4-2\nu) \approx 0{,}09$ [4], where ν – Poisson's constant.



a *б*

Ris. 3. **Contact displacement in a zone of sticking (*a*) and slipping (*b*)**



Ris. 4. **The scheme of displacement of points contact of rigid sphere and flat**

Magnitude slip˙ in a ring $c \le r \le a$ we determined from the equation:

$$s = \frac{3\mu P}{16Ga}(2-\nu)\left[\left(1-\frac{2}{\pi}\arcsin\frac{c}{r}\right)\left(1-2\frac{c}{r}\right)+\frac{2c}{\pi r}\left(1-\frac{c^2}{r^2}\right)^{1/2}\right] \tag{7}$$

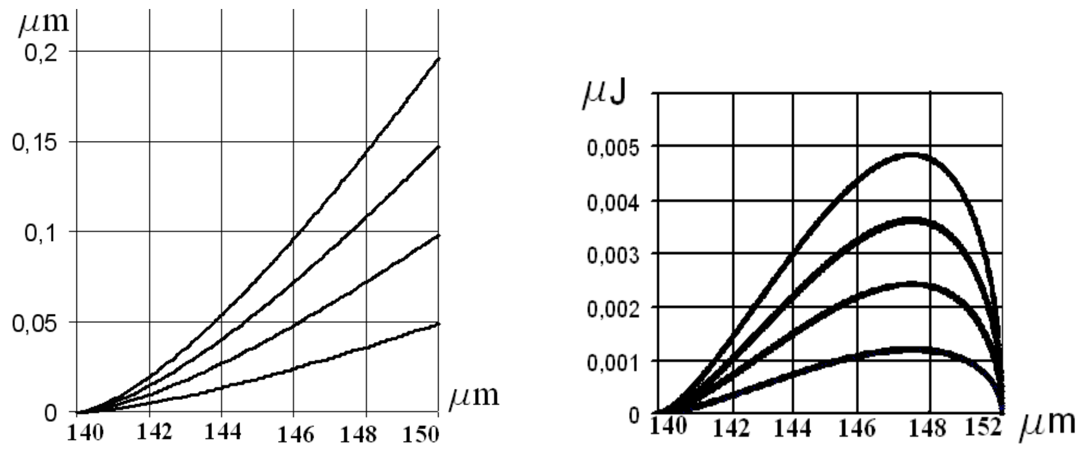
Relative tangential displacement [4]:

$$\delta_x = \frac{3\mu P}{16a}\left(\frac{2-\nu_1}{G_1}+\frac{2-\nu_2}{G_2}\right)\left[1-\left(1-\frac{Q_x}{\mu P}\right)^{2/3}\right] \tag{8}$$

Dissipation of energy for a cycle of oscillations:

$$\Delta W = \frac{9\mu^2 P_0^2}{16a}\left(\frac{2-\nu_1}{G_1}+\frac{2-\nu_2}{G_2}\right)\times\left\{1-\left(\frac{Q_x}{\mu P}\right)^{5/3}-\frac{5Q_x}{\mu P_0}\left[1-\left(1-\frac{Q_x}{\mu P_0}\right)^{2/3}\right]\right\} \tag{9}$$

Settlement dependence of magnitude of slip˙ of area $c \le r \le a$ depending on coefficient of friction is shown in a fig. 4. Significance of a breadth of a ring zone and normal gain are taken from experiment. It is visible, that maximum slip takes place on the boundary of area of contact and their magnitude small enough.



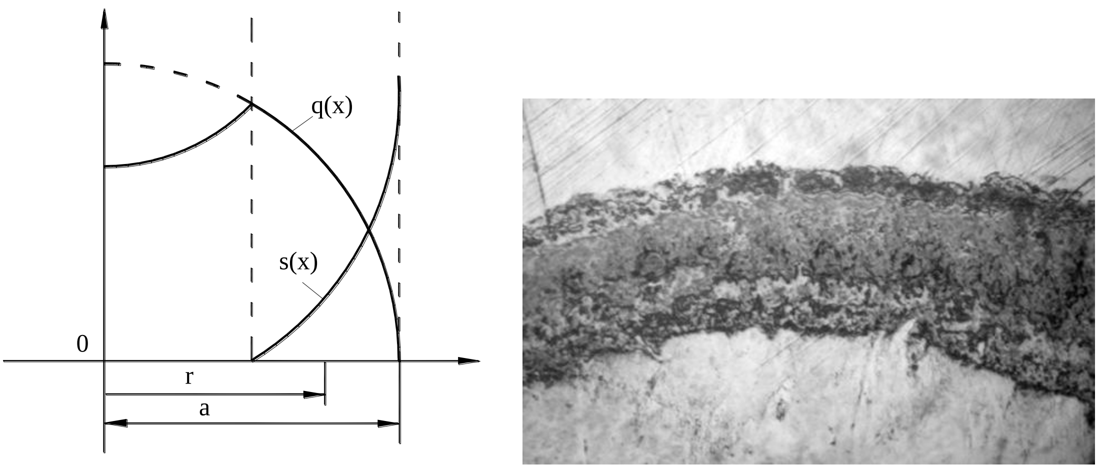
a ***в***

Ris. 5. **Significance of tangential displacements of points of contact in ring area (a) and work of friction in slip zone (b) depending on of friction coefficient $0{,}1 \le f \le 0.4$.**

Here c = 140 μm, a = 150 μm, P = 40 H, Ω = 100 Hz

Distribution of tangential stress, at condition of absence slip for only in two points of a ring zone in the (beginning and the end contact) extremity is determined from a ratio:

$$q = \mu P_0 \left(1 - \frac{r^2}{a^2}\right)^{1/2} = \mu \frac{2P}{\pi a}\left(1 - \frac{r^2}{a^2}\right)^{1/2} \tag{10}$$



a ***b***

Ris. 6. **The distribution of tangential stress and relative displacements in a zone slip (*a*). Structures of a zone slip in a result of small amplitude fretting (*b*)**

The magnitude of load P and radius of contact was taken from experiment. By such, the work of forces of friction in slip area is described by a configuration of two association's $q(x)$ and $s(x)$ (ris. 6).

Conclusions

Intensive fretting-corrosion develops for very small peak tangential displacement.

Is more greatest fretting damage 1/3 breadths of a ring zone of a sliding from edges of contact are expected inside slip area on a distance.

The origin fretting – fatigue crack is possible inside area of slipping.

The frictional processes on a start stage of oscillations and accompanying by them adsorption phenomenon on a surface call flocculation of molecules of water and iron, that observes as a congestion of oxide particles

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Поведение частичного проскальзывания шаровой зоны соприкосновения и плоской поверхности

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В статье исследуется поведение стальных поверхностей при субмикронных циклических проскальзываниях. Определена мера активации поверхностей при динамическом контактировании.

Ключевые слова: субмикронные, активация, контактирование.

The conduct of partial slip in contact zone of the ball and flat surface

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In the article is explored the conduct of steel surfaces at submicrometer cyclic slip. The measure of activating of surfaces is certain at a dynamic contact.

Keywords: submicrometer, activating, contact.