

STICK– SLIP REGIME OF FRETTING FOR NOMINALLY – FIXED JOINTS

Fretting-processes are determined by a complicated complex of mechanical, natural and chemical processes, which occur into the 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 [1,2,3]. 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 body 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 up to a several micron. It is enough of it for intensive evolution of fretting in the boundaries of a preliminary displacement of surfaces (fig. 1).

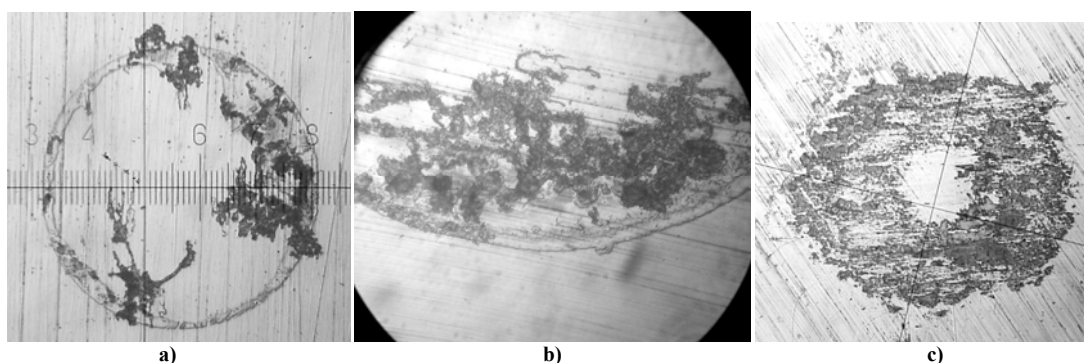


Fig. 1. Initiation of fretting-processes on an edge of nominal – fixed contact (a, b) and further development of process (c) for $N=10^7$ cycle, $\Omega = 100$ Hz, diameter sphere $\varnothing 12$ mm

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, operation of tangential, which do not exceed a limiting force of friction ($Q < \mu P$) 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 checked 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 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. Contrspeciment is ball-bearing steel by a diameter 12 mm.

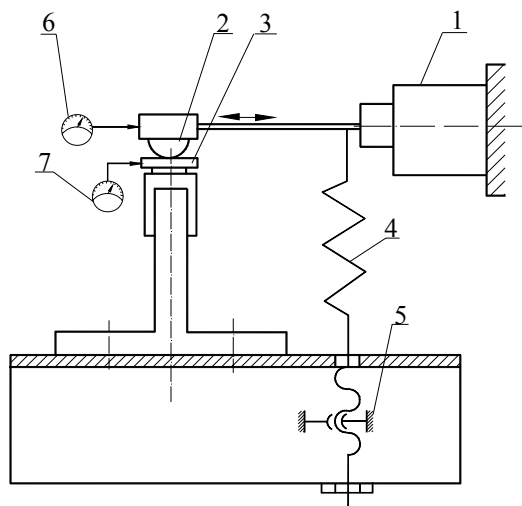


Fig. 2. The plant for a research of frictional contact in conditions fretting.

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 (fig. 3, a). The difference $\Delta x = x_1 - x_2$ gives a relative displacement of two bodies (fig. 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.

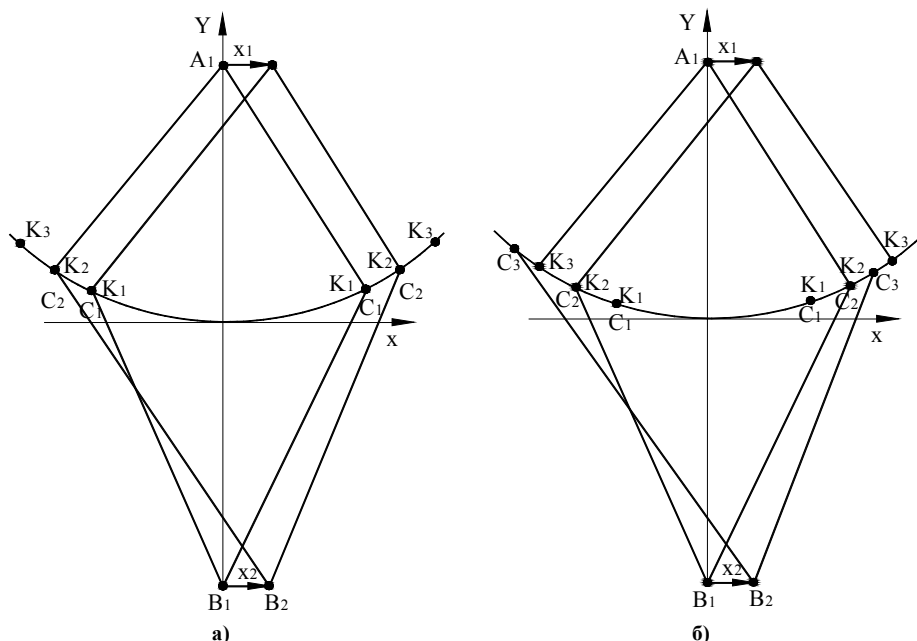


Fig. 3. Contact displacement in a zone of sticking (a) and slipping (b)

Let's consider a rigidity of a ball absolute. Then displacement Δx coincides with displacement of points of contact of ball $\Delta x = K_1 K_2$. And point C tests elastic tangential displacement distinct from Δx .

Significances of slip' will be:

$$\delta_s = x_k - x_c = (\Delta x + x_2) - (x_2 + u_e) = \Delta x - u_e \quad (1)$$

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:

$$\mu \sigma_c < \tau_c, \quad (2)$$

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 axis's 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.

Magnitude slip' in a ring $c \leq r \leq a$ we determined from the equation:

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

Relative tangential displacement [4]:

$$\delta_x = \frac{3\mu P}{16a} \left(\frac{2 - \nu_1}{G_1} + \frac{2 - \nu_2}{G_2} \right) \left[1 - \left(1 - \frac{Q_x}{\mu P} \right)^{2/3} \right] \quad (4)$$

Dissipation of energy for a cycle of oscillations:

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

Settlement dependence of magnitude of slip' of area $c \leq r \leq a$ 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.

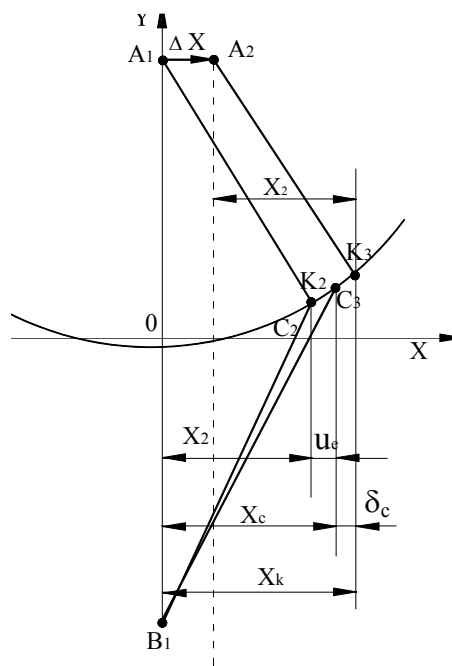


Fig. 4. The scheme of a displacement of point's contact of rigid sphere and planes

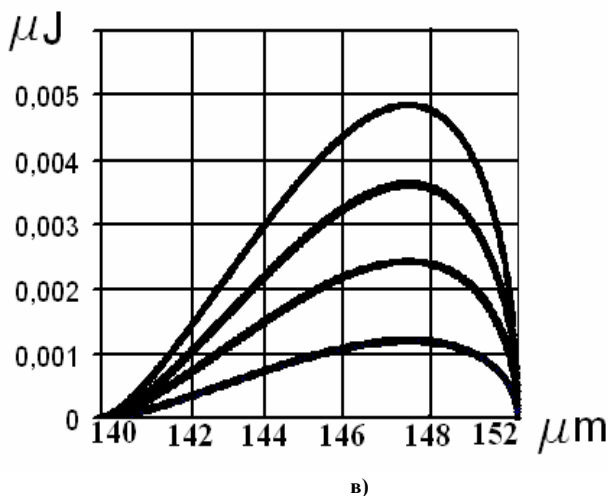
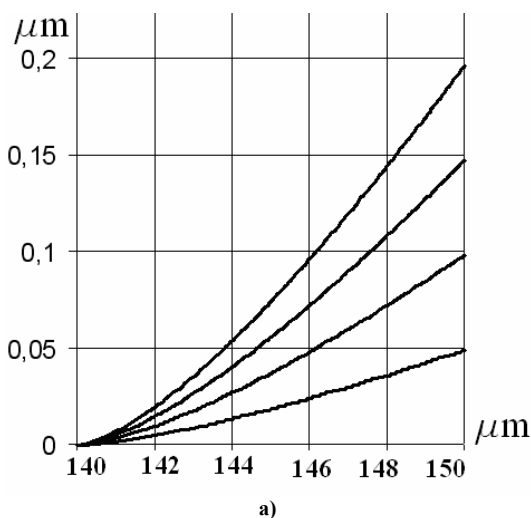


Fig. 5. Significance of tangential displacements of points of contact in ring area (a) and work of friction in slip zone (b) depending on of friction coefficient $0,1 \leq f \leq 0,4$. For $c = 140 \mu\text{m}$, $a = 150 \mu\text{m}$, $P = 40 \text{ H}$, $\Omega = 100 \text{ Hz}$

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:

$$q(x) = \mu P_0 \left(1 - \frac{r^2}{a^2}\right)^{1/2} = \mu \frac{2P}{\pi a} \left(1 - \frac{r^2}{a^2}\right)^{1/2} \quad (6)$$

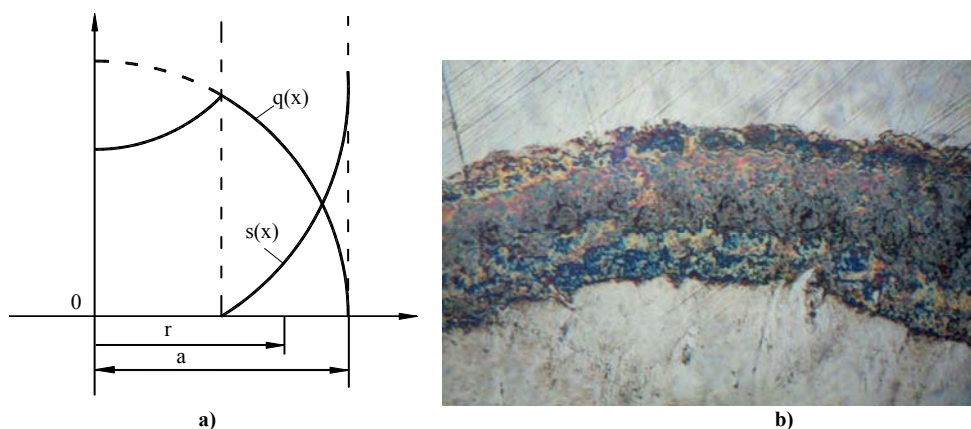


Fig. 6. A configuration of tangential stress and relative displacements in a zone slip (a). Structures of a zone slip in a result of small amplitude fretting (b)

Significance P and radius of contact 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 $s(x)$ (fig. 6).

On the basis of Johnson integrated decisions the analytical model of stress condition of a contact zone in conditions of existence partial slip into of contact has been developed. The detailed description model is a material of separate article. However, we shall result some illustrations which concern to a theme of the given work. On fig.7 the configuration tangential stress $q(x)$ on depth of a contact zone and in view of presence partial slip in contact is shown. Distributions of stress Mizes for contact of a sphere to a plane are shown. It is possible to observe that at some value of shifting effort maximal. Which are on the certain depth, merge with the maximal surface stress (fig. 7, b, c, d).

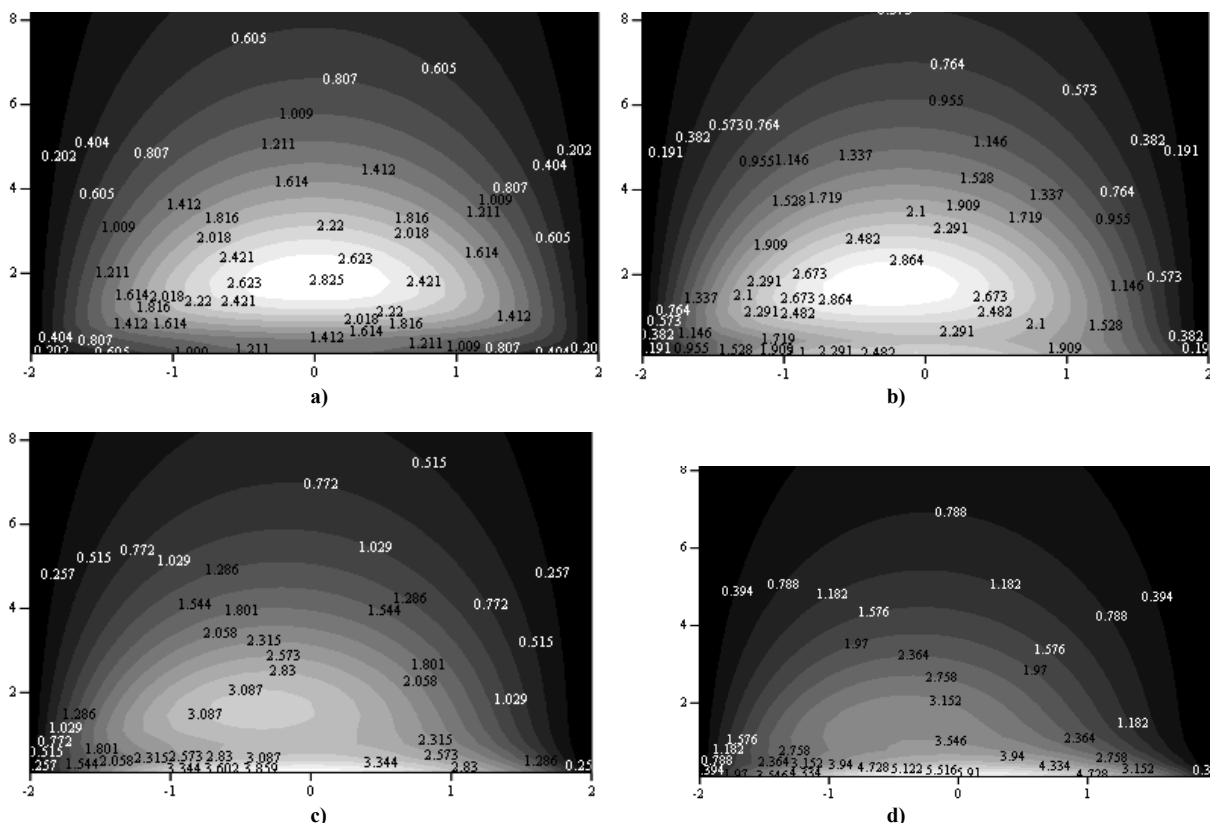


Fig. 7. The stress Mizes for contact a sphere – plane: a) distribution of stress in absence of shifting force; б) $Q/P=0,25$, в) $Q/P=0,375$, г) $Q/P=0,5$

For relation $Q/P=0,32$ the maximal equivalent stress move to a surface of contact.

As stress in contact for conditions of existence in the interface of proof adhesive joints, which arise at gradual

increase tangential force (fig. 8) have been designed.

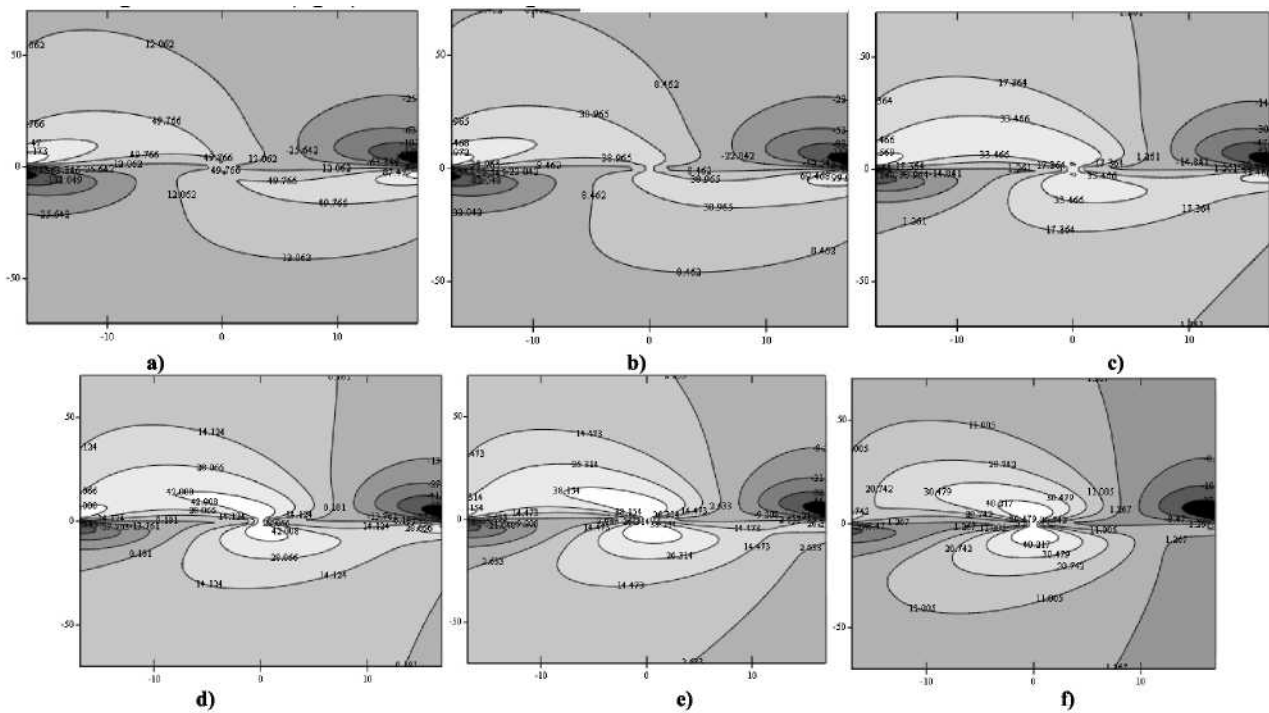


Fig. 8. Distribution of equivalent stress fon Mizes in the field of existence of local strong adhesion

Conclusions

1. Intensive fretting-corrosion develops for very small peak tangential displacement.
2. 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.
3. The origin fretting - fatigue crack is possible inside area of slipping.
4. 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

Literature

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