INFLUENCE OF STRESS-STRAIN STATE CAUSED BY NON-CONTACT FORCES ON FORMATION OF CONTACT BOUNDARY CONDITIONS

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1. Introduction

Traditionally friction force is considered dependent only on one force factor that is normal contact load [1]. Research of mechanical systems named active stress-strain state of which is conditioned by action of both contact and non-contact loads showed that stresses and strains caused by not-contact loads form additional boundary conditions on contact surface [2]. It therefore leads to essential change of characteristics of friction.

2. Formation of boundary condition

Friction force F in an active system can be considered as some function of usual friction force $F^{(c)}$ [1] in sliding (or rolling) and non-contact component of friction force $F^{(b)}$ that appear due to action of non-contact (cyclic) stresses and strains. Generally friction force in active system may be considered as the vector sum of components $F^{(c)}$ and $F^{(b)}$:

(1) $$\mathbf{F} = \mathbf{F}^{(c)} + \mathbf{F}^{(b)},$$

In (1) $P_b = \int_S p_b(s)ds$ is additional contact load caused by distribution of contact pressure

(2) $$p_b = p_b\left(\sigma_{zz}\big|_{S(z=0)}, \mathbf{u}_b\big|_{S(z=0)}\right),$$

where $z \perp S$, S – contact area.

In formula (2) $\sigma_{zz}\big|_{S(z=0)}, \mathbf{u}_b\big|_{S(z=0)}$ are boundary conditions in the field of contact the emerge due to the action of non-contact force.

Let us consider their formation using roller-shaft active system as an example.

In the neighborhood of contact nonzero components of console shaft stress-strain state caused by bending force Q are defined according to following formulas

(3) $$\sigma_{yy}^{(b)} = \frac{Q(y-l)}{4(1+\nu)I}(R+z),\ \varepsilon_{yy}^{(b)} = \frac{1}{E}\sigma_{yy}^{(b)},\ \varepsilon_{zz}^{(b)} = \varepsilon_{xx}^{(b)} = -\frac{\nu}{E}\sigma_{yy}^{(b)}$$

where $I = \pi R_2^4/64$, R – shaft radius, l=l_1–l_2, l_1 – shaft length, l_2 – distance from a point of the fixing of the shaft to the centre of contact

Displacements corresponding to stress-strain state (3) of contact area points are

(4) $$\bar{u}_i^{(b)} = \int \varepsilon_{ii}^{(b)} di\Big|_{z=0}\quad (i = x,y,z)$$

Let us consider the simplest approach to definition of contact tractions p_b for the given displacements $\bar{u}_z^{(b)}$.

We will assume that contact platform and half-space underneath as a compressed cylinder with the cross-section in the form of contact platform. Cylinder's height is R because in coordinate system originating in the centre of contact area displacements $u_z^{(b)}\Big|_{z=-R} = 0$. Then contact force P_b (compressing cylinder) corresponds to displacements $\bar{u}_z^{(b)}$ on the surface of contact (upper surface of cylinder). Force P_b is found from the equality of $\bar{u}_z^{(b)}$ and the value of displacement of upper surface of compressed cylinder:

(5) $$P_b = p_b S = \frac{\bar{u}_z^{(b)} E}{R_2}.$$

In a case of Coulomb dependences between normal force and friction force friction coefficient in the active system will be

$$(6)\quad f = F/F_N = \left(F^{(c)} + F^{(b)}\right)/F_N = \left(f^{(c)}F_N + f^{(c)}P_b\right)/F_N = f^{(c)}\left(1 + P_b/F_N\right) = f^{(c)}\left[1 + k_{\sigma/p}\left(\frac{\sigma_{yy}^{(b)}}{p_0}\right)\right].$$

In formula (6) $k_{\sigma/p}\left(\frac{\sigma_{yy}^{(b)}}{p_0}\right) = \frac{F^{(b)}}{F_N} = \frac{3p_b}{2p_0} = -3\nu\frac{\left.\sigma_{yy}^{(b)}\right|_{z=0}}{p_0}$, p_0 is the maximum contact pressure in the center of contact

Analysis of formula (6) and a figure 1.a,b shows that in active system under simultaneous action of contact and non-contact loads the resulting coefficient (force) of friction in extension zone of the shaft decreases and in a compression zone increases in comparison with coefficient (force) of pure friction.

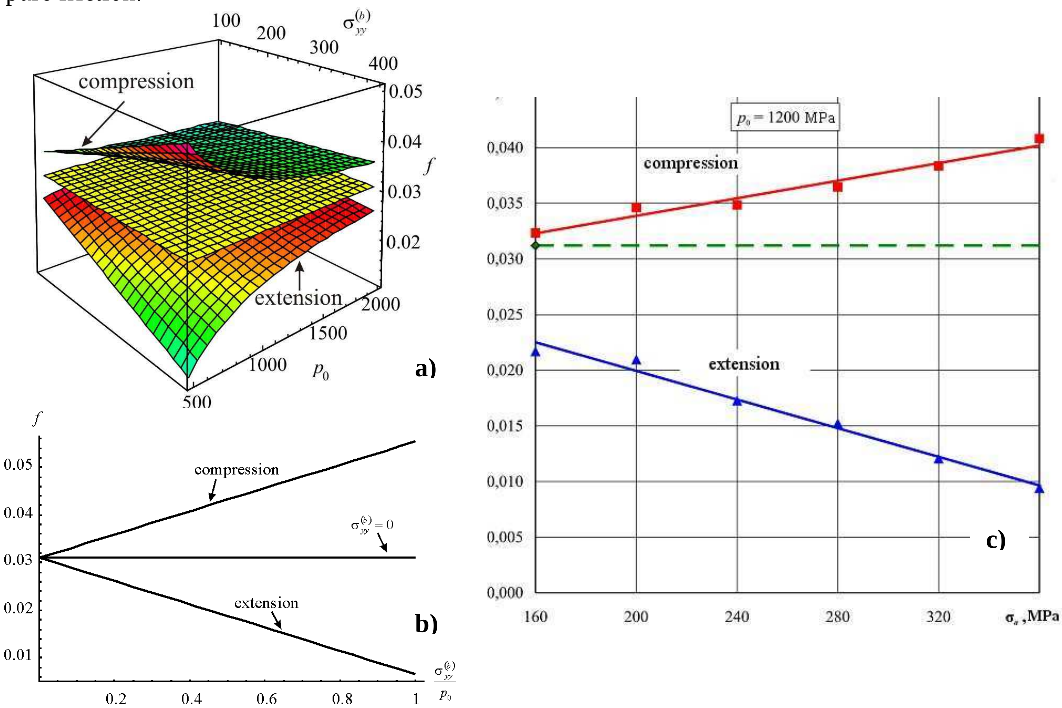

Figure 1. Analytical (a,b) and experimental (c) dependences between coefficient of friction and stresses caused by non-contact load in active system.

Figure 1 shows that analytical dependence qualitatively corresponds to the results of experiments.

The presented dependence is practically significant because it gives the possibility to control friction process by means of non-contact loading as effectively as by means of contact loading.

3. References

[1] K.L. Johnson. (1985). Contact Mechanics, Cambridge University Press, Cambridge.

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