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WEAR IN SLIDING BEARINGS FROM MINING AND ORE-PROCESSING MACHINES

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ABSTRACT
The article treats a theoretical method for determination of the wear in self-aligning bearings from mining and ore-concentration machines. On the basis of parameters characterizing the wear in a "shaft - sliding bearing" friction pair, there have been obtained relationships for estimation of bearing wear, which gives possibility for prognostication of the bearings resource.

The conditions in which mining machines operate are characterized by higher dynamic loads, dust-loading of the working space and a number of other negative factors, which cause rapid wear of units and details in the mining machines. In this regard, of interest are the bearing units with self-aligning bearings in-built in a number of mining and ore-processing machines, such as bearing type EKG, KU, etc.

The wear in those units operating in the conditions of dry friction or border lubrication is an isolated case of the task of determining the wear in a friction pair "rotating cylinder – sleeve" [2] for $\alpha_0 = \frac{\pi}{2}$, where α_0 is the angle determining the dimensions of the contact surface according to the designations in Fig. 1.

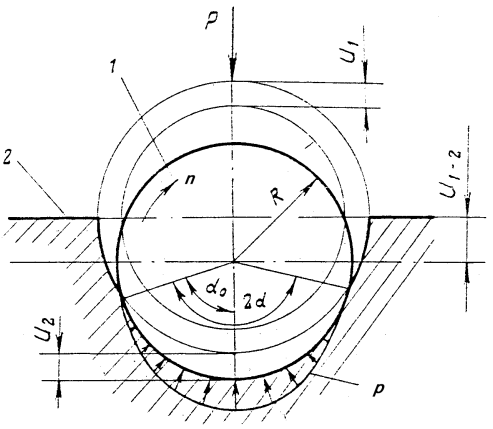

Figure 1. Wear in the shaft and bearing
1 - shaft, 2 –bearing, U_1 - wear in the shaft, U_2 - wear in the sliding bearing, U_{1-2} - wear in the units

To determine the wear U_2 and the wear intensity I_2 in the bearing, it is necessary to determine wear U_{1-2} and wear rate I_{1-2} in the friction pair of two mutually perpendicular cross-sections. According to the general law of wear [1]

$$I_2 = k_2 p v \qquad (1)$$

where: k_2 - wear coefficient of the bearing material;
p - pressure;
$v = 2\pi nR = const$ - speed of the friction surfaces.

The wear intensity in the bearing I_2 depends on the pressure in the friction pair, and the latter on its part is a function of angle α, i.e.

$$I_2 = I_{1-2}\cos\alpha - I_1 \qquad (2)$$

where: I_1 is wear rate in the shaft;
I_{1-2} is wear rate in the unit.

The angle α changes from $-\alpha_0$ to $+\alpha_0$, and the quantities k_2, v, I_{1-2} and I_1 are constant for the specific wear conditions. To determine the numerical values of I_{1-2} and I_1, a relationship between force *P* and pressure *p*, distributed over contact surface *S* has to be established:

$$P = \int_S p\cos\alpha\, ds = 2\pi\int_{y_1}^{y_2} p\cos\alpha\,\rho\, dy = 2\pi\cos^2\alpha\int_{y_1}^{y_2} pydy \qquad (3)$$

where: $y_1 = \frac{r}{\cos\alpha}$, $y_2 = \frac{R}{\cos\alpha}$, $\rho = y\cos\alpha$, $dS = \ell_0 R d\alpha$,
ℓ_0 - bearing length.

$$P = R\ell_0\int_{-\alpha_0}^{\alpha_0} p\cos\alpha\, d\alpha = R\ell_0\int_{-\alpha_0}^{\alpha_0}\frac{I_{1-2}\cos\alpha - I_1}{k_2 v}\cos\alpha\, d\alpha \qquad (4)$$

After integration and transformation of (4), follows:

$$P = \frac{R\ell_0}{k_2\nu}\left[I_{1-2}\left(0,5\sin 2\alpha_0 + \alpha_0\right) - I_1 2\sin\alpha_0\right] \qquad (5)$$

From equation (5) for wear intensities I_{1-2} and I_1, follows

$$I_{1-2} = \frac{2\pi k_2 P n}{\ell_0\left(0,5\sin\alpha_0 + \alpha_0 - \dfrac{k_1\sin\alpha_0}{\pi k_2 + \alpha_0 k_1}\right)} \qquad (6)$$

$$I_1 = I_{1-2} = \frac{k_2\sin\alpha_0}{\pi k_2 + \alpha_0 k_1} \qquad (7)$$

where k_1 - wear coefficient of the shaft material

n – circular shaft frequency, $\min^{-1}$.

From equations (2) and (7) for bearing wear U_2 and shaft wear U_1 follows:

$$\left|\begin{aligned} U_1 &= I_{1-2}\frac{k_1\sin\alpha_0}{\alpha_0 k_1 + \pi k_2}.t \\ U_2 &= I_{1-2}\left(\cos\alpha - \frac{k_1\sin\alpha_0}{\alpha_0 k_1 + \pi k_2}\right).t \end{aligned}\right. \qquad (8)$$

Equations (6) and (8) were obtained in considering a diametral section of the bearings unit, but they are applicable in determining the wear over the whole friction surface if force P is applied centrally lengthwise of bearing ℓ_0.

In this case, the wear in the axial cross-section of the bearing unit will be uniform and will be determined from equation (6), through the distributed load of a $\frac{P}{\ell_0}$ unit of length from the bearing. If force P is not applied centrally, but with eccentricity x (Fig. 2), then the wear in the bearing unit will be determined from two parameters:

$$\left|\begin{aligned} U'_{1-2} &= I_{1-2}.t \\ U''_{1-2} &= I_{1-2}.t \end{aligned}\right. \qquad (9)$$

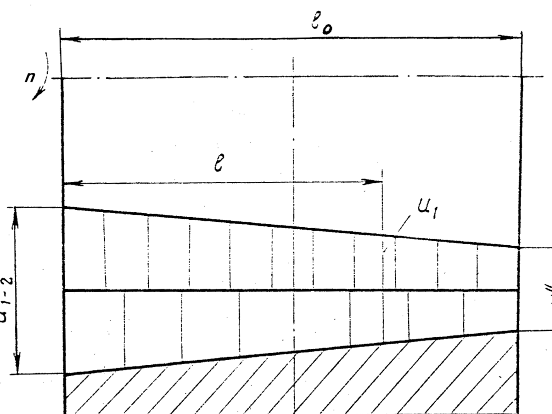

Figure 2. Wear in the units axial cross - section

The relationship between the wear in the friction surfaces and in the coupling will be obtained from the contact conditions of the friction surfaces, and namely:

$$U_1 + U_2 = U''_{1-2}\left(1 - \frac{1}{\ell_0}\right) + U''_{1-2}\frac{\ell}{\ell_0} \qquad (10)$$

and for wear intensity in the bearing unit, follows:

$$I_{1-2} = I_1 + I_2 = I'_{1-2}\left(1 - \frac{\ell}{\ell_0}\right) + I''_{1-2}\frac{\ell}{\ell_0} \qquad (11)$$

for $\ell = 0 \quad I_1 + I_2 = I'_{1-2}$

for $\ell = \ell_0 \quad I_1 + I_2 = I''_{1-2}$

As follows from formula (6), wear intensity I_{1-2} depends on the relative force $\frac{P}{\ell_0}$ acting in a given cross-section. If we designate with P_e the force of a unit of length from the axial cross-section, applied in a point with a ℓ coordinate (Fig. 3), then:

$$I_{1-2} = \frac{P_e}{A} \qquad (12)$$

where: $A = \dfrac{k_2}{\left(0,5\sin 2\alpha + \alpha_0 - \dfrac{k_1\sin\alpha}{\pi k_2 + \alpha_0 k_1}\right)}$

After replacement in (11) and transformation, follows:

$$P_e = A\left[I_{1-2} - \frac{\ell}{\ell_0}\left(I'_{1-2} - I''_{1-2}\right)\right] \qquad (13)$$

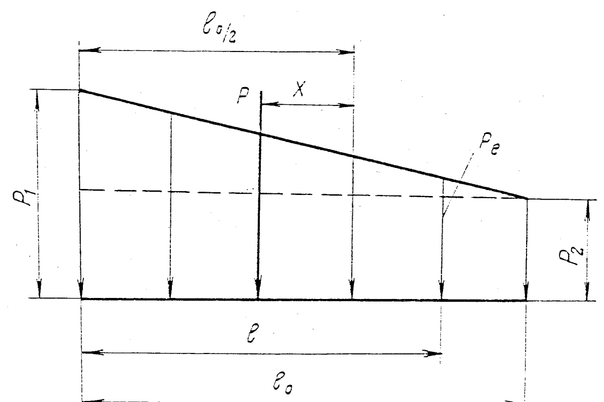

Figure 3. Pressure diagram in an axial cross - section

For a linear character of the pressure diagram in an axial cross-section, the relationship between the force P applied with eccentricity x and the force P_e in the cross section with coordinate ℓ is:

$$P_e = \frac{p}{\ell_0}\left(1 + \frac{6x}{\ell_0} - \frac{12x}{\ell_0^2}.\ell\right) \qquad (14)$$

If in equation (6), instead of $\frac{P}{\ell_0}$ we substitute P_e from equation (14) for I_{1-2}, we obtain:

$$I_{1-2} = \frac{P_0\left(\ell_0^2 + 6x\ell_0 - 12x\ell\right)2\pi nk_2}{\ell_0\left(0{,}5\sin 2\alpha_0 + \alpha_0 - \frac{k_1 \sin\alpha_0}{\pi k_2 + \alpha_0 k_1}\right)} \qquad (15)$$

Shaft wear U_1 and bearing wear U_2 in an arbitrary point of the friction surface can be obtained from equation (8) after replacement of the I_{1-2} quantity estimated by equation (15). Determination of shaft and bearing wear for two border values - minimal and maximal admissible - enables estimation of wear-resistance by formula (9) for each separate case of in-building and prognostication of the bearing resource.

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