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EHD Lubrication Working Conditions in High Speed Bearings

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Abstract
At the level of the contacts between the rolling bodies and the ring races of the bearings are, generally, accomplished the conditions of EHD lubrication working conditions. At the level of the contacts between the cage and the rolling frames, the lubrication systems vary among large limits (limited, mixed, EHD or HD conditions), while at the contacts between the cage and the guiding level prevail the mixed or HD lubrication conditions. The paper presents the theoretical and experimental importance of studying the thickness of the lubricant film and proposes methods of determining it. The diminished quantity of lubricant generates the phenomenon that determines the reduction of the film's thickness.

Keywords
radial bearings, high speeds bearings, thickness of lubricant film

1. Introduction

In the case of the bearings, the accidental contact voltage reach high values (1,000-3,000) MPa**,** this way developing lubrication systems dependent on factors such as: load, springiness of the interlocking gear's materials, variation of the lubricant's viscosity with the pressure, peripheral speed and also geometry [1].

2. Theoretical and Experimental Aspects

In the case of the point contact, solving the Reynolds equation becomes difficult because of the sideway leaks that can not be ignored. So, in this case, the starting point is Reynolds equation for the bidirectional leak:

$$\frac{\partial}{\partial x}\left(\rho\frac{h^3}{\eta}\cdot\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial y}\left(\rho\frac{h^3}{\eta}\cdot\frac{\partial p}{\partial y}\right)=12\frac{\partial}{\partial x}(\rho\cdot h\cdot v_x)+12\frac{\partial}{\partial y}(\rho\cdot h\cdot v_y) \tag{1}$$

and

$$v_x=\frac{v_{1x}+v_{2x}}{2}; \qquad v_y=\frac{v_{1y}+v_{2y}}{2}$$

Where v_x and v_y represent the medium peripheral speeds on the rolling Ox direction and on the lateral Oy direction, according to Figure 1.

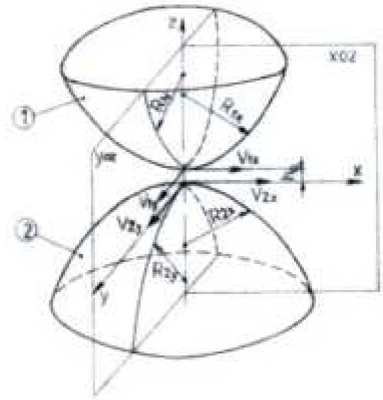

Fig. 1. The geometry of the Hertzian rolling point contact

The contact between the two bodies (1) and (2) may be equated with a contact between a plane and an equivalent revolution bodies which has in the contact point the equivalent curved shaped Rx and Ry beams, where:

$$\frac{1}{R_x} = \frac{1}{R_{1x}} + \frac{1}{R_{2x}} \quad \text{and} \quad \frac{1}{R_y} = \frac{1}{R_{1y}} + \frac{1}{R_{2y}}$$

In the case when the two bodies are distorted elastically under the action of the normal load Q, the vertical distance between two points situated on the distorted surfaces is identical with the similar distance between the equivalent body and the plane, like in Figure 2, where:

$$h(x,y) = h_0 + s(x,y) + w(x,y) \tag{2}$$

In equation (2) h_0 is the thickness of the lubricant film in the central area, $s(x,y)$ represent the geometrical separation of the two bodies, and $w(x,y)$ is the elastic distortion [2].

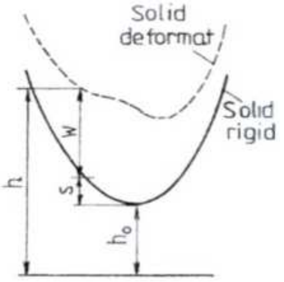

Fig. 2. The thickness of the separation film between an equivalent ellipsoid and a flat surface

The geometrical separation $s(x,y)$ is given by the formula

$$S(x,y) = \frac{x^2}{2R_x} + \frac{y^2}{2R_y} \tag{3}$$

The elastic distortion, in the case of perfect elastic, homogenous and isotropic bodies, is given by the relation

$$W(x,y) = \frac{2}{\pi E}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\frac{p(\xi\delta)d\xi d\delta}{\sqrt{(x-\xi)^2+(y-\delta)^2}} \tag{4}$$

In formula (4), $p(\xi,\delta)$ represents the pressure under a point (ξ,δ) from the contact area.

But there have to be taken into consideration both the changes of viscosity, but also of the lubricant's density, as a consequence of the high pressures from the contact area. Thus, it can be used Barus's relation for viscosity, where:

$$\eta = \eta_0 e^{\alpha p} \tag{5}$$

For the variation of the lubricant's density with the pressure, it can be used Dowson's relation [1]:

$$\rho = \rho_0\left(1 + \frac{0{,}6p}{1+1{,}7p}\right) \tag{6}$$

Solving the first equation (1) is very difficult, but as a consequence of experimental determinations, was emphasized the presence of a central plate, with h_0= the thickness of the film and of a horseshoe-shaped notch, situated in the exit area of the contact.

The practical importance presents h_{min} (the minimum thickness of the lubricant) and h_0 (the central thickness). Essentially, these depend on U, the speed parameter, and w the loading parameter (Figure 3) [3].

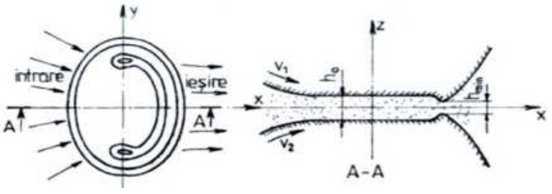

Fig. 3. Entry-Exit - The shape of the profile in an EHD point contact

Using the principle of resistive method and considering the contacts between balls and bearing races, as a consequence of their separation through the lubricant film, realizing electrical resistances when the flow passes from a level to another, the electrical resistance of a contact varies exponentially with the thickness of the film:

$$R = Ke^{h} \tag{7}$$

where proportionality factor K depends on the pressure, temperature, lubricant type, contact's dimension, rigor, etc.

The resistive method allows qualitative, comparative measurement, of the lubrication system for diverse lubrication mediums. If it is considered a cylindrical roller bearing and the equivalent electrical scheme, it can be written that the global resistance of the bearing is:

$$R = \sum_{n=1}^{2} \frac{1}{\left(R_{c,i} + R_{c,e}\right)_n} \tag{8}$$

where $R_{c,e}$ and $R_{c,i}$ represent the electrical resistances at the level of interior and exterior contacts and "2" is the number of balls.

The use of capacitive method means using a radio frequency flow of low voltage applicable to the frames among which is found lubricant's film whose thickness has to be determined, the lubricant's film functioning like a dielectric. The method requires that while testing, the dielectric constant of the oil should not vary. The method is also practicable because, when the thickness of the film is small, the measured capacity is higher and so, the measurement's precision is correct. The difficulty was caused by the frequency of the piercement of the film by the contacts of low resistance, among the surfaces' asperities or conductive particles.

3. Conclusions

Due to the radial loadings, in relation (8) takes part only the resistances from the loaded balls (balls 1 and 2), in the case of other contacts the electrical resistance is ∞.

Due to the small thicknesses of lubricant film (< 1 µm), the flow that passes through the contacts is low, varying among the limits (1÷50) µA, the unique value of the flow is dictated by avoiding the appearance of the electrical loadings at the level of the contacts.

In Figure 4 is presented the electrical schematic diagram, the supply voltage is of 1 V, and the additional resistance *Ra* has the same value as the quantity order of the electric bearing resistance.

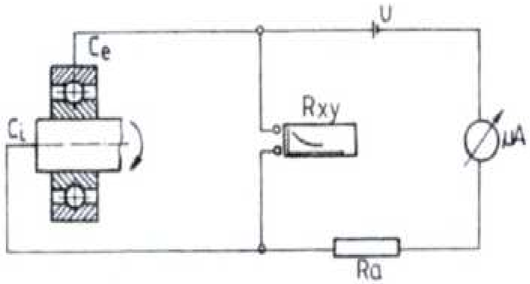

Fig. 4. The electrical schematic diagram

With the help of an acquisition plank have been registered the variations of potential dropping on the bearing and also the variation of electrical resistance of the bearing (the collector from the external ring that is immobile, while the collector from the internal ring is mobile) [4].

In Figure 5 are presented electrical resistance determinations at two tested oils. At the same time, on the diagram from the picture, according the λ parameter's values, defined as the proportion between the minimum thickness of the lubricant and the compounded rigor of the two surfaces in contact, have been separated the lubrication working conditions, according to global electrical resistance of the bearing. The diminishing of the electrical resistance under 3-4 kΩ leads to the existence of mixed or limited lubrication systems. This reduction is due to the lubricant's deterioration and precedes always its out of use.

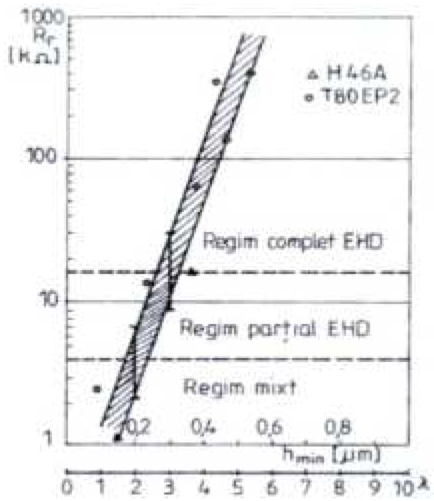

Fig. 5. Determinations of electrical resistance at diverse types of oil

In Figure 6 are presented the evolutions of the electrical resistance of the lubricant film, and also of the temperatures of 6306 MAUP bearing, in two variants of the cage's play [5].

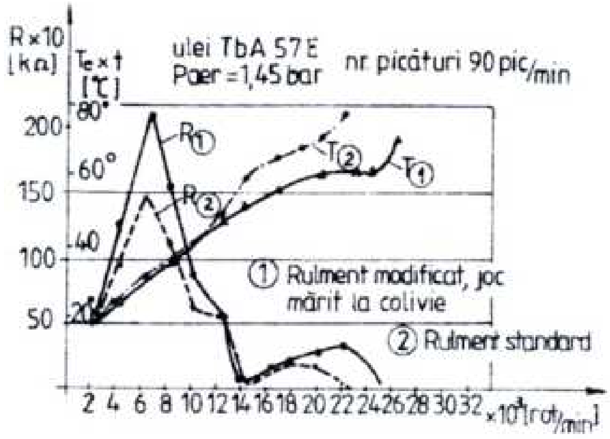

Fig. 6. Electrical resistance of the lubricant film and the temperatures in the case of the particular bearing 6306 MAUP

Using the initial principle of capacitive method for experiments (Figure 7), was used a sectioned angular contact ball bearing, the pressure being taken by a single ball, and in the third phase was used a cylindrical roller bearing with many balls. The lubrication is essential to assure the bearings' friability and the durability is directly influenced by the parameter λ of the lubrication film.

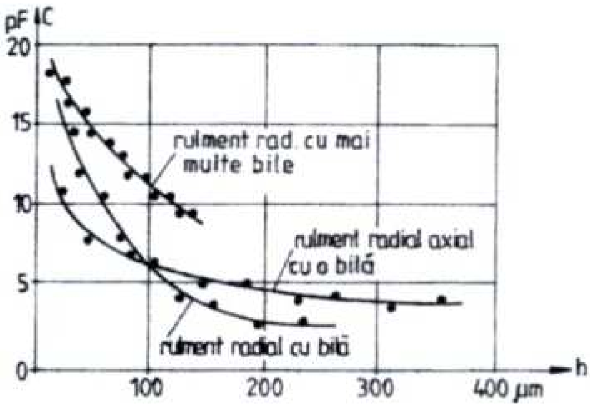

Fig. 7. The variation of electrical capacity according to the thickness of the lubricant film

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