STUDY THE POSSIBILITY OF LUBRICATION FOR ROLLING BEARINGS

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Abstract: In this paper are presented some methods of lubrication and calculating the volume of lubricant required by joints of friction, supply methods and filtering it.

Key-words: lubrication, rolling bearings, joints of friction

1. INTRODUCTION

This paper presents some possibilities regarding the methods of lubrication the friction joints, type rolling bearings, calculating the necessary lubricant volume required and it's filtering.

The lubricant generally performs three main functions, namely [3]:

- to form a continuous film between the friction surfaces;
- to dissipate heat accumulated at the contact surfaces;
- to prevent the entry of dust and other particles (contaminants) in the contact area.

2. ESTABLISHING THE NECESSARY LUBRICANT FLOW

Lubricant flow regime necessary to ensure the functioning of a hydrodynamic thrust bearing can be determined by existing methodologies in the literature. Bearing lubrication hole must be constantly supplied with enough oil to ensure film formation between the surfaces and the temperature must be maintained in satisfying limits.

The necessary volume of lubricant film in order to achieve an elasto-hydrodynamic lubrication condition is extremely small. In almost all cases, some of the fluid adheres to each of the two surfaces of the friction joints, and another part passes repeatedly through the contact zone, an additional flow is determined only by the

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losses of fluid, losses which are negligible. It results that the highest necessary of lubricant is determined by the necessity of dissipating a large quantity of heat in bearing's proximity [4].

The energy lost through friction in the axial bearings is determined by the fallowing relationship:

$$P = F \cdot V \text{, J} \tag{1}$$

and in rolling bearings,

$$P = M \cdot 2 \cdot \pi \cdot N \text{, J} \tag{2}$$

For rolling bearings, friction moment, M, can be calculated with the formula:

$$M = M_0 + M_1, \tag{3}$$

where M_0 is the moment given by hydrodynamic losses and M_1 is the moment produced by elastic deformations and partial sliding of the surfaces in contact. The moments M_0 and M_1 can be calculated with the following relations:

$$M_0 = f_0 (60 \cdot \eta \cdot N) d_m^3 \cdot 10^{-7}, \quad M_1 = f_1 \cdot g_1 \cdot P_0 \text{, N·mm,} \tag{4}$$

where f_0 is a coefficient that depends on the constructive solution of the bearing and the lubricant, and f_1 and g_1 are coefficients which depend on the force applied on the bearing and its direction. The values of these coefficients for some cases are shown in table 1.

In this table we used the following notations: $Z = (P_0/C_0)$, where P_0 is the equivalent static load of rolling bearing, measured in N, C_0 – static capacity of bearing load (from catalogue) measured in N, F_0 - axial force measured in N, F_r - radial force, measured in N, Y - axial force factor (from catalogue, $Y F_0/F_r > 1$) [2].

a) If $g_1 \cdot P_0 < F_r$, then $g_1 \cdot P_0 = F_r$ is used;

b) Lower values are used for light series bearings and the superior ones for heavy series.

Table 1. **Coefficient values f_0, f_1 and g_1, P_0**

Bearing type	**f_o**			**f_1**	**$g_1 \cdot P_o$**	**R**
	Fog (oil vapours)	**Oil tank**				
		Lubricating grease	**Vertical arbour**			
Radial ball bearings or ball bearing with deepened channel	0,7-1	1,5-2	3-4	$0{,}0009 \cdot Z$	$2{,}3 \cdot F_a - 0{,}1 \cdot F_r$	0,85-1
Oscillating ball bearings, spherical ball bearings	0,7-1	1,5-2	3-4	$0{,}0003 \cdot Z$	$1{,}4\, Y F_a - 0{,}1 \cdot F_r$	0,4-0,5

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Radial-axial ball bearing: - in a row - on two rows	 1 2	 2 4	 4 8	 0,0013 Z 0,001 Z	 F_a - 0,1·F_r 1,4·F_a-0,1·F_r	 0,4-0,5 0,6
In needle bearings: - in a row - on two rows	 3-6 6-10	 6-12 12-20	 12-24 24-40	 $25\ 10^{-5}$-$3\ 10^{-4}$ $25\ 10^{-5}$-$3\ 10^{-4}$	 F_r (F_a=0) F_r (F_a=0)	 0,5 0,5
Oscillating bearings with cask roller	2-3	4-6	8-12	$4\ 10^{-4}$-$5\ 10^{-4}$	1,2 $Y F_a$	0,3-0,4
Tapered roller bearing	1,5-2	3-4	6-8	$4\ 10^{-4}$-$5\ 10^{-4}$	2 $Y F_a$	0,3-0,4
Axial ball bearing	0,7-1	1,5-2	3-4	0,0012 Z	F_a	0,25
Axial cylindrical roller bearing	-	2	4	0,0018	F_a	0,25
Axial bearing with needles	-	2-3	4-6	0,0018	F_a	0,25
Axial bearings with cask roller	-	3-4	6-8	$5\ 10^{-4}$-$6\ 10^{-4}$	F_a (F_r)<0,55F_a	0,25

Heat which has to be removed from the bearing and whose value can be calculated with the above relations will be discharged through the usual mechanisms of transfer, namely conduction, convection and radiation.

Heat that has to be removed can be calculated with the formula:

$$P = \gamma \cdot Q \cdot c \cdot T \text{ , J} \tag{5}$$

where: T is the lubricant temperature reached when passing through the bearing, c - specific heat of lubricant, γ - specific weight of the lubricant.

For the typical oil at a temperature of 15°, specific heat, c, is set to 1.82 kJ/kg°C and for water is about 4 kJ/kg°C.

From relations (1) or (2) and the relation (5) is determined fluid flow, Q, which must be circulated through the bearing:

$$Q = \frac{P}{\gamma \cdot c \cdot T} \text{ , m}^3\text{/s} \tag{6}$$

This relationship is valid for the situation in which it is considered that all of the heat is removed by the lubricant.

In the study bearing heat problems have a high priority, especially in the case of rolling bearings or the cogwheel gears where it is not possible to ensure a high flow of lubricant. Any temperature rise has influence on the viscosity lubricant in the sense of reducing its value, which has as effect the reduction film thickness and which can obviously lead to an increase of the quantity of heat developed.

After determining the type and amount of lubricant, lubricant feeding system can be chosen regarding the possibilities below.

3. POSSIBILITIES OF LUBRICATION

The lubrication can be made with lubrication grease or oil. These two types of lubricants are frequently used, and the use of one or another only depends on the operating conditions for the lubricated surfaces. Grease is recommended for protection against contamination with impurities, being used in every situation, for low speeds. It is frequently used in rolling bearings, especially at gear where continuous supplying with lubricant is not possible or not desired. Oil lubrication is recommended for heat dissipation, especially for hydro-dynamic bearings operating at high speeds [3].

3.1. Lubricating grease supply

There are three forms of power known lubricating grease namely:

- total filling bearings;
- by means of a grease nipple chuck for each bearing to complement periodicals;
- via pipes for a number of bearings using a manual or automatic pump.

For rolling bearings elements with grease lubricating initial load should be done on the working surfaces of friction joints elements and housing should not be filled, as this may lead to the development of high temperatures [1].

Bearing lifetime of may be limited by grease degradation before it to be refill. Lubrication interval is given by:

$$T = K_G \cdot R \cdot h\,, \tag{7}$$

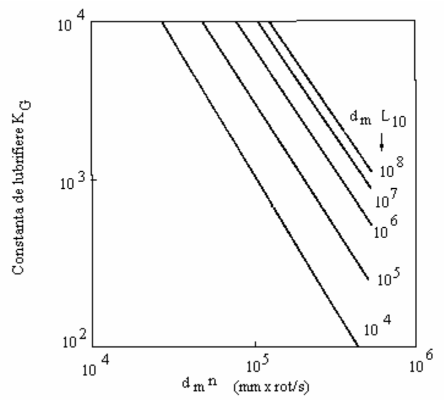

Fig. 1. Constant value when using grease lubrication [1]

where k_G is the constant of lubricating with grease, shown in Figure 1, depending on the average diameter of the bearing d_m, measured in mm, and its rotations peed, n, rps, R is the refill factor (re-lubrication) taken from table 1.

3.2. Oil supply

There are several methods of a bearing oil supply, of the most commonly used are shown in figure 2. Each of these methods are used for rolling bearings, planar and with sliding bearings, but for the fog curtains methods, with capillarity and ring lubrication are unable to provide a sufficient flow.

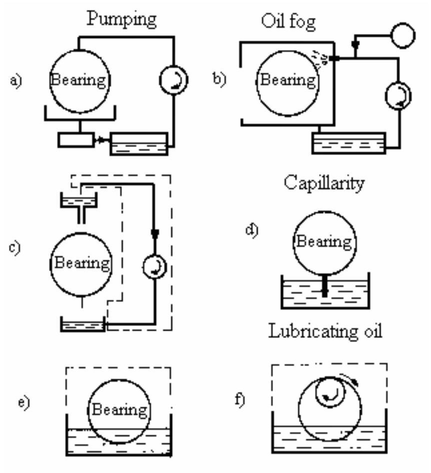

Fig .2. Oil supply systems

Pumping supply (fig. 2.*a*). In this case, the oil is introduced into the bearing under pressure using a pump. Lubricant flow rate achieved is given by the hydraulic pump, and heat from the bearing can be easily discharged. This supply system presupposes relatively high costs (total cost, cost of maintenance and initial cost of filling the lubrication circuit) and also the hydraulic pump can have relatively high energy consumption. Nonetheless, when it takes a great and guaranteed flow of lubricant, this system is the most convenient.

Supply by pumping the fog (fig. 2.*b*). The lubrication system presupposes the realization a finer fog of lubricant the form of small droplets.

Lubricant is introduced with a low speed through a nozzle orifice and driven using compressed air, reaching out from it at a speed of 40 m/s, speed which turns into finer droplet with which are sprayed bearing friction surfaces. Obviously this can be done in enclosed spaces such as the reducer housings, in which the fog it will spread in all the space. Compressed air discharged in atmosphere and the oil is collected and recirculated. In the case to this lubrication system, heat evacuation capacity produced during the bearing operation is much lower, because the capacity of compressed air to remove the heat is reduced and the oil is in small quantity. The initial cost of achieving that the oil system supply, as well as with regard to its maintenance are relatively high.

Supply by free-fall (fig. 2.*c*). In a situation where is not necessary too high flow is sufficient a free-fall lubrication supply system using by means of a oil cup, through a drip. The lubricant is collected in a tank and is pumped back into the oil cup reservoir. This system is simple and inexpensively, but is limited only to the case of low loads and slow speeds of operation from the bearings.

The capillary system supply (figure 2. *d*). This system uses a wick or cloth or felt pad in which the capillary action, moves the fluid of the tank on bearing surfaces. The oil flow increases with increasing cross section wick area and decreases when the wick length increases and decreases viscosity of lubricant. Design and implementation of such systems is very simple and the cost is reduced. However, the supply flow is much limited, which is why such a system is used in case of low loads of bearing.

Lubrication system with oil bath (figure 2. *e*). In this system, a rotating mechanism (with horizontal shaft) immersed in an oil bath, conduct the oil to the most up points from where it falls on the bearing and it sprinkles. Also in this case it can create an oil fog. If possible, it is recommended that the rolling bearing components to dip below to the level of the oil surface. In this case the immersion has to be done so that the oil reaches up to the half of the lowest element.

The ring lubrication supply (figure 2. *f*). This system consists of a ring with a diameter much higher than that of shaft, ring witch is immersed in the oil and which rotates (usually slower than shaft) and oil is transporting to the shaft. This system is used for speeds between 50 and 3500 r/min and the shaft diameter of over 50 mm, while the ring speed is limited to values of around 9 m/s. The quantity of oil transported depends on the size and speed of the ring, but if the quantity of oil required is higher, it is possible to use more rings or a chain that has a greater surface. In some cases the ring may be replaced by a disc, a situation encountered at low speed bearings and high viscosity oil.

If components of this system are intermittently immersed in oil, the oil may be sprinkled all other components of the system or it can create a fog of oil. Evidently, these methods are simple and inexpensive. But it is necessary to maintain the oil level in the tank near the limits set.

4. LUBRICANT FILTERING

In case lubricant supply a rolling bearing, is necessary to incorporate a lubrication system, a filter to remove the dust, solid particles, impurities and water. Filters can be mounted in different parts of lubrication system, as shown in figure 3.

The vent hole of the tank has the role to keep out the impurities from the air and the filter is designed to retain the coarse particles. Hydraulic pump supply may have a medium finesse filter on suction to protect the pump and one by large finesse to the output for bearing protection. On return of the circuit, between the output of the bearing and entrance to the tank is mounted a line medium finesse filter to prevent the solids entering to the tank. Particle size retained by the filter depends on its construction which range from metal sieve, which retain particles with dimensions between 100 to 1000 mm, the fabric or felt sieve with filtering fineness of 10 to 100 mm and up to the ceramic sieve with the fineness of 0.5 to 50 mm. The membranes are used for special applications when the particles are retained up to 0.005 mm [2].

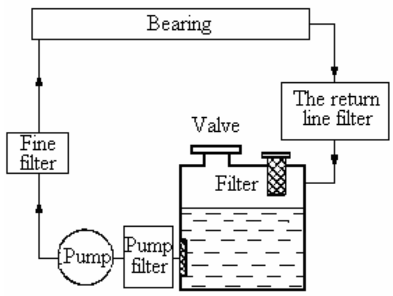

Fig. 3. The principle scheme a filtration system [2]

Moreover apart from normal filters magnetic extractors which retaining ferrous materials can be used in circuit. This has very low energy consumption and collects the very fine particles. Water can be removed using a hygroscopic element such as paper covered with silicon or Teflon fabric which enables the water to reach by gravity into a collecting tank. It is necessary to establish the degree of filtering required for a particular bearing. It can be determined taking into account pressure loss existing on the filter. Degree of filtering effect on the bearing performance is easily observed, but experience shows that filtering until of 25 mm a particle size is beneficial. Also been shown that the filtering around the order of size of 2-3 mm do not provide an important improvement.

Lost pressure on filter is given by [1]:

$$\Delta p = \frac{Q^2 \cdot K_F \cdot \gamma}{2 \cdot g \cdot A^2}, \tag{8}$$

where K_F is a filter characteristic regarded for a laminar flow regime and which decreases when becomes turbulent flowing in the filter.

This flowing is achieved for Reynolds number of 4 to 15 and this number is given by:

$$R_e = \frac{V \cdot D}{\nu}, \tag{9}$$

where D can be taken as the filter hole entrance diameter, K_F - is a coefficient depending on the filter construction and is determined by Kozeny-Carman's relationship:

$$K_F = \frac{l^3}{kS^2(1-l)^2}, \tag{10}$$

where: l is a coefficient of or the porosity; S - specific surface area of the filter/unit volume (m^2/m^3) k - constant of filter material (for cellulose $k = 5.55$).

5. CONCLUSIONS

In conclusion grease lubrication is recommended for protection against impurities contamination at joints of friction and is used in every situation for low speeds, whilst oil lubrication is recommended for heat dissipation, especially for hydrodynamic bearings operating at high speeds.

Also, the degree of filtering effect of the lubricant on the bearing performance is easily observed, but experience shows that the filtering until a 25 mm particle size is beneficial, while filtering up to 2-3 mm fineness not achieved important improvements.

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