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THEORETICAL AND PRACTICAL CONSIDERATIONS ABOUT BEARING LUBRICATION

Valeriu MIRONESCU[1,*], Aurelian VLASE[2]

[1)] Eng., PhD Student, Machine Building Technology Department, University „Politehnica" of Bucharest, Romania
[2)] PhD, Prof., Machine Building Technology Department, University „Politehnica" of Bucharest, Romania

***Abstract**: The rolling bearings operate in very different conditions. The selection of lubricant and the lubrication system is a complex and very important problem. Besides the main function of reducing the friction, a lubricant removes the heat, withstands to the high pressures, ensures the sealing of the couplings, carries the impurities, ensures the protection against the corrosion, extends the lifetime of the equipment and, finally, must be not too expensive. The paper aims to highlight the effective methods of lubrication and to choose different types of lubricants, depending on the specific situations. As a practical application, it is presented a method to determine the optimum viscosity of the lubricant for the reducer of a knitting machine.*

***Key words**: bearings, lubricating, oils, greases, viscosity.*

1. INTRODUCTION

The bearings lubrication has the following purposes:

- To ensures the lubricant layer in the contact zone, to reduce the contact wear;
- Reducing the sliding friction;
- Avoiding the phenomena of corrosion;
- The heat evacuation;
- Prevent the entry the impurities;
- Reduce the noise and of the dynamic effects.

Studies show that the main cause of bearing failure is due to the lubrication system reliability (Fig. 1) [2].

Creating a reliable lubrication system must take into account by: size of the bearing, load, speed, temperature and, according to them, the choice of lubricant. Practically, for a reducer with bearings, a method of choosing the best lubricant through the measurement of temperature is proposed. By measuring and comparing the temperatures of the reducer, lubricated with various type of oils, the lubricant with the lowest temperature will be the best.

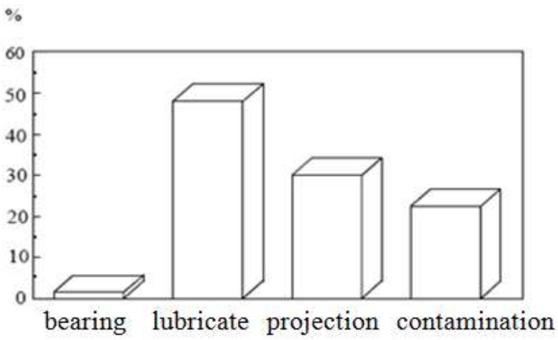

Fig. 1. The main causes of the bearing failure [2].

[*] Corresponding author: Splaiul Independentei 313, 060042 Bucharest, Romania
Tel.: 0746 175 102
E-mail addresses: *mironescu.valeriu@gmail.com* (V. Mironescu), *aurelvlase@yahoo.com* (A. Vlase)

2. CLASSIFICATION OF LUBRICANTS

Depending on the speed, load and other parameters, the bearings are anointed with liquid lubricants (oils) and plastic lubricants (grease), according to comparative data in Table 1 [1].

The lubricants can be used in accordance with some parameters. In terms of speed:

- for speeds v = 5…6 m/s can be used both oils and greases, the temperature will determining when you use oil or grease.
- for speeds v > 6 m/s can be used only oil.

Depending on the temperature:

- at temperatures below 0^{o}C, are mainly oils, whose freezing point is with 15º…20º lower than the operating temperature.
- at temperatures t = (0…70) ºC, oils or greases are used, the speed with decisive role.
- at temperatures t = (70…80) ºC, are used greases or oil; their viscosity must increases with the temperature.
- at temperatures higher than 80^o, are used very viscous oils.

Depending on the environment:

- the environment with dust, gas, water vapour, requires grease, if the temperature and speed allows.

Table 1

Comparison between liquid and solid lubricants [1]

Essential feature	Oils	Greases
Speed	Any	Low, medium
Lubricity	Excellent	Good
Sealing requirements	Complicated	Simple
Replacement	Easy	Relatively difficult
Sustainability of lubricant	Long	Relatively short
Effects of cooling	High	Weak
Filtration of contaminated particles	Relatively simple	Impossible

- the bearings dimensions; if are small, the oil must have a low viscosity.
- a great load requires a more viscous lubricants.

In comparison, the oil has a higher stability and lower friction losses; grease has a lower tendency to leak and allows a more efficient sealing.

3. MINERAL OILS

The most important characteristics of mineral oils, according to the lubricating ability, are: viscosity, density, compressibility, stability, neutrality, flammability, purity, viscosity index Davis, lubricity.

The lubrication with oil is recommended for:

- the bearings which work in a confined space, where oil is used to lubricate machine parts in rotating (reducers, gear boxes etc.);
- the bearings at high temperature, where the heat must be removed;
- the bearings with a continuous monitoring of anointing;
- the bearings with an easy replacement of the lubricant; high speed.

Anointing with oil of the bearings can be realised by these lubrication systems:

- with oil bathroom (Fig. 2).The knitting machine 2-C Special has a motor reducer, running at low speeds; the oil level not exceeds the lower half of the rolling bodies;
- the circulating oil system (Fig. 3) [9]; using a pump, the oil is sprayed directly through some nozzles; Recommended for high speeds and loads, when is required intense cooling.
- by splashing, at reducers, gearboxes etc.; the oil drops are produced by the rotating parts(Fig. 4) [9], partially introduced into the oil bathroom;
- by dripping, with an oil cup with wicks (Fig. 5) [9];
- with oil mist, achieved through an air jet, directed on to places with inaccessible lubrication.

As a practical application, is presented a method to determine the optimum viscosity of the lubricant for a reducer to a knitting machine. The knitting machine 2-C Special was bought with the oil presented in Fig. 6. The picture shows that oil must be changed.

The machine has a motor reducer, with oil bathroom.

Because we had no technical book, I did not know the viscosity the oil to be replaced. To determine an appropriate lubricant for such reducer, I found that the lubricant is heated by the action of two factors:

Fig. 2. Motor reducer with oil bathroom system.

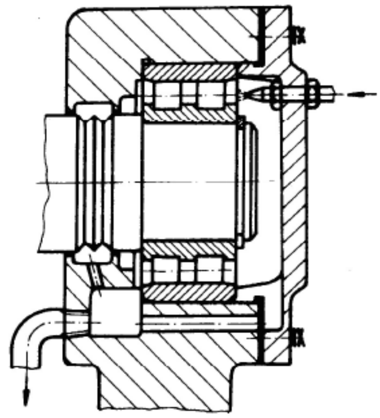

Fig. 3. Circulating oil system [9].

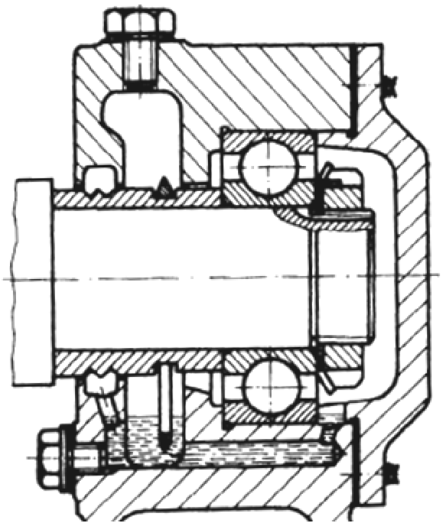

Fig. 4. By splashing system [9].

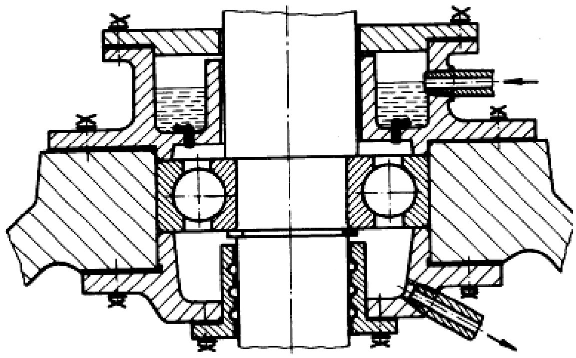

Fig. 5. By dripping system [9].

Fig. 6. Used oil.

Table 2

Results

Type of oil	Viscosity [mm^2 / s]	Temperature [^{0}C]	Fig. 8
Aral Autin B (for sewing machines)	10.1	61	a
Elf 10W-40	25	57	b
Aral 15W-40	28	57	c
Elf 75W-80	77	54	d
T90 EP 2S	90	53	e
MOL Ultrans EP 150	152	57	f
MOL Ultrans EP 220	222	62	g

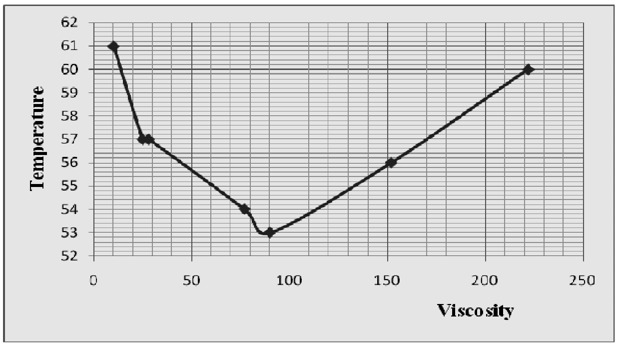

Fig. 7. Variation of temperature function of viscosity.

1. the heat generated by friction from gear (with two steps) and of the bearings;
2. heat generated due to lubricant viscosity.

A lubricant with high viscosity reduces the friction between the moving elements, but will warm up faster, due to the internal frictions.

A lubricant with too low viscosity will not provide continuous fluid film between moving elements, so the first factor becomes predominant.

The lubricant with an optimal viscosity must found, to achieve a balance between the two factors, i.e. to obtain the lubricant with the minimum temperature.

We proceeded as follows:

- We introduced an oil with high viscosity and after 4-5 hours of operation I measured the temperature;
- I changed this oil with another type, whose viscosity is lower and, after the same number of hours, I measured the temperature again.

I repeated the operation several times. The oil that gave the lowest temperature was the optimal lubricant

Basically, I tried some oils, keeping the bearings without sealing, and then, after we found the optimal oil, we introduced sealed bearings.

The results were the follows (Table 2, Figs. 7 and 8):

Note that:

- The lubricant which gave the lowest temperature is T90 EP 2S, corresponding to a viscosity of 90 mm^2/s.
- At viscosities below 20 mm^2/s vibrations occur.

After the introduction of sealed bearings and keeping this type of oil, resulted the 54 ^{0}C temperature.

4. PLASTIC LUBRICANTS (GREASE)

They are dispersions of soaps in oils minerals. Are for general use (U), for bearings (RUL), for the open bearings (LD), for the extreme pressure (EP),for multiple uses (MU).

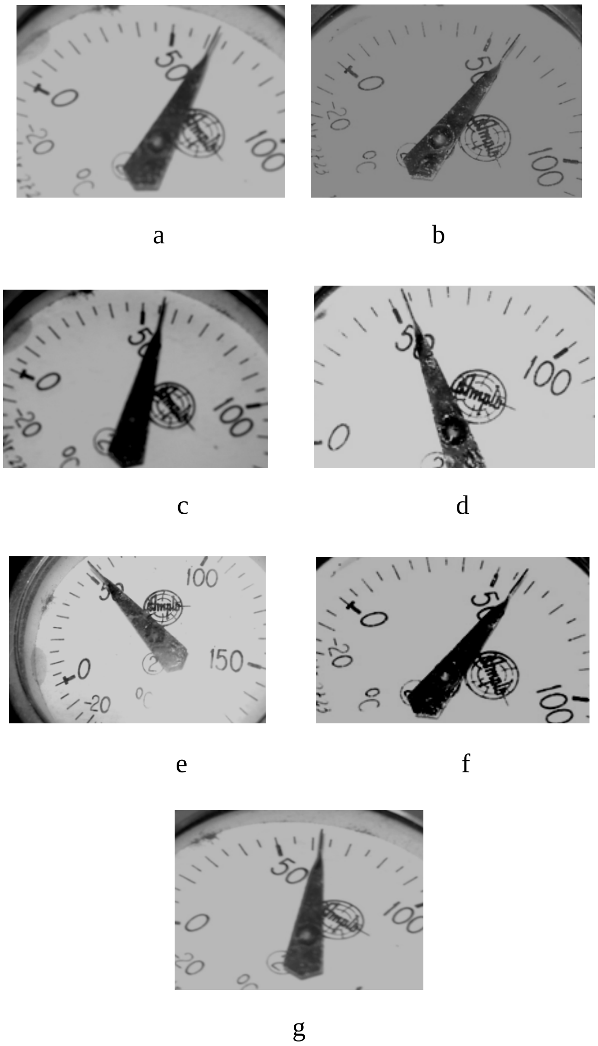

Fig. 8. Temperature reached by each type of oil.

The lubrication with grease is recommended for normal operating conditions, for bearings mounted in places where are not other machine parts which needs oil, when the oil from the bath reaches not the bearings, or for the gear that works with large wear.

After the scope , the greases are:

- for rolling bearings (in which the main purpose is to reduce the friction and, thus, the wear),
- protective greases (corrosion),
- to increase the friction,
- for avoiding slippage,
- for dispersion,
- for sealed bearings,
- different greases.

In normal working conditions, the bearings lubricated with grease are widespread due to the following advantages:

- less costly maintenance;
- very good protection against dust, dirt and moisture from the outside;
- reducing the noise;
- reducing the friction in case of big loads.

As a disadvantage, compared with the lubricating oil, the grease leads to a higher internal friction and therefore to a greater heat release. Greases can be used in centralized system or local.

In the first case, pumpability is an important property, especially at low temperatures. In this connection, it is recommended a calcium based grease, (Patent 114342 B – 30.03.1999) of class 000 (which is not contained in STAS 4951/81), has a kinematic viscosity 30-65 cSt at 50^0C, good pumpability, tightness and lubrication even at low temperatures, inexpensive, compatible with seal materials, which allows a high degree of contamination with water.

In case of a large amounts of grease, the rolling elements from the downloaded zone can be braked.

When arrive in the load zone, they will not roll, but will slip, could thus lead to scuffing. At the lubricating with grease to the bearings, should be taken into account:

- the speed (high speed – low consistency),
- the size of the bearing (big size – increased consistency),
- the load (increased pressure between the contact surfaces - increased consistency of grease),
- the temperature (for high temperature greases are chosen with high dropping points).

For a bearing, is not indicated the complete filling with grease, but maximum 1/2 – 3/4 from the free space.

Larger amounts of grease can be used at low speeds; in other cases, the friction to the bodies rolling with the grease leads to significant increases of temperature and to the expulsion of lubricant (Fig. 9 [4]).

Of the entire amount of lubricant introduced into the bearing, only 5 percent remain inside, the rest works as a sealing element and only 2 percent participates in the anointing of the contact surfaces.

The lubricating properties of the greases are good only in a certain interval of temperatures and, therefore, it is necessary to know the temperature of the bearing, which is measured on the fixed ring of the bearing.

Its dropping point must be to minimum of 30°C above the temperature of the bearing.

If not, the grease loses the lubricating properties and thickening substances obstruct the pipelines, forming the so-called plugs.

At low temperatures, the grease loses its lubricating properties, becoming crumbly, but a slow heating regains its original properties.

In determining the type of bearing grease, must take into account the speed and the load, the working conditions and environment.

Fig. 9. The expulsion of lubricant [4].

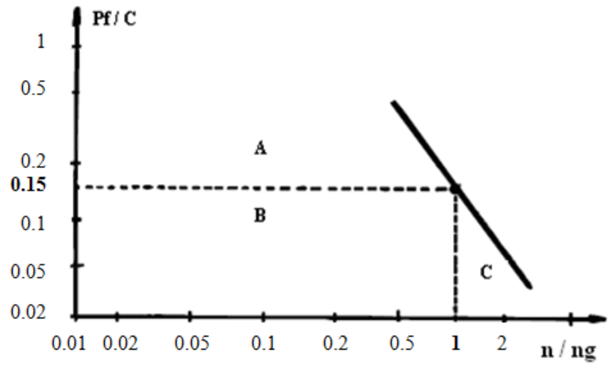

Fig. 10. Diagram for adoption a grease [1].

Determining the type of grease, depending on speed and load, is can make with the diagram in Fig. 10[1].

The influence of speed is the ratio *n* / *ng*, where:

- *n* – the speed under working regime;
- *ng* – the speed limits with lubrication by grease, from the bearings tables.

The influence of the load is assessed by the report P/C, where:

- *P* – the equivalent dynamic load;
- *C* – the dynamic capacity of base.

Three areas are highlighted in the chart:

- area *A*, between *n / ng* = 1 and *Pf /C* = 0.15: the influence of speed and load is insignificant. Only near the diagonal line there may be high temperatures; here are necessary the greases which are resistant on temperature and pressures;
- area *B* corresponds to the bearings subjected to high loads; will be used the high viscosity greases, extreme pressure additives, with good lubricating properties.
- area *C* corresponds to the bearings with high speeds and small tasks; will be used greases with good adhesion.

For lubrication of the rolling bearings is recommended Table 3 [1].

If there are heavy loads and hostile environment, the time for regrease will decreases accordingly , using the relations:

$$T_d = T\,q, \tag{1}$$

$$q = f_1\, f_2\, f_3, \tag{2}$$

where:

T_d – regrease time diminished,

q – mitigating factor,

f_1 – the influence of dust and moisture,

f_2 – the influence of shock and vibration,

f_3 – the influence of high temperatures.

These factors can take values from Table 4[1].

Table 3

The consumption of grease [1]

Shaft diameter [mm]	For radial bearings [g]	For axial bearings [g]
10	40	20
15	60	28
20	80	40
30	108	62
100	320	226

Table 4

Values of the influence factors [1]

Conditions	f_1, f_2, f_3
heavy	0.1 − 0.4
very heavy	0.4 − 0.7
moderate	0.7 − 0.95

Table 5

Values of *X* factor [1]

X factor	Lubrication intervals
0.0012-0.0015	daily
0.0015-0.002	weekly
0.002-0.003	monthly
0.003-0.0045	yearly;
0.0045-0.0055	2-3 years

Table 6

Greases for bearings [1]

Working tempera-ture [°C]	Working conditions	Recommended Grease Speed, [rpm]	
		< 1500	≥ 500
< 65	Small and medium loads	U 85 Ca 3	-
	Large loads	RUL 100 Ca 3	-
	Small and medium loads with pressure lubrication	U 75 Ca 2, U 80 Ca 2	-
	Large loads, with centralized lubrication system	Li Ca Pb 1	-
65 … 90	All loading conditions	RUL 145 Na 3, UM 165 Li Ca 1, Li Ca Pb 2	
90…110	Idem + humidity	RUL 165 Na 4, UM 170 Li Ca 2, Li Ca Pb 2	
110…30	Idem	UM 175 Li Ca 3, Li Ca Pb 3	
> 130	Different loads	RUL S 180 Na 3/4	

The amount of grease *m* necessary for regreasing is determined by the relationship:

$$m = D\,B\,X\ \text{[g]}, \tag{3}$$

where:

D – the outer diameter of the bearing [mm],

B – the width [mm],

X – factor, dependent to the interval of regrease (Table 5) [1].

Based on: the type of lubricant, the lubrication system, environmental conditions, the peripheral speed of the shaft, temperature, the construction and the position of the bearing in the assembly, it is selected the sealing device. Examples of greases, which must satisfy combined working conditions, are presented in Table 6[1].

The greasing is done using automatic lubrication systems (Fig. 11) [13], or manual lubrication equipment (Fig. 12) [13].

The knitting machine "VERA" made in the Czech Republic by UNIPLET company is composed of many tapered roller bearing. These are lubricated by grease nipples with ball (Fig. 13).

Fig. 11. Automatic lubrication systems [13].

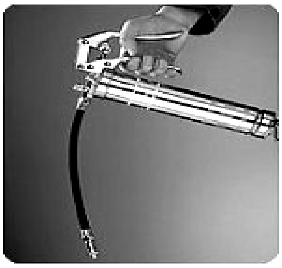

Fig. 12. Manual lubrication equipment [13].

Fig. 13. Grease nipple with ball.

You can choose sealing s with or without contact, and if the space does not allow one of these sealings, are used sealed bearings, with protective cover or sealing.

The sealed bearings are used for peripherical speeds of maximum 6 m/s, and their effectiveness depends by the size of the clearance between the washer and the shaft, or by the radial play of the bearing.

For this reason, the bearings must be used with minimum radial clearance.

The elastic sealing washers work in grease or in liquid lubricants. Sealed bearings can be grouped into two categories:

- with sealing washers (Fig. 14a, [5]), such as 2RS (2RSR);
- with protective washers (Fig. 14b, [5]), such as 2Z (2ZR);

They are greased for life. Simplicity is the solution for a high guarantee at using sealing bearings, especially in the field of moderate temperatures and mechanical loads. This type of bearings has been tested for 15 years in manufacturing of socks, at S.C. Emadi Prod S.R.L., on all knitting machines.

The lubrication of the open bearings was realized at the beginning of each shift, manually. The sealed bearings replaced the sliding bearings or the rolling bearings, where was possible.

a b

Fig. 14. Sealed bearings: *a* − width sealing washers [5]; *b* − width protective washers [5].

The results were unexpectedly good:

- I eliminated the need for the periodic lubrication to these bearings and lubricant consumption.
- It is obtained the protection against contaminating environment and a bearing with cleaner outside.

In many sectors is necessary to be established lubrication points, with all data necessary for planning the lubrication of any machine. A nomenclature for lubricants should include guidelines for:

- number of points of lubrication for any equipment,
- bath capacity, the minimum and maximum frequencies of control,
- program for additions and changes of the lubricant.

5. CONCLUSIONS

A lubricant must reduce friction, remove the heat, withstand high pressures, ensure sealing of couplings, transport the impurities , protect against corrosion, reduce the costs of lubrication and, finally, extend the lifetime of the equipment.

The areas of use for oils and greases partially overlap, the first having precedence to extreme requests or if the bearings operate in a confined space and the oil is used for other parts of machine (gearboxes, reducers).

To determine the oil with optimal viscosity, for a reducer or gearbox, it can applies the following method: must try on some types of oils with different viscosities and to measure their temperature after several hours of working. The lubricant which gave the lowest temperature has a viscosity of 90 mm^2/s. At viscosities below 20 mm^2/s vibrations occur.

By introduction of sealed bearings and keeping this type of oil it resulted a temperature increase of 10 ºC.

In normal working conditions, the bearings with grease lubrication are widespread due to the simplicity and to the low costs. The tapered bearings for the knitting machines are lubricated by grease nipples.

Are notable the advantages of using the sealed bearings. Generally, sealed bearings are lubricated for life and are protected against a dirty environment; so, this bearings realize savings of maintenance, time and cost.

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