

# Maximizing Bearing Service Life

Lubrication is a key part of tribology — the science of keeping bearings running.

BY ROLAND GRUBER

Correct and efficient lubrication is essential for the satisfactory function and the attainment of a maximum service life of rolling element bearings. Therefore it is advisable for both design engineers and maintenance technicians to thoroughly understand the basics of tribology and its effects on the proper function of rolling element bearings.

Each rolling element bearing represents a ‘tribological system’ consisting of the bearing and an adequate lubricant.

In this system, i.e. in a rolling element bearing, the lubricant primarily separates the metallic surfaces and thereby reduces friction. As well, it preserves the steel parts and prevents or neutralizes the effects of contamination.

In many cases the bearing life is determined by the service life of the lubricant, i.e. the failure of the lubricant will definitely terminate the bearing life.

In case of oil lubrication, the lubricant may also act as a coolant, i.e. actively taking part in the heat dissipation, thereby supporting the thermal equilibrium in bearings operating at high speeds.

## Types of bearing lubrication

Generally three types of lubrication are used in rolling element bearings — grease, oil, and solid or dry lubricants. The selection of a suitable lubrication method should be made in the early stages of design. The operating conditions — such as operating speeds, temperature and environment — have to be carefully evaluated. The latest state-of-the-art lubricants feature special agents — additives — for enhancing specific lubricant properties, i.e. high pressure characteristics, temperature stabilization, etc.

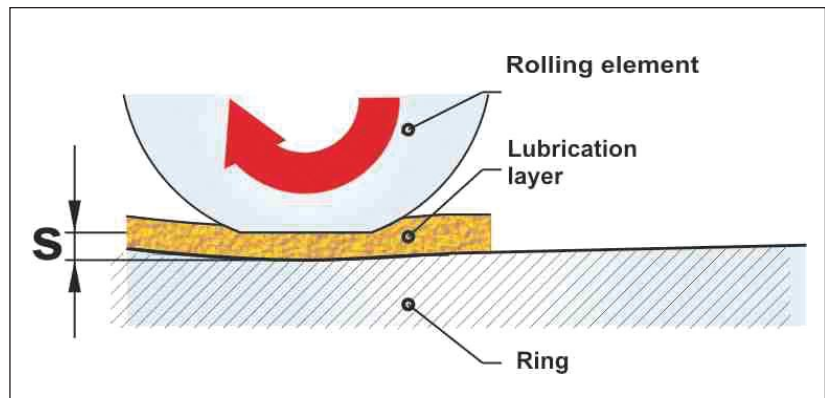


Fig. 1: The lubricant film separates the metal parts of a bearing.

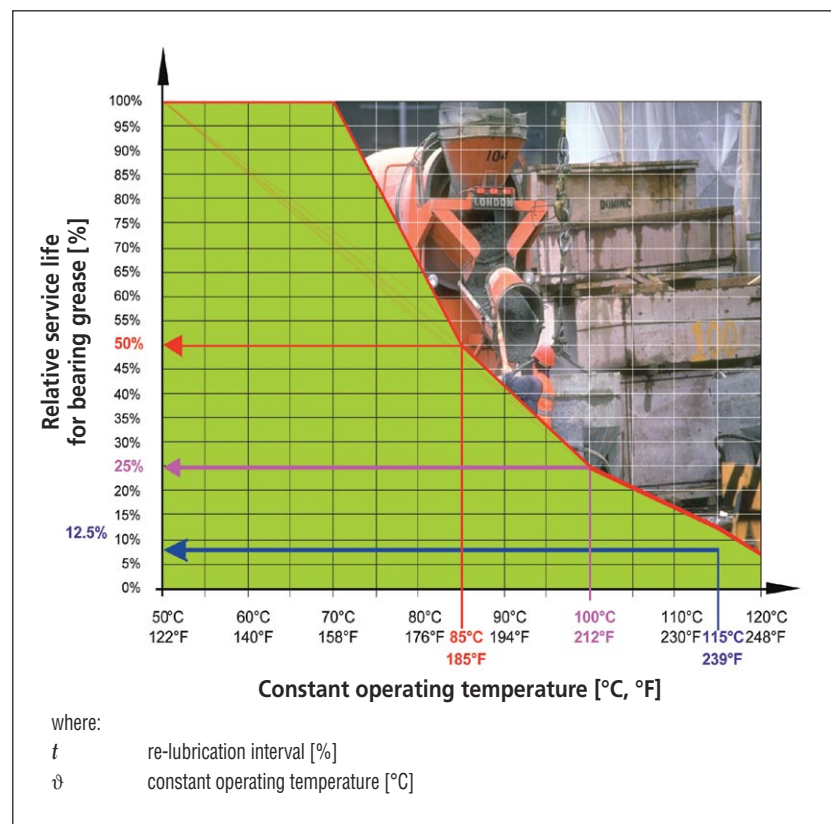


Fig. 2: Relationship between operating temperatures and re-lubrication intervals.

Lubricating method	$n \times d_m$
<b>Grease lubrication</b>	
Standard bearing greases	$\leq 500.000$
Special greases	$\leq 1.000.000$
<b>Oil lubrication</b>	
Oil bath lubrication	$\leq 500.000$
Circulating oil lubrication	$\leq 750.000$
Splash oil lubrication	$\leq 800.000$
Oil mist lubrication*	$\leq 1.500.000$
Minimum quantity lubrication*	$\leq 3.000.000$

Table 1: Typical  $n \times d_m$  values of different lubricant types.

\* For  $n \times d_m$  values of  $> 1.000.000$ , practical experience is of major importance as special appliances such as oil coolers, additional pumps or a separate compressed air system for oil and air lubrication may become necessary.

All values are for guidance only. Contact your lubricant supplier for detailed and accurate values for a specific lubricant.

**Grease lubrication:** Grease is by far the most common form of lubrication; in fact about 90% of all rolling element bearings are grease-lubricated. Simple application, minimal maintenance, easy sealing, a wide spectrum of lubricants and the availability of pre-greased and greased-for-life bearings are some of the main advantages of grease lubrication. Grease consists of a soap structure that in most cases is a metal soap based on lithium soap with a base oil and additives.

**Oil lubrication:** Oil is usually used for bearing lubrication if an oil supply system is already incorporated into the design of a machine for other purposes (e.g. gearbox lubrication). Oil lubrication

is also used for special operating conditions that require effective heat dissipation. In certain high-speed applications, the use of oil allows for a highly accurate and easily dosed application, i.e. via oil jet or oil mist.

**Solid and dry lubrication:** Where applications do not allow the use of oil or grease, i.e. due to heat, several other materials can be used, such as graphite powder or pressed graphite cages, Polytetrafluorethylene (PTFE) powder, metallic coatings, sliding varnish and various other surface treatments.

### Speed ability of bearing lubricants

Different lubricants and lubrication methods have different abilities for operating under given speeds. The most important factor for evaluating the speed ability of a certain lubrication method is the speed characteristic ( $n \times d_m$ ), where 'n' is the bearing operating speed [ $\text{min}^{-1}$ ] and  $d_m$  the bearing pitch diameter [mm]:

$$d_m = \frac{d + D}{2}$$

Table 1 shows typical  $n \times d_m$  values of various lubricating methods.

### Characteristic features of lubricants

**Viscosity ( $\nu$ ):** This is one of the most important features for selecting oil or grease. The term viscosity describes the ability of oil to flow under given conditions and temperatures. A low figure indicates thin oil, higher figures denote thicker oils.

In the case of grease, the viscosity of the respective base oil is indicated. Since the viscosity of a lubricant depends considerably on its temperature, the nominal viscosity of a lubricant is usually indicated with a defined reference temperature, usually  $40^\circ\text{C}$  ( $\nu_{40}$ ).

**Consistency:** The consistency indicates the 'stiffness' of grease. It is classified by the NLGI (National Lubricating Grease Institute) scale according to DIN 51818, where the penetration depth of a standardized test cone into a grease specimen at a standardized test temperature and after a standardized time gets mea-

sured. The deeper the test cone penetrates, the softer the grease, and hence the lower the NLGI grade (see Table 2).

Stiffer lubricants have higher consistency and therefore higher NLGI grades. For lubricating rolling bearings, grease lubricants of NLGI grades 2 and 3 are widely used. For certain high-speed applications, i.e. spindle bearings, grades 0 and 1 greases may be used.

Soft greases are optimal for small and miniature bearings, low temperatures, high speeds or when a central lubrication system is installed. Stiffer greases are suitable for large bearings running at low speeds or for high-temperature applications. Stiffer greases also provide a better sealing effect.

NLGI consistency grades (DIN 51818)	Worked penetration (0.1 mm)
000	445 to 475
00	400 to 430
0	355 to 385
1	310 to 340
2	265 to 295
3	220 to 250
4	175 to 205
5	130 to 160
6	85 to 115

Table 2: NLGI-consistency grades of greases.

### Selection of required lubricant viscosity

The most significant function of any lubricant is to separate the metallic surfaces in the 'load zone'. As shown in Figure 1, optimum separation in rolling bearings is achieved when the thickness of the lubricating film ( $S$ ), which builds up in the contact area between the rolling element surface and the bearing rings, is large enough to separate them completely.

In most applications only an incom-

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Speed ratio *		Grease filling **
>	≤	[%]
–	20	80 ÷ 90
20	75	30 ÷ 50
75		25

\* In % of the speed ratings with grease lubrication given in the bearing product tables.

\*\* In % of bearing housing cavities volume.

Table 3: Relationship between speed ratios and grease filling volumes.

plete separation, the so-called ‘mixed’ lubrication, is achieved.

The actual operating viscosity and thus the actual film thickness under given operating conditions is determined by the nominal viscosity of the lubricant, the bearing size, the speed and the operating temperature.

### Grease quantity in bearing housings

The lubricating grease fill volume in bearing housings is determined mainly by the bearing design and its actual operating speed. The free space within the bearing itself has to be fully filled with grease in all cases. The grease fill volume for the bearing housing cavities should be chosen according to Table 3.

### Grease service life and relubrication

Bearing lubricants undergo permanent mechanical stress as they are over-rolled by the rolling elements continuously. Additionally, lubricants change their characteristics, particularly when operating at high temperatures, and in the presence of humidity, pollution or chemical agents. Therefore the service life of lubricants is limited; its length depends on the individual operating conditions, particularly the operating temperature and the speed.

In the case of greased-for-life bearings, mainly those with shields or seals on both sides, the service life of the lubricant is expected to be longer than the required bearing life rating.

When considering the maintenance of bearings, it is essential to estimate the

service life of the lubricant realistically and schedule regular re-lubrication.

### Relubrication intervals

Re-lubrication intervals are very much related to the actual operating conditions and the individual characteristics of the lubricant in question. Modern high-performance lubricants allow for much longer service life due to the progress in lubricant research, development and manufacturing. For accurate figures on specific lubricants, consult your grease vendor. For standard lubricants, the realistic service life can be roughly estimated with the following equation:

$$t_n = \frac{a \times 10^6}{n \times \sqrt{d}} - b \times d \text{ [h]}$$

where:

- a and b** bearing type and series coefficients (see Table 4)
- n** bearing operating speed [min<sup>-1</sup>]
- d** bearing bore diameter [mm]
- t<sub>n</sub>** service life (operating hours).

For safety reasons the relubrication intervals of new machines — or in plants where no practical experience exists — should not exceed 50% to 60% of the initial calculated service life of the lubricant.

The values obtained from this formula are only valid for standard lithium soap mineral oil greases at consistent operating temperatures not exceeding 70°C (158°F). Above 70°C, the mineral oil based lubricants undergo an extremely accelerated ageing process.

When the lubricant is exposed to constant operating temperatures above 70°C, the calculated values for relubricating intervals must be halved for each 15°C (27°F) increase in operating temperature. The course of this reduction is illustrated in Figure 2.

If the grease that is lubricating the bearing also has to act as a seal against the entry of pollution, or when the bearing outer ring rotates, the relubrication intervals must be further reduced. This also applies in the presence of moisture, dust, chemicals or vibration.

Additional and more precise informa-

tion on specific characteristics of lubricants, their chemical reactions with some elements, and the anticipated service life of the lubricant under certain operating conditions, are available from the lubricant manufacturer. **IL**

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Bearing types and series	Coefficients	
	a	b
<b>Deep groove ball bearings</b>		
160, 60, 62	75	18
63	65	18
64	55	18
<b>Angular contact ball bearing</b>		
72 B	65	18
73 B	55	18
32	55	18
33	55	18
<b>Four-point contact bearings</b>		
QJ 2	65	18
QJ 3	55	18
<b>Self-aligning ball bearings</b>		
12, 22	75	18
13, 23	65	18
<b>Cylindrical roller bearings</b>		
N.10, N.2, N.2.. E	75	18
N. 3, N. 3 . . E	65	18
N. 4	55	18
<b>Taper roller bearings</b>		
302.., 320 .., 322..,	20	7
303.., 313	18	7
323..,	15	7
<b>Spherical roller bearings</b>		
222..	20	7
223..	15	7

Table 4: Bearing type and series coefficients for calculating lubricant service life.