12. Lubrication

Lubrication can be defined as the application of some materials between two objects moving relative to each other to allow smooth operation as much as necessary.

Either oil or grease is used for rolling bearings to prevent noise, wear and tear, and heat from being generated from their rolling and sliding movements, and in some special cases, solid lubricants are occasionally used.

The amounts and kinds of lubricants for rolling bearings are determined depending on operation speed, temperature, and surrounding condition, etc. And because the lubricants spent their service-life or polluted with foreign materials can not serve their function well, they have to be periodically replaced or oiled.

12-1 Purpose of Lubrication

Main purposes of lubrication are as follows;

- To prevent wear and premature fatigue by forming the lubrication film on the surface of load transferring parts to prevent contacts between metals.
- To enhance the favorable driving characteristics, such as low noise or friction.
- To prevent overheating of bearings and to prevent lubricant's own deterioration by radiating the generated heat to outside. It works particularly well if the circulation lubrication method is adopted.
- To prevent foreign material penetration, rust, and corrosion.

12-2 Lubrication Methods

For bearing lubrications, either grease or oil is used. It is important to choose the appropriate lubrication method that suits bearing's operating conditions and purpose, for the bearing to perform well.

Oil lubrication is generally better than grease lubrication in many respects, but grease lubrication is also widely used, because they have merits in that bearings have the available inside spaces for grease and that it is comparatively quite simple to use them.

Table 12-1 Comparisons between Grease and Oil Lubrications

Kinds	Grease Lubrication	Oil Lubrication
Lubrication Effect	Good	Excellent
Cooling Effect	None	Good when circulation lubrication is adopted
Permissible Load	Average load	High load
Speed	Allowable velocity is 60～80% of oil lubrication.	High allowable speed
Sealing and Housing Structure	Simple	Complex
Dust Protection	Easy	Difficult
Leaking of Lubricant	Small	Large
Repairing	Easy	Difficult
Lubricant Replacing	Difficult	Convenient
Torque	Comparatively large	Small
Removing of Foreign Materials	Impossible	Easy
Periodic Inspection	Long	Short

12-3 Grease Lubrication

12-3-1 Lubricating Grease

Grease can be defined as the lubricant of solid or semi-solid state that contains the thickener, and some greases contain various special ingredients. Because various kinds of greases have their own distinct characteristics, and sometimes even the same kind of greases produce quite different performance results, one has to be careful when selecting the greases.

Table 12-2 Types and Performances of Greases

Name	Lithium Grease			Sodium Grease	Calcium Grease	Mixed Grease	Compound Grease	Non-soap Type Grease	
Thickener	Li Soap			Na Soap	Ca Soap	Na+Ca Soap Li+Ca Soap	Ca Compound Soap Al Compound Soap	Urea, Carbon, Black Fluorine Heat-Resistant Organic compound.	
base oil	mineral oil	diester Oil polyol-ester Oil	Silicon Oil	mineral Oil	mineral Oil	mineral Oil	mineral Oil	mineral Oil	Compound grease (Ester Oil, Polyol-ester Oil, Silicon Oil, Combined carbohydrate Oil, Fluorine Oil
Dropping Point(℃)	170…195	170…195	200…210	170…210	70…90	160…190	180…300	230…	230…
Operating Temperature (℃)	-20…110	-50…130	-50…160	-20…130	-20…60	-20…80	-20…130	-10…130	…220
Permissible Speed Ratio (%)	70	100	60	70	40	70	70	70	40…100
Pressure Resistance	◎	◎	◎	◎	×	◎	◎	◎	◎
Mechanical Stability	△	△	×	○	×	○	○	○	△
Water Resistance	◎	◎	◎	×	◎	one that contains Na is bad	◎	◎	◎
Rust Prevention	◎	◎	×	△	◎	○	○	△	△
Remarks	General Purpose	Excellent low temperature and friction charactersticss Suitable	For high temperature Advantageous in high speed and high load	Caution when in contact with water or under high temperature	Excellent Pressure resistance when it contains EP resistance	Used mainly for large bearings	Excellent in pressure resistance and mechanical stability	General purpose	for special purposse such as heat-resistance and acid resistance

Remarks ◎ Excellent ○ Good △ Average × Poor

(1) Base Oil

Base oil in the grease is the main ingredient which actually provides lubricating function, and it forms 80～90% of grease. So, it is important to select the right kind of base oil and its viscosity.

There are two main types of base oil, mineral base oils and compound base oils.

Mineral oils from low to high viscosity are widely used. Generally, the mineral oils with higher viscosity are used for the locations requiring the lubrications of high load, low speed, and high temperature, and the ones with lower viscosity for the locations requiring the lubrications of low load, low speed, and low temperatures.

Compound base oils are generally very expensive and used for the locations requiring the

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lubrications of extremely high or low temperatures, or wide temperature ranges, and fast speed and high precision. Compound base oils of mainly esther, poly-α-olefine, or silicon series are generally used, but the use of fluorine compound oils are increasing nowadays.

(2) Thickener

Thickener is one of the most important elements in deciding the properties of the grease, and the thickness of grease depends on how much thickener is mixed in the grease.

There are mainly three kinds of thickeners, namely, metal soap, non-organic non-soap, and organic non-soap, but the metal soap thickeners are mostly used, and the non-organic non-soap thickeners are generally used only for the special cases, such as operationin in high temperature.

Generally speaking, the grease with high dropping point can be used in high temperatures, and the water-resistance of grease depends on that of thickener. Also for the bearings that come in contact with water or are operated under the high humidity level, the Na soap grease or the grease that contains Na soap can not be used, because they deteriorate quickly when in contact with the water or moisture.

(3) Additives

Various kinds of additives are used to enhance the grease performance and to meet the customers' demands for different functions. These additives enhance the physical or chemical properties of grease, and/or minimize the wear, corrosion, or rust to the lubricated metals.

There are various kinds of additives used for prevention of oxidization, wear and tear, or rust. There are also the EP additives. The appropriate grease containing right kind of additives to the applied location has to be used.

(4) Worked Penetration

Worked penetration is used to represent the hardness of grease, and it is shown as the penetrated depth(1/10mm) to grease by the pendulum of specified weight, and the greater the value is, the softer the grease is.

12-3-2 Polymer Grease

Polymer grease of hardened lubricant mixed with polyamid is generally used, and it allows to supply the grease for a long period.

It is widely used for the bearings to which the strong centrifugal force is applied, such as the ones in wire stranding machines or compressors, or to which leaking and pollution to the environment or insufficient lubrication is easy to happen.

12-3-3 Injection of Grease

(1) Injection Amount of Grease

The grease usually occupies 30% of bearing space, initially, and it is distributed evenly during the

Table 12-3 shows the greases of different worked penetrations and their usage.

NLGI Worked Penetration No.	KS Worked Penetrations of Mixtures	State	Usage
0	355...385	Semi-gel or soft	Centralized lubrication system
1	310...340	Soft	Centralized lubrication system
2	265...295	Ordinary	For general use, sealed ball bearings
3	220...250	Ordinary or rather hard	For general use, high temperature use
4	175...205	Rather hard	For special purposes

* NLGI : National Lubricating Grease Institute

Fig. 12-1 Bearings Filled with Polymer Grease

initial few hours of operation. And then, it is operated with just 30～50% of initial friction of the bearing.

The bearings purchased without grease inside, have to be filled with grease by the users themselves, and following cautions have to be taken while filling.

(a) The space inside the bearing has to be filled completely, but, in case of high speed rotation($n \cdot dm > 500{,}000\ min^{-1} \cdot mm$), only 20～25% of free space has to be filled.

(b) It is recommended to fill only up to 60% of housing space adjacent to the bearing, so as to leave sufficient room for the dispelled grease from the bearing.

(c) In case of low speed rotation($n \cdot dm > 50{,}000\ min^{-1} \cdot mm$), whole space of bearing and housing can be filled with grease.

(d) For the bearings rotating at a very high speed, it is necessary to test-run the bearings in advance, so as to distribute the grease evenly.

(2) Life Span of Grease

The life span of grease is a period from the start of bearing operation to bearing failure due to its insufficient lubricating action.

The life span of a grease with 10% of bearing failure possibility is denoted by F_{10}. The F_{10} Life Span Curves can be obtained by laboratory experiments set up close to the real operation situations. In most cases, because users do not know the values of F_{10}, the lubrication interval, t_f, is recommended as the minimum value for the life span of the standard grease. Refilling inte-rval is set considerably shorter than the lubrication interval, so as to provide stability. Reliability can be increased sufficiently even for the greases barely meeting the minimum requirements, if lubricated in accordance with the lubrication interval curves in the Fig. 12-2.

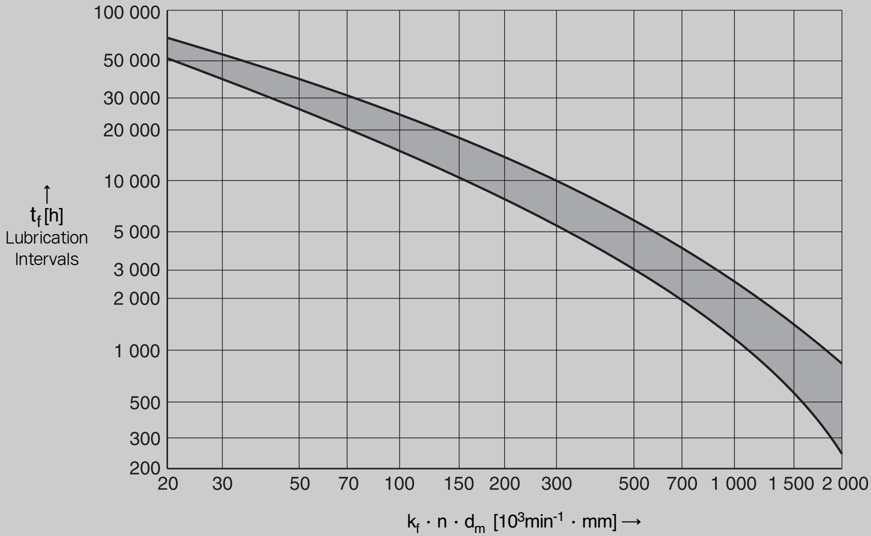
The lubrication intervals are determined by the values of $k_f \cdot n \cdot d_m$, which can be obtained from the speed formula related to bearings, and the different values of k_f have been assigned to various kinds of bearings.

The bearings with larger load capacities have larger k_f values, and vice versa. The graph in the Fig. 12-2 shows the lubrication intervals under the conditions of below 70℃ measured at the outer ring and $P/C<1$ for average load.

If either load and/or temperature rise, then the lubrication intervals should be shortened. Furthermore, if the operating and surrounding conditions are not favorable, then they should be even shorter. Also, If the life span of grease is considerably shorter than that of bearing, then it has to be recharged again with grease or the grease has to be totally exchanged. If it is just recharged again with grease, then only a part of whole grease gets to be replaced, therefore, the recharging intervals should be shorter than the lubrication intervals(Generally, between $0.5 \cdot t_f$ and $0.7 \cdot t_f$).

When recharging with grease, different kinds of greases could be mixed together. It is comparatively safe to mix different kinds of greases as follows.

- Greases containing the same thickener
- Lithium grease/calcium grease
- Calcium grease/bentonite grease



Kinds of Bearings		k_f
Deep Groove Ball Bearing	Single row	0.9 . . . 1.1
	Double row	1.5
Angular Contact Ball Bearing	Single row	1.6
	Double row	2
Spindle Bearing	$\alpha = 15^\circ$	0.75
	$\alpha = 25^\circ$	0.9
4-Point Contact Bearing		1.6
Self-Aligning Ball Bearing		1.3 . . . 1.6
Thrust Ball Bearing		5 . . . 6
Thrust Angular Contact Ball Bearing	Double row	1.4

Kinds of Bearings		k_f
Cylindrical Roller Bearing	Single row	3 . . . 3.5*)
	Double row	3.5
	Full complement	25
Thrust Cylindrical Roller Bearing		90
Needle Roller Bearing		3.5
Tapered Roller Bearing		4
Barrel Roller Bearing		10
Lipless Spherical Roller Bearing (E)		7 . . . 9
Spherical Roller Bearing with Center Lip		9 . . . 12

Note : 1) Bearing applied with radial load and constant axial load ; When axial loads fluctuate, $K_f = 2$.

Remarks 1) Lubrication intervals under fairly good conditions.

2) Grease life span applied to Lithium soap of 10% break possibility under 70℃.

Fig. 12-2 Lubrication Intervals

12-3-4 Properties of Greases

Table 12-4 Grease Property and Application Table-Grease.

Grease	Color	Thickener	Base Oil Viscosity (40℃) mm²/s	Worked Penetration NLGI	Operating Temperature ℃	Limit Rotating Ratio (%)	Main Properties	Main Applications
G6	Light Brown	Lithium soap	ISO VG 90	2	-15…+90	60	Medium speed Heavy load	General industrial Machinery
G9	Brown	Lithium soap	ISO VG 20	2	-55…+130	100	Ultra high speed	Machining tools spinning machine, spindle bearing, small precision bearing
G12	White	Lithium soap	ISO VG 38	2/3	-30…+200	60	Medium speed	OA equipment, electric motor and high temperature use high temperature equipment bearing
G14	Green	Polyurea	ISO VG 110	2	-30…+175	100	Ultra high speed	Coupling, electric equipment(elecric motor, generator)
G15	Pale	Lithium soap	ISO VG 28	3	-40…+150	100	High speed	Electric motor precision tools and machinery automotive elecrical equipment
G26	Beige	Polyurea	ISO VG 31	2	-40…+160	100	High speed High temperature Long life	Automotive generator, electronic clutch, electric motor
G33	White	Fluorine	ISO VG 400	2	-35…+300	60	Low speed Ultra high temp Special purpose	Chemical equipment, vacuum and semi-conductor equipment, kiln truck
G35	Light green	Polyurea	ISO VG 43	2	-50…+170	100	Hign speed Wide range temp Chemical resistance Radioactive resistance	Automotive generator automtive electric equipment, household appliances
G42	Beige	Polyurea	ISO VG 95	2	-40…+170	100	High speed Wide range temp	Automtive generator household appliances
G100	Light green	Lithium soap	ISO VG 100	2	-30…+130	70	Standard grease General bearings	Electrical motor, agricultural equipment construction equipment
G101	Pale Yellow	Lithium soap	ISO VG 33	3	-40…+150	100	High speed Wide range temp	Electrical motor Household appliances

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12-4 Oil Lubrication

12-4-1 Lubricants

Lubricants can be largely divided into two groups, namely mineral oil base lubricants and synthetic lubricants.

When selecting a lubricant, its viscosity is one of the most important factors to be considered. If its viscosity is too low at its operating temperature, oil film can't be sufficiently formed, causing abrasion and/or burning-and-sticking. And, if it's too high, its viscosity resistance becomes higher, causing temperature/friction rise and subsequent abnormal power loss.

In general, lubricants with low viscosity are used when it runs at high speed and low load, and ones with high viscosity when at low speed and high load.

The minimum viscosity at its operating temperature during normal operation is shown at the Table 12-5 shown below, and it should not go under these minimum values.

Lubricants should be selected in accordance with viscosity specified by ISO, and its viscosity index can be used conveniently for references. Although it depends on viscosity indices, its viscosity gets reduced by half whenever the temperature of lubricant increases by 10℃.

Typical lubricants to be selected depending on bearing's operating condition are shown on Table 12-6.

Table 12-5 Bearing types and minmum dynamic viscosity required for lubricants

Bearing Type	Dyminic viscosity during operation(cSt)
Ball Bearing, Cylindrical roller bearing, Needle roller bearing	over 13
Tapered roller bearing, Cylindrical roller bearing Thrust needle roller bearing	over 20
Thrust spherical roller bearing	over 32

Table 12-6 Selection of Lubricants

Operating temperature ℃	Revolving Speed	ISO Viscosity Class (VG) of Lubricant	
		Light Load or Nomal Load	High Load Impact Load
-30…0	Up to allowable speed	15, 22, 32	46
0…50	up to one half of allowable speed	32, 46, 68	68, 100
	Up to allowable speed	15, 22, 32	32, 46
	Same or above allowable speed	10, 15, 22	-
50…80	up to one half of allowable speed	100, 150, 200	220, 320
	Up to allowable speed	46, 68, 100	100, 150
	Same or above allowable speed	32, 46, 68	-
80…100	up to one half of allowable speed	320, 460	460, 680
	Up to allowable speed	150, 220	220, 320
	Same or above allowable speed	68	-

Remarks: 1) In case of oil sump or circulation lubrication
2) Contact KBC if operating conditions are beyond the values of this Table.

12-4-2 Oil Lubrication Methods

(1) Oil Sump Lubrication

It is the most generally used lubrication method, especially for low or medium speed operations.

Oil surface should be, in principle, placed at the center of lowest rolling element, and it is better to be able to confirm the location of oil surface by using the oil gauge(Fig. 12-3).

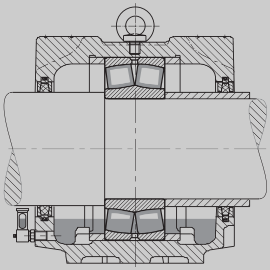

Fig. 12-3 Oil Sump Lubrication

(2) Drip Feed Lubrication

This method is widely used for small bearings that operate at a relatively high speed, and oil supply is controlled by adjusting the volume of oil drip(Fig. 12-4).

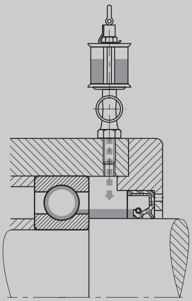

Fig. 12-4 Drip Feed Lubrication

(3) Throwaway Lubrication

This is a method that utilizes gear or circulation ring to supply oil to bearings. It is widely used for automotive transmissions or gears(Fig. 12-5).

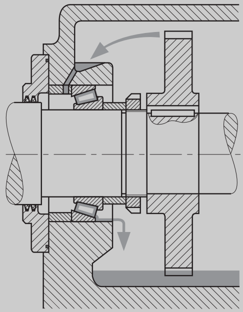

Fig. 12-5 Throwaway Lubrication

(4) Circulation Lubrication

It is widely used when it is necessary to cool the bearing parts that revolve at a high speed, or that with high surrounding temperature. Oil is fed through feed pipe and recovered through recovery pipe, which is cooled down and re-fed again.

The diameter of recovery pipe should be bigger than that of feed pipe, so as to prevent back pressure from occurring to the oil inside a bearing(Fig. 12-6).

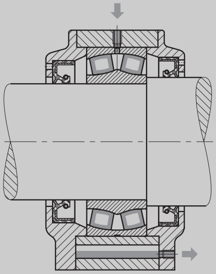

Fig. 12-6 Circulation Lubrication

(5) Jet Lubrication

Jet lubrication is widely used for high speed revolution bearings(for $n \cdot dm \geq 1{,}000{,}000$), and oil is jet-sprayed through one or several nozzles under constant pressure into the inside of a bearing.

In general, jet stream speed should be faster than 1/5 of circumferential speed of inner ring outer surface because air wall formed by surrounding air revolving with bearing tends to weaken the jet stream.

Provided that total volume of lubricant is same, the more the number of nozzles are, the smoother and the greater the cooling effect is(Fig. 12-7).

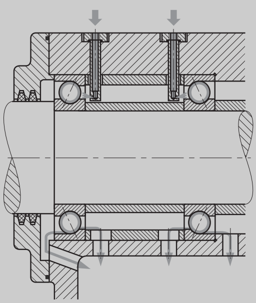

Fig. 12-7 Jet Lubrication

(6) Spray Lubrication

Spray lubrication is a method that vaporizes the lubricant by blowing in the air to be sprayed into bearing. It has following merits.

- Due to small volume of lubricant required, its churning resistance gets smaller, which in return makes it suitable for high speed revolution bearings.
- Because it minimizes volume of discharged lubricant, the pollution to the equipment can be also kept to the minimum.
- Because fresh lubricant is fed all the time, bearing life can be extended.

Therefore, it is widely used for various machining tools, such as high speed spindle, high speed revolution pump, or roll neck bearing of roller(Fig. 12-8).

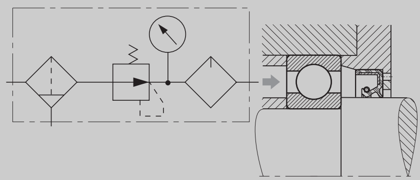

Fig. 12-8 Spray Lubrication

(7) Oil Air Lubrication

Oil air lubrication is a method that forcefully feeds the exactly calculated minimum amount of required lubricant at an optimum interval to each bearing to the end.

Because the minimum amount of fresh lubricant is fed exactly and continuously, lubricant contamination is also kept to the minimum, and air cooling effect is maximized to keep the bearing temperature sufficiently low. Also, pollution to the environment is also kept to the minimum due to the bare minimum amount of lubricant used(Fig. 12-9)

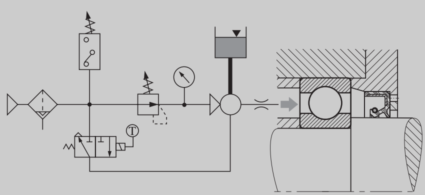

Fig. 12-9 Oil Air Lubrication