Purposes of Lubrication

The main purposes of lubrication are to reduce friction and wear inside the bearing that may cause premature failure. The effects of lubrication may be briefly explained as follows:

(1) Reduction of Friction and Wear

Direct metallic contact between the bearing rings, rolling elements, and cage, which are the basic parts of a bearing, is prevented by an oil film which reduces the friction and wear in the contact areas.

(2) Extension of Fatigue Life

The rolling fatigue life of bearings depends greatly upon the viscosity and film thickness between the rolling contact surfaces. A heavy film thickness prolongs the fatigue life, but it is shortened if the viscosity of the oil is too low so the film thickness is insufficient.

(3) Dissipation of Heat

Circulating lubrication may be used to carry away frictional heat or heat transferred from the outside to prevent the bearing from overheating and oil from deteriorating.

(4) Others

Adequate lubrication also helps to prevent foreign material from entering the bearings and guards against corrosion or rusting.

Lubricating Methods

For machine tool spindles in which high accuracy is important, it is necessary to prevent excessive temperature rise of the spindle to reduce thermal deformation.

Bearing heat generation is divided into a load term determined by the bearing type and load, and a speed term determined by the lubricating method and speed.

Generally, the speed term is greater, but if a lubricating method resulting in a small speed term is selected, the influence of the load term cannot be disregarded. Therefore, it is important to select a low heat generating bearing (load term) and lubricating method (speed term).

Regarding heat generation, both the lubrication method and quantity of lubricant have important effects. Lubrication using a small amount of grease is common since this method is economical, maintenance free, and there is little heat generation. At high speeds, to maintain a constant low temperature, the oil-air lubrication method, which requires a minimum quantity of oil, was developed.

The relation between oil quantity and heat generation (frictional loss) and temperature rise is already known as shown in Fig. 6.1. Therefore, for machine tool spindles, to avoid excessive temperature rise, adoption of a lubricating method aiming at either zone A or B is necessary.

The lubricating methods in zones A and B are summarized in Table 6.1.

Dynamic torque of bearing (heat generation) $M=Ml+Mv$

- Load term (Determined by bearing type and load)
  $Ml=f_1 F d_m$
  where f_1 : Coefficient determined by bearing type and load
  F : Load
  d_m : Pitch circle diameter of rolling element
- Speed term (Determined by oil viscosity, amount, speed)
  $Mv=f_0(\nu_0 n)^{2/3} dm^3$
  where f_0 : Coefficient determined by bearing and lubricating method
  ν_0 : Kinematic viscosity of oil
  n : Speed

Fig. 6.1 Oil Quantity and Temperature Rise

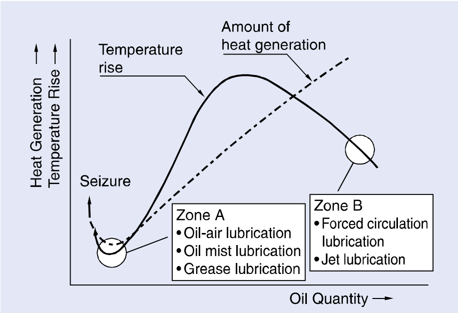


Table 6.1 Comparison of Lubricating Methods

Lubricating Methods	Advantages	Disadvantages
Grease Lubrication	○Cost is low. ○Limitation of temperature rise is possible. ○Maintenance free.	○If packed grease deteriorates, seizure may occur. ○May allow penetration of dust or cutting fluid.
Oil Mist Lubrication	○Since new oil is always fed, no fear of oil deterioration. ○Dust and cutting fluid cannot easily enter.	○Pollution of environment. ○Oil supply quantity varies depending on the oil viscosity and temperature, so control of a small flow rate is difficult. ○It is difficult to confirm that oil is actually fed.
Jet Lubrication	○Since the oil flow rate is high, dust and cutting fluid cannot enter and seizure hardly ever occurs. ○Because of cooling by oil, the bearing temperature can be controlled to some degree.	○Frictional loss is high. ○Since oil leaks, it is difficult to use for vertical spindles. ○Cost is high.
Oil-Air Lubrication	○Since oil quantity control is possible, the optimum quantity of oil is fed and heat generation is low. ○Besides little heat-generation, there is a cooling effect of the air, so the temperature is low. ○Since new oil is always fed, no fear of oil deterioration. ○Dust, cutting fluid cannot easily enter. ○Environmental pollution mist is slight.	○Cost is rather high. ○Confirmation of whether oil is actually fed to bearing is difficult.

Grease Lubrication

(1) Recommended Greases

Lithium base greases with mineral oil as the base oil have good sticking properties and excellent characteristics for rolling bearings. These are usually usable over a temperature range of –10˚C to +110˚C.

As grease for high speed machine tool spindles that require low temperature rise and long life, a consistency No.2 grease with a synthetic base oil (diester, diester + mineral oil, etc.) is recommended.

Table 6.2 lists the brand names and properties of greases widely used in machine tools main spindles and ball screw support bearings.

(2) Grease Life

Grease life depends greatly upon operating temperature; therefore, it is necessary to keep the temperature of the bearing (including atmospheric temperature) cooler, in order to extend the grease life.

High performance wide range grease is often used for high speed spindle bearings, or spindle motor bearings.

The following equation shows the mean life of wide range grease:

$$\log t = 6.12 - 1.4 n/N_{max} - (0.018 - 0.006 n/N_{max})\, T$$

where t : Mean Grease life (h)
N_{max} : Limiting speed (min⁻¹)
n : Operating speed (min⁻¹)
T : Bearing running temperature (˚C)

(3) Quantity of Grease for High Speed Spindle Bearings

To operate bearings at high speed with grease lubrication, the recommended quantity to be packed is 10% to 20% of internal space. If too much grease is packed, during running in, abnormal heat generation occurs and this may cause the grease to deteriorate. To avoid such a risk, it is necessary to run in spindles for a sufficient time. Based on their experience, NSK determines the packing quantity which allows easy running in and will provide sufficient lubrication. For the amount, please refer to the tables on Page 175.

Table 6.2 Grease Brand Names and Properties

Brand names	Manufacturers	Thickeners	Base oils	Base oils viscosity mm²/s(40˚C)	Dropping point (˚C)	Working temperature range, (˚C)	Main application
MTE	NSK	Barium complex	Ester oil	20	200	–30 to +120	Bearings for high speed spindles, high speed cylindrical roller bearings
MTS	NSK	Urea	Ester+Synthetic hydro carbon oil	22	220	–40 to +130	Bearings for high speed spindles
Isoflex NCA15	Klüber	Barium complex	Diester oil + Mineral oil	20	250	–30 to +120	Bearings for main spindles
Multemps PS No.2	Kyodo Yushi	Lithium	Diester oil + Mineral oil	16	189	–50 to +110	Bearings for main spindles
Mobilux 2	Mobil	Lithium	Mineral oil	26	190	–10 to +110	Bearings for boring heads, live centers
Multemp LRL3	Kyodo Yushi	Lithium	Tetraester oil	37	208	–30 to +130	Bearings for main spindles
Stabragus NBU8EP	Klüber	Barium complex	Mineral oil	105	220	–30 to +130	Heavy load cylindrical roller bearings
Alvania 2	Shell	Lithium	Mineral oil	130	182	–10 to +110	Ball screw support bearings
ENS	NSK	Urea	Tetraester oil	32	260	–40 to +160	Bearings for motors
WPH	NSK	Diurea	Tetraester oil	96	259	–40 to +150	Ball screw support bearings

Lubrication

Oil Lubrication

(1) Oil Mist Lubrication and Oil-Air Lubrication (Minimal Oil Quantity Lubrication)

Spray oiling is a method of spraying oil by turning it into a mist using compressed air. It is also called oil mist lubrication.

Oil-air lubrication is a method of feeding oil continuously by injecting oil into a compressed air stream by means of a mixing valve that intermittently discharges the minimum quantity of oil using a constant-quantity piston.

Fig. 6.2 shows the recommended oil quantity for the lubrication methods described above, each quantity is for one bearing.

In case of oil mist lubrication, it's necessary to adjust the oil quantity to accommodate for the effects of the branches in path tubing, and leakage from the gaps around the spacers.

Please ask NSK, as the oil quantity should be increased, in cases where the $d_m n$ value is higher than 1 800 000.

For the position of the spray nozzle, please refer to Page 192.

(2) Jet Lubrication

Jet lubrication is mainly used for high speed bearings with a $d_m n$ value 100 × 10^4. Through one to several nozzles, jets of lubricating oil under a constant pressure pass through the bearings. At high speed, the air surrounding the bearing rotates together with the bearing and forms an air wall. The speed of the jet from each nozzle must be faster by 20% than the circumferential speed of the inner ring outside surface. Since the jet lubrication uses a large quantity of oil, there is much agitation resistance, so it is necessary to dissipate the heat effectively using a large oil discharge outlet and forced discharge.

For machine tool spindle bearings, this method is used in some applications as a means for stable operation at ultra high speeds (see Fig. 6.3).

For the position of the spray nozzle, please refer to page 192.

Fig. 6.2 Recommended Oil Quantity for Each Bore Size of Bearing (Minimal Oil Quantity Lubrication)

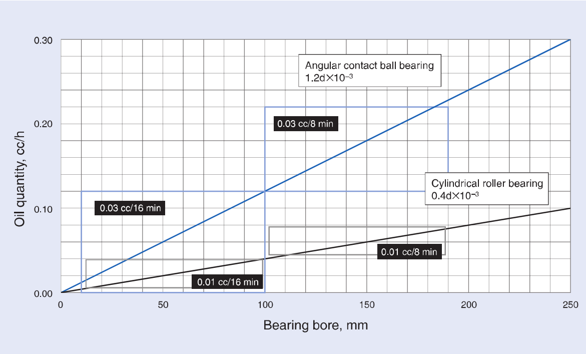
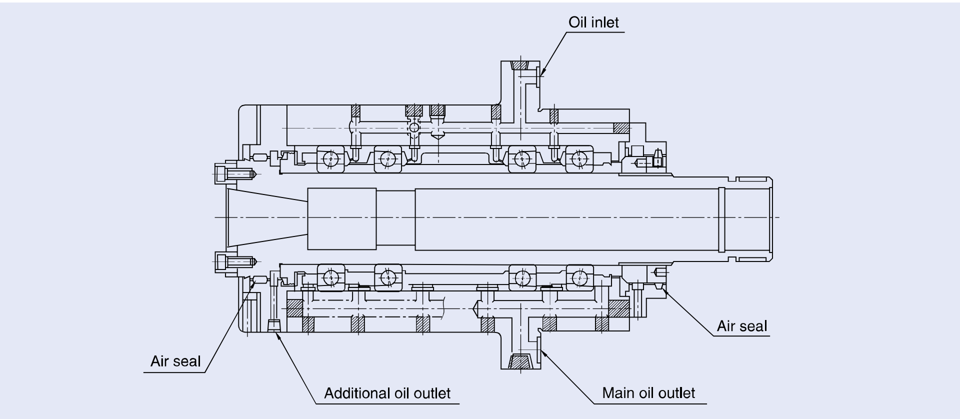


Fig. 6.3 Spindle Structure with Jet Lubrication



The Recommended Grease Quantities for High-speed Spindle Bearings

Unit: cc/bearing

Bore number	Bore diameter (mm)	Angular contact ball bearing : 15% of internal space				Cylindrical roller bearing : 10% of internal space			
		BNR19 BGR19 79xx	BGR10 70xx	BGR02 72xx	BNR10 BAR10 BTR10	NN49	NN39	NN30	N10
		X-quantity	X-quantity	X-quantity	X-quantity	X-quantity	X-quantity	X-quantity	X-quantity
5	5	–	–	0.03	–	–	–	–	–
6	6	–	0.04	0.07	–	–	–	–	–
7	7	–	0.07	–	–	–	–	–	–
8	8	–	0.12	0.10	–	–	–	–	–
00	10	0.06	0.13	0.16	–	–	–	–	–
01	12	0.06	0.14	0.23	–	–	–	–	–
02	15	0.11	0.18	0.29	–	–	–	–	–
03	17	0.13	0.24	0.41	–	–	–	–	–
04	20	0.23	0.44	0.68	–	–	–	–	–
05	25	0.27	0.52	0.85	–	–	–	0.4	–
06	30	0.31	0.69	1.2	0.58	–	–	0.6	0.4
07	35	0.48	0.98	1.7	0.78	–	–	0.8	0.6
08	40	0.75	1.2	2.1	0.92	–	–	1.0	0.7
09	45	0.83	1.5	2.6	1.2	–	–	1.3	1.0
10	50	0.91	1.6	3.0	1.2	–	–	1.4	1.1
11	55	1.1	2.4	3.9	1.7	–	–	2.0	1.5
12	60	1.2	2.6	4.8	1.8	–	–	2.1	1.6
13	65	1.3	2.6	5.7	1.9	–	–	2.2	1.6
14	70	2.1	3.6	6.5	2.8	–	–	3.2	2.4
15	75	2.3	3.6	7.0	2.9	–	–	3.5	2.5
16	80	2.4	5.1	8.7	3.8	–	–	4.7	3.5
17	85	3.5	5.3	11	4.0	–	–	4.9	3.7
18	90	3.6	6.6	13	5.5	–	–	6.5	4.5
19	95	3.6	6.8	16	5.7	–	–	6.6	4.7
20	100	4.9	7.2	19	6.1	5.4	4.5	6.8	4.9
21	105	5.1	9.0	23	7.6	5.6	4.6	9.3	5.9
22	110	5.2	12	27	9.1	5.7	4.8	11	7.5
24	120	7.9	12	31	9.8	8.4	6.5	12.5	8.1
26	130	9.0	18	34	15	11	8.5	18	12.4
28	140	9.9	20	42	17	12	9.3	20	12.9
30	150	14	25	53	22	24	14	23	–
32	160	16	34	–	26	20	15	29	–
34	170	14	42	–	33	21	15	38	–
36	180	22	51	–	46	28	23	51	–
38	190	27	47	–	50	30	24	54	–
40	200	39	76	–	61	44	35	69	–
44	220	42	–	–	–	–	37	–	–
48	240	41	–	–	–	–	40	–	–
52	260	77	–	–	–	–	70	–	–
56	280	80	–	–	–	–	75	–	–

The grease quantity of "xxTAC20(29)X(D)" should be same as the double row cylindrical roller bearing's, which is assembled with this bearing together.
Use the grease listed on Page 173, and multiply 0.93 (density) to the quantity above, for the weight of the grease.
For the recomended grease quantity for angular contact thrust ball bearing for ball screw support, please refer to Page 110-113.

Lubrication