9. Lubrication

9.1 Lubrication amount for the forced lubrication method

When a rolling bearing runs at high speed, the rolling friction of the bearing itself and the churning of lubricant cause heat generation, resulting in substantial temperature rise. Positive removal or dissipation of such generated heat serves greatly to prevent overheating in bearings. The maintenance of a sufficient lubrication oil film ensures stable and continuous operation of bearings at high speed.

Various heat removal or dissipation methods are available. An effective method is to remove the heat directly from bearings by forcing a large quantity of lubricating oil to circulate inside the bearing. This method is called the forced lubrication method. In this case, the amount of oil supplied is mostly determined on the basis of the actual operating conditions. Important factors to be considered include the allowable temperature of the machine or system, radiation effect, and heat generation caused by oil stirring.

Below is an empirical equation which can be used to estimate the amount of forced circulation oil needed for a bearing.

$$\left.\begin{aligned} Q &= \frac{0.19\times10^{-5}}{T_2-T_1}\, d\,\mu\,n\,F \ \text{(N)} \\ &= \frac{1.85\times10^{-5}}{T_2-T_1}\, d\,\mu\,n\,F \ \{\text{kgf}\} \end{aligned}\right\} \cdots\cdots\cdots\cdots\cdots (1)$$

where, Q: Oil supply rate (liters/min)
T_1: Oil temperature at the oil inlet (°C)
T_2: Oil temperature at the oil outled (°C)
d: Bearing bore (mm)
μ: Coefficient of dynamic friction (Table 1)
n: Bearing speed (min^{-1})
F: Load on a bearing (N), {kgf}

Systems employing the forced circulation lubrication method include large industrial machinery, such as a paper making machines, presses, steel-making machines, and various speed reducers. Most of these machines incorporate a large bearing. As an example, the calculation of the supply rate for a spherical roller bearing used in a speed reducer is shown below:

Bearing: 22324 CAM E4 C3
d=120 mm
μ=0.0028
Speed: n=1 800 min^{-1}
Bearing load: F=73 500 N, {7 500 kgf}
Temperature difference: Assumed to be
T_2-T_1=20°C

$$Q \fallingdotseq \frac{0.19\times10^{-5}}{20}\times120\times0.0028\times1\,800 \times73\,500 \fallingdotseq 4.2$$

The calculated value is about 4 liters/min. This value is only a guideline and may be modified after considering such factors as restrictions on the oil supply and oil outlet bore.

Note that the oil drain pipe and oil drain port must be designed large enough to prevent stagnation of the circulating oil in the housing. For a large bearing with a bore exceeding 200 mm, which is exposed to a heavy load, the oil amount according to Equation (1) is calculated to be slightly larger. However, the user may select a value of about 1/2 to 2/3 of the above calculated value for most practical applications.

Table 1 Coefficients of Dynamic Friction

Bearing Types	Approximate Values of μ
Deep Groove Ball Bearings	0.0013
Angular Contact Ball Bearings	0.0015
Self-Aligning Ball Bearings	0.0010
Thrust Ball Bearings	0.0011
Cylindrical Roller Bearings	0.0010
Tapered Roller Bearings	0.0022
Spherical Roller Bearings	0.0028
Needle Roller Bearings with Cages	0.0015
Full Complement Needle Roller Bearings	0.0025
Spherical Thrust Roller Bearings	0.0028

9.2 Grease filling amount of spindle bearing for machine tools

Recent machine tools, such as machining centers and NC lathes, show a remarkable trend towards increased spindle speeds. The positive results of these higher speeds include enhanced machining efficiency and improved accuracy of the machined surface. But a problem has emerged in line with this trend. Faster spindle speeds cause the spindle temperature to rise which adversely affects the machining accuracy.

In general, grease lubrication is employed with spindle bearings and in particular, for spindle bearings with bores of 150 mm or less. When grease lubrication is employed, filling the bearing with too much grease may cause abnormal heat generation. This is an especially severe problem during the initial operation immediately after filling, and may even result in the deterioration of the grease. It is essential to prevent such a problem by taking sufficient time for a thorough warm-up. In other words, the spindle bearing needs to be accelerated gradually during its initial operation.

Based on its past experience, NSK recommends that spindle bearings for machine tools be filled with the standard amount of grease, which is equivalent to 10% of the cylindrical roller bearing free internal space or 15% of the angular contact ball bearing free internal space, so as to facilitate the initial warm-up wihtout adversely affecting the lubrication performance.

Table 1 shows the standard grease filling amount for bearings used in spindles which is equivalent to 10% of the bearing free space. As an alternative to this table, the simplified equation shown next may be used to estimate the value.

$$V_{10}=f\times10^{-5}\,(D^2-d^2)\,B$$

where, V_{10}: Approximate filling amount (cm^3)
D: Nominal outside diameter (mm)
d: Nominal bore (mm)
B: Nominal bearing width (mm)
f=1.5 for NN30 series and BA10X and BT10X series
f=1.7 for 70 and 72 series
f=1.4 for NN49 series

The grease for high-speed bearings should be a quality grease: use a grease with a synthetic oil as a base if the application involves ball bearings; use a grease with a mineral oil as a base if the application involves roller bearings.

Table 1 Standard grease filling amounts for spindle bearings for machine tools

Units: cm^3

Bearing bore No.	Bearing bore dimension (mm)	Filling amount (per bearing)					
		Cylindrical roller bearing		High-speed angular contact thrust ball bearing BA, BT series	Angular contact ball bearing		High-speed angular contact ball bearing
		NN30 series	N10B series		70 series	72 series	BNC10 series
10	50	1.4	1.1	1.2	1.7	3.1	1.5
11	55	2.0	1.5	2.0	2.3	4.0	2.0
12	60	2.1	1.7	2.0	2.4	4.9	2.0
13	65	2.2	1.8	2.1	2.7	5.7	2.3
14	70	3.2	2.4	3.0	3.6	6.6	3.3
15	75	3.5	2.5	3.2	3.8	7.2	3.6
16	80	4.7	3.3	4.2	5.1	8.8	4.4
17	85	4.9	3.5	4.4	5.3	10.9	4.7
18	90	6.5	4.7	6.0	6.9	13.5	6.2
19	95	6.6	4.8	6.3	7.2	16.3	6.5
20	100	6.8	5.1	6.5	7.4	19.8	6.8
21	105	9.3	6.7	8.4	9.3	23.4	8.1
22	110	11	7.8	10.1	11.9	27.0	10.1
24	120	12.5	8.1	10.8	12.3	32.0	10.8
26	130	18	12.4	16.5	19.5	35.3	16.1
28	140	20	—	17.1	20.7	42.6	17.0
30	150	23	—	21.8	25.8	53.6	21.2
32	160	29	—	26.9	33.8	62.6	25.5
44	170	38	—	32.4	41.6	81.4	33.2

Remarks For the ○○TAC20D double-direction angular-contact thrust ball bearings, grease should be filled to the same amount as that for the NN30 double-row cylindrical roller bearing.

9.3 Free space and grease filling amount for deep groove ball bearings

Grease lubrication can simplify the bearing's peripheral construction. In place of oil lubrication, grease lubrication is now employed along with enhancement of the grease quality for applications in many fields. It is important to select a grease appropriate to the operating conditions. Due care is also necessary as to the filling amount, since too much or too little grease greatly affects the temperature rise and torque. The amount of grease needed depends on such factors as housing construction, free space, grease brand, and environment. A general guideline is described next.

First, the bearing is filled with an appropriate amount of grease. In this case, it is essential to push grease onto the cage guide surface. Then, the free space, whic excludes the spindle and bearing inside the housing, is filled with an amount of grease as shown next:

1/2 to 2/3 when the bearing speed is 50% or less of the allowable speed specified in the catalog.

1/3 to 1/2 when the bearing speed is 50% or more.

Roughly, low speeds require more grease while high speeds require less grease. Depending on the particular application, the filling amount may have to be reduced further to reduce the torque and to prevent heat generation. When the bearing speed is extremely low, on the other hand, grease may be packed almost full to prevent dust and water entry. Accordingly, it is necessary to know the extent of the housing's free space for the specific bearing to determine the correct filling amount. As a reference, the volume of free space is shown in Table 1 for an open type deep groove ball bearing.

Note that the free space of the open type deep groove ball bearing is the volume obtained by subtracting the volume of the balls and cage from the space formed between inner and outer rings.

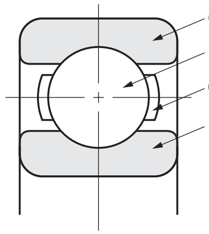


Table 1 Free space of open type deep groove ball bearing

Units: cm^3

Bearing bore No.	Bearing free space			Bearing bore No.	Bearing free space		
	Bearing series				Bearing series		
	60	62	63		60	62	63
00	1.2	1.5	2.9	14	34	61	148
01	1.2	2.1	3.5	15	35	67	180
02	1.6	2.7	4.8	16	47	84	213
03	2.0	3.7	6.4	17	48	104	253
04	4.0	6.0	7.9	18	63	127	297
05	4.6	7.7	12	19	66	155	345
06	6.5	11	19	20	68	184	425
07	9.2	15	25	21	88	216	475
08	11	20	35	22	114	224	555
09	14	23	49	24	122	310	675
10	15	28	64	26	172	355	830
11	22	34	79	28	180	415	1 030
12	23	45	98	30	220	485	1 140
13	24	54	122	32	285	545	1 410

Remarks The table above shows the free space of a bearing using a pressed steel cage. The free space of a bearing using a high-tension brass machined cage is about 50 to 60% of the value in the table.

9.4 Free space of angular contact ball bearings

Angular contact ball bearings are used in various components, such as spindles of machine tools, vertical pump motors, and worm gear reducers.

This kind of bearing is used mostly with grease lubrication. But such grease lubrication may affect the bearing in terms of temperature rise or durability. To allow a bearing to demonstrate its full performance, it is essential to fill the bearing with the proper amount of a suitable grease. A prerequisite for this job is a knowledge of the bearing's free space.

The angular ball bearing is available in various kinds which are independent of the combinations of bearing series, contact angle, and cage type. The free space of the bearing used most frequently is described below. Table 1 shows the free space of a bearing with a pressed cage for general use and Table 2 shows that of a bearing with a high-tension brass machined cage. The contact angle symbols A, B, and C in each table refer to the nominal contact angle of 30°, 40°, and 15° of each bearing.

Table 1 Free space of angular contact ball bearing (1)
(with pressed steel cage)

Units: cm^3

Bearing bore No.	Bearing free space			
	Bearing series — Contact angle symbol			
	72-A	72-B	73-A	73-B
00	1.5	1.4	2.9	2.8
01	2.1	2.0	3.7	3.5
02	2.8	2.7	4.8	4.6
03	3.7	3.6	6.2	5.9
04	6.2	5.9	8.4	8.0
05	7.8	7.4	13	12
06	12	11	20	19
07	16	15	26	24
08	20	19	36	34
09	25	24	48	45
10	28	27	63	60

Table 2 Free space of angular contact ball bearing (2)
(with high-tension brass machined cage)

Units: cm^3

Bearing bore No.	Bearing free space				
	Bearing series — Contact angle symbol				
	70-C	72-A 72-C	72-B	73-A 73-C	73-B
00	0.9	1.0	1.0	2.2	2.1
01	0.9	1.6	1.6	2.5	2.5
02	1.2	1.9	1.9	3.4	3.3
03	1.6	2.7	2.7	4.6	4.4
04	3.0	4.7	4.2	6.1	5.9
05	3.5	6.0	5.3	9.2	9.0
06	4.3	8.5	8.1	14	13
07	6.5	12	11	18	17
08	8.3	14	14	25	24
09	10	18	17	34	33
10	11	20	20	45	44
11	16	26	25	57	55
12	17	33	31	71	69
13	18	38	37	87	83
14	24	43	42	107	103
15	24	47	45	129	123
16	34	58	57	152	146
17	37	71	70	179	172
18	44	88	85	207	201
19	44	105	105	261	244
20	47	127	127	282	278

9.5 Free space of cylindrical roller bearings

Cylindrical roller bearings employ grease lubrication in many cases because it makes maintenance easier and simplifies the peripheral construction of the housing. It is essential to select a grease brand appropriate for the operating conditions while paying due attention to the filling amount and position of the bearing as well as its housing.

The cylindrical roller bearings can be divided into NU, NJ, N, NF, NH, and NUP types of construction according to the collar, collar ring, and position of the inner or outer ring ribs. Even if bearings belong to the same dimension series, they may have different amounts of free space. The free space also differs depending on whether the cage provided is made from pressed steel or from machined high-tension brass. When determining the grease filling amount, please refer to Tables 1 and 2 which show the free space of NU type bearings. (By the way, the cylindrical roller bearing type is used most frequently).

For types other than the NU type, the free space can be determined from the free space ratio with the NU type. Table 3 shows the approximate free space ratio for each type of cylindrical roller bearing. For example, the free space of NJ310 with a pressed steel cage may be calculated approximately at 47 cm^3. This result was calculated by multiplying the free space 52 cm^3 of NU310 in Table 1 by the space ratio 0.90 for the NJ type (Table 3).

Table 1 Free space of cylindrical roller bearing (NU type) (1) (with pressed cage)

Units: cm^3

Bearing bore No.	Bearing free space			
	Bearing series			
	NU2	NU3	NU22	NU23
05	6.6	11	7.8	16
06	9.6	17	12	24
07	14	22	18	35
08	18	31	22	44
09	20	42	23	62
10	23	52	26	80
11	30	68	35	102
12	37	85	45	130
13	44	107	57	156
14	51	124	62	179
15	58	155	70	226
16	71	177	85	260
17	85	210	104	300
18	103	244	134	365
19	132	283	164	415
20	151	335	200	540

Table 2 Free space of cylindrical roller bearing (NU type) (2) (with high-tension brass machined cage)

Units: cm^3

Bearing bore No.	Bearing free space			
	Bearing series			
	NU2	NU3	NU22	NU23
05	5.0	7.6	5.7	10
06	7.4	12	7.9	16
07	9.6	16	12	27
08	12	21	15	32
09	15	29	16	45
10	18	38	17	58
11	22	52	24	77
12	26	62	31	88
13	31	74	43	104
14	37	92	44	129
15	42	102	50	149
16	51	122	60	181
17	64	164	74	200
18	79	193	96	279
19	94	218	116	280
20	115	221	137	355

Table 3 Free space ratio of each type of cylindrical roller bearing

NU Type	NJ Type	N Type	NF Type
1	0.90	1.05	0.95

9.6 Free space of tapered roller bearings

The tapered roller bearing can carry radial load and uni-direction axial loads. It offers high capacity. This type of bearing is used widely in machine systems with relatively severe loading conditions in various combinations by opposing or combining single-row bearings.

With a view towards easier maintenance and inspection, this kind of bearing is lubricated with grease in most cases. It is important to select a grease appropriate to the operating conditions and to use the proper amount of grease for the housing internal space. As a reference, the free space of a tapered roller bearing is shown in Table 1.

The free space of a tapered roller bearing is the space (shadowed portion) of the bearing outer volume less the inner and outer rings and cage, as shown in Fig. 1. The bearing is filled so that grease reaches the inner ring rib surface and pocket surface in sufficient amount. Due attention must also be paid to the grease filling amount and state, especially if grease leakage occurs or maintenance of low running torque is important.

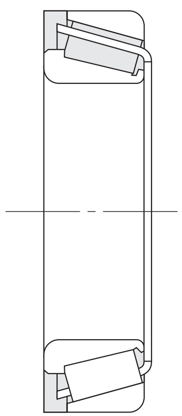


Fig. 1 Free space of tapered roller bearing

Table 1 Free space of tapered roller bearing

Units: cm^3

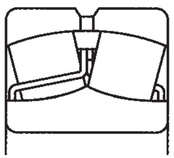
Bearing bore No.	Bearing free space									
	Bearing series									
	HR329-J	HR320-XJ	HR330-J	HR331-J	HR302-J	HR322-J	HR332-J	HR303-J	HR303-DJ	HR323-J
02	—	—	—	—	—	—	—	4.5	—	—
03	—	—	—	—	3.3	4.3	—	5.7	—	—
04	—	3.5	—	—	5.3	6.6	—	7.2	—	9.2
/22	—	3.6	—	—	—	7.3	—	9.1	—	—
05	—	3.7	4.3	—	6.3	7.4	7.5	11	13	15
/28	—	5.3	—	—	8.8	9.8	10	16	—	—
06	—	6.2	6.7	—	9.2	11	12	18	21	23
/32	—	6.6	—	—	11	13	14	20	—	—
07	4.0	7.5	8.9	—	13	17	18	23	26	35
08	5.8	9.1	11	—	18	23	25	31	35	45
09	—	11	—	18	22	24	26	41	48	58
10	—	12	15	20	23	26	29	55	59	77
11	8.8	19	21	29	30	36	40	72	78	99
12	9.0	20	23	—	39	47	53	88	95	130
13	—	21	25	—	45	62	65	110	120	150
14	17	29	33	—	53	67	69	130	150	190
15	—	30	34	—	58	73	74	160	180	230
16	—	40	—	—	75	91	100	200	200	270
17	—	43	49	76	92	120	130	230	250	320
18	28	58	—	110	110	150	—	260	310	370
19	29	60	—	—	140	170	—	310	350	430
20	37	64	—	150	160	210	240	380	460	580

9.7 Free space of spherical roller bearings

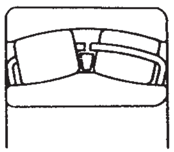
The spherical roller bearing has self-aligning ability and capacity to carry substantially large radial and bi-axial loads. For these reasons, this bearing is used widely in many applications. Application problems include a long span, which causes substantial deflection of the shaft, as well as installation errors and axial misalignment. These bearings may be exposed to a large radial or shock loads. By the way, this bearing is used in plumber blocks.

Grease lubrication is common for spherical roller bearings because it simplifies the seal construction around the housing and makes maintenance and inspection easier. In this case, it is important to select a grease appropriate to the operating conditions and to fill the bearing with the proper amount of grease considering the housing internal space.

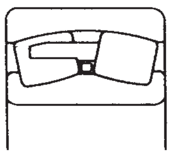
As a reference, the bearing free space for conventional types plus four other types (EA, C, CD, and CA) is shown in Table 1. Under general operating conditions, it is appropriate to pack a large quantity of grease into the bearing internal space and to pack grease into the housing internal space other than the bearing itself, to the extent of 1/3 to 2/3 that of the free space.



EA type



C, CD type



CA type

Table 1 Free space of spherical roller bearing (EA, C, CD, and CA)

Units: cm^3

Bearing bore No.	Bearing free space				
	Bearing series				
	230	231	222	232	223
11	—	—	29	—	78
12	—	—	42	—	96
13	—	—	48	—	113
14	—	—	52	—	139
15	—	—	57	—	170
16	—	—	71	—	206
17	—	—	91	—	234
18	—	—	110	130	283
19	—	—	135	—	327
20	—	—	169	203	410
22	100	150	242	294	560
24	109	228	297	340	700
26	161	240	365	405	955
28	170	292	400	530	1 230
30	209	465	505	680	1 430
32	254	575	680	850	1 710
34	355	610	785	1 090	2 070
36	465	785	810	1 120	2 460
38	565	970	1 160	1 340	2 830
40	715	1 160	1 400	1 640	2 900
44	940	1 500	1 880	2 270	3 750
48	1 030	1 900	2 550	3 550	4 700
52	1 530	2 940	3 300	4 750	5 900
56	1 820	3 150	3 400	4 950	7 250
60	2 200	4 050	4 300	6 200	8 750

Remarks 22211 to 22226, 22311 to 22324 are EA type bearings.
23122 to 23148, 23218 to 23244 are C type bearings.
23022 to 23036, 22228 to 22236 are CD type bearings.
23038 to 23060, 23152 to 23160, 22238 to 22260,
23248 to 23260, and 22326 to 22360 are CA type bearing.

9.8 NSK's dedicated greases

9.8.1 NS7 and NSC greases for induction motor bearings

NS7 and NSC greases have been developed by NSK mainly for lubrication of bearings for induction motors. These greases consist of ingredients such as synthetic oil and lithium soap. Synthetic oil is superior in oxidation, thermal stability, and low-temperature fluidity while lithium soap is superior in water resistance, and shearing stability.

NS7 and NSC greases are applicable over a wide range of temperature from –40°C to +140°C. The viscosity of the base oil is lowest in NS7 and highest in NSC. Namely, NS7 grease is best suited when the low-temperature performance is important and NSC grease for high-temperature performance.

Features

(1) Superior in high-temperature durability, with long grease life
(2) Superior in low-temperature performance, with less abnormal sound and vibration in a bearing at cold start
(3) Superior in high-speed running performance, with little grease leakage
(4) Reduction of the friction torque of a bearing at low and room temperature
(5) Fewer particle inclusions and satisfactory acoustic performance. Moreover, NSC grease can maintain superior acoustic performance over a long period (long acoustic life).
(6) Superior in water resistance
(7) Superior in anti-rusting performance against salt water

Table 1 Characteristics of NS7 and NSC greases

Characteristics	NS7	NSC	Test method
Appearance	Light brown	Light brown	—
Thickener	Li soap	Li soap	—
Base oil	Polyolester diester	Polyolester diphenylether	—
Kinematic viscosity of base oil, mm^2/s 40°C 100°C	 26.0 5.0	 53.0 8.3	JIS K 2283
Worked penetration, 25°C, 60W	250	235	JIS K 2220: 2003 (Clause 7)
Dropping point, °C	192	192	JIS K 2220: 2003 (Clause 8)
Corrosiveness, (Copper strip) 100°C, 24 h	Good	Good	JIS K 2220: 2003 (Clause 9)
Evaporation, % 99°C, 22 h	0.30	0.25	JIS K 2220: 2003 (Clause 10)
Oil separation, % 100°C, 24 h	1.2	1.1	JIS K 2220: 2003 (Clause 11)
Oxidative stability, kPa 99°C, 100 h	25	20	JIS K 2220: 2003 (Clause 12)
Worked stability, 25°C, 10^5W	306	332	JIS K 2220: 2003 (Clause 15)
Water wash-out, % 38°C, 1 h	1.4	1.4	JIS K 2220: 2003 (Clause 16)
Low temperature torque, mN·m −30°C {−40°C} Starting Running	 {115} {25}	 421 84	JIS K 2220: 2003 (Clause 18)
Rust protection test, 0.1%, NaCl 25°C, 48 h, 100% RH	1,1,1	1,1,1	ASTM D 1743

Remarks The value of parentheses is low temperature torque value at −40℃.

Application

* Motor for home electric products (video cassette recorder, air conditioner fan motor, electric oven hood fan motor)
* Motor for office automation equipment (fixed disk drive spindle, floppy disk drive spindle, stepping motor, IC cooling fan motor)
* Industrial motor (blower motor, pump motor, large and medium motor)
* Automotive equipment (starter, distributor, wind shield wiper motor)

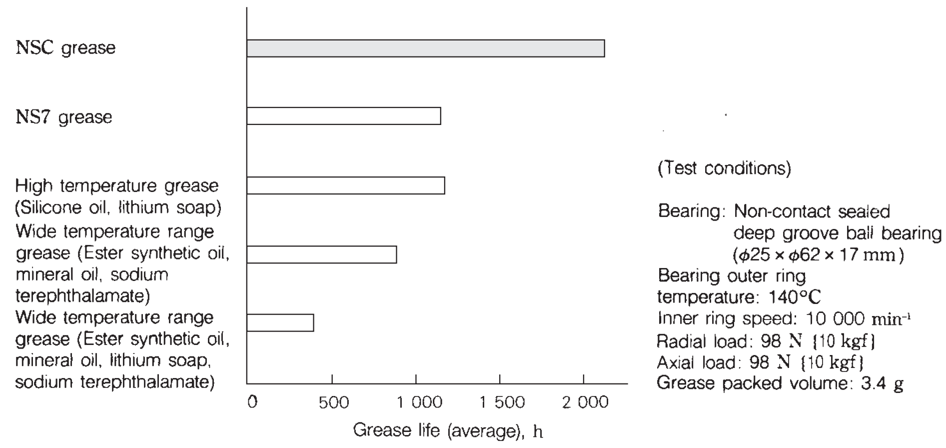


Fig. 1 Grease life

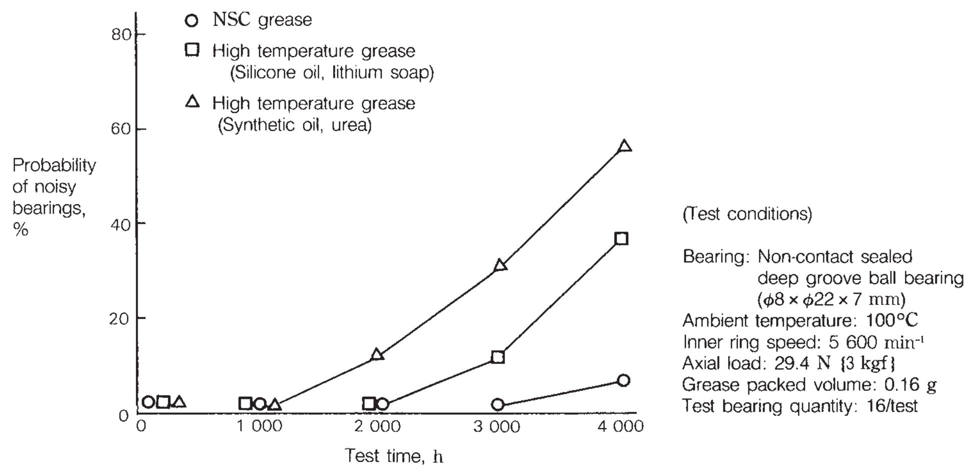


Fig. 2 Acoustic life

9.8.2 ENS and ENR greases for high-temperature/speed ball bearings

The performances demanded of bearings for electric parts and auxiliary engine equipment installed around the engine are growing more and more severe in order to achieve functional improvement, fuel saving, and life extension of automobiles. These kinds of bearings are mostly operated at high speed and in a high-temperature environment, and they may be subjected to salt or turbid (muddy) water depending on the application and installation position. Certain bearings are also exposed to vibration and high load. ENS and ENR are the greases best suited for bearings used in such stringent conditions.

Features

The ENS and ENR greases use polyester and a urea compound. Polyolester is superior in oxidation and thermal stability and low-temperature fluidity as a base oil while the urea compound is superior in heat and water resistance, shearing stability as a thickener. High-grade additives are also properly combined. Features of this grease are as follows:

(1) Superior in high-temperature durability, with long grease life at a temperature as high as 160°C
(2) Superior shearing stability, with less grease leakage during high-speed rotation and outer ring rotation
(3) Low base oil viscosity and drop point, showing the low torque performance. Less abnormal noise in bearing during a cold start
(4) Superior water resistance of the thickener, which makes softening and outflow difficult even when water may enter the bearing.
(5) Mixing of an adequate rust-preventive agent offers satisfactory rust-prevention performance without any degradation of the grease life. In particular, the ENR grease has powerful rust-preventive capacity, preventing rusting even when water enters a bearing.
(6) However, attention is necessary because it swells the acrylic based materials and deteriorates the fluorine based materials.

Table 1 Characteristics of ENS and ENR grease

Characteristics	ENS	ENR	Test method
Appearance	Milky white	Milky white	—
Thickener	Diurea	Diurea	—
Base oil	Polyolester	Polyolester	—
Kinematic viscosity of base oil, mm^2/s 40°C 100°C	 30.5 5.4	 30.5 5.4	JIS K 2283
Worked penetration, 25°C, 60W	264	237	JIS K 2220: 2003 (Clause 7)
Dropping point, °C	≧260	≧260	JIS K 2220: 2003 (Clause 8)
Corrosiveness, (Copper strip) 100°C, 24 h	Good	Good	JIS K 2220: 2003 (Clause 9)
Evaporation, % 99°C, 22 h	0.39	0.48	JIS K 2220: 2003 (Clause 10)
Oil separation, % 100°C, 24 h	1.1	1.4	JIS K 2220: 2003 (Clause 11)
Oxidative stability, kPa 99°C, 100 h	25	30	JIS K 2220: 2003 (Clause 12)
Worked stability, 25°C, 10^5W	310	288	JIS K 2220: 2003 (Clause 15)
Water wash-out, % 79°C, 1 h	2.0	1.0	JIS K 2220: 2003 (Clause 16)
Low temperature torque, −30°C, mN·m Starting Running	 150 60	 230 48	JIS K 2220: 2003 (Clause 18)
Rust protection test, 0.1%, NaCl 25°C, 48 h, 100% RH	1,1,1	1,1,1	ASTM D 1743

Applications
* Electric equipment (electromagnetic clutch, alternator, starter, idler pulley)
* Engine auxiliary equipment (timing belt tensioner, clutch release)
* Office automation equipment (copying machine heat roller)
* Motors (inverter motor, servo motor)

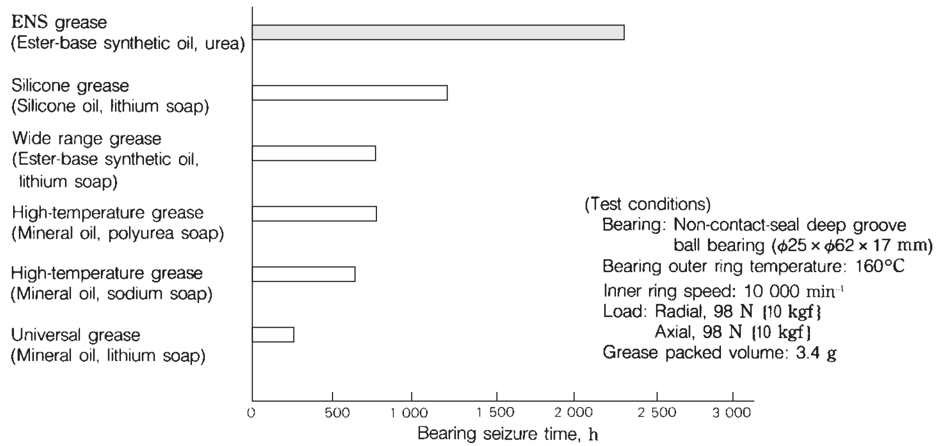


Fig. 1 Grease life

Table 2 Bearing rust-prevention test

Base oil / thickener — Test conditions	ENS Table 1	ENR Table 1	Wide range grease: Ester synthetic oil	Wide range grease: Ester synthetic oil and mineral oil	High-temp grease: Mineral oil	High-temp grease: Mineral oil
	Table 1	Table 1	Li soap	Na terephtalamate	Li complex soap	Polyurea
0.1% salt 25°C, 48 h	1,1,1	1,1,1	1,1,1	1,1,1	3,3,3	1,1,1
0.5% salt 52°C, 24 h	2,2,3	1,1,1	1,2,2	1,1,1	—	1,2,2
1.0% salt 52°C, 24 h	—	1,1,1	—	1,2,2	—	—

Test method As per ASTM D 1743
Bearing: Tapered roller bearing 09074R/09194R (φ19.05× φ49.23×23.02 mm)
Relative humidioy: 100 %
Evaluation: 1; No rusting, 2; Minor rusting in three or less points, 3; Worse than Rank 2

9.8.3 EA3 and EA6 greases for commutator motor shafts

An electric fan is used to cool an automotive radiator and air-conditioner compressor. Since an FF model cannot use a cooling fan directly coupled to the engine, an electric fan is used. For this reason, the production of electric fans is growing.

The electric fan is installed near the engine, and the motor bearing temperature reaches around 130 to 160°C and will rise further in the future.

Conventional greases have therefore developed seizure within a shorter period though the speed was lower at 2 000 and 3 000 min^{-1} than that of other electric equipment. One probable reason is entry of carbon brush worn powder into a bearing. Greases best suited for an electric fan motor used in such severe environment and EA3 and EA6.

The cleaner motor tends to have a higher speed to enhance the suction efficiency, and has come to be used at speeds as high as 40 000 to 50 000 min^{-1} these days. Much lower torque, lower noise, and longer life are expected for grease along with speed increase. The grease best suited for such cleaner motor bearing is EA3.

Features and Applications

The EA3 grease uses poly-α-olefine superior in oxidation and thermal stability and low-temperature fluidity as a base oil and urea compound superior in heat and water resistance as a thickener. Moreover, a high-grade additive is added. EA6 is a grease with an EA3 base oil viscosity enhancement to extend the grease life at high temperature.

(1) Superior oxidation stability, wear resistance, and grease sealing performance, preventing entry of carbon brush abrasion powder into a bearing. The grease life in the electric fan motor bearing is long. EA3 is suitable when low-torque performance is important and EA6 is suitable when the bearing temperature exceeds 150°C.

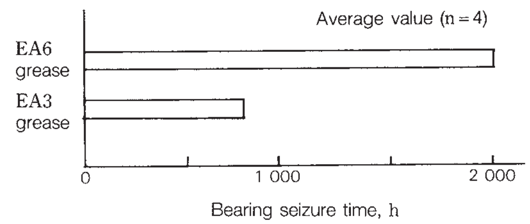
(2) EA3 grease is superior in low-torque and low-noise performances, with superior fluidity, showing superb lubrication performance during rotation as fast as 40 000 to 50 000 min^{-1}. Also, the grease life of a cleaner motor bearing is longer.

(3) Superior rust-preventive performance and less adverse effect on rubber and plastics.

(4) However, attention is necessary because it deteriorates the fluorine based materials.

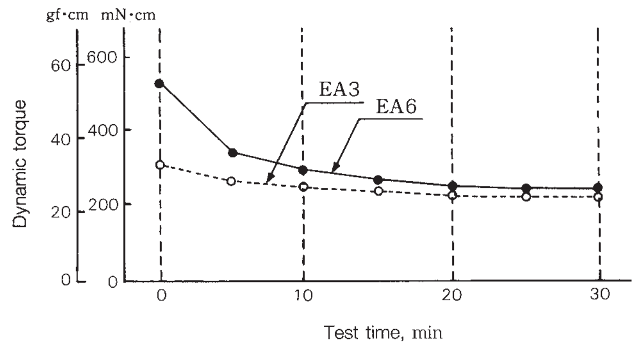
Table 1 Characteristics of EA3 and EA6 grease

Characteristics	EA3	EA6	Test method
Appearance	Light yellow	Light yellow	—
Thickener	Diurea	Diurea	—
Base oil	Poly-α-olefine oil	Poly-α-olefine oil	—
Kinematic viscosity of base oil, mm^2/s 40°C 100°C	 47.8 8.0	 112 15	JIS K 2283
Worked penetration, 25°C, 60W	230	220	JIS K 2220: 2003 (Clause 7)
Dropping point, °C	≧260	≧260	JIS K 2220: 2003 (Clause 8)
Corrosiveness, (Copper strip) 100°C, 24 h	Good	Good	JIS K 2220: 2003 (Clause 9)
Evaporation, % 99°C, 22 h	0.40	0.40	JIS K 2220: 2003 (Clause 10)
Oil separation, % 100°C, 24 h	0.5	0.5	JIS K 2220: 2003 (Clause 11)
Oxidative stability, kPa 99°C, 100 h	25	25	JIS K 2220: 2003 (Clause 12)
Worked stability, 25°C, 10^5W	364	320	JIS K 2220: 2003 (Clause 15)
Water wash-out, % 79°C, 1 h	2.0	1.0	JIS K 2220: 2003 (Clause 16)
Low temperature torque, −30°C, mN·m Starting Running	 150 24	 180 48	JIS K 2220: 2003 (Clause 18)
Rust protection test, 0.1%, NaCl 25°C, 48 h, 100% RH	1,1,1	1,1,1	ASTM D 1743



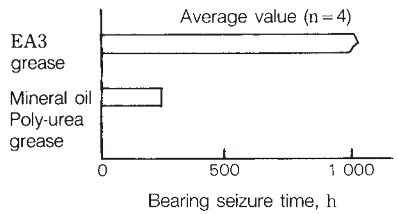
(Test conditions)
Bearing: Non-contact sealed deep groove ball bearing (ϕ8 × ϕ16 × 4 mm)
Bearing outer ring temperature: 150 to 160°C
Inner ring speed: 1 700 to 2 000 min^{-1}
Applied voltage: DC 13.5 V
Grease packed volume: 0.06 g

Fig. 1 Durability test with electric fan motors



(Test conditions)
Bearing: Non-contact sealed deep groove ball bearing (ϕ8 × ϕ22 × 7 mm)
Ambient temperature: 30°C
Inner ring speed: 2 500 min^{-1}
Axial load: 29.4 N {3 kgf}
Grease packed volume: 0.16 g

Fig. 2 Running torque



(Test conditions)
Bearing: Non-contact sealed deep groove ball bearing (ϕ8 × ϕ22 × 7 mm)
Bearing outer ring temperature: 90°C
Inner ring speed: 50 000 min^{-1}
Axial load: 58.8 N {6 kgf}
Grease packed volume: 0.16 g

Fig. 3 Grease life

9.8.4 WPH grease for water pump bearings

An automotive water pump is a pump to circulate cooling water through the engine. A typical bearing for a water pump is a bearing unit which measures 16 mm in shaft diameter and 30 mm in outer shell diameter and uses either balls with balls or balls with rollers. Though the water pump bearing unit is equipped with a high-performance seal, cooling water may enter the unit. In fact, most water pump bearing failures can be attributed to entry of coolant into the bearing.

Recently, the bearing speed tends to rise in line with performance and efficiency enhancement of engines. Moreover, the bearing temperature rises further along with temperature rise of the cooling water and engine. The bearing load is also growing these days as the number of models employing poly V-belts is growing rapidly.

The grease guaranteeing high reliability and best applicability for water pump bearings and bearing units used in such severe environment is WPH.

Features

The WPH grease uses poly-α-olefine, which is superior in oxidation and thermal stability, as a base oil and a urea compound, which is superior in heat and water resistance, as a thickener. A high-grade additive is also used. Features are as described below:

(1) This grease does not readily soften and outflow even if coolant enters the bearing. Also, this grease can maintain satisfactory lubrication performance over an extended period of time. As a result, this grease can prevent flaking in a bearing.

(2) Superior in high-temperature durability, preventing deterioration and seizure even when the bearing temperature rises.

(3) Superior rust-preventive performance prevents rusting even if water or coolant enters the bearing.

Table 1 Characteristics of WPH grease

Characteristics	WPH	Test method
Appearance	Butter-like milky yellow	—
Thickener	Diurea	—
Base oil	Poly-α-olefine oil	—
Kinematic viscosity of base oil, mm^2/s 40°C 100°C	 95.8 14.4	JIS K 2283
Worked penetration, 25°C, 60W	240	JIS K 2220: 2003 (Clause 7)
Dropping point,°C	259	JIS K 2220: 2003 (Clause 8)
Corrosiveness, (Copper strip) 100°C, 24 h	Good	JIS K 2220: 2003 (Clause 9)
Evaporation, % 99°C, 22 h	0.20	JIS K 2220: 2003 (Clause 10)
Oil separation, % 100°C, 24 h	0.2	JIS K 2220: 2003 (Clause 11)
Oxidative stability, kPa 99°C, 100 h	20	JIS K 2220: 2003 (Clause 12)
Worked stability, 25°C, 10^5W	306	JIS K 2220: 2003 (Clause 15)
Water wash-out, % 79°C, 1 h	0	JIS K 2220: 2003 (Clause 16)
Low temperature torque, −30°C, mN·m Starting Running	 240 45	JIS K 2220: 2003 (Clause 18)
Rust protection test, 0.1%, NaCl 25°C, 48 h, 100% RH	1,1,1	ASTM D 1743

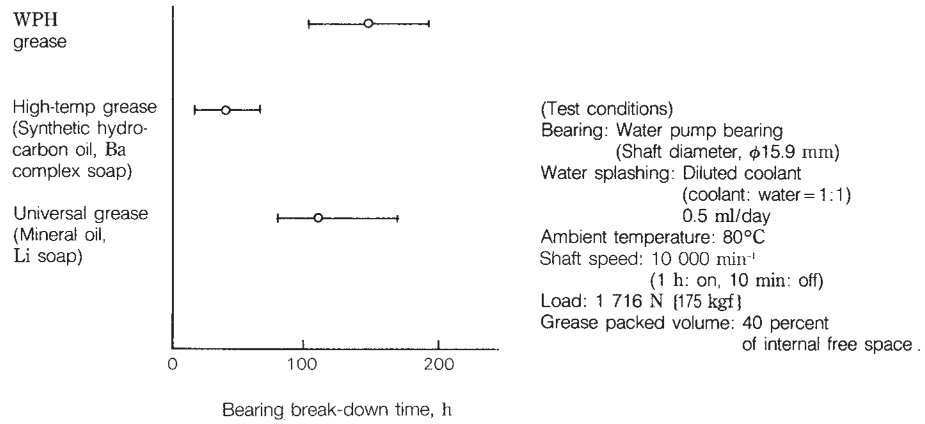


Fig. 1 Water resistant test of grease for water pump bearings

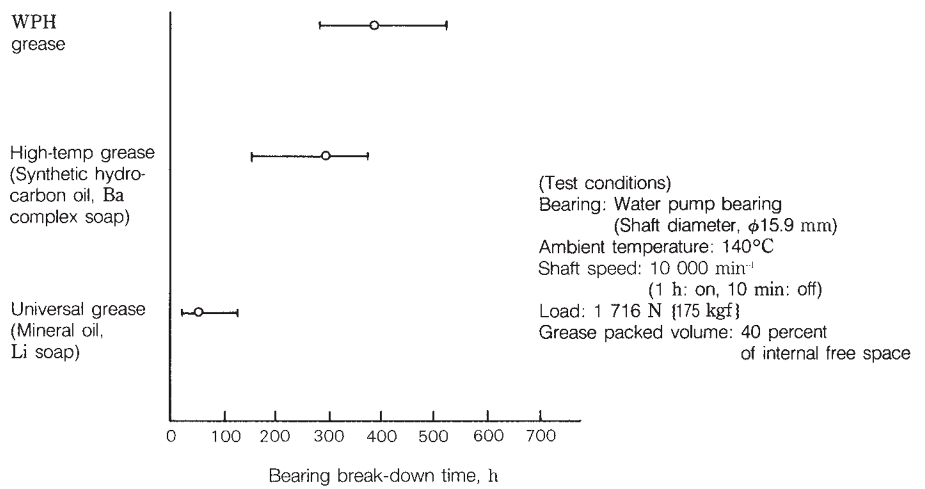


Fig. 2 Life test of water pump bearings

9.8.5 MA7 and MA8 greases for automotive electric accessory bearings

Severe performance criteria for automotive electric accessory or engine auxiliary equipment bearings are increasingly requested to meet the high-capability, fuel saving, and long-life requirements of cars. These bearings are located in narrow engine compartments, which generally provide a hot environment. Furthermore, the adoption of poly-V-belts, which have excellent endurance, results in constantly high loads on the bearings. Also, depending on the conditions, salty or muddy water may enter the bearings. MA7 and MA8 greases are the optimum greases for use in bearings which run under such severe operating conditions.

Table 1 Characteristics of MA7 and MA8 grease

Characteristics	MA7	MA8	Test method
Appearance	Light brown	Milky white	—
Thickener	Diurea	Diurea	—
Base oil	Ether-base synthetic oil	Ether-base synthetic hydrocarbon oil	—
Kinematic viscosity of base oil, mm²/s			
40°C	103	76	JIS K 2283
100°C	13	11	
Worked penetration, 25°C, 60W	290	277	JIS K 2220: 2003 (Clause 7)
Dropping point, °C	248	≧260	JIS K 2220: 2003 (Clause 8)
Corrosiveness, (Copper strip) 100°C, 24 h	Good	Good	JIS K 2220: 2003 (Clause 9)
Evaporation, % 99°C, 22 h	0.18	0.39	JIS K 2220: 2003 (Clause 10)
Oil separation, % 100°C, 24 h	0.6	0.6	JIS K 2220: 2003 (Clause 11)
Oxidative stability, kPa 99°C, 100 h	20	125	JIS K 2220: 2003 (Clause 12)
Worked stability, 25°C, 10⁵W	335	330	JIS K 2220: 2003 (Clause 15)
Water wash-out, % 79°C, 1 h	1.0	1.0	JIS K 2220: 2003 (Clause 16)
Low temperature torque, −30°C, mN·m			
Starting	304	280	JIS K 2220: 2003 (Clause 18)
Running	206	57	
Rust protection test, 0.1%, NaCl 25°C, 48 h, 100% RH	1,1,1	1,1,1	ASTM D 1743

MA7 grease has excellent flaking and seizure resistance and rust preventiveness, since it consists of ether oil as a base oil, which has strong oxidative and heat stability, urea compound as a thickener, which also has excellent heat and water resistance and shearing stability, and high-quality additives.

MA8 grease consists of ether oil and synthetic hydrocarbon oil, which have excellent oxidative and heat stability, as the base oil, urea compound as a thickener, which has excellent heat and water resistance and shearing stability, and high-quality additives. It has excellent flaking and seizure resistance, rust preventiveness, and quiet running at low temperature. However, attention is necessary because it deteriorates the fluorine based materials.

Applications

MA7: Alternators

MA8: Magnetic clutches, idler pulleys

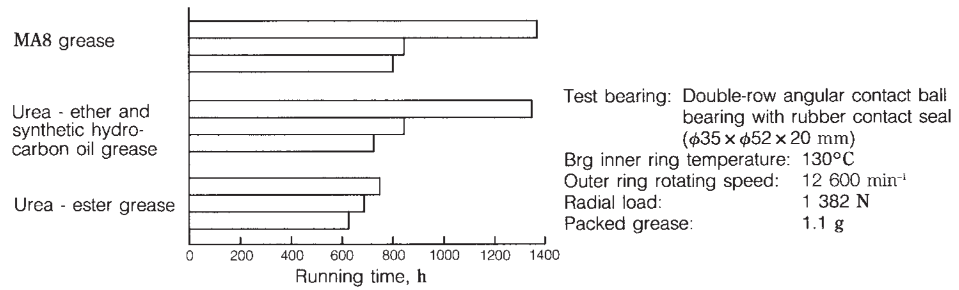


Fig. 1 Grease life

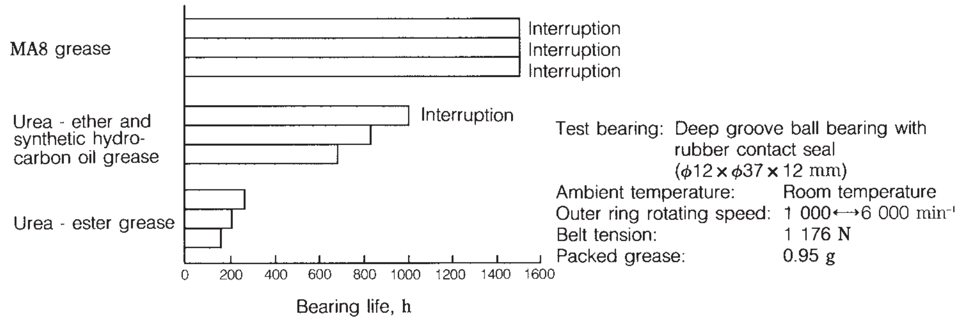


Fig. 2 Bearing life

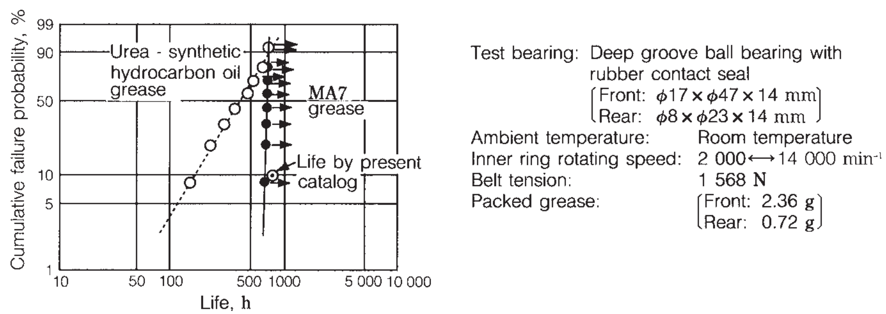


Fig. 3 Alternator bearing life using actual engine