13. NSK special bearings

13.1 Ultra-precision ball bearings for gyroscopes

(1) Gyroscope bearings

Gyroscopes are used to detect and determine traveling position and angular velocity in airplanes and ships. Gyros are structurally divided into two groups depending on the number of directions and speeds of movement to be detected: those with one degree of freedom and those with two degrees of freedom. (See Fig. 1)
The performance of a gyro depends on the characteristics of the bearing. Thus, a gyro bearing is required to demonstrate top grade performance among the ultra-precision miniature bearings. Gyros have two sets of bearings. One set supports the rotor shaft running at high speed and the other set supports the frame (gimbal). Both must have stable, low frictional torque. Principal types and application environments of rolling bearings for gyros are shown in Table 1.

The inch series of ultra-precision bearings are almost exclusively used for rotors and gimbals. Boundary dimensions and typical NSK bearing numbers are shown in Table 2.

Special-shaped bearings dedicated to gyro applications are also used in large quantity.

Table 1 Type and running conditions of gyro bearings

Application	Principal bearing type	Typical running conditions
Rotor	Angular contact ball bearing End-cap ball bearing	12 000, 24 000 min^{-1} or 36 000 min^{-1}, 60 to 80°C helium gas
Gimbal	Deep groove ball bearing Other special-shaped bearings	Oscillation within ±2°, Normal temperatures to 80°C, Silicon oil or air

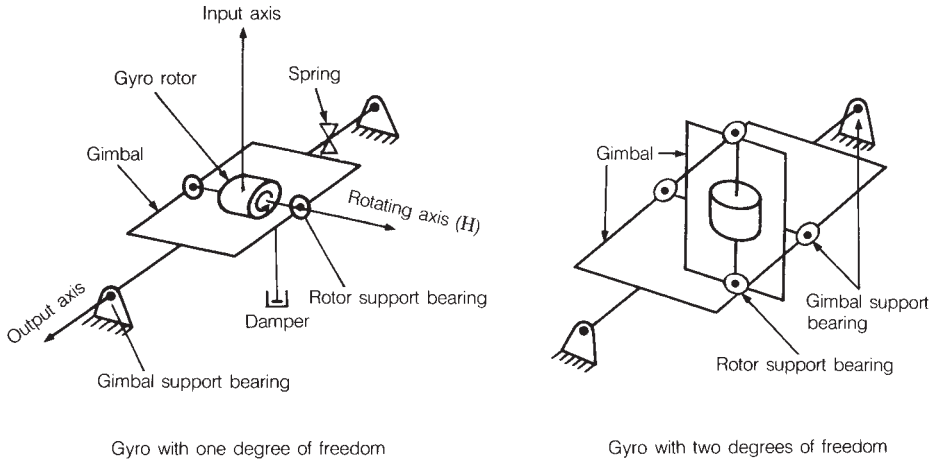
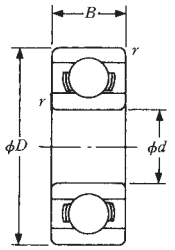
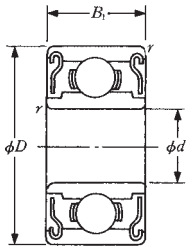


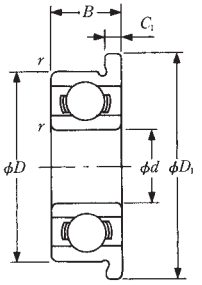
Fig. 1 Gyro type



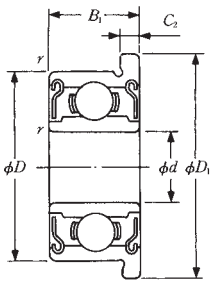
Open type



Shielded on both sides type



Open type with flange



Shielded on both sides type with flange

Table 2 Boundary dimensions and bearing number of gyroscope bearings

Boundary dimensions (mm)					Bearing numbers	
d	D	B	B_1	r (min.)	Open	Both-side shielded
1.016	3.175	1.191	—	0.1	R 09	—
1.191	3.967	1.588	2.380	0.1	R 0	R 0 ZZ
1.397	4.762	1.984	2.779	0.1	*R 1	R 1 ZZ
1.984	6.350	2.380	3.571	0.1	*R 1-4	R 1-4 ZZ
2.380	4.762	1.588	—	0.1	*R 133	—
	4.762	—	2.380	0.1	—	R 133 ZZS
	7.938	2.779	3.571	0.15	*R 1-5	R 1-5 ZZ
3.175	6.350	2.380	2.779	0.1	*R 144	R 144 ZZ
	7.938	2.779	3.571	0.1	R 2-5	R 2-5 ZZ
	9.525	2.779	3.571	0.15	*R 2-6	R 2-6 ZZS
	9.525	3.967	3.967	0.3	*R 2	R 2 ZZ
	12.700	4.366	4.366	0.3	R 2 A	R 2 AZZ
3.967	7.938	2.779	3.175	0.1	R 155	R 155 ZZS
4.762	7.938	2.779	3.175	0.1	R 156	R 156 ZZS
	9.525	3.175	3.175	0.1	R 166	R 166 ZZ
	12.700	3.967	4.978	0.3	*R 3	R 3 ZZ
6.350	9.525	3.175	3.175	0.1	R 168 B	R 168 BZZ
	12.700	3.175	4.762	0.15	R 188	R 188 ZZ
	15.875	4.978	4.978	0.3	*R 4 B	R 4 BZZ
	19.050	5.558	7.142	0.4	*R 4 AA	R 4 AAZZ
7.938	12.700	3.967	3.967	0.15	R 1810	R 1810 ZZ
9.525	22.225	5.558	7.142	0.4	R 6	R 6 ZZ

Boundary dimensions (mm)			Bearing numbers	
D_1	C_1	C_2	Open, with flange	Both-side shielded, with flange
—	—	—	—	—
5.156	0.330	0.790	FR 0	FR 0 ZZ
5.944	0.580	0.790	FR 1	FR 1 ZZ
7.518	0.580	0.790	FR 1-4	FR 1-4 ZZ
5.944	0.460	—	FR 133	—
5.944	—	0.790	—	FR 133 ZZS
9.119	0.580	0.790	FR 1-5	FR 1-5 ZZ
7.518	0.580	0.790	FR 144	FR 144 ZZ
9.119	0.580	0.790	FR 2-5	FR 2-5 ZZ
10.719	0.580	0.790	FR 2-6	FR 2-6 ZZS
11.176	0.760	0.760	FR 2	FR 2 ZZ
—	—	—	—	—
9.119	0.580	0.910	FR 155	FR 155 ZZS
9.119	0.580	0.910	FR 156	FR 156 ZZS
10.719	0.580	0.790	FR 166	FR 166 ZZ
14.351	1.070	1.070	FR 3	FR 3 ZZ
10.719	0.580	0.910	FR 168 B	FR 168 BZZ
13.894	0.580	1.140	FR 188	FR 188 ZZ
17.526	1.070	1.070	FR 4 B	FR 4 BZZ
—	—	—	—	—
13.894	0.790	0.790	FR 1810	FR 1810 ZZ
24.613	1.570	1.570	FR 6	FR 6 ZZ

* Angular contact type bearing is also available for rotor.

(2) Characteristics of gyroscope bearings

(2.1) Rotor bearing

The rotor bearing is required to offer extremely-low, torque at high speed, and free from variation and long term stability. To meet these demands, the bearing uses an oil-immersed cage in most cases. A lubrication method of injecting the lubricating oil dissolved with solvent into a bearing is also available, but this method requires adequate concentration adjustment because the frictional torque is affected by the oil amount (Fig. 2). In such an event, the oil amount is adjusted through centrifugal separation to obtain variation-free running torque. A special bearing type, in which an end cap is integrated with the outer ring, may also be used (Fig. 3).

(2.2) Gimbal bearing

Requirements on the gimbal bearing as a gyro output axis include low frictional torque and vibration resistance. Table 3 shows the maximum starting frictional torque for typical bearings. Much smaller starting torque can be obtained through precision machining of the raceway groove and special design of the cage.

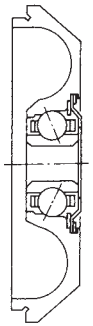


Fig. 3 Typical end-cap ball bearing

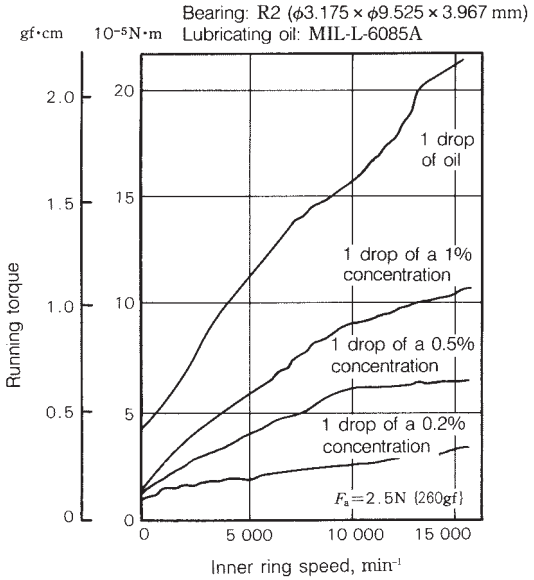


Fig. 2 Oil amount and running torque

Table 3 Maximum starting torque

Bearing No.	Measuring load mN {gf}	Radial internal clearance (μm) MC2 3 to 8	MC3 5 to 10	MC4 8 to 13	MC5 13 to 20	MC6 20 to 28
		Maximum starting torque (μN·m) {mgf·mm}				
R1	735 {75}	7.95 {810}	7.35 {750}	6.75 {690}	6.10 {620}	5.20 {530}
R1-5	735 {75}	13.2 {1 350}	12.3 {1 250}	11.8 {1 200}	10.7 {1 090}	9.70 {990}
R144	735 {75}	8.92 {910}	8.35 {840}	7.65 {780}	6.85 {700}	6.08 {620}
R2	735 {75}	14.7 {1 500}	13.7 {1 400}	12.7 {1 300}	11.8 {1 200}	11.4 {1 160}
R3	3 900 {400}	63.5 {6 500}	54.0 {5 500}	54.0 {5 500}	49.0 {5 000}	44.0 {4 500}
R4B	3 900 {400}	68.5 {7 000}	59.0 {6 000}	59.0 {6 000}	54.0 {5 500}	49.0 {5 000}

Table 4 Specifications of bearings for rotors and gimbals

Item	Rotor bearing	Gimbal bearing
Bearing type	Angular contact ball	Deep groove ball or angular contact ball
Bearing accuracy	CLASS 7P or above	CLASS 5P or CLASS 7P
Lubrication method	Oil-immersed cage and self-lubrication (dual use grease available)	Oil lubrication, filled with an adequate quantity
Cage	Laminated phenol	Steel sheet (low torque design)
Ball accuracy	Around Grade 3	Around Grade 5 or above
Bearing contact angle (°)	20 to 28	—

13.2 Bearings for vacuum use —ball bearings for X-ray tube—

A ball bearing for a rotary anode of an X-ray tube is used under severe conditions such as high vacuum, high temperature, and high speed. An X-ray tube is constructed as shown in Fig. 1, with the internal pressure set below 0.13 mPa (10^{-6} Torr). Thermoelectrons flow from a cathode (filament) toward an anode (target) to generate X-rays at the anode.

A rotor is a part of a motor and driven electromagnetically from the outside. Common speeds range from 3 000 to 10 000 min^{-1}. The anode rotation involves inner ring or outer ring rotation (Fig. 2). Generally, inner ring rotation enables high rigidity and low bearing temperature, but the construction becomes complicated.

Because of heat generation of the anode, the bearing reaches the maximum temperature of 400 to 500°C on the anode side and the bearing on the opposite side reaches a temperature of 200 to 300°C. The bearing is therefore made from high-speed tool steel which is superior in heat resistance.

Most X-ray tubes are used for medical purposes and thus silent rotation is essential. However, difficulty of enhancing the rigidity because of its construction and change in the bearing internal clearance under heavy temperature fluctuation are hindrances to vibration proof.

In this respect, minute care must be taken during the design of a bearing and its neighboring parts. The common range of bearing bores is 6 to 10 mm. Fig. 3 shows examples of typical constructions.

(a) is a type with pressed cage.
(b) has the entire outer ring raceway shaped as a cylindrical surface.
(c) has one side of the outer ring raceway shaped as a cylindrical surface to relieve deviation of inner and outer rings (such as caused by thermal expansion) in the axial direction.

Note that (b) and (c) normally apply to full complement type ball bearings.

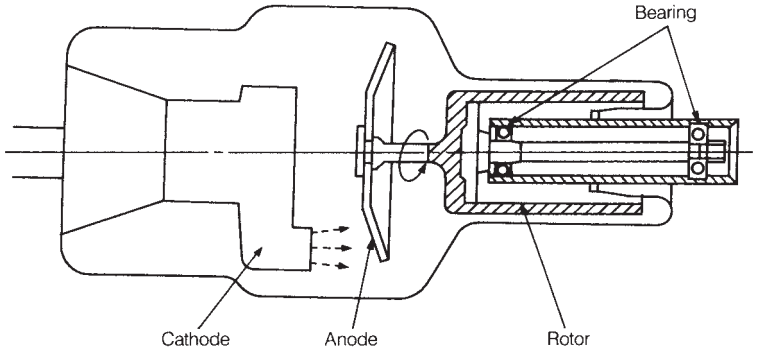


Fig. 1 Typical construction of X-ray tube

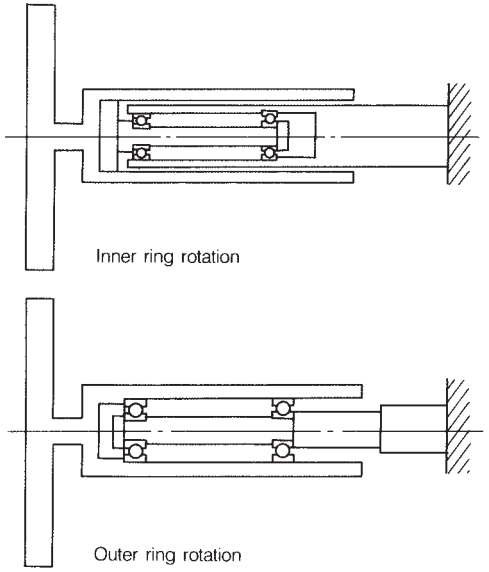


Fig. 2 Anode bearing and rotating ring

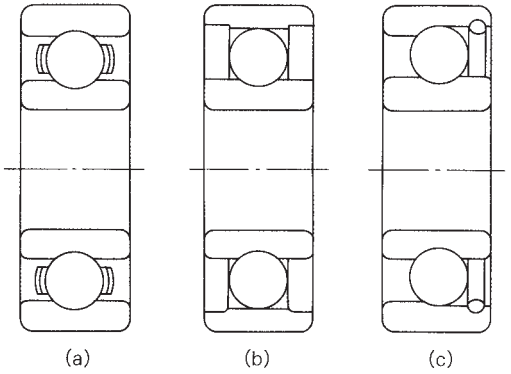


Fig. 3 Typical construction of X-ray tube bearings

One of the greatest challenges facing X-ray tube ball bearings is the lubrication method. Because of the vacuum and high temperature environment, a solid lubricant is used with one of the methods described below:
(1) Provision of laminated solid lubrication (molybdenum disulfide) to the pocket surface of a cage
(2) Provision of thin film of mild metal (silver or lead) over the surface of balls, inner ring/outer ring raceway

The method (2) above applies mostly to full-complement type ball bearings and the thin film is provided by plating, ion plating, etc. The results of a durability test performed on a ball bearing with a soft metal coating in a vacuum are shown in Fig. 4. By the way, Fig. 4 shows a comparison of the endurance time for different conditions of ball bearings (8 mm in bore and 22 mm in outside diameter) that are rotated at 9 000 min^{-1} under an axial load of 20 N {2 kgf} at 0.13 mPa {10^{-6} Torr} while at room temperature. Fig. 5 shows a graph of the change in running torque as a function of time.

The raceway wear becomes substantial only when the balls are made of ceramics and there is no lubrication. However, if a lubrication film is provided for the raceway, then the torque variation becomes small and stable. Fig. 6 shows an example of a test with the housing temperature set at 300°C for a ball bearing of 9.5 mm in bore and 22 mm in outside diameter which rotates at 9 000 min^{-1} under an axial load of 5 N {0.5 kgf} or 20 N {2 kgf}.

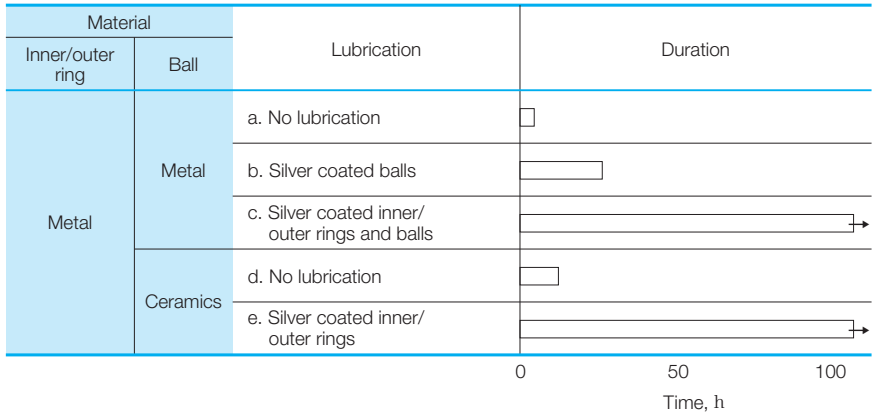


Fig. 4 Lubricating conditions and durable time (room temperature)

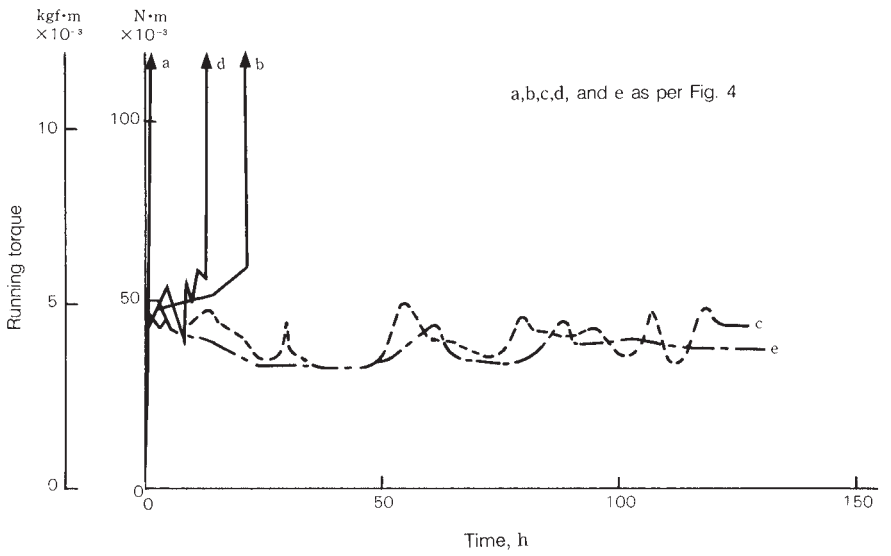


Fig. 5 Torque and duration

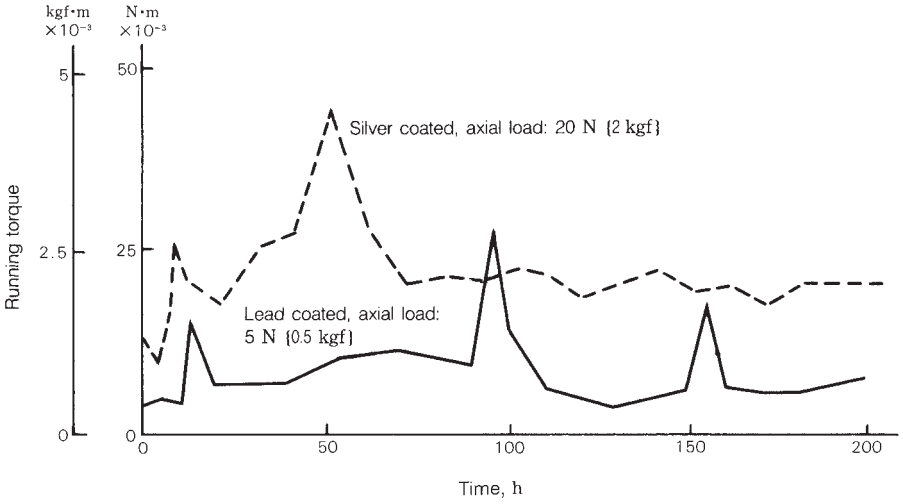


Fig. 6 Lubricating conditions and duration at high temperature

13.3 Ball bearing for high vacuum

A ball bearing coated with a solid lubricant is available for high-vacuum use where normal lubricants or grease cannot be used. **Table 1** shows the bearing number and boundary dimensions of these bearings. They can be classified into a type with a cage or a type without cage (full complement type) which is available with a flange or a shield to suit the specific application.

A bearing with a cage can be made to achieve low-torque stable rotation at low speeds by selecting a cage material and shape suited to the application. At high speeds, however, slip friction grows between the cage and ball.

Table 1 Boundary dimensions of a high-vacuum ball bearings

Bearing No.	Boundary dimensions (mm)		
	d	D	B
U-694hS	4	11	4
U-625hS	5	16	5
U-626hS	6	19	6
U-627hS	7	22	7
U-608hS	8	22	7
U-629hS	9	26	8
U-6000hS	10	26	8
U-6200hS	10	30	9
U-6001hS	12	28	8
U-6201hS	12	32	10
U-6002hS	15	32	9
U-6202hS	15	35	11
U-6003hS	17	35	10
U-6203hS	17	40	12
U-6004hS	20	42	12
U-6204hS	20	47	14
U-6005hS	25	47	12
U-6205hS	25	52	15
U-6006hS	30	55	13
U-6206hS	30	62	16
U-6007hS	35	62	14
U-6207hS	35	72	17
U-6008hS	40	68	15
U-6208hS	40	80	18

Remarks This bearing type is available in open, shielded, and full-complement types. The material used is SAE 51440C.

Accordingly, a full-complement type ball bearing is better suited for high speeds. When compared to a bearing with a cage, the full-complement type ball bearing develops slightly larger running torque due to slide contact between balls, but develops less wear and less torque fluctuation. As a result, a full-complement type ball bearing is used for a wide range of speeds from low to high.

Solid lubricants used include laminated structures of soft metals such as Ag (silver) and Pb (lead) and molybdenum disulfide (MoS_2). **Table 2** and **Figs. 1** through **3** show typical friction and wear characteristics of bearings lubricated via a thin film of solid lubricants at 100 to 9 000 min^{-1}. As is known from **Table 2**, Ag is used when low wear is demanded while Pb and MoS_2 are used when low torque is demanded.

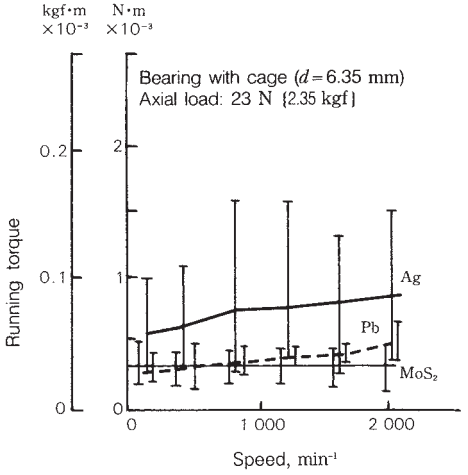


Fig. 1 Speed and running torque

Table 2 Characteristics of high-vacuum ball bearing

Kind of coating	Friction characteristics				Wear amount
	Torque	Relationship with rotating speed		Relationship with axial load with Fig. 3	
		Relatively low speed Fig. 1	Relatively high speed Fig. 2		
Ag	Large △	Almost no change ○	Increase along with rotating speed △	Rapid increase along with load △	Less ○
Pb	Normal ○	Almost no change ○	Increase along with rotating speed △	Increase slightly along with load △	More than Ag △
MoS_2	Small ○	Almost no change ○	Almost no change ○	Increase slightly along with load ○	More than Ag △

Remarks ○: Superior △: Relatively inferior

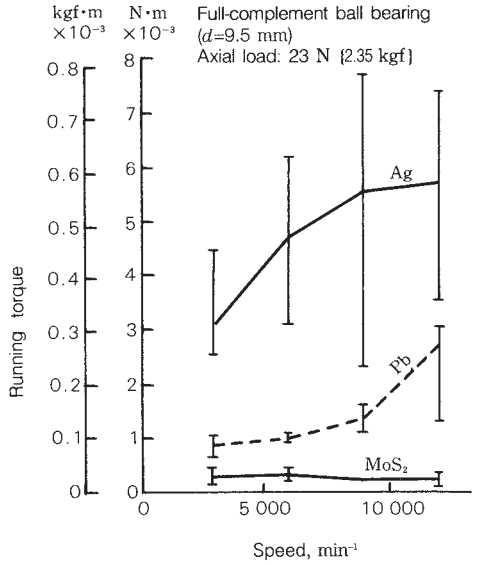


Fig. 2 Speed and running torque

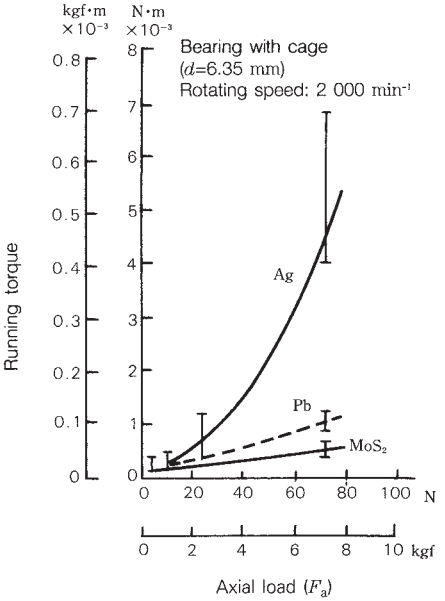


Fig. 3 Axial load and running torque

13.4 Light-contact-sealed ball bearings

Bearings are required to have low torque combined with high sealing effectiveness in order to meet the machine requirements of small-size, light-weight, and low-energy-comsumption.

NSK has developed DDW seals to meet these requirements. They have the following advantages compared with DDU seals, which are NSK's standard contact seals.

(1) There is light contact between the main seal lip and inner ring because the support for the main lip is long and thin resulting in low torque.
(2) The main lip contacts the bevelled portion of the inner ring seal groove where, if there is centrifugal force, the dust moves outward, so the dust resistance is excellent.
(3) The main lip has outward contact with the inner ring seal groove, so internal pressure does not open the seal and allow grease leakage.

The available bearing bore diameters are 10 to 50 mm now. Please consult NSK about other sizes.

In the case of nitrile rubber, the color code is as follows:

DDW (light-contact seal): Green
DDU (standard contact seal): Brown
VV (non-contact seal): Black

Fig. 1 shows the design of DDW sealed bearings and Fig. 2 shows the results of evaluation tests.

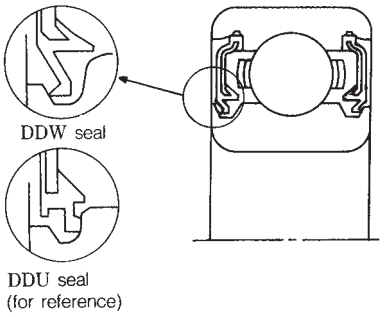
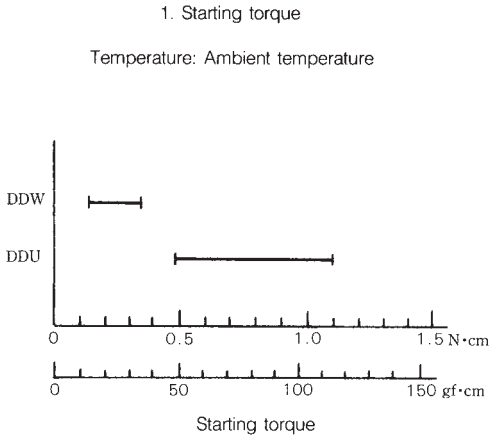
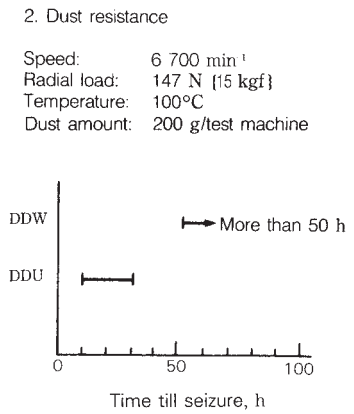
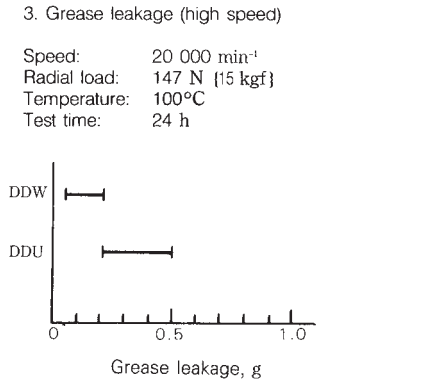


Fig. 1 DDW sealed bearing







Test bearings: 6203 4 bearings/test
Grease: Ester-base lithium grease, 45% of free space

Fig. 2 Evaluation test results of DDW sealed bearings

13.5 Bearing with integral shaft

In consideration of the need for improved Audio-Visual (AV) and Office Automation (OA) equipment, bearings used in rotary mechanisms of small precision motors and so forth are increasingly demanded to demonstrate much higher performance. Enhanced quality of Video Cassette Recorders (VCR) and Digital Audio Terminals (DAT), increased density of Hard Disk Drives (HDD), and improved printing quality of Laser Beam Printers (LBP) have imposed severe requirements on equipment. These severe design requirements cover improvement of the runout accuracy (rotational repetitive runout, non-repetitive runout), low-noise, and reduction of power consumption as well as being easy-to-assemble. An NSK bearing with integral shaft is available and meets these exacting demands.

The bearing with integral shaft is a unit, which has no inner ring while having the raceway groove directly on the shaft to incorporate a preload spring between both outer rings (Fig. 1). This type of bearing has the following advantages over normal bearings:

(1) Improved recording/reproduction accuracy
- ○ Integration of the shaft and inner ring, thereby eliminating movement of the shaft caused by fitting between the shaft and inner ring
- ○ Thick-wall design of the outer ring as required, thereby reducing deformation of the outer ring due to interference

(2) Reduced power consumption of motor
- ○ Integration of the shaft and inner ring, thereby reducing the ball pitch diameter for the same shaft diameter and resulting in a decrease of torque

(3) High shaft rigidity and compactness
- ○ Integration of the shaft and inner ring, thereby reducing the bearing's outside diameter for a given size shaft diameter.

(Example) 684ZZ: Shaft diameter 4 mm, outside diameter 9 mm (without shaft)
4BVD: Shaft diameter 4 mm, outside diameter 8 mm (with integral shaft)

(4) Aiming at "easy-to-assemble" designs
- ○ No parts are required for preload adjustment and preloading
- ○ No need for selective fitting and adhesion securing of the shaft and inner ring

Specifications on the NSK bearing with integral shaft are shown in Table 1.

Table 1 Specifications on bearing with integral shaft

	Boundary dimensions (mm)			Basic load Ratings (N)		{kgf}	
d	D_1	D_2	W	C_r	C_{or}	C_r	C_{or}
3	6.45	7.05	3.5	435	124	45	13
4	8	10	4	550	173	56	18
5	9	10	4	640	223	65	23
6	10	12	4	710	271	73	28
7	13	15	5	980	365	100	37
8	15	17	6	1 330	505	135	52

Remarks Consult NSK for the shaft length.

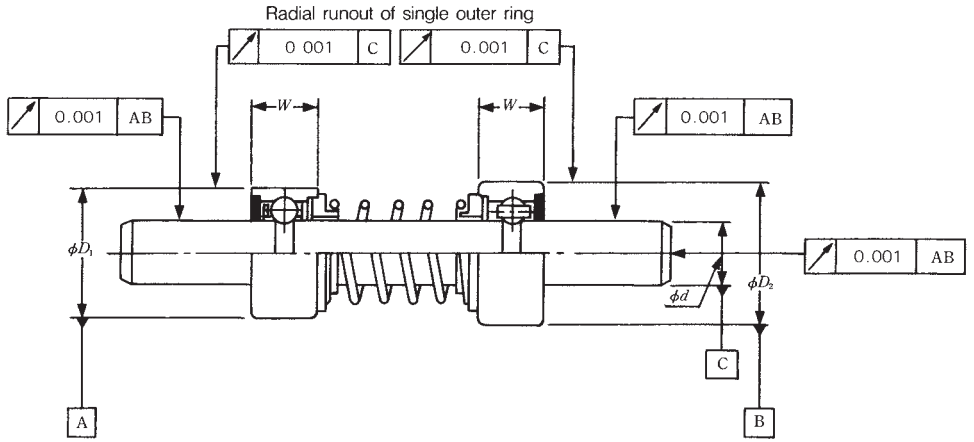


Fig. 1 Composition and runout accuracy of bearing with integral shaft

13.6 Bearings for electromagnetic clutches in car air-conditioners

The electromagnetic clutch is an important part and is necessary to activate the compressor of a car air-conditioner. The performance required of an electromagnetic clutch bearing differs depending on the type of compressor.

Table 1 shows the relationship between the compressor type and the application conditions for electromagnetic clutch bearings.

Values shown in Table 1 are the maximum during practical operation. A bench test is made under more severe conditions to confirm the durability of the bearing.

The electromagnetic clutch bearing must prove durable under these conditions. Principal performances required of the bearing are listed below:

- ○ Durability at high speed
- ○ Durability at high temperature
- ○ Bearing angular clearance should be kept small to assure maintenance of a proper clearance between disk and armature

When deciding the bearing specifications, the appropriateness of the following points should be considered:

- ○ Bearing internal design for high speed and longer life
- ○ Long-life grease for high temperatures and high speeds
- ○ Proper radial clearance
- ○ Effective sealing system with low grease leakage and superior in terms of dust proof and water proof

Most of the bearings for electromagnetic clutches have a bore in the range of 30 to 45 mm. One common arrangement is to use a pair of single-row deep groove ball bearings, and another is to use a double-row angular contact ball bearing.

A bearing for an electromagnetic clutch is required to have high speed, long grease life, proper internal clearance, and superior seal effectiveness. NSK bearings for electromagnetic clutches have the dimensions and features described below to meet the above performance requirements:

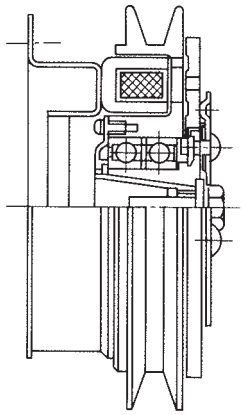


Fig. 1 Electromagnetic clutch for a reciprocating type compressor

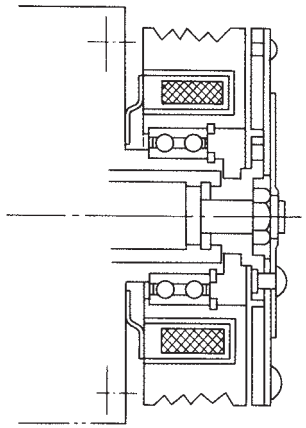


Fig. 2 Electromagnetic clutch for axial type and rotary type compressors

(1) Bearing type and dimensions

An electromagnetic clutch bearing is described below, and its representative bearing numbers and boundary dimensions are shown in Table 2.

Table 1 Compressor type and bearing running conditions

Running conditions of clutch bearing		Compressor type			
		Reciprocating	Vane	Scroll	Swash Plate
Rotating ring	Clutch ON	Inner and outer rings	Outer ring	Outer ring	Outer ring
	Clutch OFF	Outer ring	Outer ring	Outer ring	Outer ring
Maximum speed (min^{-1})		5 500	7 000	12 000	9 000
Maximum bearing temperature (°C) Inner ring		120	120	120	160

Table 2 Boundary dimensions of electromagnetic clutch bearings

Bearing type	Bearing No.	Boundary dimensions (mm)			
		d	D	B	r (min.)
Single-row deep groove ball bearing (2 bearings)	6006	30	55	13×2	1
	6008	40	68	15×2	1
Double-row angular contact ball bearing	30BD40	30	55	23	1
	35BD219	35	55	20	0.6
	40BD219	40	62	24	0.6
	30BD4718	30	47	18	0.5
	35BD5020	35	50	20	0.3
	35BD5220	35	52	20	0.5

(1.1) Double-row angular contact ball bearings
This type of bearing is used in the greatest quantity as an electromagnetic clutch bearing and common features include those listed below:
- ○ Easier to handle and superior in economy to a combination of single-row deep groove ball bearings
- ○ Use of plastic cage (long life)
- ○ Securing of a contact angle (generally 25°) favorable for pulley overhang

(1.2) Combination of single-row deep groove ball bearings
In most cases, this type is replaced by double-row angular contact ball bearings. At present, they are still used in relatively large vehicles and general industrial machinery.

(2) Dedicated grease
NSK has developed dedicated greases MA6, MA8 and HA2 that ensure long life under high-temperature and high-speed conditions. These greases are already in practical use. The main features of MA6, MA8 and HA2 greases can be described as follows:
- ○ Superior in resistance at high temperature. Long grease life is ensured even at the high temperature of 160°C.
- ○ Less grease leakage due to superior shearing stability
- ○ Ensures longer grease life and high anti-rusting performance by the addition of a suitable anti-rusting agent.

(3) Bearing seal
The following performances are required of a bearing seal for an electromagnetic clutch:
- ○ Less grease leakage
- ○ Superior dust and water resistance
- ○ Small torque

NSK seals have a good balance of the above performances (**Table 3**). NSK offers the types of seals shown on the next page.

Table 3 Type and performance of NSK bearing seals

Seal performance	Seal type		
	DU	DUK	DUM
Grease leakage	Fair	Good	Superior
Seal effectiveness (dust and water resistance)	Fair	Good	Superior
Torque	Good	Good	Good
Seal groove-seal lip contact condition	Contact (with air hole)	Contact (without air hole)	Contact (without air hole)

13.7 Sealed clean bearings for transmissions

A sealed clean bearing for a transmission is a bearing with a special seal that can prevent entry of foreign matters into a gear box and thereby extend the fatigue life of a bearing substantially.

This type of bearing has proven in actual transmission endurance tests to have a durability life which is 6 to 10 times longer than that of standard ball bearings.

The special seal prevents harmful, extremely-small foreign matters suspended in the gear oil from entering the gear box. Thereby minimizing the number of dents and foreign matter that become embedded in the raceway. The bearing fatigue pattern is thus changed from a surface fatigue pattern to an internal fatigue pattern (a reference to be used in judgment of the bearing fatigue), which contributes to extension of the bearing life. This is not much affected by the recent trend to use low viscosity gear oil, either. In these respects, this kind of bearing is better than open type bearings.

Sealed clean bearings as described above are generally called transmission (TM) ball bearings. They are dedicated bearings for use in transmission applications and have the following major features:

1. Satisfactory design and specifications for a transmission bearing
2. Grease with an affinity for gear oil is filled to assist initial lubrication
3. The seal lip construction allows inflow of lubricating oil while preventing entry of foreign matters. (**Fig. 1**)
4. Lower torque when compared with normal contact seal bearings

These TM ball bearings are produced as series products as shown in **Table 1**. TM ball bearings have the same nominal dimensions as the open type bearing series 62 and 63 currently in use. Thus, they can readily be substitued.

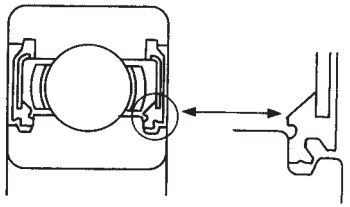


Fig. 1 Sectional and expanded views

Table 1 Specifications of TM ball bearings

Bearing No.	Boundary dimensions (mm)			Basic load ratings (N)		{kgf}	
	d	D	B	C_r	C_{0r}	C_r	C_{0r}
TM203	17	40	12	9 550	4 800	975	490
TM303	17	47	14	13 600	6 650	1 390	675
TM204	20	47	14	12 800	6 600	1 300	670
TM304	20	52	15	15 900	7 900	1 620	805
TM2/22	22	50	14	12 900	6 800	1 320	695
TM3/22	22	56	16	18 400	9 250	1 870	940
TM205	25	52	15	14 000	7 850	1 430	800
TM305	25	62	17	20 600	11 200	2 100	1 150
TM2/28	28	58	16	16 600	9 500	1 700	970
TM3/28	28	68	18	26 700	14 000	2 730	1 430
TM206	30	62	16	19 500	11 300	1 980	1 150
TM306	30	72	19	26 700	15 000	2 720	1 530
TM2/32	32	65	17	20 700	11 600	2 120	1 190
TM3/32	32	75	20	29 400	17 000	3 000	1 730
TM207	35	72	17	25 700	15 300	2 620	1 560
TM307	35	80	21	33 500	19 200	3 400	1 960
TM208	40	80	18	29 100	17 800	2 970	1 820
TM308	40	90	23	40 500	24 000	4 150	2 450
TM209	45	85	19	31 500	20 400	3 200	2 080
TM309	45	100	25	53 000	32 000	5 400	3 250
TM210	50	90	20	35 000	23 200	3 600	2 370
TM310	50	110	27	62 000	38 500	6 300	3 900
TM211	55	100	21	43 500	29 300	4 450	2 980
TM311	55	120	29	71 500	44 500	7 300	4 550
TM212	60	110	22	52 500	36 000	5 350	3 700
TM312	60	130	31	82 000	52 000	8 350	5 300
TM213	65	120	23	57 500	40 000	5 850	4 100
TM313	65	140	33	92 500	60 000	9 450	6 100
TM214	70	125	24	62 000	44 000	6 350	4 500
TM314	70	150	35	104 000	68 000	10 600	6 950

13.8 Double-row cylindrical roller bearings, NN30 T series (with polyamide resin cage)

For machine tool spindle systems which require particularly high rigidity, double-row cylindrical roller bearings (NN30 series) are used in increasing quantities. New machine tools are required to have the following improvements: reduction of the machining time, enhancement of the surface finishing accuracy through reduction of cutting resistance, extension of the tool life, and performance of light, high-speed cutting of materials such as aluminum, graphite, and copper.

NSK has developed double-row cylindrical roller bearings to meet these requirements. These bearings have polyamide cages which are far superior in high speed, low friction, and low noise over conventional types. Key features are listed below:

(1) Superiority in high speed

The polyamide cage is extremely light (about 1/6 that of copper alloy) and satisfactory in self-lubrication, with a lower coefficient of friction. As a result, heat generation is small and superior high speed characteristics are obtainable during high-speed rotation.

(2) Low noise

Low coefficient of friction, superior vibration absorption, and dampening contribute to reduction of the cage-induced noise to a level lower than that of conventional types.

(3) Extension of grease life

The polyamide cage avoids metallic contact with rollers while offering superior wear resistance. Accordingly, grease discoloration and deterioration due to wear of the cage is minimized, helping to further extend the grease life.

Polyamide cage are also used in single-row cylindrical roller bearings (N10 series). They are used mainly as bearings for the rear side of the spindle and are now marketed as the N10B T series.

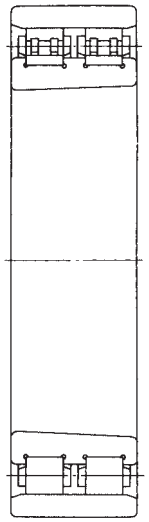


Fig. 1

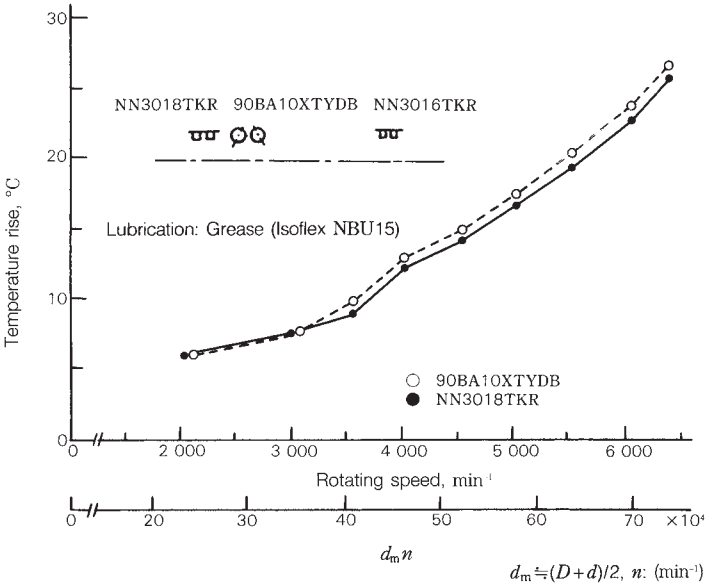


Fig. 2 Rotating speed and temperature rise

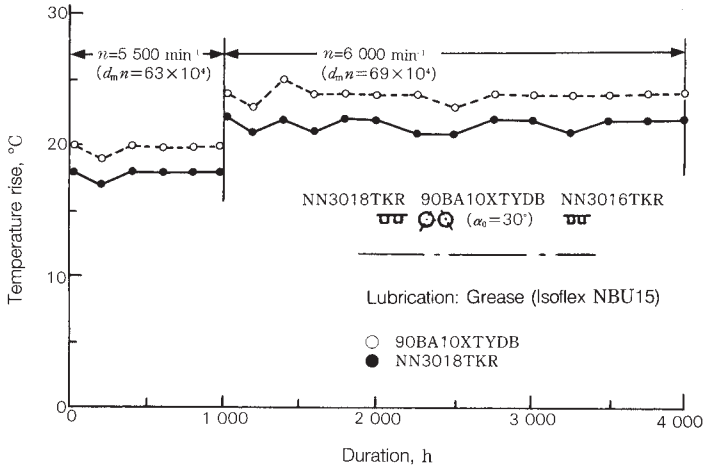


Fig. 3 Temperature change during endurance test

13.9 Single-row cylindrical roller bearings, N10B T series (cage made of polyamide resin)

Bearings to support the rear portion of the head spindle in machining centers and NC lathes are exposed to the belt tension and transmission gear reaction. Accordingly, double-row cylindrical roller bearings with large load capacity are used.

The number of applications are increasing for a drive system with a motor directly coupled or a motor built-in system with a motor arranged directly inside the spindle to meet the demand for faster spindle speeds. In this case, the single-row cylindrical roller bearing has come to be increasingly used because it can reduce the load acting on the rear support bearing and minimize heat generation in the bearing.

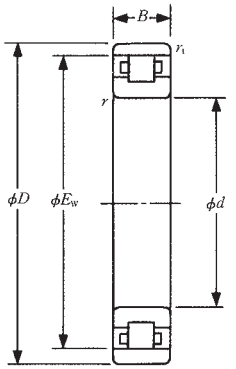
NSK has developed the N10B T series of bearings with polyamide cages for single-row cylindrical roller bearings (N10 series).

Key features of these bearings are listed below:

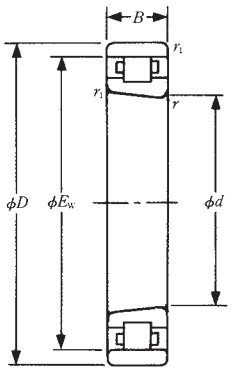
(1) The tapered bore bearing has been included, in addition to the cylindrical bore bearing, into series products. The tapered bore bearing allows easy setting of a proper radial internal clearance through adjustment of the axial push-in amount of the inner ring.
(2) The use of a developed polyamide cage proves favorable for use with grease and oil-air lubrication.

The developed polyamide cage is the same as the one used in the NN30B T series. Polyamide cages extend the grease life beyond that obtained with conventional copper alloy machined cages. Moreover, change of the cage guide method from the inner ring guide to the roller guide makes it easier to supply lubricating oil to the target zone between the cage bore surface and inner ring outside surface by an oil-air lubrication.

Accordingly, the design specifications are different from those of the conventional N10 series (as described in the bearing general catalog and the precision rolling bearing catalog for machining tools).



Cylindrical bore



Tapered bore

Bearing No.	
Cylindrical bore	Tapered bore
N1007B T	N1007B TKR
N1008B T	N1008B TKR
N1009B T	N1009B TKR
N1010B T	N1010B TKR
N1011B T	N1011B TKR
N1012B T	N1012B TKR
N1013B T	N1013B TKR
N1014B T	N1014B TKR
N1015B T	N1015B TKR
N1016B T	N1016B TKR
N1017B T	N1017B TKR
N1018B T	N1018B TKR
N1019B T	N1019B TKR
N1020B T	N1020B TKR
N1021B T	N1021B TKR
N1022B T	N1022B TKR
N1024B T	N1024B TKR
N1026B T	N1026B TKR

Boundary dimensions (mm)						Basic load ratings (N)		Basic load ratings {kgf}	
d	D	B	r (min.)	r_1 (min.)	E_w	C_r	C_{0r}	C_r	C_{0r}
35	62	14	1	0.6	55	22 900	25 000	2 340	2 550
40	68	15	1	0.6	61	25 200	27 700	2 570	2 830
45	75	16	1	0.6	67.5	30 000	34 500	3 100	3 500
50	80	16	1	0.6	72.5	31 000	36 500	3 150	3 700
55	90	18	1.1	1	81	40 500	48 500	4 100	4 900
60	95	18	1.1	1	86.1	42 500	53 000	4 350	5 400
65	100	18	1.1	1	91	45 000	58 000	4 600	5 900
70	110	20	1.1	1	100	55 000	71 500	5 650	7 300
75	115	20	1.1	1	105	56 500	74 500	5 750	7 600
80	125	22	1.1	1	113	69 500	93 000	7 100	9 500
85	130	22	1.1	1	118	71 000	97 000	7 250	9 900
90	140	24	1.5	1.1	127	83 500	114 000	8 500	11 600
95	145	24	1.5	1.1	132	85 000	119 000	8 700	12 100
100	150	24	1.5	1.1	137	87 000	124 000	8 850	12 600
105	160	26	2	1.1	146	112 000	155 000	11 400	15 800
110	170	28	2	1.1	155	130 000	180 000	13 200	18 400
120	180	28	2	1.1	165	136 000	196 000	13 800	20 000
130	200	33	2	1.1	182	166 000	238 000	16 900	24 300

13.10 Sealed clean bearings for rolling mill roll neck

A large quantity of roll cooling water (or rolling oil) or scales is splasthed around the roll neck bearing of the rolling mill. Moreover, the roll and chock must be removed and installed quickly. In this environment, the oil seal provided on the chock may be readily damaged and the roll neck bearing may be exposed to entry of cooling water or scale.

Upon investigation, used grease from the bearing was found to be high in water content. Also, the bearing raceway often shows numerous dents due to inclusion of foreign matter, indicating progress of fatigue on the raceway surface.

The roll neck sealed clean bearing, which NSK has developed on the basis of the above investigation and analytical results, is already employed in large quantity inside and outside of Japan.

Features of the roll neck sealed clean bearing are listed below:

(1) Reduce the frequency of grease replenishment. The conventional man-hour needed for grease supply each day per bearing becomes totally unnecessary. In this way, maintenance costs can be reduced substantially.

(2) Seals are incorporated on both ends of the bearing, thus eliminating the possibility of damaging a seal during handling and effectively preventing entry of water and scale into the bearing. As a result, the rolling fatigue life can be improved substantially and there are fewer accidental seizures.

(3) The grease consumption can be reduced. For example, when assuming a case of three turns of chock for the cold rolling mill work rolls of five stands, the total number of bearings becomes 60 (4 × 5 stands × 3 turns) and, in this case, 10 to 15 tons of grease can be saved annually.

(4) The cleaning interval of a bearing can be extended. Conventional interval of partial cleaning every three months or so can be extended to every six months or more, thereby reducing the amount of maintenance work. However, the optimum interval needs to be determined after considering and experimenting with the particular conditions of the specific rolling mill.

(5) Reduction of the grease supply man-hour and of the grease consumption can decrease the contamination around a roll mill and roll shop and thus improves the cleanliness of the work environment.

Fig. 1 shows a typical assembly of a sealed clean bearing for the roll neck. Table 1 shows typical dimensions of a representative sealed clean bearing. For details, refer to the NSK catalog “Large-Size Rolling Bearings”, CAT. No. E125.

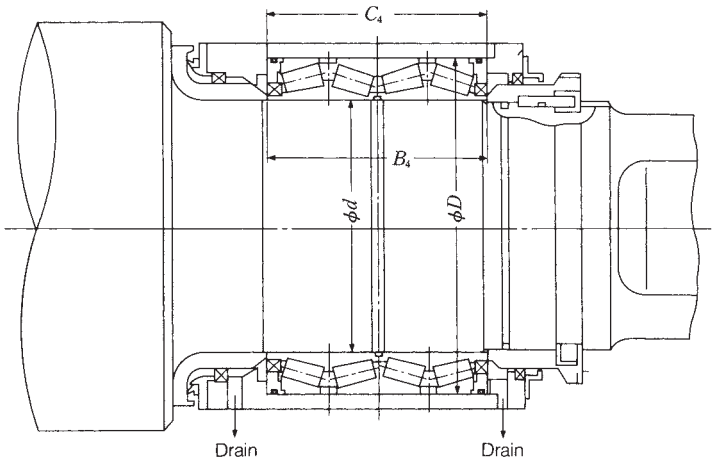


Fig. 1 Typical assembly of sealed clean bearing for roll neck

Table 1 Boundary dimensions of a sealed clean bearing for a roll neck

Bearing No.	Boundary dimensions (mm)			
	d	D	B_4	C_4
STF 343 KVS 4551 Eg	343.052	457.098	254.000	254.000
STF 457 KVS 5951 Eg	457.200	596.900	276.225	279.400
STF 482 KVS 6151 Eg	482.600	615.950	330.200	330.200

13.11 Bearings for chain conveyors

Many chain conveyors are used to transport semi-finished products and finished products (coil, etc.) between processes in a steelmaking plant. Bearings dedicated to these chain conveyors are used. The inner ring is fixed to the pin connecting the link plates while the outer ring functions as a wheel to carry the load on the rail by rolling.

Though varying in design depending on the purpose, typical conveyors used in steelmaking plant are shown in Figs. 1 and 2.

The bearing for chain conveyors rotates with outer rings at extremely low speed while being exposed to relatively heavy load and shock load. They are also used in poor environments with lots of water and scale at high temperature. In view of enhancing the breakdown strength by providing the roller (outer ring) with high wear resistance, a thick-wall design is employed and carburization or special heat treatment is made to increase the shock resistance. A full-complement type cylindrical roller bearing is designed to sustain these heavy loads. A double-row cylindrical roller bearing is not needed usually.

Either the S type (side seal type, Fig. 3) or labyrinth type (Figs. 4 and 5) is available. Thus, dust-proof and water-resistance as well as grease sealing are ensured. In particular, the S type has achieved further improvements in seal effectiveness through the use of a contact seal.

Normally, the outer ring outside has a cylindrical surface. There are various types: some with the outer ring width longer than the inner ring width (Figs. 3 and 4) and some with the outer ring and inner ring widths nearly equal (Fig. 5). Features of the chain conveyor bearing may be summarized as follows:

(1) The rollers (outer rings) are thick and made resistant to shock load and wear through carburization or special heat treatment.
(2) Special tempering allows use at high temperature.
(3) Optimum grease is filled for maintenance free operation, ensuring superior durability and economic feasibility.
(4) The seal construction is superior in grease sealing and dust- and water-proof, with a measure incorporated to prevent dislodgement of the seal by shock. In particular, the S type, which uses a contact seal, can realize improved sealing. The benefits of improved sealing include extension of the bearing life, substantial reduction of both supply grease and supply man-hours, and even cleaner surroundings.

Typical specifications on this bearing are shown in Table 1. Please contact NSK for information on bearings not shown in Table 1.

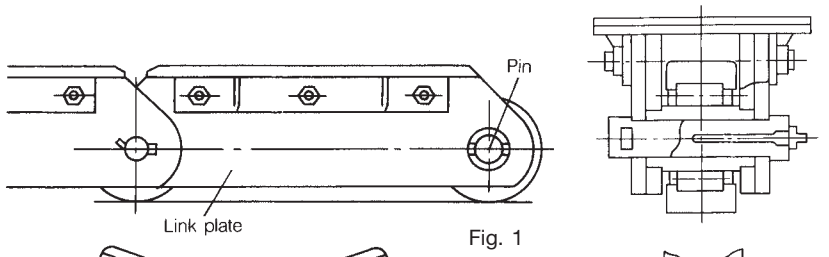


Fig. 1

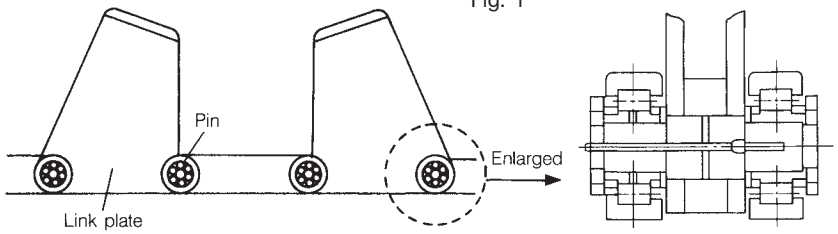


Fig. 2

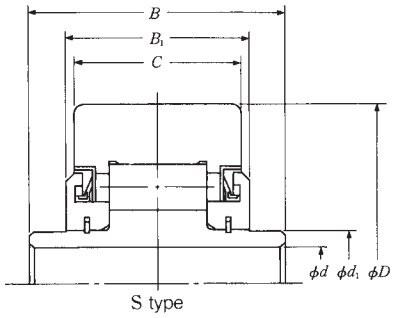


Fig. 3

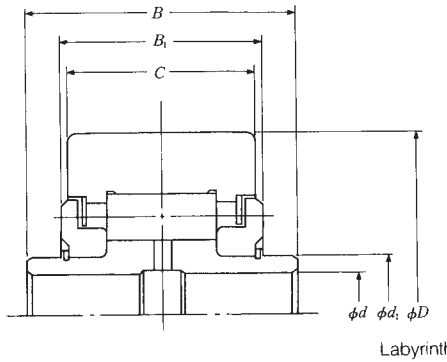


Fig. 4

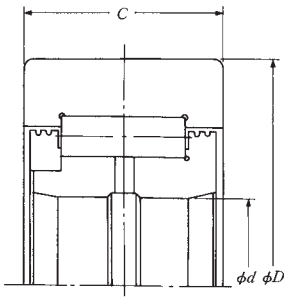


Fig. 5

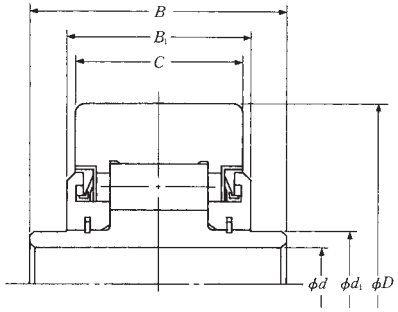


Fig. 3

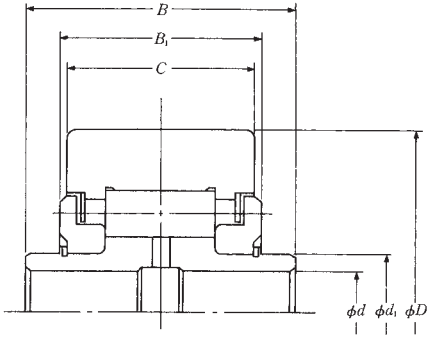


Fig. 4

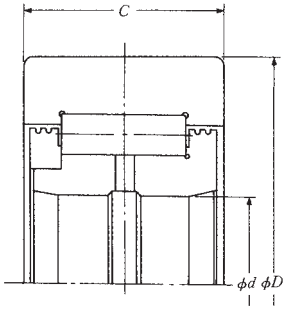


Fig. 5

Table 1 Representative chain conveyor bearings

Bearing No.		Example figure	Dimensions (mm)						Basic load ratings S-type (N)		S-type {kgf}		Labyrinth type (N)		Labyrinth type {kgf}	
S-type	Labyrinth type		d	d_1	D	C	B	B_1	C_r	C_{0r}	C_r	C_{0r}	C_r	C_{0r}	C_r	C_{0r}
—	28RCV05	4	28.2	44.03	125	50	91.4	65	—	—	—	—	198 000	233 000	20 200	23 800
28RCV13	28RCV06	3,4	28.2	39.95	125	55	85.4	60	160 000	177 000	16 400	18 100	175 000	198 000	17 800	20 200
30RCV16	30RCV07	3,4	30.2	45	135	71	110	78	275 000	330 000	28 000	34 000	285 000	350 000	29 100	35 500
30RCV17	30RCV09	3,4	30.3	50.03	135	65	103	78	253 000	298 000	25 800	30 500	253 000	298 000	25 800	30 500
30RCV21	30RCV05	3,4	30.2	45	135	55	94	62	196 000	215 000	20 000	22 000	196 000	215 000	20 000	22 000
30RCV23	—	3	30.3	50.03	135	65	111	78	253 000	298 000	25 800	30 500	—	—	—	—
30RCV25	—	3	30.3	50.03	135	65	105	70	242 000	282 000	24 700	28 700	—	—	—	—
38RCV07	—	3	38.25	55.75	150	70	114.2	83.2	294 000	350 000	30 000	35 500	—	—	—	—
38RCV13	38RCV05	3,4	38.7	56	150	70	114.2	76	294 000	350 000	30 000	35 500	305 000	365 000	31 000	37 500
38RCV19	—	3	38.7	56	150	70	116	78	294 000	350 000	30 000	35 500	—	—	—	—
—	38RCV06	4	38.25	55.75	150	70	114.2	75	—	—	—	—	305 000	365 000	31 000	37 500
41RCV07	41RCV05	3,4	41.75	64.16	175	80	125	85	380 000	485 000	39 000	49 500	380 000	485 000	39 000	49 500
—	41RCV06	4	41.75	64.16	175	85	134.8	90.5	—	—	—	—	415 000	540 000	42 000	55 000
45RCV09	45RCV06	3,4	45.3	70.03	180	90	140.6	95	435 000	590 000	44 500	60 000	485 000	690 000	49 500	70 500
—	48RCV02	5	48.2	—	140	50	—	—	—	—	—	—	229 000	278 000	23 400	28 400
—	70RCV02	5	70	—	180	80	—	—	—	—	—	—	380 000	675 000	39 000	69 000

13.12 RCC bearings for railway rolling stock

Recent trains as well as the rolling stock are required to be high speeds and maintenance-free to satisfy the technical trends and environments.

Among the railway rolling stock, the axlebox bearings which run under the severe conditions such as large vibration and strong shocks when passing the rail joints or points, harsh environments with dust, rain and snow, are required to be high reliability for a long time.

NSK developed RCC bearings (Sealed cylindrical roller bearings for railway axle) to meet the above requirements. The RCC (Rotating end Cap type Cylindrical roller bearing) is a sealed bearing unit in which specially designed oil seals are attached directly to both ends of a double-row cylindrical roller bearing with double collars and filled with a dedicated long-life grease. (Fig. 1) The exclusive greases are the greases which are popularly used at AAR (Association of American Railroads) or long-life grease for axlebox developed by NSK.

The RCC bearings have the following features.

1. Unit construction, enabling easy handling.
2. The axle end can be exposed simply by removing an end cap, facilitating flaw detection of the axles or grinding of axles.
3. The roller and cage sub-unit can be removed from inner and outer rings during disassembly, making cleaning and inspection easier.
4. This unit bearing has an anti-rusting coating applied over the outer ring outside. An adaptor to be set on the outer ring is enough for a bearing box, thereby making the construction around the bearing simpler and reducing the weight.

Now, due to the good results, RCC bearings are widely used in new electric and passenger cars of both private and semi-national (JR) railways in Japan. Specifications of principal NSK RCC bearing units are shown in Table 1.

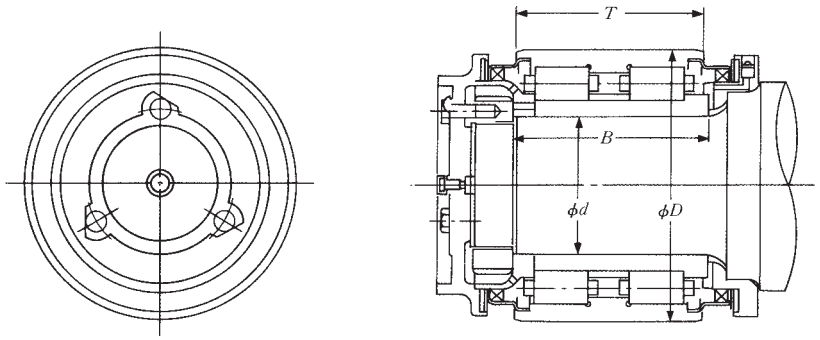


Fig. 1 Construction of RCC bearing

Table 1 Specifications on RCC bearing units

Unit No.	Boundary dimensions (mm)			Basic dynamic load rating	Bearing No. (reference)
	d	D	B	T	C_r (N)	
J-801	130	240	160	160	825 000	130JRF03A
J-803	120	220	188	175	850 000	120JRF04A
J-805	120	220	157	155	765 000	120JRF06
J-806	120	220	172	160	765 000	120JRF07
J-807	130	240	160	160	825 000	130JRF03
J-810A	120	220	185.5	160	765 000	120JRF09
J-811	120	220	204	160	815 000	120JRT07
J-814	130	230	185.5	160	800 000	130JRF05
J-816	130	240	160	160	825 000	130JRF03A
J-817	120	220	175	175	850 000	120JRF04J
J-818	90	154	107	115	315 000	90JRF01
J-819	120	230	185.5	170	945 000	120JRF10
J-820	85	154	135	105	365 000	85JRF01