1. TYPES AND FEATURES OF ROLLING BEARINGS

1.1 Design and Classification

Rolling bearings generally consist of two rings, rolling elements, and a cage, and they are classified into radial bearings or thrust bearings depending on the direction of the main load. In addition, depending on the type of rolling elements, they are classified into ball bearings or roller bearings, and they are further segregated by differences in their design or specific purpose.

The most common bearing types and nomenclature of bearing parts are shown in Fig.1.1, and a general classification of rolling bearings is shown in Fig. 1.2.

1.2 Characteristics of Rolling Bearings

Compared with plain bearings, rolling bearings have the following major advantages:

(1) Their starting torque or friction is low and the difference between the starting torque and running torque is small.

(2) With the advancement of worldwide standardization, rolling bearings are internationally available and interchangeable.

(3) Maintenance, replacement, and inspection are easy because the structure surrounding rolling bearings is simple.

(4) Many rolling bearings are capable of taking both radial and axial loads simultaneously or independently.

(5) Rolling bearings can be used under a wide range of temperatures.

(6) Rolling bearings can be preloaded to produce a negative clearance and achieve greater rigidity.

Furthermore, different types of rolling bearings have their own individual advantages. The features of the most common rolling bearings are described on Pages A10 to A12 and in Table 1.1 (Pages A14 and A15).

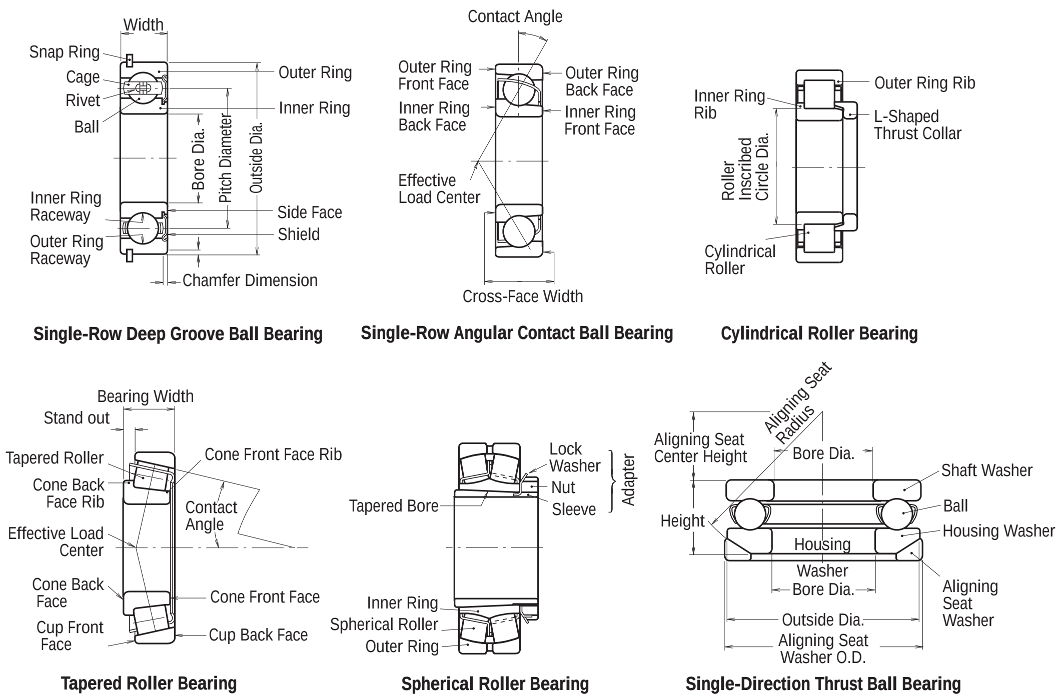


Fig. 1.1 Nomenclature for Bearing Parts

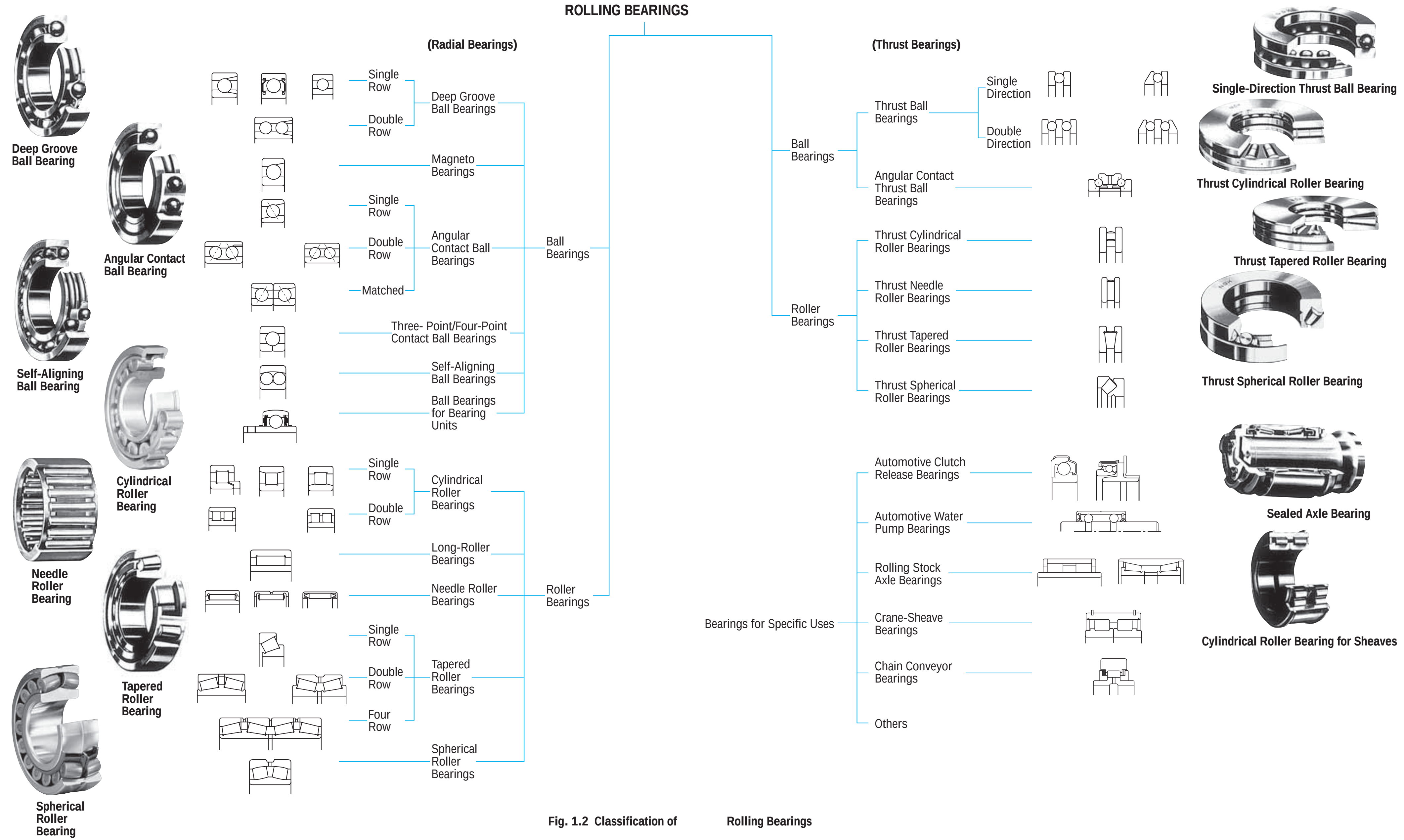
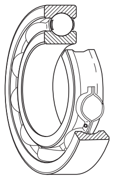


Fig. 1.2 Classification of Rolling Bearings

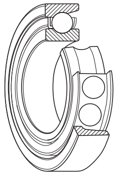
Single-Row Deep Groove Ball Bearings



Single-row deep groove ball bearings are the most common type of rolling bearings. Their use is very widespread. The raceway grooves on both the inner and outer rings have circular arcs of slightly larger radius than that of the balls. In addition to radial loads, axial loads can be imposed in either direction. Because of their low torque, they are highly suitable for applications where high speeds and low power loss are required.

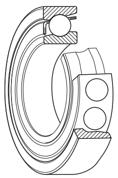
In addition to open type bearings, these bearings often have steel shields or rubber seals installed on one or both sides and are prelubricated with grease. Also, snap rings are sometimes used on the periphery. As to cages, pressed steel ones are the most common.

Magneto Bearings



The inner groove of magneto bearings is a little shallower than that of deep groove bearings. Since the outer ring has a shoulder on only one side, the outer ring may be removed. This is often advantageous for mounting. In general, two such bearings are used in duplex pairs. Magneto bearings are small bearings with a bore diameter of 4 to 20 mm and are mainly used for small magnetos, gyroscopes, instruments, etc. Pressed brass cages are generally used.

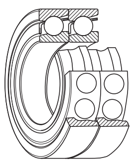
Single-Row Angular Contact Ball Bearings



Individual bearings of this type are capable of taking radial loads and also axial loads in one direction. Four contact angles of 15°, 25°, 30°, and 40° are available. The larger the contact angle, the higher the axial load capacity. For high speed operation, however, the smaller contact angles are preferred. Usually, two bearings are used in duplex pairs, and the clearance between them must be adjusted properly.

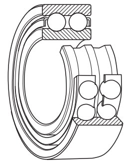
Pressed-steel cages are commonly used, however, for high precision bearings with a contact angle less than 30°, polyamide resin cages are often used.

Duplex Bearings



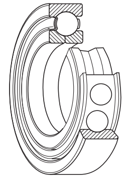
A combination of two radial bearings is called a duplex pair. Usually, they are formed using angular contact ball bearings or tapered roller bearings. Possible combinations include face-to-face, which have the outer ring faces together (type DF), back-to-back (type DB), or both front faces in the same direction (type DT). DF and DB duplex bearings are capable of taking radial loads and axial loads in either direction. Type DT is used when there is a strong axial load in one direction and it is necessary to impose the load equally on each bearing.

Double-Row Angular Contact Ball Bearings



Double-row angular contact ball bearings are basically two single-row angular contact ball bearings mounted back-to-back except that they have only one inner ring and one outer ring, each having raceways. They can take axial loads in either direction.

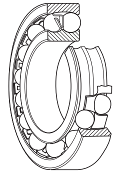
Four-Point Contact Ball Bearings



The inner and outer rings of four-point contact ball bearings are separable because the inner ring is split in a radial plane. They can take axial loads from either direction. The balls have a contact angle of 35° with each ring. Just one bearing of this type can replace a combination of face-to-face or back-to-back angular contact bearings.

Machined brass cages are generally used.

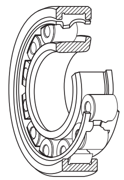
Self-Aligning Ball Bearings



The inner ring of this type of bearing has two raceways and the outer ring has a single spherical raceway with its center of curvature coincident with the bearing axis. Therefore, the axis of the inner ring, balls, and cage can deflect to some extent around the bearing center. Consequently, minor angular misalignment of the shaft and housing caused by machining or mounting error is automatically corrected.

This type of bearing often has a tapered bore for mounting using an adapter sleeve.

Cylindrical Roller Bearings



In bearings of this type, the cylindrical rollers are in linear contact with the raceways. They have a high radial load capacity and are suitable for high speeds.

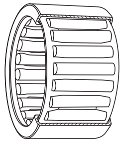
There are different types designated NU, NJ, NUP, N, NF for single-row bearings, and NNU, NN for double-row bearings depending on the design or absence of side ribs.

The outer and inner rings of all types are separable.

Some cylindrical roller bearings have no ribs on either the inner or outer ring, so the rings can move axially relative to each other. These can be used as free-end bearings. Cylindrical roller bearings, in which either the inner or outer rings has two ribs and the other ring has one, are capable of taking some axial load in one direction. Double-row cylindrical roller bearings have high radial rigidity and are used primarily for precision machine tools.

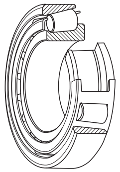
Pressed steel or machined brass cages are generally used, but sometimes molded polyamide cages are also used.

Needle Roller Bearings



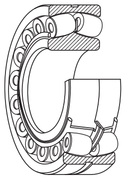
Needle roller bearings contain many slender rollers with a length 3 to 10 times their diameter. As a result, the ratio of the bearing outside diameter to the inscribed circle diameter is small, and they have a rather high radial load capacity.
There are numerous types available, and many have no inner rings. The drawn-cup type has a pressed steel outer ring and the solid type has a machined outer ring. There are also cage and roller assemblies without rings. Most bearings have pressed steel cages, but some are without cages.

Tapered Roller Bearings



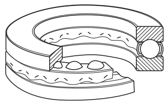
Bearings of this type use conical rollers guided by a back-face rib on the cone. These bearings are capable of taking high radial loads and also axial loads in one direction. In the HR series, the rollers are increased in both size and number giving it an even higher load capacity.
They are generally mounted in pairs in a manner similar to single-row angular contact ball bearings. In this case, the proper internal clearance can be obtained by adjusting the axial distance between the cones or cups of the two opposed bearings. Since they are separable, the cone assemblies and cups can be mounted independently.
Depending upon the contact angle, tapered roller bearings are divided into three types called the normal angle, medium angle, and steep angle. Double-row and four-row tapered roller bearings are also available. Pressed steel cages are generally used.

Spherical Roller Bearings

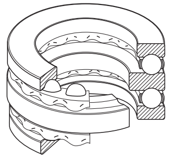


These bearings have barrel-shaped rollers between the inner ring, which has two raceways, and the outer ring which has one spherical raceway. Since the center of curvature of the outer ring raceway surface coincides with the bearing axis, they are self-aligning in a manner similar to that of self-aligning ball bearings. Therefore, if there is deflection of the shaft or housing or misalignment of their axes, it is automatically corrected so excessive force is not applied to the bearings.
Spherical roller bearings can take, not only heavy radial loads, but also some axial loads in either direction. They have excellent radial load-carrying capacity and are suitable for use where there are heavy or impact loads.
Some bearings have tapered bores and may be mounted directly on tapered shafts or cylindrical shafts using adapters or withdrawal sleeves.
Pressed steel and machined brass cages are used.

Single-Direction Thrust Ball Bearings

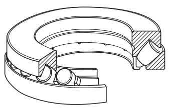


Double-Direction Thrust Ball Bearings



Single-direction thrust ball bearings are composed of washer-like bearing rings with raceway grooves. The ring attached to the shaft is called the shaft washer (or inner ring) while that attached to the housing is called the housing washer(or outer ring).
In double-direction thrust ball bearings, there are three rings with the middle one (center ring) being fixed to the shaft.
There are also thrust ball bearings with an aligning seat washer beneath the housing washer in order to compensate for shaft misalignment or mounting error.
Pressed steel cages are usually used in the smaller bearings and machined cages in the larger ones.

Spherical Thrust Roller Bearings



These bearings have a spherical raceway in the housing washer and barrel-shaped rollers obliquely arranged around it. Since the raceway in the housing washer in spherical, these bearings are self-aligning. They have a very high axial load capacity and are capable of taking moderate radial loads when an axial load is applied.
Pressed steel cages or machined brass cages are usually used.

Table 1. 1 Types and Characteristics of Rolling Bearings

Features \ Bearing Types		Deep Groove Ball Bearings	Magneto Bearings	Angular Contact Ball Bearings	Double-Row Angular Contact Ball Bearings	Duplex Angular Contact Ball Bearings	Four-Point Contact Ball Bearings	Self-Aligning Ball Bearings	Cylindrical Roller Bearings	Double-Row Cylindrical Roller Bearings	Cylindrical Roller Bearings with Single Rib
Load Capacity	Radial Loads	◯	○	◎	◎	◎	○	◯	◎	⊚	◎
	Axial Loads	⟷ ◯	⟵ ○	⟵ ◎	⟷ ◎	⟷ ◎	⟷ ◎	⟷ ○	×	×	⟵ ◯
	Combined Loads	◯	○	◎	◎	◎	◯	○	×	×	◯
High Speeds		⊚	◎	⊚	◯	◎	◎	◎	⊚	◎	◎
High Accuracy		⊚		⊚		⊚	◎		⊚	⊚	
Low Noise and Torque		⊚							◎		
Rigidity						◎			◎	⊚	◎
Angular Misalignment		◎	○	○	○	○	○	⊚	◯	○	◯
Self-Aligning Capability								☆			
Ring Separability			☆				☆		☆	☆	☆
Fixed-End Bearing		☆			☆	☆	☆	☆			
Free-End Bearing		★			★	★	★	★	☆	☆	
Tapered Bore in Inner Ring								☆		☆	
Remarks			Two bearings are usually mounted in opposition.	Contact angles of 15°, 25° 30°, and 40°. Two bearings are usually mounted in opposition. Clearance adjustment is necessary.		Combination of DF and DT pairs is possible, but use on free-end is not possible.	Contact angle of 35°		Including N type	Including NNU type	Including NF type
Page No.		B5 B31	B5 B28	B47	B47 B70	B47	B47 B72	B77	B85	B85 B110	B85

Features \ Bearing Types		Cylindrical Roller Bearings with Thrust Collars	Needle Roller Bearings	Tapered Roller Bearings	Double-and Multiple-Row Tapered Roller Bearings	Spherical Roller Bearings	Thrust Ball Bearings	Thrust Ball Bearings with Aligning Seat	Double-Direction Angular Contact Thrust Ball Bearings	Thrust Cylindrical Roller Bearings	Thrust Tapered Roller Bearings	Thrust Spherical Roller Bearings	Page No.
Load Capacity	Radial Loads	◎	◎	◎	⊚	⊚	×	×	×	×	×	○	—
	Axial Loads	⟷ ◯	×	⟵ ◎	⟷ ◎	⟷ ◯	⟵ ◎	⟵ ◎	⟷ ◎	⟵ ⊚	⟵ ⊚	⟵ ⊚	—
	Combined Loads	◯	×	◎	⊚	◎	×	×	×	×	×	○	—
High Speeds		◎	◎	◯	◯	◯	×	×	◯	○	○	○	A18 A37
High Accuracy				◎			◎		⊚				A19 A58 A81
Low Noise and Torque													A19
Rigidity		◎	◎	◎	⊚				◎	⊚	⊚		A19 A96
Angular Misalignment		◯	○	◯	○	⊚	×	⊚	×	×	×	⊚	A18 Blue pages of each brg. type
Self-Aligning Capability						☆		☆				☆	A18
Ring Separability		☆	☆	☆	☆		☆	☆	☆	☆	☆	☆	A19 A20
Fixed-End Bearing		☆			☆	☆							A20 ~A21
Free-End Bearing			☆		★	★							A20 ~A27
Tapered Bore in Inner Ring						☆							A80 A118 A122
Remarks		Including NUP type		Two bearings are usually mounted in opposition. Clearance adjustment is necessary.	KH, KV types are also available but use on free-end is impossible.					Including needle roller thrust bearings		To be used with oil lubrication	
Page No.		B85	—	B115	B115 B176 B299	B183	B207	B207	B235	B207 B224	—	B207 B228	

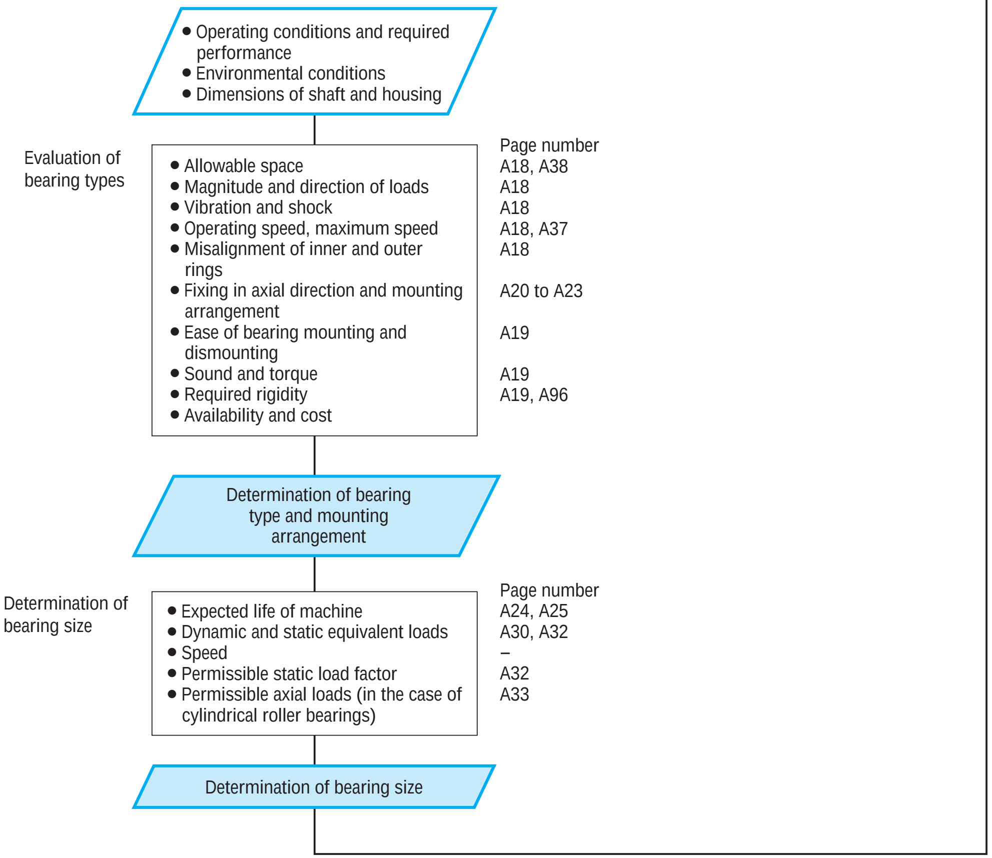
⊚ Excellent ◎ Good ◯ Fair ○ Poor × Impossible ⟵ One direction only ⟷ Two directions

☆ Applicable ★ Applicable, but it is necessary to allow shaft contraction/elongation at fitting surfaces of bearings.

2. BEARING SELECTION PROCEDURE

The number of applications for rolling bearings is almost countless and the operating conditions and environments also vary greatly. In addition, the diversity of operating conditions and bearing requirements continue to grow with the rapid advancement of technology. Therefore, it is necessary to study bearings carefully from many angles to select the best one from the thousands of types and sizes available.
Usually, a bearing type is provisionally chosen considering the operating conditions, mounting arrangement, ease of mounting in the machine, allowable space, cost, availability, and other factors.

Then the size of the bearing is chosen to satisfy the desired life requirement. When doing this, in addition to fatigue life, it is necessary to consider grease life, noise and vibration, wear, and other factors.
There is no fixed procedure for selecting bearings. It is good to investigate experience with similar applications and studies relevant to any special requirements for your specific application. When selecting bearings for new machines, unusual operating conditions, or harsh environments, please consult with NSK.
The following diagram (Fig.2.1) shows an example of the bearing selection procedure.



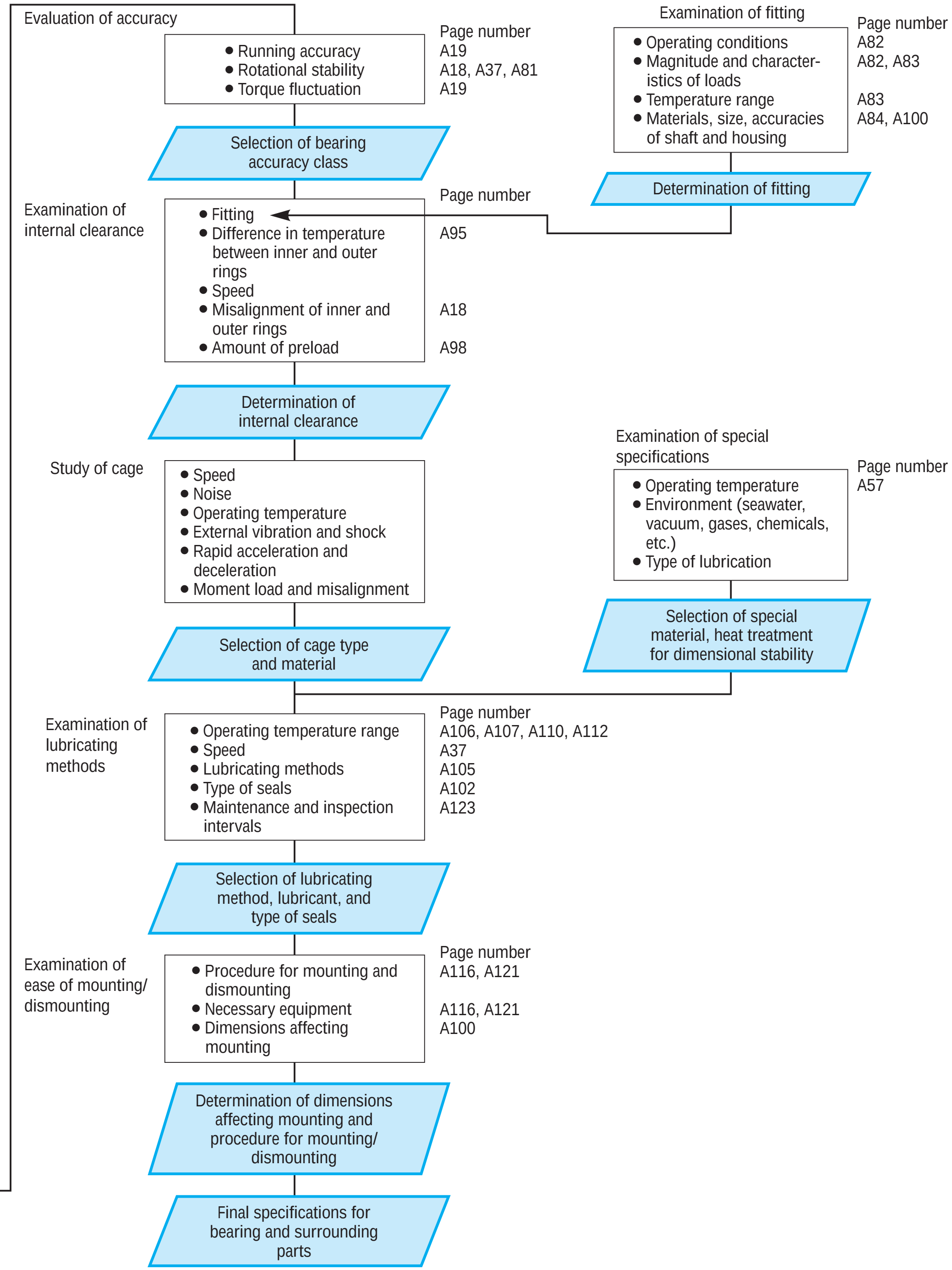


Fig. 2.1 Flow Chart for Selection of Rolling Bearings

3. SELECTION OF BEARING TYPES

3.1 Allowable Bearing Space

The allowable space for a rolling bearing and its adjacent parts is generally limited so the type and size of the bearing must be selected within such limits. In most cases, the shaft diameter is fixed first by the machine design; therefore, the bearing is often selected based on its bore size. For rolling bearings, there are numerous standardized dimension series and types, and the selection of the optimum bearing from among them is necessary. Fig. 3.1 shows the dimension series of radial bearings and corresponding bearing types.

3.2 Load Capacity and Bearing Types

The axial load carrying capacity of a bearing is closely related to the radial load capacity (see Page A24) in a manner that depends on the bearing design as shown in Fig. 3.2. This figure makes it clear that when bearings of the same dimension series are compared, roller bearings have a higher load capacity than ball bearings and are superior if shock loads exist.

3.3 Permissible Speed and Bearing Types

The maximum speed of rolling bearings varies depending, not only the type of bearing, but also its size, type of cage, loads, lubricating method, heat dissipation, etc. Assuming the common oil bath lubrication method, the bearing types are roughly ranked from higher speed to lower as shown in Fig. 3.3.

3.4 Misalignment of Inner/Outer Rings and Bearing Types

Because of deflection of a shaft caused by applied loads, dimensional error of the shaft and housing, and mounting errors, the inner and outer rings are slightly misaligned. The permissible misalignment varies depending on the bearing type and operating conditions, but usually it is a small angle less than 0.0012 radian (4').

When a large misalignment is expected, bearings having a self-aligning capability, such as self-aligning ball bearings, spherical roller bearings, and certain bearing units should be selected (Figs. 3.4 and 3.5).

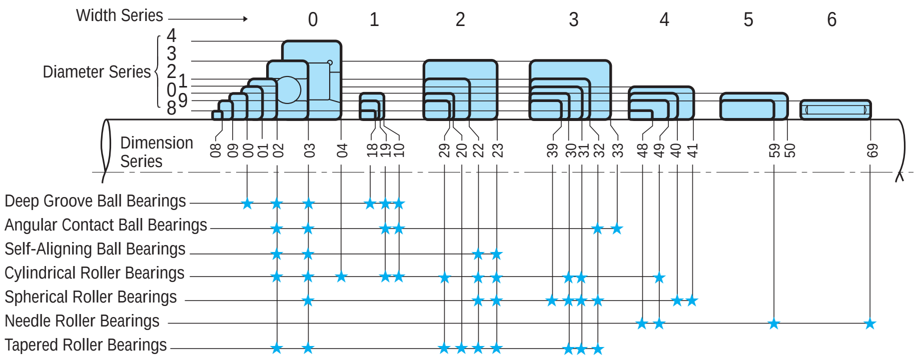
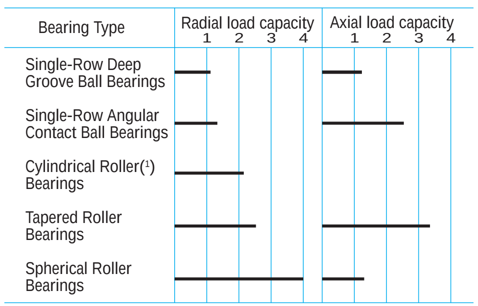


Fig. 3.1 Dimension Series of Radial Bearings



Note(1) The bearings with ribs can take some axial loads.

Fig. 3.2 Relative Load Capacities of Various Bearing Types

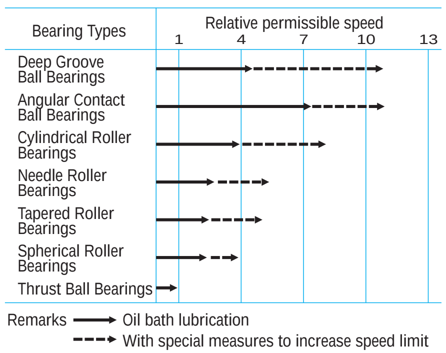


Fig. 3.3 Relative Permissible Speeds of Various Bearing Types

Permissible bearing misalignment is given at the beginning of the dimensional tables for each bearing type.

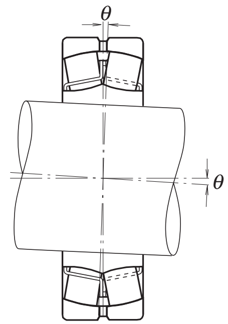


Fig. 3.4 Permissible Misalignment of Spherical Roller Bearings

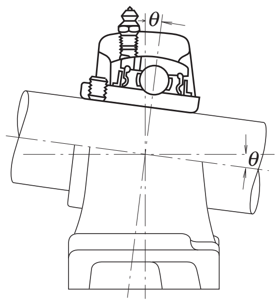


Fig. 3.5 Permissible Misalignment of Ball Bearing Units

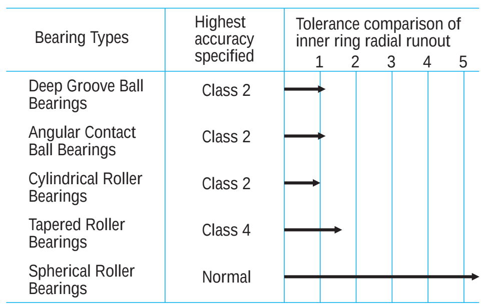


Fig. 3.6 Relative Inner Ring Radial Runout of Highest Accuracy Class for Various Bearing Types

3.5 Rigidity and Bearing Types

When loads are imposed on a rolling bearing, some elastic deformation occurs in the contact areas between the rolling elements and raceways. The rigidity of the bearing is determined by the ratio of bearing load to the amount of elastic deformation of the inner and outer rings and rolling elements. For the main spindles of machine tools, it is necessary to have high rigidity of the bearings together with the rest of the spindle. Consequently, since roller bearings are deformed less by load, they are more often selected than ball bearings. When extra high rigidity is required, bearings are given a preload, which means that they have a negative clearance. Angular contact ball bearings and tapered roller bearings are often preloaded.

3.6 Noise and Torque of Various Bearing Types

Since rolling bearings are manufactured with very high precision, noise and torque are minimal. For deep groove ball bearings and cylindrical roller bearings particularly, the noise level is sometimes specified depending on their purpose. For high precision miniature ball bearings, the starting torque is specified. Deep groove ball bearings are recommended for applications in which low noise and torque are required, such as motors and instruments.

3.7 Running Accuracy and Bearing Types

For the main spindles of machine tools that require high running accuracy or high speed applications like superchargers, high precision bearings of Class 5, 4 or 2 are usually used.

The running accuracy of rolling bearings is specified in various ways, and the specified accuracy classes vary depending on the bearing type. A comparison of the inner ring radial runout for the highest running accuracy specified for each bearing type is shown in Fig. 3.6.

For applications requiring high running accuracy, deep groove ball bearings, angular contact ball bearings, and cylindrical roller bearings are most suitable.

3.8 Mounting and Dismounting of Various Bearing Types

Separable types of bearings like cylindrical roller bearings, needle roller bearings and tapered roller bearings are convenient for mounting and dismounting. For machines in which bearings are mounted and dismounted rather often for periodic inspection, these types of bearings are recommended. Also, self-aligning ball bearings and spherical roller bearings (small ones) with tapered bores can be mounted and dismounted relatively easily using sleeves.

4. SELECTION OF BEARING ARRANGEMENT

In general, shafts are supported by only two bearings. When considering the bearing mounting arrangement, the following items must be investigated:

(1) Expansion and contraction of the shaft caused by temperature variations.
(2) Ease of bearing mounting and dismounting.
(3) Misalignment of the inner and outer rings caused by deflection of the shaft or mounting error.
(4) Rigidity of the entire system including bearings and preloading method.
(5) Capability to sustain the loads at their proper positions and to transmit them.

4.1 Fixed-End and Free-End Bearings

Among the bearings on a shaft, only one can be a "fixed-end" bearing that is used to fix the shaft axially. For this fixed-end bearing, a type which can carry both radial and axial loads must be selected.

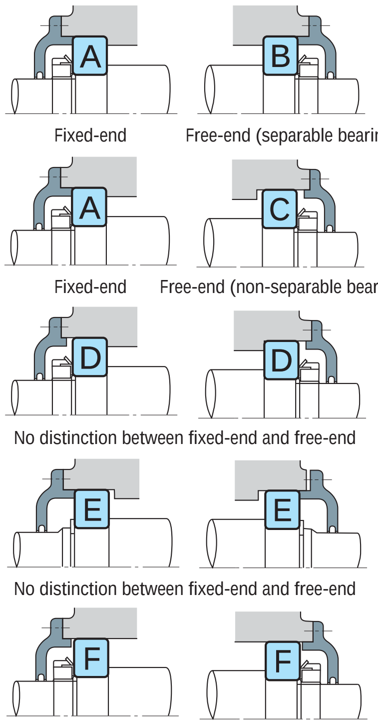
Bearings other than the fixed-end one must be "free-end" bearings that carry only radial loads to relieve the shaft's thermal elongation and contraction.

If measures to relieve a shaft's thermal elongation and contraction are insufficient, abnormal axial loads are applied to the bearings, which can cause premature failure.

For free-end bearings, cylindrical roller bearings or needle roller bearings with separable inner and outer rings that are free to move axially (NU, N types, etc.) are recommended. When these types are used, mounting and dismounting are also easier.

When non-separable types are used as free-end bearings, usually the fit between the outer ring and housing is loose to allow axial movement of the running shaft together with the bearing. Sometimes, such elongation is relieved by a loose fitting between the inner ring and shaft.

When the distance between the bearings is short and the influence of the shaft elongation and contraction is negligible, two opposed angular contact ball bearings or tapered roller bearings are used. The axial clearance (possible axial movement) after the mounting is adjusted using nuts or shims.



BEARING A
- Deep Groove Ball Bearing
- Matched Angular Contact Ball Bearing
- Double-Row Angular Contact Ball Bearing
- Self-Aligning Ball Bearing
- Cylindrical Roller Bearing with Ribs (NH, NUP types)
- Double-Row Tapered Roller Bearing
- Spherical Roller Bearing

BEARING B
- Cylindrical Roller Bearing (NU, N types)
- Needle Roller Bearing (NA type, etc.)

BEARING C(1)
- Deep Groove Ball Bearing
- Matched Angular Contact Ball Bearing (back-to-back)
- Double-Row Angular Contact Ball Bearing
- Self-Aligning Ball Bearing
- Double-Row Tapered Roller Bearing (KBE type)
- Spherical Roller Bearing

BEARING D,E(2)
- Angular Contact Ball Bearing
- Tapered Roller Bearing
- Magneto Bearing
- Cylindrical Roller Bearing (NJ, NF types)

BEARING F
- Deep Groove Ball Bearing
- Self-Aligning Ball Bearing
- Spherical Roller Bearing

Notes: (1) In the figure, shaft elongation and contraction are relieved at the outside surface of the outer ring, but sometimes it is done at the bore.
(2) For each type, two bearings are used in opposition.

Fig. 4.1 Bearing Mounting Arrangements and Bearing Types

The distinction between free-end and fixed-end bearings and some possible bearing mounting arrangements for various bearing types are shown in Fig. 4.1.

4.2 Example of Bearing Arrangements

Some representative bearing mounting arrangements considering preload and rigidity of the entire assembly, shaft elongation and contraction, mounting error, etc. are shown in Table 4.1.

Table 4. 1 Representative Bearing Mounting Arrangements and Application Examples

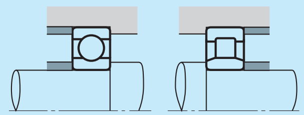
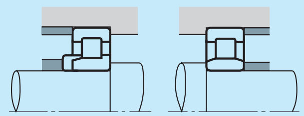
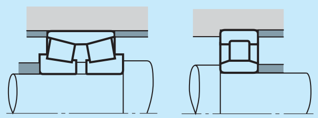
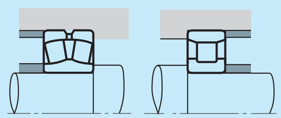
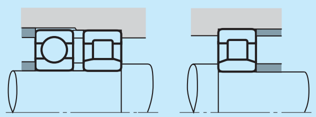
Bearing Arrangements (Fixed-end / Free-end)	Remarks	Application Examples
	◯This is a common arrangement in which abnormal loads are not applied to bearings even if the shaft expands or contracts. ◯If the mounting error is small, this is suitable for high speeds.	Medium size electric motors, blowers
	◯This can withstand heavy loads and shock loads and can take some axial load. ◯Every type of cylindrical roller bearing is separable. This is helpful when interference is necessary for both the inner and outer rings.	Traction motors for rolling stock
	◯This is used when loads are relatively heavy. ◯For maximum rigidity of the fixed-end bearing, it is a back-to-back type. ◯Both the shaft and housing must have high accuracy and the mounting error must be small.	Table rollers for steel mills, main spindles of lathes
	◯This is also suitable when interference is necessary for both the inner and outer rings. Heavy axial loads cannot be applied.	Calender rolls of paper making machines, axles of diesel locomotives
	◯This is suitable for high speeds and heavy radial loads. Moderate axial loads can also be applied. ◯It is necessary to provide some clearance between the outer ring of the deep groove ball bearing and the housing bore in order to avoid subjecting it to radial loads.	Reduction gears in diesel locomotives

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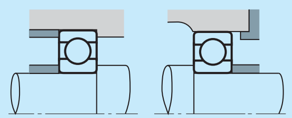
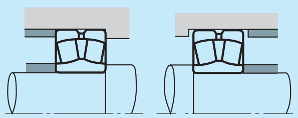
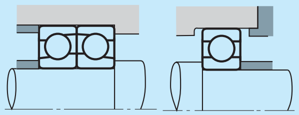
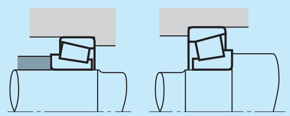
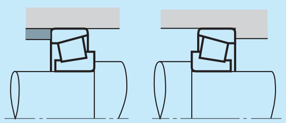
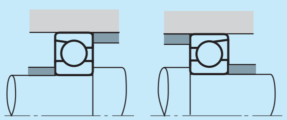
Table 4. 1 Representative Bearing Mounting Arrangements and Application Examples (cont'd)

Bearing Arrangements (Fixed-end / Free-end)	Remarks	Application Examples
	◯This is the most common arrangement. ◯It can sustain not only radial loads, but moderate axial loads also.	Double suction volute pumps, automotive transmissions
	◯This is the most suitable arrangement when there is mounting error or shaft deflection. ◯It is often used for general and industrial applications in which heavy loads are applied.	Speed reducers, table rollers of steel mills, wheels for overhead travelling cranes
	◯This is suitable when there are rather heavy axial loads in both directions. ◯Double row angular contact bearings may be used instead of a arrangement of two angular contact ball bearings.	Worm gear reducers
When there is no distinction between fixed-end and free-end	**Remarks**	**Application Examples**
 Back-to-back mounting  Face-to-face mounting	◯This arrangement is widely used since it can withstand heavy loads and shock loads. ◯The back-to-back arrangement is especially good when the distance between bearings is short and moment loads are applied. ◯Face-to-face mounting makes mounting easier when interference is necessary for the inner ring. In general, this arrangement is good when there is mounting error. ◯To use this arrangement with a preload, affection must be paid to the amount of preload and clearance adjustment.	Pinion shafts of automotive differential gears, automotive front and rear axles, worm gear reducers
 Back-to-back mounting	◯This is used at high speeds when radial loads are not so heavy and axial loads are relatively heavy. ◯It provides good rigidity of the shaft by preloading. ◯For moment loads, back-to-back mounting is better than face-to-face mounting.	Grinding wheel shafts

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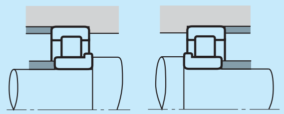
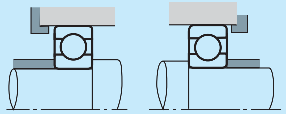
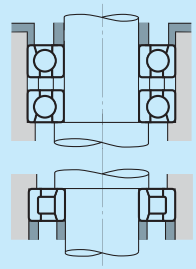
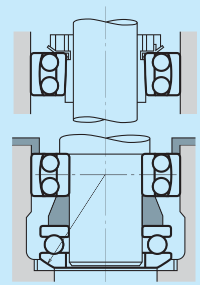
When there is no distinction between fixed-end and free-end	Remarks	Application Examples
 NJ + NJ mounting	◯This can withstand heavy loads and shock loads. ◯It can be used if interference is necessary for both the inner and outer rings. ◯Care must be taken so the axial clearance doesn't become too small during running. ◯NF type + NF type mounting is also possible.	Final reduction gears of construction machines
	◯Sometimes a spring is used at the side of the outer ring of one bearing.	Small electric motors, small speed reducers, small pumps
Vertical arrangements	**Remarks**	**Application Examples**
	◯Matched angular contact ball bearings are on the fixed end. ◯Cylindrical roller bearing is on the free end.	Vertical electric motors
	◯The spherical center of the self-aligning seat must coincide with that of the self-aligning ball bearing. ◯The upper bearing is on the free end.	Vertical openers (spinning and weaving machines)

5. SELECTION OF BEARING SIZE

5.1 Bearing Life

The various functions required of rolling bearings vary according to the bearing application. These functions must be performed for a prolonged period. Even if bearings are properly mounted and correctly operated, they will eventually fail to perform satisfactorily due to an increase in noise and vibration, loss of running accuracy, deterioration of grease, or fatigue flaking of the rolling surfaces.

Bearing life, in the broad sense of the term, is the period during which bearings continue to operate and to satisfy their required functions. This bearing life may be defined as noise life, abrasion life, grease life, or rolling fatigue life, depending on which one causes loss of bearing service.

Aside from the failure of bearings to function due to natural deterioration, bearings may fail when conditions such as heat-seizure, fracture, scoring of the rings, damage of the seals or the cage, or other damage occurs.

Conditions such as these should not be interpreted as normal bearing failure since they often occur as a result of errors in bearing selection, improper design or manufacture of the bearing surroundings, incorrect mounting, or insufficient maintenance.

5.1.1 Rolling Fatigue Life and Basic Rating Life

When rolling bearings are operated under load, the raceways of their inner and outer rings and rolling elements are subjected to repeated cyclic stress. Because of metal fatigue of the rolling contact surfaces of the raceways and rolling elements, scaly particles may separate from the bearing material (Fig. 5.1). This phenomenon is called "flaking". Rolling fatigue life is represented by the total number of revolutions at which time the bearing surface will start flaking due to stress. This is called fatigue life. As shown in Fig. 5.2, even for seemingly identical bearings, which are of the same type, size, and material and receive the same heat treatment and other processing, the rolling fatigue life varies greatly even under identical operating conditions. This is because the flaking of materials due to fatigue is subject to many other variables. Consequently, "basic rating life", in which rolling fatigue life is treated as a statistical phenomenon, is used in preference to actual rolling fatigue life.

Suppose a number of bearings of the same type are operated individually under the same conditions. After a certain period of time, 10 % of them fail as a result of flaking caused by rolling fatigue. The total number of revolutions at this point is defined as the basic rating life or, if the speed is constant, the basic rating life is often expressed by the total number of operating hours completed when 10 % of the bearings become inoperable due to flaking.

In determining bearing life, basic rating life is often the only factor considered. However, other factors must also be taken into account. For example, the grease life of grease-prelubricated bearings (refer to Section 12, Lubrication, Page A107) can be estimated. Since noise life and abrasion life are judged according to individual standards for different applications, specific values for noise or abrasion life must be determined empirically.

5.2 Basic Load Rating and Fatigue Life

5.2.1 Basic Load Rating

The basic load rating is defined as the constant load applied on bearings with stationary outer rings that the inner rings can endure for a rating life of one million revolutions (10^6 rev). The basic load rating of radial bearings is defined as a central radial load of constant direction and magnitude, while the basic load rating of thrust bearings is defined as an axial load of constant magnitude in the same direction as the central axis. The load ratings are listed under C_r for radial bearings and C_a for thrust bearings in the dimension tables.

5.2.2 Machinery in which Bearings are Used and Projected Life

It is not advisable to select bearings with unnecessarily high load ratings, for such bearings may be too large and uneconomical. In addition, the bearing life alone should not be the deciding factor in the selection of bearings. The strength, rigidity, and design of the shaft on which the bearings are to be mounted should also be considered. Bearings are used in a wide range of applications and the design life varies with specific applications and operating conditions. Table 5.1 gives an empirical fatigue life factor derived from customary operating experience for various machines. Also refer to Table 5.2.

Fig. 5.1 Example of Flaking

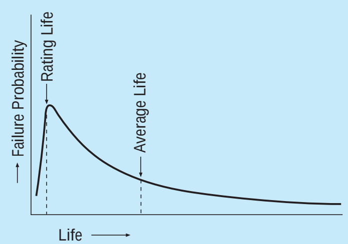


Fig. 5.2 Failure Probability and Bearing Life

Table 5. 1 Fatigue Life Factor f_h for Various Bearing Applications

Operating Periods	Fatigue Life Factor f_h ~3	2~4	3~5	4~7	6~
Infrequently used or only for short periods	·Small motors for home appliances like vacuum cleaners and washing machines ·Hand power tools	·Agricultural equipment			
Used only occasionally but reliability is important		·Motors for home heaters and air conditioners ·Construction equipment	·Conveyors ·Elevator cable sheaves		
Used intermittently for relatively long periods	·Rolling mill roll necks	·Small motors ·Deck cranes ·General cargo cranes ·Pinion stands ·Passenger cars	·Factory motors ·Machine tools ·Transmissions ·Vibrating screens ·Crushers	·Crane sheaves ·Compressors ·Specialized transmissions	
Used intermittently for more than eight hours daily		·Escalators	·Centrifugal separators ·Air conditioning equipment ·Blowers ·Woodworking machines ·Large motors ·Axle boxes on railway rolling stock	·Mine hoists ·Press flywheels ·Railway traction motors ·Locomotive axle boxes	·Paper making machines
Used continuously and high reliability is important					·Waterworks pumps ·Electric power stations ·Mine draining pumps

5.2.3 Selection of Bearing Size Based on Basic Load Rating

The following relation exists between bearing load and basic rating life:

For ball bearings $\quad L = \left(\frac{C}{P}\right)^3$ .... **(5.1)**

For roller bearings $\quad L = \left(\frac{C}{P}\right)^{\frac{10}{3}}$ .... **(5.2)**

where L : Basic rating life (10^6 rev)
P : Bearing load (equivalent load) (N), {kgf} ....(Refer to Page A30)
C : Basic load rating (N), {kgf}
For radial bearings, C is written C_r
For thrust bearings, C is written C_a

In the case of bearings that run at a constant speed, it is convenient to express the fatigue life in terms of hours. In general, the fatigue life of bearings used in automobiles and other vehicles is given in terms of mileage.

By designating the basic rating life as L_h (h), bearing speed as n (min^{-1}), fatigue life factor as f_h, and speed factor as f_n, the relations shown in Table 5.2 are obtained:

Table 5. 2 Basic Rating Life, Fatigue Life Factor and Speed Factor

Life Parameters	Ball Bearings	Roller Bearings
Basic Rating Life	$L_h = \frac{10^6}{60n}\left(\frac{C}{P}\right)^3 = 500 f_h^{\,3}$	$L_h = \frac{10^6}{60n}\left(\frac{C}{P}\right)^{\frac{10}{3}} = 500 f_h^{\,\frac{10}{3}}$
Fatigue Life Factor	$f_h = f_n \frac{C}{P}$	$f_h = f_n \frac{C}{P}$
Speed Factor	$f_n = \left(\frac{10^6}{500\times 60n}\right)^{\frac{1}{3}}$ $= (0.03n)^{-\frac{1}{3}}$	$f_n = \left(\frac{10^6}{500\times 60n}\right)^{\frac{3}{10}}$ $= (0.03n)^{-\frac{3}{10}}$

n, f_n······Fig. 5.3 (See Page A26), Appendix Table 12 (See Page C24)
L_h, f_h····Fig. 5.4 (See Page A26), Appendix Table 13 (See Page C25)

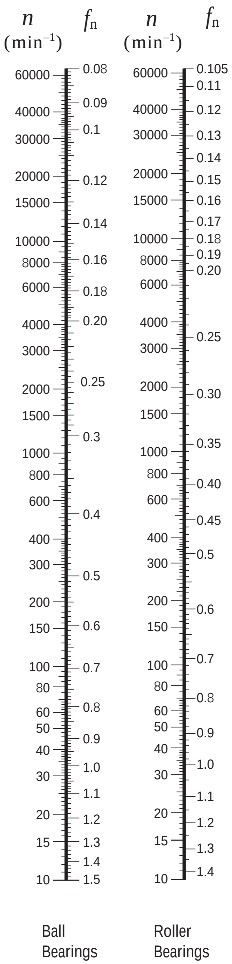


Fig. 5.3 Bearing Speed and Speed Factor

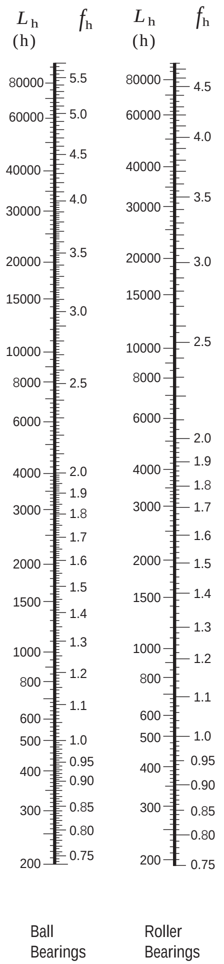


Fig. 5.4 Fatigue Life Factor and Fatigue Life

If the bearing load P and speed n are known, determine a fatigue life factor f_h appropriate for the projected life of the machine and then calculate the basic load rating C by means of the following equation.

$$C = \frac{f_h \cdot P}{f_n} \quad \text{..................} \textbf{(5.3)}$$

A bearing which satisfies this value of C should then be selected from the bearing tables.

5.2.4 Temperature Adjustment for Basic Load Rating

If rolling bearings are used at high temperature, the hardness of the bearing steel decreases. Consequently, the basic load rating, which depends on the physical properties of the material, also decreases. Therefore, the basic load rating should be adjusted for the higher temperature using the following equation:

$$C_t = f_t \cdot C \quad \text{..................} \textbf{(5.4)}$$

where C_t : Basic load rating after temperature correction (N), {kgf}

f_t : Temperature factor (See Table 5.3.)

C : Basic load rating before temperature adjustment (N), {kgf}

If large bearings are used at higher than 120°C, they must be given special dimensional stability heat treatment to prevent excessive dimensional changes. The basic load rating of bearings given such special dimensional stability heat treatment may become lower than the basic load rating listed in the bearing tables.

Table 5.3 Temperature Factor f_t

Bearing Temperature °C	125	150	175	200	250
Temperature Factor f_t	1.00	1.00	0.95	0.90	0.75

5.2.5 Correction of Basic Rating Life

As described previously, the basic equations for calculating the basic rating life are as follows:

For ball bearings $L_{10} = \left(\frac{C}{P}\right)^3$ .... **(5.5)**

For roller bearings $L_{10} = \left(\frac{C}{P}\right)^{\frac{10}{3}}$ .... **(5.6)**

The L_{10} life is defined as the basic rating life with a statistical reliability of 90%. Depending on the machines in which the bearings are used, sometimes a reliability higher than 90% may be required. However, recent improvements in bearing material have greatly extended the fatigue life. In addition, the developent of the Elasto-Hydrodynamic Theory of Lubrication proves that the thickness of the lubricating film in the contact zone between rings and rolling elements greatly influences bearing life. To reflect such improvements in the calculation of fatigue life, the basic rating life is adjusted using the following adjustment factors:

$$L_{na} = a_1\, a_2\, a_3\, L_{10} \quad \text{..........................} \textbf{(5.7)}$$

where L_{na} : Adjusted rating life in which reliability, material improvements, lubricating conditions, etc. are considered

L_{10} : Basic rating life with a reliability of 90%

a_1 : Life adjustment factor for reliability

a_2 : Life adjustment factor for special bearing properties

a_3 : Life adjustment factor for operating conditions

The life adjustment factor for reliability, a_1, is listed in Table 5.4 for reliabilities higher than 90%.
The life adjustment factor for special bearing properties, a_2, is used to reflect improvements in bearing steel.
NSK now uses vacuum degassed bearing steel, and the results of tests by NSK show that life is greatly improved when compared with earlier materials. The basic load ratings C_r and C_a listed in the bearing tables were calculated considering the extended life achieved by improvements in materials and manufacturing techniques. Consequently, when estimating life using Equation (5.7), it is sufficient to assume that is greater than one.

Table 5.4 Reliability Factor a_1

Reliability (%)	90	95	96	97	98	99
a_1	1.00	0.62	0.53	0.44	0.33	0.21

The life adjustment factor for operating conditions a_3 is used to adjust for various factors, particularly lubrication. If there is no misalignment between the inner and outer rings and the thickness of the lubricating film in the contact zones of the bearing is sufficient, it is possible for a_3 to be greater than one; however, a_3 is less than one in the following cases:

- When the viscosity of the lubricant in the contact zones between the raceways and rolling elements is low.
- When the circumferential speed of the rolling elements is very slow.
- When the bearing temperature is high.
- When the lubricant is contaminated by water or foreign matter.
- When misalignment of the inner and outer rings is excessive.

It is difficult to determine the proper value for a_3 for specific operating conditions because there are still many unknowns. Since the special bearing property factor a_2 is also influenced by the operating conditions, there is a proposal to combine a_2 and a_3 into one quantity($a_2 \times a_3$), and not consider them independently. In this case, under normal lubricating and operating conditions, the product ($a_2 \times a_3$) should be assumed equal to one. However, if the viscosity of the lubricant is too low, the value drops to as low as 0.2.
If there is no misalignment and a lubricant with high viscosity is used so sufficient fluid-film thickness is secured, the product of ($a_2 \times a_3$) may be about two.

When selecting a bearing based on the basic load rating, it is best to choose an a_1 reliability factor appropriate for the projected use and an empirically determined C/P or f_h value derived from past results for lubrication, temperature, mounting conditions, etc. in similar machines.

The basic rating life equations (5.1), (5.2), (5.5), and (5.6) give satisfactory results for a broad range of bearing loads. However, extra heavy loads may cause detrimental plastic deformation at ball/raceway contact points. When P_r exceeds C_{0r} (Basic static load rating) or 0.5 C_r, whichever is smaller, for radial bearings or P_a exceeds 0.5 C_a for thrust bearings, please consult NSK to establish the applicablity of the rating fatigue life equations.

5.3 Calculation of Bearing Loads

The loads applied on bearings generally include the weight of the body to be supported by the bearings, the weight of the revolving elements themselves, the transmission power of gears and belting, the load produced by the operation of the machine in which the bearings are used, etc. These loads can be theoretically calculated, but some of them are difficult to estimate. Therefore, it becomes necessary to correct the estimated using empirically derived data.

5.3.1 Load Factor

When a radial or axial load has been mathematically calculated, the actual load on the bearing may be greater than the calculated load because of vibration and shock present during operation of the machine. The actual load may be calculated using the following equation:

$$\left.\begin{array}{l} F_r = f_w \cdot F_{rc} \\ F_a = f_w \cdot F_{ac} \end{array}\right\} \quad \ldots\ldots(5.8)$$

where F_r, F_a : Loads applied on bearing (N), {kgf}

F_{rc}, F_{ac} : Theoretically calculated load (N), {kgf}

f_w : Load factor

The values given in Table 5.5 are usually used for the load factor f_w.

Table 5. 5 Values of Load Factor f_w

Operating Conditions	Typical Applications	f_w
Smooth operation free from shocks	Electric motors, Machine tools, Air conditioners	1 to 1.2
Normal operation	Air blowers, Compressors, Elevators, Cranes, Paper making machines	1.2 to 1.5
Operation accompanied by shock and vibration	Construction equipment, Crushers, Vibrating screens, Rolling mills	1.5 to 3

5.3.2 Bearing Loads in Belt or Chain Transmission Applications

The force acting on the pulley or sprocket wheel when power is transmitted by a belt or chain is calculated using the following equations.

$$\left.\begin{array}{l} M = 9\,550\,000 H / n \;\ldots(\mathrm{N\cdot mm}) \\ \;\;\; = \;\;974\,000 H / n \;\ldots\{\mathrm{kgf\cdot mm}\} \end{array}\right\} \quad \ldots\ldots(5.9)$$

$$P_k = M / r \quad \ldots\ldots(5.10)$$

where M : Torque acting on pulley or sprocket wheel (N·mm), {kgf·mm}

P_k : Effective force transmitted by belt or chain (N), {kgf}

H : Power transmitted(kW)

n : Speed ($\mathrm{min^{-1}}$)

r : Effective radius of pulley or sprocket wheel (mm)

When calculating the load on a pulley shaft, the belt tension must be included. Thus, to calculate the actual load K_b in the case of a belt transmission, the effective transmitting power is multiplied by the belt factor f_b, which represents the belt tension. The values of the belt factor f_b for different types of belts are shown in Table 5.6.

$$K_b = f_b \cdot P_k \quad \ldots\ldots(5.11)$$

In the case of a chain transmission, the values corresponding to f_b should be 1.25 to 1.5.

Table 5. 6 Belt Factor f_b

Type of Belt	f_b
Toothed belts	1.3 to 2
V belts	2 to 2.5
Flat belts with tension pulley	2.5 to 3
Flat belts	4 to 5

5.3.3 Bearing Loads in Gear Transmission Applications

The loads imposed on gears in gear transmissions vary according to the type of gears used. In the simplest case of spur gears, the load is calculated as follows:

$$\left.\begin{array}{l} M = 9\,550\,000 H / n \;\ldots(\mathrm{N\cdot mm}) \\ \;\;\; = \;\;974\,000 H / n \;\ldots\{\mathrm{kgf\cdot mm}\} \end{array}\right\} \quad \ldots\ldots(5.12)$$

$$P_k = M / r \quad \ldots\ldots(5.13)$$

$$S_k = P_k \tan\theta \quad \ldots\ldots(5.14)$$

$$K_c = \sqrt{P_k^2 + S_k^2} = P_k \sec\theta \quad \ldots\ldots(5.15)$$

where M : Torque applied to gear (N·mm),{kgf·mm}

P_k : Tangential force on gear (N), {kgf}

S_k : Radial force on gear (N), {kgf}

K_c : Combined force imposed on gear (N), {kgf}

H : Power transmitted (kW)

n : Speed ($\mathrm{min^{-1}}$)

r : Pitch circle radius of drive gear (mm)

θ : Pressure angle

In addition to the theoretical load calculated above, vibration and shock (which depend on how accurately the gear is finished) should be included using the gear factor f_g by multiplying the theoretically calculated load by this factor.
The values of f_g should generally be those in Table 5.7. When vibration from other sources accompanies gear operation, the actual load is obtained by multiplying the load factor by this gear factor.

Table 5. 7 Values of Gear Factor f_g

Gear Finish Accuracy	f_g
Precision ground gears	1 ∼1.1
Ordinary machined gears	1.1∼1.3

5.3.4 Load Distribution on Bearings

In the simple examples shown in Figs. 5.5 and 5.6. The radial loads on bearings Ⅰ and Ⅱ can be calculated using the following equations:

$$F_{C\,\mathrm{I}} = \frac{b}{c} K \quad \ldots\ldots(5.16)$$

$$F_{C\,\mathrm{II}} = \frac{a}{c} K \quad \ldots\ldots(5.17)$$

where $F_{C\,\mathrm{I}}$: Radial load applied on bearing Ⅰ (N), {kgf}

$F_{C\,\mathrm{II}}$: Radial load applied on bearing Ⅱ (N), {kgf}

K : Shaft load (N), {kgf}

When these loads are applied simultaneously, first the radial load for each should be obtained, and then, the sum of the vectors may be calculated according to the load direction.

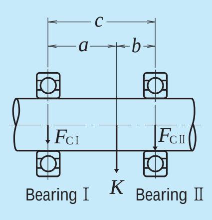


Fig. 5.5 Radial Load Distribution (1)

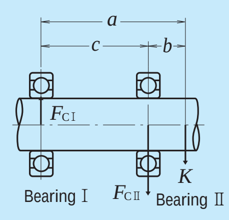


Fig. 5.6 Radial Load Distribution (2)

5.3.5 Average of Fluctuating Load

When the load applied on bearings fluctuates, an average load which will yield the same bearing life as the fluctuating load should be calculated.

(1) When the relation between load and rotating speed is divided into the following steps (Fig. 5.7)

Load F_1 : Speed n_1 ; Operating time t_1
Load F_2 : Speed n_2 ; Operating time t_2
⋮
Load F_n : Speed n_n ; Operating time t_n

Then, the average load F_m may be calculated using the following equation:

$$F_m = \sqrt[p]{\frac{F_1^{\,p} n_1 t_1 + F_2^{\,p} n_2 t_2 + \cdots + F_n^{\,p} n_n t_n}{n_1 t_1 + n_2 t_2 + \cdots\cdots + n_n t_n}} \quad \ldots\ldots(5.18)$$

where F_m : Average fluctuating load (N), {kgf}

p = 3 for ball bearings

p = 10/3 for roller bearings

The average speed n_m may be calculated as follows:

$$n_m = \frac{n_1 t_1 + n_2 t_2 + \cdots + n_n t_n}{t_1 + t_2 + \cdots\cdots + t_n} \quad \text{.......................(5.19)}$$

(2) When the load fluctuates almost linearly (Fig. 5.8), the average load may be calculated as follows:

$$F_m \fallingdotseq \frac{1}{3}(F_{min} + 2F_{max}) \quad \text{.........................(5.20)}$$

where F_{min} : Minimum value of fluctuating load (N), {kgf}

F_{max} : Maximum value of fluctuating load (N), {kgf}

(3) When the load fluctuation is similar to a sine wave (Fig. 5.9), an approximate value for the average load F_m may be calculated from the following equation:

In the case of Fig. 5.9 (a)

$$F_m \fallingdotseq 0.65\, F_{max} \quad \text{......................................(5.21)}$$

In the case of Fig. 5.9 (b)

$$F_m \fallingdotseq 0.75\, F_{max} \quad \text{......................................(5.22)}$$

(4) When both a rotating load and a stationary load are applied (Fig. 5.10).

F_R : Rotating load (N), {kgf}

F_S : Stationary load (N), {kgf}

An approximate value for the average load F_m may be calculated as follows:

a) Where $F_R \geqq F_S$

$$F_m \fallingdotseq F_R + 0.3F_S + 0.2\frac{F_S^{\,2}}{F_R} \quad \text{.........................(5.23)}$$

b) Where $F_R < F_S$

$$F_m \fallingdotseq F_S + 0.3F_R + 0.2\frac{F_R^{\,2}}{F_S} \quad \text{.........................(5.24)}$$

5.4 Equivalent Load

In some cases, the loads applied on bearings are purely radial or axial loads; however, in most cases, the loads are a combination of both. In addition, such loads usually fluctuate in both magnitude and direction. In such cases, the loads actually applied on bearings cannot be used for bearing life calculations; therefore, a hypothetical load that has a constant magnitude and passes through the center of the bearing, and will give the same bearing life that the bearing would attain under actual conditions of load and rotation should be estimated. Such a hypothetical load is called the equivalent load.

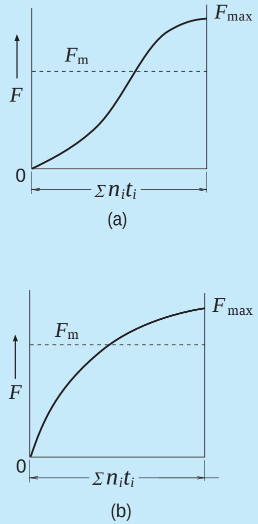


Fig. 5.9 Sinusoidal Load Variation

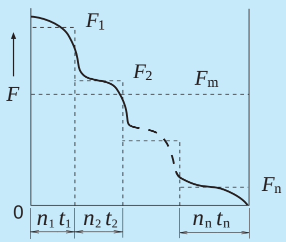


Fig. 5.7 Incremental Load Variation

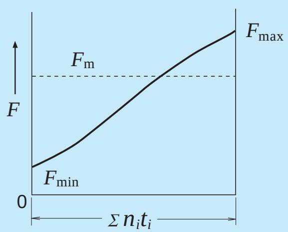


Fig. 5.8 Simple Load Fluctuation

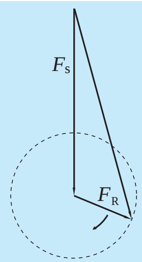


Fig. 5.10 Rotating Load and Stationary Load

5.4.1 Calculation of Equivalent Loads

The equivalent load on radial bearings may be calculated using the following equation:

$$P = XF_r + YF_a \quad \text{......................................(5.25)}$$

where P : Equivalent Load (N), {kgf}

F_r : Radial load (N), {kgf}

F_a : Axial load (N), {kgf}

X : Radial load factor

Y : Axial load factor

The values of X and Y are listed in the bearing tables. The equivalent radial load for radial roller bearings with $\alpha = 0°$ is

$$P = F_r$$

In general, thrust ball bearings cannot take radial loads, but spherical thrust roller bearings can take some radial loads. In this case, the equivalent load may be calculated using the following equation:

$$P = F_a + 1.2F_r \quad \text{.................................(5.26)}$$

where $\frac{F_r}{F_a} \leqq 0.55$

5.4.2 Axial Load Components in Angular Contact Ball Bearings and Tapered Roller Bearings

The effective load center of both angular contact ball bearings and tapered roller bearings is at the point of intersection of the shaft center line and a line representing the load applied on the rolling element by the outer ring as shown in Fig. 5.11. This effective load center for each bearing is listed in the bearing tables.

When radial loads are applied to these types of bearings, a component of load is produced in the axial direction. In order to balance this component load, bearings of the same type are used in pairs, placed face to face or back to back. These axial loads can be calculated using the following equation:

$$F_{a\,i} = \frac{0.6}{Y} F_r \quad \text{.................................(5.27)}$$

where $F_{a\,i}$: Component load in the axial direction (N), {kgf}

F_r : Radial load (N), {kgf}

Y : Axial load factor

Assume that radial loads $F_{r\,\mathrm{I}}$ and $F_{r\,\mathrm{II}}$ are applied on bearings I and II (Fig. 5.12) respectively, and an external axial load F_{ae} is applied as shown. If the axial load factors are Y_{I}, Y_{II} and the radial load factor is X, then the equivalent loads P_{I}, P_{II} may be calculated as follows:

where $F_{ae} + \frac{0.6}{Y_{\mathrm{II}}} F_{r\,\mathrm{II}} \geqq \frac{0.6}{Y_{\mathrm{I}}} F_{r\,\mathrm{I}}$

$$\left.\begin{aligned} P_{\mathrm{I}} &= XF_{r\,\mathrm{I}} + Y_{\mathrm{I}}\left(F_{ae} + \frac{0.6}{Y_{\mathrm{II}}} F_{r\,\mathrm{II}}\right) \\ P_{\mathrm{II}} &= F_{r\,\mathrm{II}} \end{aligned}\right\} \quad \text{..............(5.28)}$$

where $F_{ae} + \frac{0.6}{Y_{\mathrm{II}}} F_{r\,\mathrm{II}} < \frac{0.6}{Y_{\mathrm{I}}} F_{r\,\mathrm{I}}$

$$\left.\begin{aligned} P_{\mathrm{I}} &= F_{r\,\mathrm{I}} \\ P_{\mathrm{II}} &= XF_{r\,\mathrm{II}} + Y_{\mathrm{II}}\left(\frac{0.6}{Y_{\mathrm{I}}} F_{r\,\mathrm{I}} - F_{ae}\right) \end{aligned}\right\} \quad \text{..............(5.29)}$$

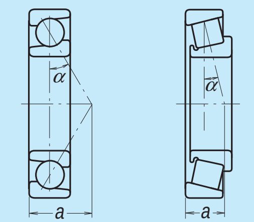


Fig. 5.11 Effective Load Centers

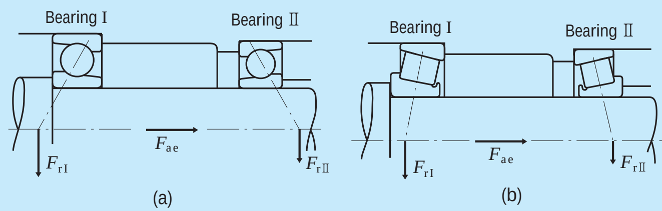


Fig. 5.12 Loads in Opposed Duplex Arrangement

5.5 Static Load Ratings and Static Equivalent Loads

5.5.1 Static Load Ratings

When subjected to an excessive load or a strong shock load, rolling bearings may incur a local permanent deformation of the rolling elements and permanent deformation of the rolling elements and raceway surface if the elastic limit is exceeded. The nonelastic deformation increases in area and depth as the load increases, and when the load exceeds a certain limit, the smooth running of the bearing is impeded.
The basic static load rating is defined as that static load which produces the following calculated contact stress at the center of the contact area between the rolling element subjected to the maximum stress and the raceway surface.

For self-aligning ball bearings	4 600MPa {469kgf/mm²}
For other ball bearings	4 200MPa {428kgf/mm²}
For roller bearings	4 000MPa {408kgf/mm²}

In this most heavily stressed contact area, the sum of the permanent deformation of the rolling element and that of the raceway is nearly 0.0001 times the rolling element's diameter. The basic static load rating C_o is written C_{or} for radial bearings and C_{oa} for thrust bearings in the bearing tables.
In addition, following the modification of the criteria for basic static load rating by ISO, the new C_o values for NSK's ball bearings became about 0.8 to 1.3 times the past values and those for roller bearings about 1.5 to 1.9 times. Consequently, the values of permissible static load factor f_s have also changed, so please pay attention to this.

5.5.2 Static Equivalent Loads

The static equivalent load is a hypothetical load that produces a contact stress equal to the above maximum stress under actual conditions, while the bearing is stationary (including very slow rotation or oscillation), in the area of contact between the most heavily stressed rolling element and bearing raceway. The static radial load passing through the bearing center is taken as the static equivalent load for radial bearings, while the static axial load in the direction coinciding with the central axis is taken as the static equivalent load for thrust bearings.

(a) Static equivalent load on radial bearings

The greater of the two values calculated from the following equations should be adopted as the static equivalent load on radial bearings.

$$P_o = X_oF_r + Y_oF_a \quad \text{.......(5.30)}$$

$$P_o = F_r \quad \text{.......(5.31)}$$

where
P_o : Static equivalent load (N), {kgf}
F_r : Radial load (N), {kgf}
F_a : Axial load (N), {kgf}
X_o : Static radial load factor
Y_o : Static axial load factor

(b)Static equivalent load on thrust bearings

$$P_o = X_oF_r + F_a \qquad \alpha \neq 90° \quad \text{.......(5.32)}$$

where
P_o : Static equivalent load (N), {kgf}
α : Contact angle

When $F_a < X_oF_r$, this equation becomes less accurate. The values of X_o and Y_o for Equations (5.30) and (5.32) are listed in the bearing tables.
The static equivalent load for thrust roller bearings with $\alpha = 90°$ is $P_o = F_a$

5.5.3 Permissible Static Load Factor

The permissible static equivalent load on bearings varies depending on the basic static load rating and also their application and operating conditions.
The permissible static load factor f_s is a safety factor that is applied to the basic static load rating, and it is defined by the ratio in Equation (5.33). The generally recommended values of f_s are listed in Table 5.8. Conforming to the modification of the static load rating, the values of f_s were revised, especially for bearings for which the values of C_o were increased, please keep this in mind when selecting bearings.

$$f_s = \frac{C_o}{P_o} \quad \text{.......(5.33)}$$

where
C_o : Basic static load rating (N), {kgf}
P_o : Static equivalent load (N), {kgf}

For spherical thrust roller bearings, the values of f_s should be greater than 4.

Table 5. 8 Values of Permissible Static Load Factor f_s

Operating Conditions	Lower Limit of f_s	
	Ball Bearings	Roller Bearings
Low-noise applications	2	3
Bearings subjected to vibration and shock loads	1.5	2
Standard operating conditions	1	1.5

5.6 Maximum Permissible Axial Loads for Cylindrical Roller Bearings

Cylindrical roller bearings having inner and outer rings with ribs, loose ribs or thrust collars are capable of sustaining radial loads and limited axial loads simultaneously. The maximum permissible axial load is limited by an abnormal temperature rise or heat seizure due to sliding friction between the end faces of rollers and the rib face, or the rib strength.
The maximum permissible axial load (the load considered the heat generation between the end face of rollers and the rib face) for bearings of diameter series 3 that are continuously loaded and lubricated with grease or oil is shown in Fig. 5.13.

Grease lubrication (Empirical equation)

$$C_A = 9.8f\left\{\frac{900\,(k\cdot d)^2}{n+1\,500} - 0.023\times(k\cdot d)^{2.5}\right\}\text{...(N)}$$
$$= f\left\{\frac{900\,(k\cdot d)^2}{n+1\,500} - 0.023\times(k\cdot d)^{2.5}\right\}\text{.....\{kgf\}} \quad \text{.......(5.34)}$$

Oil lubrication (Empirical equation)

$$C_A = 9.8f\left\{\frac{490\,(k\cdot d)^2}{n+1\,000} - 0.000135\times(k\cdot d)^{3.4}\right\}\text{...(N)}$$
$$= f\left\{\frac{490\,(k\cdot d)^2}{n+1\,000} - 0.000135\times(k\cdot d)^{3.4}\right\}\text{.....\{kgf\}} \quad \text{...(5.35)}$$

where
C_A : Permissible axial load (N), {kgf}
d : Bearing bore diameter (mm)
n : Speed (min^{-1})

f : Load Factor

Loading Interval	Value of f
Continuous	1
Intermittent	2
Short time only	3

k : Size Factor

Diameter series	Value of k
2	0.75
3	1
4	1.2

In the equations (5.34) and (5.35), the examination for the rib strength is excluded. Concerning the rib strength, please consult with NSK.
In addition, for cylindrical roller bearings to have a stable axial-load carrying capacity, the following precautions are required for the bearings and their surroundings:

- Radial load must be applied and the magnitude of radial load should be larger than that of axial load by 2.5 times or more.
- Sufficient lubricant must exist between the roller end faces and ribs.
- Superior extreme-pressure grease must be used.
- Sufficient running-in should be done.
- The mounting accuracy must be good.
- The radial clearance should not be more than necessary.

In cases where the bearing speed is extremely slow, the speed exceeds the limiting speed by more than 50%, or the bore diameter is more than 200mm, careful study is necessary for each case regarding lubrication, cooling, etc. In such a case, please consult with NSK.

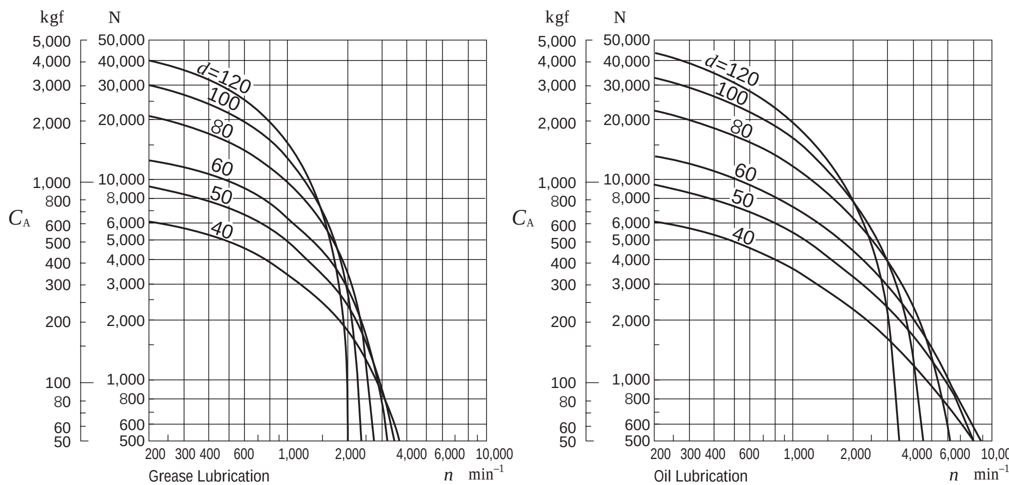


Fig. 5.13 Permissible Axial Load for Cylindrical Roller Bearings
For Diameter Series 3 bearings (k=1.0) operating under a continuous load and lubricated with grease or oil.

5.7 Examples of Bearing Calculations

(Example1)
Obtain the fatigue life factor f_h of single-row deep groove ball bearing **6208** when it is used under a radial load F_r=2 500 N, {255kgf} and speed n =900 min^{-1}.

The basic load rating C_r of **6208** is 29 100N, {2 970kgf} (Bearing Table, Page B10). Since only a radial load is applied, the equivalent load P may be obtained as follows:

$P = F_r = 2\ 500\text{N}$, {255kgf}

Since the speed is n = 900 min^{-1}, the speed factor f_n can be obtained from the equation in Table 5.2 (Page A25) or Fig. 5.3(Page A26).

$f_n = 0.333$

The fatigue life factor f_h, under these conditions, can be calculated as follows:

$$f_h = f_n \frac{C_r}{P} = 0.333 \times \frac{29\ 100}{2\ 500} = 3.88$$

This value is suitable for industrial applications, air conditioners being regularly used, etc., and according to the equation in Table 5.2 or Fig. 5.4 (Page A26), it corresponds approximately to 29 000 hours of service life.

(Example 2)
Select a single-row deep groove ball bearing with a bore diameter of 50 mm and outside diameter under 100 mm that satisfies the following conditions:

Radial load F_r = 3 000N, {306kgf}

Speed n =1 900 min^{-1}

Basic rating life $L_h \geqq 10\ 000$h

The fatigue life factor f_h of ball bearings with a rating fatigue life longer than 10 000 hours is $f_h \geqq 2.72$.
Because f_n = 0.26, $P = F_r$ = 3 000N. {306kgf}

$$f_h = f_n \frac{C_r}{P} = 0.26 \times \frac{C_r}{3\ 000} \geqq 2.72$$

therefore, $C_r \geqq 2.72 \times \dfrac{3\ 000}{0.26} = 31\ 380\text{N}$, {3 200kgf}

Among the data listed in the bearing table on Page B12, **6210** should be selected as one that satisfies the above conditions.

(Example3)
Obtain C_r / P or fatigue life factor f_h when an axial load F_a=1 000N, {102kgf} is added to the conditions of (Example 1)

When the radial load F_r and axial load F_a are applied on single-row deep groove ball bearing **6208**, the dynamic equivalent load P should be calculated in accordance with the following procedure.
Obtain the radial load factor X, axial load factor Y and constant e obtainable, depending on the magnitude of $f_0 F_a / C_{or}$, from the table above the single-row deep groove ball bearing table.
The basic static load rating C_{or} of ball bearing **6208** is 17 900N, {1 820kgf} (Page B10)

$$f_0 F_a / C_{or} = 14.0 \times 1\ 000/17\ 900 = 0.782$$

$$e \fallingdotseq 0.26$$

and $F_a / F_r = 1\ 000/2\ 500 = 0.4 > e$

$X = 0.56$

$Y = 1.67$ (the value of Y is obtained by linear interpolation)

Therefore, the dynamic equivalent load P is

$$P = XF_r + YF_a$$
$$= 0.56 \times 2\ 500 + 1.67 \times 1\ 000$$
$$= 3\ 070\text{N}, \text{ \{313kgf\}}$$

$$\frac{C_r}{P} = \frac{29\ 100}{3\ 070} = 9.48$$

$$f_h = f_n \frac{C_r}{P} = 0.333 \times \frac{29\ 100}{3\ 070} = 3.16$$

This value of f_h corresponds approximately to 15 800 hours for ball bearings.

(Example 4)
Select a spherical roller bearing of series 231 satisfying the following conditions:

Radial load F_r = 45 000N, {4 950kgf}

Axial load F_a = 8 000N, {816kgf}

Speed n = 500min^{-1}

Basic rating life $L_h \geqq 30\ 000$h

The value of the fatigue life factor f_h which makes $L_h \geqq 30\ 000$h is bigger than 3.45 from Fig. 5.4 (Page A26).

The dynamic equivalent load P of spherical roller bearings is given by:

when $F_a / F_r \leqq e$

$$P = XF_r + YX_a = F_r + Y_3 F_a$$

when $F_a / F_r > e$

$$P = XF_r + YF_a = 0.67\ F_r + Y_2 F_a$$

$$F_a / F_r = 8\ 000/45\ 000 = 0.18$$

We can see in the bearing table that the value of e is about 0.3 and that of Y_3 is about 2.2 for bearings of series 231:

Therefore, $P = XF_r + YF_a = F_r + Y_3 F_a$
$= 45\ 000 + 2.2 \times 8\ 000$
$= 62\ 600\text{N}$, {6 380kgf}

From the fatigue life factor f_h, the basic load rating can be obtained as follows:

$$f_h = f_n \frac{C_r}{P} = 0.444 \times \frac{C_r}{62\ 600} \geqq 3.45$$

consequently, $C_r \geqq 490\ 000\text{N}$, {50 000kgf}
Among spherical roller bearings of series 231 satisfying this value of C_r, the smallest is **23126CE4**
(C_r = 505 000N, {51 500kgf})
Once the bearing is determined, substitute the value of Y_3 in the equation and obtain the value of P.

$$P = F_r + Y_3 F_a = 45\ 000 + 2.4 \times 8\ 000$$
$$= 64\ 200\text{N}, \text{ \{6 550kgf\}}$$

$$L_h = 500 \left(f_n \frac{C_r}{P} \right)^{\frac{10}{3}}$$
$$= 500 \left(0.444 \times \frac{505\ 000}{64\ 200} \right)^{\frac{10}{3}}$$
$$= 500 \times 3.49^{\frac{10}{3}} \fallingdotseq 32\ 000\text{ h}$$

(Example 5)
Assume that tapered roller bearings **HR30305DJ** and **HR30206J** are used in a back-to-back arrangement as shown in Fig. 5.14, and the distance between the cup back faces is 50 mm.
Calculate the basic rating life of each bearing when beside the radial load F_r = 5 500N, {561kgf}, axial load F_{ae}=2 000N,{204kgf} are applied to **HR30305DJ** as shown in Fig. 5.14. The speed is 600 min^{-1}.

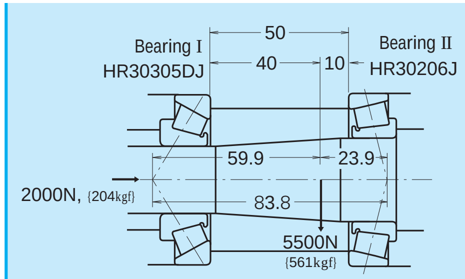


Fig. 5.14 Loads on Tapered Roller Bearings

To distribute the radial load F_r on bearings Ⅰ and Ⅱ, the effective load centers must be located for tapered roller bearings. Obtain the effective load center a for bearings Ⅰ and Ⅱ from the bearing table, then obtain the relative position of the radial load F_r and effective load centers. The result will be as shown in Fig. 5.14. Consequently, the radial load applied on bearings Ⅰ (**HR30305DJ**) and Ⅱ (**HR30206J**) can be obtained from the following equations:

$$F_{r\mathrm{I}} = 5\ 500 \times \frac{23.9}{83.8} = 1\ 569\text{N}, \text{ \{160kgf\}}$$

$$F_{r\mathrm{II}} = 5\ 500 \times \frac{59.9}{83.8} = 3\ 931\text{N}, \text{ \{401kgf\}}$$

From the data in the bearing table, the following values are obtained;

Bearings	Basic dynamic load rating C_r (N) {kgf}	Axial load factor Y_1	Constant e
Bearing Ⅰ (**HR30305DJ**)	38 000 {3 900}	$Y_{\mathrm{I}} = 0.73$	0.83
Bearing Ⅱ (**HR30206J**)	43 000 {4 400}	$Y_{\mathrm{II}} = 1.6$	0.38

When radial loads are applied on tapered roller bearings, an axial load component is produced, which must be considered to obtain the dynamic equivalent radial load (Refer to Paragraph 5.4.2, Page A31).

$$F_{ae} + \frac{0.6}{Y_{\mathrm{II}}} F_{r\,\mathrm{II}} = 2\,000 + \frac{0.6}{1.6} \times 3\,931$$

$$= 3\,474\text{N}, \ \{354\text{kgf}\}$$

$$\frac{0.6}{Y_{\mathrm{I}}} F_{r\,\mathrm{I}} = \frac{0.6}{0.73} \times 1\,569 = 1\,290\text{N}, \ \{132\text{kgf}\}$$

Therefore, with this bearing arrangement, the axial load $F_{ae} + \frac{0.6}{Y_{\mathrm{II}}} F_{r\,\mathrm{II}}$ is applied on bearing Ⅰ but not on bearing Ⅱ.

For bearing Ⅰ

$F_{r\,\mathrm{I}} = 1\,569\text{N}$, {160kgf}

$F_{a\,\mathrm{I}} = 3\,474\text{N}$, {354kgf}

since $F_{a\,\mathrm{I}} / F_{r\,\mathrm{I}} = 2.2 > e = 0.83$

the dynamic equivalent load $P_{\mathrm{I}} = XF_{r\,\mathrm{I}} + Y_{\mathrm{I}} F_{a\,\mathrm{I}}$

$= 0.4 \times 1\,569 + 0.73 \times 3\,474$

$= 3\,164\text{N}$, {323kgf}

The fatigue life factor $f_h = f_n \frac{C_r}{P_{\mathrm{I}}}$

$$= \frac{0.42 \times 38\,000}{3\,164} = 5.04$$

and the rating fatigue life $L_h = 500 \times 5.04^{\frac{10}{3}} = 109\,750\text{h}$

For bearing Ⅱ

since $F_{r\,\mathrm{II}} = 3\,931\text{N}$, {401kgf}, $F_{a\,\mathrm{II}} = 0$

the dynamic equivalent load

$P_{\mathrm{II}} = F_{r\,\mathrm{II}} = 3\,931\text{N}$, {401kgf}

the fatigue life factor

$$f_h = f_n \frac{C_r}{P_{\mathrm{II}}} = \frac{0.42 \times 43\,000}{3\,931} = 4.59$$

and the rating fatigue life $L_h = 500 \times 4.59^{\frac{10}{3}} = 80\,400\text{h}$ are obtained.

Remarks　For face-to-face arrangements (DF type), please contact NSK.

(Example 6)
Select a bearing for a speed reducer under the following conditions:
Operating conditions

Radial load　$F_r = 245\,000\text{N}$, {25 000kgf}

Axial load　$F_a = 49\,000\text{N}$, {5 000kgf}

Speed　$n = 500\text{min}^{-1}$

Size limitation

Shaft diameter: 300mm

Bore of housing: Less than 500mm

In this application, heavy loads, shocks, and shaft deflection are expected; therefore, spherical roller bearings are appropriate.
The following spherical roller bearings satisfy the above size limitation (refer to Page B196)

d	D	B	Bearing No.	Basic dynamic load rating C_r (N)	{kgf}	Constant e	Factor Y_3
300	420	90	**23960 CAE4**	1 230 000	125 000	0.19	3.5
	460	118	**23060 CAE4**	1 920 000	196 000	0.24	2.8
	460	160	**24060 CAE4**	2 310 000	235 000	0.32	2.1
	500	160	**23160 CAE4**	2 670 000	273 000	0.31	2.2
	500	200	**24160 CAE4**	3 100 000	315 000	0.38	1.8

since　$F_a / F_r = 0.20 < e$
the dynamic equivalent load P is

$$P = F_r + Y_3 F_a$$

Judging from the fatigue life factor f_h in Table 5.1 and examples of applications (refer to Page A25), a value of f_h, between 3 and 5 seems appropriate.

$$f_h = f_n \frac{C_r}{P} = \frac{0.444\,C_r}{F_r + Y_3 F_a} = 3 \text{ to } 5$$

Assuming that $Y_3 = 2.1$, then the necessary basic load rating C_r can be obtained

$$C_r = \frac{(F_r + Y_3 F_a) \times (3 \text{ to } 5)}{0.444}$$

$$= \frac{(245\,000 + 2.1 \times 49\,000) \times (3 \text{ to } 5)}{0.444}$$

$$= 2\,350\,000 \text{ to } 3\,900\,000\text{ N},$$

{240 000 to 400 000 kgf}

The bearings which satisfy this range are **23160CAE4**, and **24160CAE4**.

6. LIMITING SPEED

The speed of rolling bearings is subject to certain limits. When bearings are operating, the higher the speed, the higher the bearing temperature due to friction. The limiting speed is the empirically obtained value for the maximum speed at which bearings can be continuously operated without failing from seizure or generation of excessive heat. Consequently, the limiting speed of bearings varies depending on such factors as bearing type and size, cage form and material, load, lubricating method, and heat dissipating method including the design of the bearing's surroundings.
The limiting speeds for bearings lubricated by grease and oil are listed in the bearing tables. The limiting speeds in the tables are applicable to bearings of standard design and subjected to normal loads, i. e. $C/P \geqq 12$ and $F_a/F_r \leqq 0.2$ approximately. The limiting speeds for oil lubrication listed in the bearing tables are for conventional oil bath lubrication.
Some types of lubricants are not suitable for high speed, even though they may be markedly superior in other respects. When speeds are more than 70 percent of the listed limiting speed, it is necessary to select an oil or grease which has good high speed characteristics.

(Refer to)
Table 12.2　Grease Properties (Pages A110 and 111)
Table 12.5　Example of Selection of Lubricant for Bearing Operating Conditions (Page A113)
Table 15.8　Brands and Properties of Lubricating Grease (Pages A138 to A141)

6.1 Correction of Limiting Speed

When the bearing load P exceeds 8 % of the basic load rating C, or when the axial load F_a exceeds 20 % of the radial load F_r, the limiting speed must be corrected by multiplying the limiting speed found in the bearing tables by the correction factor shown in Figs. 6.1 and 6.2.
When the required speed exceeds the limiting speed of the desired bearing; then the accuracy grade, internal clearance, cage type and material, lubrication, etc., must be carefully studied in order to select a bearing capable of the required speed. In such a case, forced-circulation oil lubrication, jet lubrication, oil mist lubrication, or oil-air lubrication must be used.
If all these conditions are considered. The maximum permissible speed may be corrected by multiplying the limiting speed found in the bearing tables by the correction factor shown in Table 6.1. It is recommended that NSK be consulted regarding high speed applications.

6.2 Limiting Speed for Rubber Contact Seals for Ball Bearings

The maximum permissible speed for contact rubber sealed bearings (DDU type) is determined mainly by the sliding surface speed of the inner circumference of the seal. Values for the limiting speed are listed in the bearing tables.

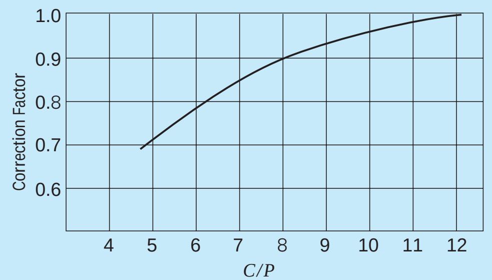


Fig. 6.1 Limiting Speed Correction Factor Variation with Load Ratio

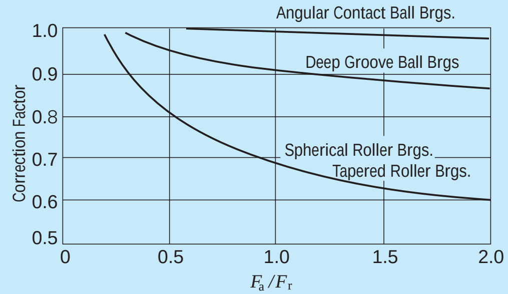


Fig. 6.2 Limiting Speed Correction Factor for Combined Radial and Axial Loads

Table 6.1 Limiting Speed Correction Factor for High-Speed Applications

Bearing Types	Correction Factor
Cylindrical Roller Brgs.(single row)	2
Needle Roller Brgs.(except broad width)	2
Tapered Roller Brgs.	2
Spherical Roller Brgs.	1.5
Deep Grooove Ball Brgs.	2.5
Angular Contact Ball Brgs.(except matched bearings)	1.5

7. BOUNDARY DIMENSIONS AND IDENTIFYING NUMBERS FOR BEARINGS

7.1 Boundary Dimensions and Dimensions of Snap Ring Grooves

7.1.1 Boundary Dimensions

The boundary dimensions of rolling bearings, which are shown in Figs.7.1 through 7.5, are the dimensions that define their external geometry. They include bore diameter d, outside diameter D, width B, bearing width(or height) T, chamfer dimension r, etc. It is necessary to know all of these dimensions when mounting a bearing on a shaft and in a housing. These boundary dimensions have been internationally standardized (ISO15) and adopted by JIS B 1512 (Boundary Dimensions of Rolling Bearings).

The boundary dimensions and dimension series of radial bearings, tapered roller bearings, and thrust bearings are listed in Table 7.1 to 7.3 (Pages A40 to A49).

In these boundary dimension tables, for each bore number, which prescribes the bore diameter, other boundary dimensions are listed for each diameter series and dimension series. A very large number of series are possible; however, not all of them are commercially available so more can be added in the future. Across the top of each bearing table (7.1 to 7.3), representative bearing types and series symbols are shown (refer to Table 7.5, Bearing Series Symbols, Page A55).

The relative cross-sectional dimensions of radial bearings (except tapered roller bearings) and thrust bearings for the various series classifications are shown in Figs. 7.6 and 7.7 respectively.

7.1.2 Dimensions of Snap Ring Grooves and Locating Snap Rings

The dimensions of Snap ring grooves in the outer surfaces of bearings are specified by ISO 464. Also, the dimensions and accuracy of the locating snap rings themselves are specified by ISO 464. The dimensions of snap ring grooves and locating snap ring for bearings of diameter series 8, 9, 0, 2, 3, and 4, are shown in Table 7.4 (Pages A50 to A53).

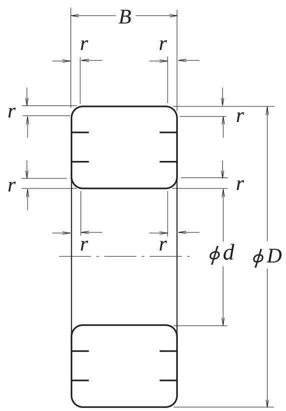


Fig. 7.1 Boundary Dimensions of Radial Ball and Roller Bearings

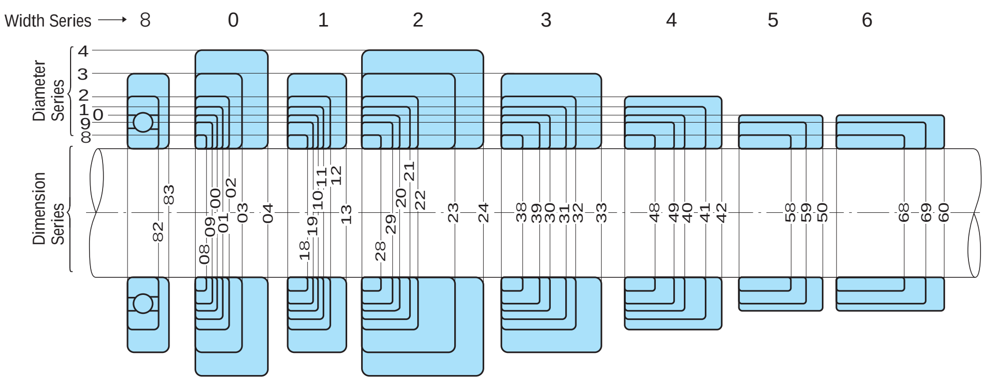


Fig. 7.6 Comparison of Cross Sections of Radial Bearings (except Tapered Roller Bearings) for various Dimensional Series

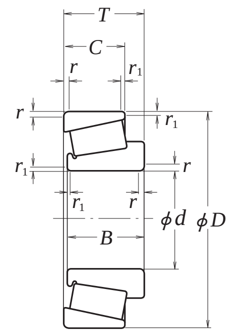


Fig. 7.2 Tapered Roller Bearings

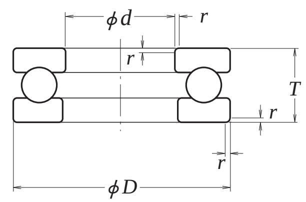


Fig. 7.3 Single-Direction Thrust Ball Bearings

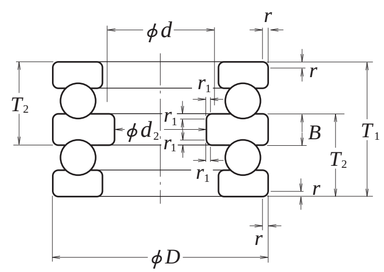


Fig. 7.4 Double-Direction Thrust Ball Bearings

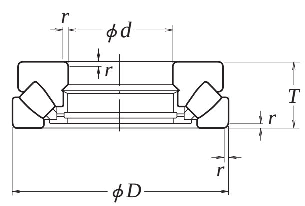


Fig. 7.5 Spherical Thrust Roller Bearings

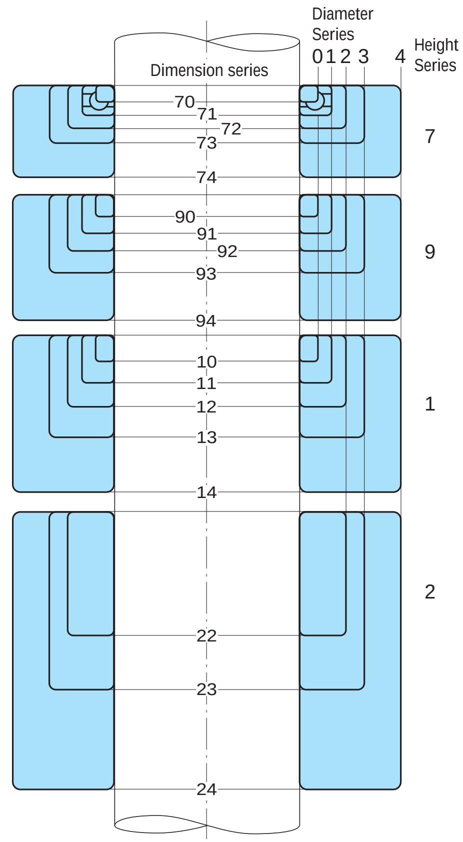


Fig. 7.7 Comparison of Cross Sections of Thrust Bearings (except Diameter Series 5) for Various Dimension Series

Table 7. 1 Boundary Dimensions of Radial Bearings (except Tapered Roller Bearings) — 1 —

Units: mm

Single-Row Ball Brgs.									68										69 79										160	60 70							
Double-Row Ball Brgs.																																					
Cylindrical Roller Brgs.										N28	NN38	NN48							N19	N29	NN39	NN49								N10	N20	NN30	NN40				
Needle Roller Brgs.												NA48										NA49	NA59	NA69													
Spherical Roller Brgs.																					239											230	240				
Bore Number	d	Diameter Series 7					Diameter Series 8										Diameter Series 9											Diameter Series 0									
		D	Dimension Series				D	Dimension Series							Dimension Series		D	Dimension Series							Dimension Series			D	Dimension Series							Dimension Series	
			17	27	37	17~37		08	18	28	38	48	58	68	08	18~68		09	19	29	39	49	59	69	09	19~39	49~69		00	10	20	30	40	50	60	00	10~60
			B			r (min.)		B							r (min.)			B							r (min.)				B							r (min.)	
—	0.6	2	0.8	—	—	0.05	2.5	—	1	—	1.4	—	—	—	—	0.05	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	1	2.5	1	—	—	0.05	3	—	1	—	1.5	—	—	—	—	0.05	4	—	1.6	—	2.3	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—
—	1.5	3	1	—	1.8	0.05	4	—	1.2	—	2	—	—	—	—	0.05	5	—	2	—	2.6	—	—	—	—	0.15	—	6	—	2.5	—	3	—	—	—	—	0.15
2	2	4	1.2	—	2	0.05	5	—	1.5	—	2.3	—	—	—	—	0.08	6	—	2.3	—	3	—	—	—	—	0.15	—	7	—	2.8	—	3.5	—	—	—	—	0.15
—	2.5	5	1.5	—	2.3	0.08	6	—	1.8	—	2.6	—	—	—	—	0.08	7	—	2.5	—	3.5	—	—	—	—	0.15	—	8	—	2.8	—	4	—	—	—	—	0.15
3	3	6	2	2.5	3	0.08	7	—	2	—	3	—	—	—	—	0.1	8	—	3	—	4	—	—	—	—	0.15	—	9	—	3	—	5	—	—	—	—	0.15
4	4	7	2	2.5	3	0.08	9	—	2.5	3.5	4	—	—	—	—	0.1	11	—	4	—	5	—	—	—	—	0.15	—	12	—	4	—	6	—	—	—	—	0.2
5	5	8	2	2.5	3	0.08	11	—	3	4	5	—	—	—	—	0.15	13	—	4	—	6	10	—	—	—	0.2	0.15	14	—	5	—	7	—	—	—	—	0.2
6	6	10	2.5	3	3.5	0.1	13	—	3.5	5	6	—	—	—	—	0.15	15	—	5	—	7	10	—	—	—	0.2	0.15	17	—	6	—	9	—	—	—	—	0.3
7	7	11	2.5	3	3.5	0.1	14	—	3.5	5	6	—	—	—	—	0.15	17	—	5	—	7	10	—	—	—	0.3	0.15	19	—	6	8	10	—	—	—	—	0.3
8	8	12	2.5	—	3.5	0.1	16	—	4	5	6	8	—	—	—	0.2	19	—	6	—	9	11	—	—	—	0.3	0.2	22	—	7	9	11	14	19	25	—	0.3
9	9	14	3	—	4.5	0.1	17	—	4	5	6	8	—	—	—	0.2	20	—	6	—	9	11	—	—	—	0.3	0.3	24	—	7	10	12	15	20	27	—	0.3
00	10	15	3	—	4.5	0.1	19	—	5	6	7	9	—	—	—	0.3	22	—	6	8	10	13	16	22	—	0.3	0.3	26	—	8	10	12	16	21	29	—	0.3
01	12	18	4	—	5	0.2	21	—	5	6	7	9	—	—	—	0.3	24	—	6	8	10	13	16	22	—	0.3	0.3	28	7	8	10	12	16	21	29	0.3	0.3
02	15	21	4	—	5	0.2	24	—	5	6	7	9	—	—	—	0.3	28	—	7	8.5	10	13	18	23	—	0.3	0.3	32	8	9	11	13	17	23	30	0.3	0.3
03	17	23	4	—	5	0.2	26	—	5	6	7	9	—	—	—	0.3	30	—	7	8.5	10	13	18	23	—	0.3	0.3	35	8	10	12	14	18	24	32	0.3	0.3
04	20	27	4	—	5	0.2	32	4	7	8	10	12	16	22	0.3	0.3	37	7	9	11	13	17	23	30	0.3	0.3	0.3	42	8	12	14	16	22	30	40	0.3	0.6
/22	22	—	—	—	—	—	34	4	7	—	10	—	16	22	0.3	0.3	39	7	9	11	13	17	23	30	0.3	0.3	0.3	44	8	12	14	16	22	30	40	0.3	0.6
05	25	32	4	—	5	0.2	37	4	7	8	10	12	16	22	0.3	0.3	42	7	9	11	13	17	23	30	0.3	0.3	0.3	47	8	12	14	16	22	30	40	0.3	0.6
/28	28	—	—	—	—	—	40	4	7	—	10	—	16	22	0.3	0.3	45	7	9	11	13	17	23	30	0.3	0.3	0.3	52	8	12	15	18	24	32	43	0.3	0.6
06	30	37	4	—	5	0.2	42	4	7	8	10	12	16	22	0.3	0.3	47	7	9	11	13	17	23	30	0.3	0.3	0.3	55	9	13	16	19	25	34	45	0.3	1
/32	32	—	—	—	—	—	44	4	7	—	10	—	16	22	0.3	0.3	52	7	10	13	15	20	27	36	0.3	0.6	0.6	58	9	13	16	20	26	35	47	0.3	1
07	35	—	—	—	—	—	47	4	7	8	10	12	16	22	0.3	0.3	55	7	10	13	15	20	27	36	0.3	0.6	0.6	62	9	14	17	20	27	36	48	0.3	1
08	40	—	—	—	—	—	52	4	7	8	10	12	16	22	0.3	0.3	62	8	12	14	16	22	30	40	0.3	0.6	0.6	68	9	15	18	21	28	38	50	0.3	1
09	45	—	—	—	—	—	58	4	7	8	10	13	18	23	0.3	0.3	68	8	12	14	16	22	30	40	0.3	0.6	0.6	75	10	16	19	23	30	40	54	0.6	1
10	50	—	—	—	—	—	65	5	7	10	12	15	20	27	0.3	0.3	72	8	12	14	16	22	30	40	0.3	0.6	0.6	80	10	16	19	23	30	40	54	0.6	1
11	55	—	—	—	—	—	72	7	9	11	13	17	23	30	0.3	0.3	80	9	13	16	19	25	34	45	0.3	1	1	90	11	18	22	26	35	46	63	0.6	1.1
12	60	—	—	—	—	—	78	7	10	12	14	18	24	32	0.3	0.3	85	9	13	16	19	25	34	45	0.3	1	1	95	11	18	22	26	35	46	63	0.6	1.1
13	65	—	—	—	—	—	85	7	10	13	15	20	27	36	0.3	0.6	90	9	13	16	19	25	34	45	0.3	1	1	100	11	18	22	26	35	46	63	0.6	1.1
14	70	—	—	—	—	—	90	8	10	13	15	20	27	36	0.3	0.6	100	10	16	19	23	30	40	54	0.6	1	1	110	13	20	24	30	40	54	71	0.6	1.1
15	75	—	—	—	—	—	95	8	10	13	15	20	27	36	0.3	0.6	105	10	16	19	23	30	40	54	0.6	1	1	115	13	20	24	30	40	54	71	0.6	1.1
16	80	—	—	—	—	—	100	8	10	13	15	20	27	36	0.3	0.6	110	10	16	19	23	30	40	54	0.6	1	1	125	14	22	27	34	45	60	80	0.6	1.1
17	85	—	—	—	—	—	110	9	13	16	19	25	34	45	0.3	1	120	11	18	22	26	35	46	63	0.6	1.1	1.1	130	14	22	27	34	45	60	80	0.6	1.1
18	90	—	—	—	—	—	115	9	13	16	19	25	34	45	0.3	1	125	11	18	22	26	35	46	63	0.6	1.1	1.1	140	16	24	30	37	50	67	90	1	1.5
19	95	—	—	—	—	—	120	9	13	16	19	25	34	45	0.3	1	130	11	18	22	26	35	46	63	0.6	1.1	1.1	145	16	24	30	37	50	67	90	1	1.5
20	100	—	—	—	—	—	125	9	13	16	19	25	34	45	0.3	1	140	13	20	24	30	40	54	71	0.6	1.1	1.1	150	16	24	30	37	50	67	90	1	1.5
21	105	—	—	—	—	—	130	9	13	16	19	25	34	45	0.3	1	145	13	20	24	30	40	54	71	0.6	1.1	1.1	160	18	26	33	41	56	75	100	1	2
22	110	—	—	—	—	—	140	10	16	19	23	30	40	54	0.6	1	150	13	20	24	30	40	54	71	0.6	1.1	1.1	170	19	28	36	45	60	80	109	1	2
24	120	—	—	—	—	—	150	10	16	19	23	30	40	54	0.6	1	165	14	22	27	34	45	60	80	0.6	1.1	1.1	180	19	28	36	46	60	80	109	1	2
26	130	—	—	—	—	—	165	11	18	22	26	35	46	63	0.6	1.1	180	16	24	30	37	50	67	90	1	1.5	1.5	200	22	33	42	52	69	95	125	1.1	2
28	140	—	—	—	—	—	175	11	18	22	26	35	46	63	0.6	1.1	190	16	24	30	37	50	67	90	1	1.5	1.5	210	22	33	42	53	69	95	125	1.1	2
30	150	—	—	—	—	—	190	13	20	24	30	40	54	71	0.6	1.1	210	19	28	36	45	60	80	109	1	2	2	225	24	35	45	56	75	100	136	1.1	2.1
32	160	—	—	—	—	—	200	13	20	24	30	40	54	71	0.6	1.1	220	19	28	36	45	60	80	109	1	2	2	240	25	38	48	60	80	109	145	1.5	2.1
34	170	—	—	—	—	—	215	14	22	27	34	45	60	80	0.6	1.1	230	19	28	36	45	60	80	109	1	2	2	260	28	42	54	67	90	122	160	1.5	2.1
36	180	—	—	—	—	—	225	14	22	27	34	45	60	80	0.6	1.1	250	22	33	42	52	69	95	125	1.1	2	2	280	31	46	60	74	100	136	180	2	2.1
38	190	—	—	—	—	—	240	16	24	30	37	50	67	90	1	1.5	260	22	33	42	52	69	95	125	1.1	2	2	290	31	46	60	75	100	136	180	2	2.1
40	200	—	—	—	—	—	250	16	24	30	37	50	67	90	1	1.5	280	25	38	48	60	80	109	145	1.5	2.1	2.1	310	34	51	66	82	109	150	200	2	2.1
44	220	—	—	—	—	—	270	16	24	30	37	50	67	90	1	1.5	300	25	38	48	60	80	109	145	1.5	2.1	2.1	340	37	56	72	90	118	160	218	2.1	3
48	240	—	—	—	—	—	300	19	28	36	45	60	80	109	1	2	320	25	38	48	60	80	109	145	1.5	2.1	2.1	360	37	56	72	92	118	160	218	2.1	3
52	260	—	—	—	—	—	320	19	28	36	45	60	80	109	1	2	360	31	46	60	75	100	136	180	2	2.1	2.1	400	44	65	82	104	140	190	250	3	4
56	280	—	—	—	—	—	350	22	33	42	52	69	95	125	1.1	2	380	31	46	60	75	100	136	180	2	2.1	2.1	420	44	65	82	106	140	190	250	3	4
60	300	—	—	—	—	—	380	25	38	48	60	80	109	145	1.5	2.1	420	37	56	72	90	118	160	218	2.1	3	3	460	50	74	95	118	160	218	290	4	4
64	320	—	—	—	—	—	400	25	38	48	60	80	109	145	1.5	2.1	440	37	56	72	90	118	160	218	2.1	3	3	480	50	74	95	121	160	218	290	4	4
68	340	—	—	—	—	—	420	25	38	48	60	80	109	145	1.5	2.1	460	37	56	72	90	118	160	218	2.1	3	3	520	57	82	106	133	180	243	325	4	5
72	360	—	—	—	—	—	440	25	38	48	60	80	109	145	1.5	2.1	480	37	56	72	90	118	160	218	2.1	3	3	540	57	82	106	134	180	243	325	4	5
76	380	—	—	—	—	—	480	31	46	60	75	100	136	180	2	2.1	520	44	65	82	106	140	190	250	3	4	4	560	57	82	106	135	180	243	325	4	5
80	400	—	—	—	—	—	500	31	46	60	75	100	136	180	2	2.1	540	44	65	82	106	140	190	250	3	4	4	600	63	90	118	148	200	272	355	5	5
84	420	—	—	—	—	—	520	31	46	60	75	100	136	180	2	2.1	560	44	65	82	106	140	190	250	3	4	4	620	63	90	118	150	200	272	355	5	5
88	440	—	—	—	—	—	540	31	46	60	75	100	136	180	2	2.1	600	50	74	95	118	160	218	290	4	4	4	650	67	94	122	157	212	280	375	5	6
92	460	—	—	—	—	—	580	37	56	72	90	118	160	218	2.1	3	620	50	74	95	118	160	218	290	4	4	4	680	71	100	128	163	218	300	400	5	6
96	480	—	—	—	—	—	600	37	56	72	90	118	160	218	2.1	3	650	54	78	100	128	170	230	308	4	5	5	700	71	100	128	165	218	300	400	5	6
/500	500	—	—	—	—	—	620	37	56	72	90	118	160	218	2.1	3	670	54	78	100	128	170	230	308	4	5	5	720	71	100	128	167	218	300	400	5	6
/530	530	—	—	—	—	—	650	37	56	72	90	118	160	218	2.1	3	710	57	82	106	136	180	243	325	4	5	5	780	80	112	145	185	250	335	450	6	6
/560	560	—	—	—	—	—	680	37	56	72	90	118	160	218	2.1	3	750	60	85	112	140	190	258	345	5	5	5	820	82	115	150	195	258	355	462	6	6
/600	600	—	—	—	—	—	730	42	60	78	98	128	175	236	3	3	800	63	90	118	150	200	272	355	5	5	5	870	85	118	155	200	272	365	488	6	6
/630	630	—	—	—	—	—	780	48	69	88	112	150	200	272	3	4	850	71	100	128	165	218	300	400	5	6	6	920	92	128	170	212	290	388	515	6	7.5
/670	670	—	—	—	—	—	820	48	69	88	112	150	200	272	3	4	900	73	103	136	170	230	308	412	5	6	6	980	100	136	180	230	308	425	560	6	7.5
/710	710	—	—	—	—	—	870	50	74	95	118	160	218	290	4	4	950	78	106	140	180	243	325	438	5	6	6	1030	103	140	185	236	315	438	580	6	7.5
/750	750	—	—	—	—	—	920	54	78	100	128	170	230	308	4	5	1000	80	112	145	185	250	335	450	6	6	6	1090	109	150	195	250	335	462	615	7.5	7.5
/800	800	—	—	—	—	—	980	57	82	106	136	180	243	325	4	5	1060	82	115	150	195	258	355	462	6	6	6	1150	112	155	200	258	345	475	630	7.5	7.5
/850	850	—	—	—	—	—	1030	57	82	106	136	180	243	325	4	5	1120	85	118	155	200	272	365	488	6	6	6	1220	118	165	212	272	365	500	670	7.5	7.5
/900	900	—	—	—	—	—	1090	60	85	112	140	190	258	345	5	5	1180	88	122	165	206	280	375	500	6	6	6	1280	122	170	218	280	375	515	690	7.5	7.5
/950	950	—	—	—	—	—	1150	63	90	118	150	200	272	355	5	5	1250	95	132	175	224	300	400	545	6	7.5	7.5	1360	132	180	236	300	412	560	730	7.5	7.5
/1000	1000	—	—	—	—	—	1220	71	100	128	165	218	300	400	5	6	1320	103	140	185	236	315	438	580	6	7.5	7.5	1420	136	185	243	308	412	560	750	7.5	7.5
/1060	1060	—	—	—	—	—	1280	71	100	128	165	218	300	400	5	6	1400	109	150	195	250	335	462	615	7.5	7.5	7.5	1500	140	195	250	325	438	600	800	9.5	9.5
/1120	1120	—	—	—	—	—	1360	78	106	140	180	243	325	438	5	6	1460	109	150	195	250	335	462	615	7.5	7.5	7.5	1580	145	200	265	345	462	615	825	9.5	9.5
/1180	1180	—	—	—	—	—	1420	78	106	140	180	243	325	438	5	6	1540	115	160	206	272	355	488	650	7.5	7.5	7.5	1660	155	212	272	355	475	650	875	9.5	9.5
/1250	1250	—	—	—	—	—	1500	80	112	145	185	250	335	450	6	6	1630	122	170	218	280	375	515	690	7.5	7.5	7.5	1750	—	218	290	375	500	—	—	—	9.5
/1320	1320	—	—	—	—	—	1600	88	122	165	206	280	375	500	6	6	1720	128	175	230	300	400	545	710	7.5	7.5	7.5	1850	—	230	300	400	530	—	—	—	12
/1400	1400	—	—	—	—	—	1700	95	132	175	224	300	400	545	6	7.5	1820	—	185	243	315	425	—	—	—	9.5	9.5	1950	—	243	315	412	545	—	—	—	12
/1500	1500	—	—	—	—	—	1820	—	140	185	243	315	—	—	—	7.5	1950	—	195	258	335	450	—	—	—	9.5	9.5	2120	—	272	355	462	615	—	—	—	12
/1600	1600	—	—	—	—	—	1950	—	155	200	265	345	—	—	—	7.5	2060	—	200	265	345	462	—	—	—	9.5	9.5	2240	—	280	365	475	630	—	—	—	12
/1700	1700	—	—	—	—	—	2060	—	160	206	272	355	—	—	—	7.5	2180	—	212	280	355	475	—	—	—	9.5	9.5	2360	—	290	375	500	650	—	—	—	15
/1800	1800	—	—	—	—	—	2180	—	165	218	290	375	—	—	—	9.5	2300	—	218	290	375	500	—	—	—	12	12	2500	—	308	400	530	690	—	—	—	15
/1900	1900	—	—	—	—	—	2300	—	175	230	300	400	—	—	—	9.5	2430	—	230	308	400	530	—	—	—	12	12	—	—	—	—	—	—	—	—	—	—
/2000	2000	—	—	—	—	—	2430	—	190	250	325	425	—	—	—	9.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Remarks The chamfer dimensions listed in this table do not necessarily apply to the following chamfers: (a) Chamfers of the grooves in outer rings that have snap ring grooves.
(b) For thin section cylindrical roller bearings, the chamfers on side without rib and bearing bore (in case of an inner ring) or outer surface (in case of an outer ring).
(c) For angular contact ball bearings, the chamfers between the front face and bore (in case of an inner ring) or outer surface (in case of an outer ring).
(d) Chamfers on inner rings of bearings with tapered bores.

Table 7. 1 Boundary Dimensions of Radial Bearings (except Tapered Roller Bearings) — 2 —

Units: mm

Single-Row Ball Brgs.												62 72		622	632						63 73		623	633				64 74		
Double-Row Ball Brgs.												12		42 22	52 53						13		43 23	53 33				104		
Cylindrical Roller Brgs.						NN 31						N 2		N 22	N 32						N 3		N 23	N 33				N 4		
Needle Roller Brgs.																														
Spherical Roller Brgs.						231	241							222	232						213		223							
Bore Number	*d*	Diameter Series 1								Diameter Series 2									Diameter Series 3								Diameter Series 4			
		D	Dimension Series					Dimension Series		*D*	Dimension Series						Dimension Series		*D*	Dimension Series					Dimension Series		*D*	Dimension Series		Dimension Series
			01	11	21	31	41	01	11~41		82	02	12	22	32	42	82	02~42		83	03	13	23	33	83	03~33		04	24	04~24
			B					*r* (min.)			*B*						*r* (min.)			*B*					*r* (min.)			*B*		*r* (min.)
—	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	1.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	2.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	3	—	—	—	—	—	—	—	—	10	2.5	4	—	—	5	—	0.1	0.15	13	—	5	—	—	7	—	0.2	—	—	—	—
4	4	—	—	—	—	—	—	—	—	13	3	5	—	—	7	—	0.15	0.2	16	—	5	—	—	9	—	0.3	—	—	—	—
5	5	—	—	—	—	7	—	—	—	16	3.5	5	—	—	8	—	0.15	0.3	19	—	6	—	—	10	—	0.3	—	—	—	—
6	6	—	—	—	8	10	—	—	—	19	4	6	—	—	10	—	0.2	0.3	22	—	7	—	11	13	—	0.3	—	—	—	—
7	7	—	—	—	9	11	14	—	—	22	5	7	—	—	11	—	0.3	0.3	26	—	9	—	13	15	—	0.3	—	—	—	—
8	8	—	—	—	10	12	15	—	—	24	5	8	—	—	12	—	0.3	0.3	28	—	9	—	13	15	—	0.3	30	10	14	0.6
9	9	—	—	—	10	12	16	—	—	26	6	8	—	—	13	—	0.3	0.3	30	—	10	—	14	16	—	0.6	32	11	15	0.6
00	10	—	—	—	12	14	18	—	—	30	7	9	—	14	14.3	—	0.3	0.6	35	9	11	—	17	19	0.3	0.6	37	12	16	0.6
01	12	—	—	—	12	14	18	—	—	32	7	10	—	14	15.9	—	0.3	0.6	37	9	12	—	17	19	0.3	1	42	13	19	1
02	15	—	—	—	12	14	18	—	—	35	8	11	—	14	15.9	20	0.3	0.6	42	9	13	—	17	19	0.3	1	52	15	24	1.1
03	17	—	—	—	13	15	20	—	—	40	8	12	—	16	17.5	22	0.3	0.6	47	10	14	—	19	22.2	0.6	1	62	17	29	1.1
04	20	—	—	—	15	18	24	—	—	47	9	14	—	18	20.6	27	0.3	1	52	10	15	—	21	22.2	0.6	1.1	72	19	33	1.1
/22	22	—	—	—	16	19	25	—	—	50	9	14	—	18	20.6	27	0.3	1	56	11	16	—	21	25	0.6	1.1	—	—	—	—
05	25	—	—	—	16	19	25	—	—	52	10	15	—	18	20.6	27	0.3	1	62	12	17	—	24	25.4	0.6	1.1	80	21	36	1.5
/28	28	—	—	—	17	20	27	—	—	58	10	16	—	19	23	30	0.6	1	68	13	18	—	24	30	0.6	1.1	—	—	—	—
06	30	—	—	—	18	21	28	—	—	62	10	16	—	20	23.8	32	0.6	1	72	13	19	—	27	30.2	0.6	1.1	90	23	40	1.5
/32	32	—	—	—	19	23	30	—	—	65	11	17	—	21	25	33	0.6	1	75	14	20	—	28	32	0.6	1.1	—	—	—	—
07	35	—	—	—	21	25	33	—	—	72	12	17	—	23	27	37	0.6	1.1	80	14	21	—	31	34.9	0.6	1.5	100	25	43	1.5
08	40	—	—	—	22	26	35	—	—	80	13	18	—	23	30.2	40	0.6	1.1	90	16	23	—	33	36.5	1	1.5	110	27	46	2
09	45	—	—	—	22	26	35	—	—	85	13	19	—	23	30.2	40	0.6	1.1	100	17	25	—	36	39.7	1	1.5	120	29	50	2
10	50	—	—	—	22	26	35	—	—	90	13	20	—	23	30.2	40	0.6	1.1	110	19	27	—	40	44.4	1	2	130	31	53	2.1
11	55	—	—	—	24	30	40	—	—	100	14	21	—	25	33.3	45	0.6	1.5	120	21	29	—	43	49.2	1.1	2	140	33	57	2.1
12	60	—	—	—	24	30	40	—	—	110	16	22	—	28	36.5	50	1	1.5	130	22	31	—	46	54	1.1	2.1	150	35	60	2.1
13	65	—	—	—	27	34	45	—	—	120	18	23	—	31	38.1	56	1	1.5	140	24	33	—	48	58.7	1.1	2.1	160	37	64	2.1
14	70	—	—	—	27	34	45	—	—	125	18	24	—	31	39.7	56	1	1.5	150	25	35	—	51	63.5	1.5	2.1	180	42	74	3
15	75	—	—	—	30	37	50	—	—	130	18	25	—	31	41.3	56	1	1.5	160	27	37	—	55	68.3	1.5	2.1	190	45	77	3
16	80	—	—	—	30	37	50	—	—	140	19	26	—	33	44.4	60	1	2	170	28	39	—	58	68.3	1.5	2.1	200	48	80	3
17	85	—	—	—	31	41	56	—	—	150	21	28	—	36	49.2	65	1.1	2	180	30	41	—	60	73	2	3	210	52	86	4
18	90	150	—	—	33	45	60	—	2	160	22	30	—	40	52.4	69	1.1	2	190	30	43	—	64	73	2	3	225	54	90	4
19	95	160	—	—	39	52	65	—	2	170	24	32	—	43	55.6	75	1.1	2.1	200	33	45	—	67	77.8	2	3	240	55	95	4
20	100	165	21	30	39	52	65	1.1	2	180	25	34	—	46	60.3	80	1.5	2.1	215	36	47	51	73	82.6	2.1	3	250	58	98	4
21	105	175	22	33	42	56	69	1.1	2	190	27	36	—	50	65.1	85	1.5	2.1	225	37	49	53	77	87.3	2.1	3	260	60	100	4
22	110	180	22	33	42	56	69	1.1	2	200	28	38	—	53	69.8	90	1.5	2.1	240	42	50	57	80	92.1	3	3	280	65	108	4
24	120	200	25	38	48	62	80	1.5	2	215	—	40	42	58	76	95	—	2.1	260	44	55	62	86	106	3	3	310	72	118	5
26	130	210	25	38	48	64	80	1.5	2	230	—	40	46	64	80	100	—	3	280	48	58	66	93	112	3	4	340	78	128	5
28	140	225	27	40	50	68	85	1.5	2.1	250	—	42	50	68	88	109	—	3	300	50	62	70	102	118	4	4	360	82	132	5
30	150	250	31	46	60	80	100	2	2.1	270	—	45	54	73	96	118	—	3	320	—	65	75	108	128	—	4	380	85	138	5
32	160	270	34	51	66	86	109	2	2.1	290	—	48	58	80	104	128	—	3	340	—	68	79	114	136	—	4	400	88	142	5
34	170	280	34	51	66	88	109	2	2.1	310	—	52	62	86	110	140	—	4	360	—	72	84	120	140	—	4	420	92	145	5
36	180	300	37	56	72	96	118	2.1	3	320	—	52	62	86	112	140	—	4	380	—	75	88	126	150	—	4	440	95	150	6
38	190	320	42	60	78	104	128	3	3	340	—	55	65	92	120	150	—	4	400	—	78	92	132	155	—	5	460	98	155	6
40	200	340	44	65	82	112	140	3	3	360	—	58	70	98	128	160	—	4	420	—	80	97	138	165	—	5	480	102	160	6
44	220	370	48	69	88	120	150	3	4	400	—	65	78	108	144	180	—	4	460	—	88	106	145	180	—	5	540	115	180	6
48	240	400	50	74	95	128	160	4	4	440	—	72	85	120	160	200	—	4	500	—	95	114	155	195	—	5	580	122	190	6
52	260	440	57	82	106	144	180	4	4	480	—	80	90	130	174	218	—	5	540	—	102	123	165	206	—	6	620	132	206	7.5
56	280	460	57	82	106	146	180	4	5	500	—	80	90	130	176	218	—	5	580	—	108	132	175	224	—	6	670	140	224	7.5
60	300	500	63	90	118	160	200	5	5	540	—	85	98	140	192	243	—	5	620	—	109	140	185	236	—	7.5	710	150	236	7.5
64	320	540	71	100	128	176	218	5	5	580	—	92	105	150	208	258	—	5	670	—	112	155	200	258	—	7.5	750	155	250	9.5
68	340	580	78	106	140	190	243	5	5	620	—	92	118	165	224	280	—	6	710	—	118	165	212	272	—	7.5	800	165	265	9.5
72	360	600	78	106	140	192	243	5	5	650	—	95	122	170	232	290	—	6	750	—	125	170	224	290	—	7.5	850	180	280	9.5
76	380	620	78	106	140	194	243	5	5	680	—	95	132	175	240	300	—	6	780	—	128	175	230	300	—	7.5	900	190	300	9.5
80	400	650	80	112	145	200	250	6	6	720	—	103	140	185	256	315	—	6	820	—	136	185	243	308	—	7.5	950	200	315	12
84	420	700	88	122	165	224	280	6	6	760	—	109	150	195	272	335	—	7.5	850	—	136	190	250	315	—	9.5	980	206	325	12
88	440	720	88	122	165	226	280	6	6	790	—	112	155	200	280	345	—	7.5	900	—	145	200	265	345	—	9.5	1030	212	335	12
92	460	760	95	132	175	240	300	6	7.5	830	—	118	165	212	296	365	—	7.5	950	—	155	212	280	365	—	9.5	1060	218	345	12
96	480	790	100	136	180	248	308	6	7.5	870	—	125	170	224	310	388	—	7.5	980	—	160	218	290	375	—	9.5	1120	230	365	15
/500	500	830	106	145	190	264	325	7.5	7.5	920	—	136	185	243	336	412	—	7.5	1030	—	170	230	300	388	—	12	1150	236	375	15
/530	530	870	109	150	195	272	335	7.5	7.5	980	—	145	200	258	355	450	—	9.5	1090	—	180	243	325	412	—	12	1220	250	400	15
/560	560	920	115	160	206	280	355	7.5	7.5	1030	—	150	206	272	365	475	—	9.5	1150	—	190	258	335	438	—	12	1280	258	412	15
/600	600	980	122	170	218	300	375	7.5	7.5	1090	—	155	212	280	388	488	—	9.5	1220	—	200	272	355	462	—	15	1360	272	438	15
/630	630	1030	128	175	230	315	400	7.5	7.5	1150	—	165	230	300	412	515	—	12	1280	—	206	280	375	488	—	15	1420	280	450	15
/670	670	1090	136	185	243	336	412	7.5	7.5	1220	—	175	243	315	438	545	—	12	1360	—	218	300	400	515	—	15	1500	290	475	15
/710	710	1150	140	195	250	345	438	9.5	9.5	1280	—	180	250	325	450	560	—	12	1420	—	224	308	412	530	—	15	—	—	—	—
/750	750	1220	150	206	272	365	475	9.5	9.5	1360	—	195	265	345	475	615	—	15	1500	—	236	325	438	560	—	15	—	—	—	—
/800	800	1280	155	212	272	375	475	9.5	9.5	1420	—	200	272	355	488	615	—	15	1600	—	258	355	462	600	—	15	—	—	—	—
/850	850	1360	165	224	290	400	500	12	12	1500	—	206	280	375	515	650	—	15	1700	—	272	375	488	630	—	19	—	—	—	—
/900	900	1420	165	230	300	412	515	12	12	1580	—	218	300	388	515	670	—	15	1780	—	280	388	500	650	—	19	—	—	—	—
/950	950	1500	175	243	315	438	545	12	12	1660	—	230	315	412	530	710	—	15	1850	—	290	400	515	670	—	19	—	—	—	—
/1000	1000	1580	185	258	335	462	580	12	12	1750	—	243	330	425	560	750	—	15	1950	—	300	412	545	710	—	19	—	—	—	—
/1060	1060	1660	190	265	345	475	600	12	15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
/1120	1120	1750	—	280	365	475	630	—	15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
/1180	1180	1850	—	290	388	500	670	—	15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
/1250	1250	1950	—	308	400	530	710	—	15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
/1320	1320	2060	—	325	425	560	750	—	15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
/1400	1400	2180	—	345	450	580	775	—	19	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
/1500	1500	2300	—	355	462	600	800	—	19	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Remarks The chamfer dimensions listed in this table do not necessarily apply to the following chamfers: (a) Chamfers of the grooves in outer rings that have snap ring grooves.
(b) For thin section cylindrical roller bearings, the chamfers on side without rib and bearing bore (in case of an inner ring) or outer surface (in case of an outer ring).
(c) For angular contact ball bearings, the chamfers between the front face and bore (in case of an inner ring) or outer surface (in case of an outer ring).
(d) Chamfers on inner rings of bearings with tapered bores.

Table 7. 2 Boundary Dimensions of Tapered Roller Bearings

Units: mm

Tapered Roller Brgs.		329									320 X				330					331					
		Diameter Series 9									Diameter Series 0									Diameter Series 1					
			Dimension Series 29						Chamfer Dimension			Dimension Series 20			Dimension Series 30			Chamfer Dimension			Dimension Series 31			Chamfer Dimension	
			I			II			Cone	Cup								Cone	Cup					Cone	Cup
Bore Number	*d*	*D*	*B*	*C*	*T*	*B*	*C*	*T*	*r* (min.)		*D*	*B*	*C*	*T*	*B*	*C*	*T*	*r* (min.)		*D*	*B*	*C*	*T*	*r* (min.)	
00	**10**	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
01	**12**	—	—	—	—	—	—	—	—	—	**28**	11	—	11	13	—	13	0.3	0.3	—	—	—	—	—	—
02	**15**	—	—	—	—	—	—	—	—	—	**32**	12	—	12	14	—	14	0.3	0.3	—	—	—	—	—	—
03	**17**	—	—	—	—	—	—	—	—	—	**35**	13	—	13	15	—	15	0.3	0.3	—	—	—	—	—	—
04	**20**	**37**	11	—	11.6	12	9	12	0.3	0.3	**42**	15	12	15	17	—	17	0.6	0.6	—	—	—	—	—	—
/22	**22**	**40**	—	—	—	12	9	12	0.3	0.3	**44**	15	11.5	15	—	—	—	0.6	0.6	—	—	—	—	—	—
05	**25**	**42**	11	—	11.6	12	9	12	0.3	0.3	**47**	15	11.5	15	17	14	17	0.6	0.6	—	—	—	—	—	—
/28	**28**	**45**	—	—	—	12	9	12	0.3	0.3	**52**	16	12	16	—	—	—	1	1	—	—	—	—	—	—
06	**30**	**47**	11	—	11.6	12	9	12	0.3	0.3	**55**	17	13	17	20	16	20	1	1	—	—	—	—	—	—
/32	**32**	**52**	—	—	—	15	10	14	0.6	0.6	**58**	17	13	17	—	—	—	1	1	—	—	—	—	—	—
07	**35**	**55**	13	—	14	14	11.5	14	0.6	0.6	**62**	18	14	18	21	17	21	1	1	—	—	—	—	—	—
08	**40**	**62**	14	—	15	15	12	15	0.6	0.6	**68**	19	14.5	19	22	18	22	1	1	**75**	26	20.5	26	1.5	1.5
09	**45**	**68**	14	—	15	15	12	15	0.6	0.6	**75**	20	15.5	20	24	19	24	1	1	**80**	26	20.5	26	1.5	1.5
10	**50**	**72**	14	—	15	15	12	15	0.6	0.6	**80**	20	15.5	20	24	19	24	1	1	**85**	26	20	26	1.5	1.5
11	**55**	**80**	16	—	17	17	14	17	1	1	**90**	23	17.5	23	27	21	27	1.5	1.5	**95**	30	23	30	1.5	1.5
12	**60**	**85**	16	—	17	17	14	17	1	1	**95**	23	17.5	23	27	21	27	1.5	1.5	**100**	30	23	30	1.5	1.5
13	**65**	**90**	16	—	17	17	14	17	1	1	**100**	23	17.5	23	27	21	27	1.5	1.5	**110**	34	26.5	34	1.5	1.5
14	**70**	**100**	19	—	20	20	16	20	1	1	**110**	25	19	25	31	25.5	31	1.5	1.5	**120**	37	29	37	2	1.5
15	**75**	**105**	19	—	20	20	16	20	1	1	**115**	25	19	25	31	25.5	31	1.5	1.5	**125**	37	29	37	2	1.5
16	**80**	**110**	19	—	20	20	16	20	1	1	**125**	29	22	29	36	29.5	36	1.5	1.5	**130**	37	29	37	2	1.5
17	**85**	**120**	22	—	23	23	18	23	1.5	1.5	**130**	29	22	29	36	29.5	36	1.5	1.5	**140**	41	32	41	2.5	2
18	**90**	**125**	22	—	23	23	18	23	1.5	1.5	**140**	32	24	32	39	32.5	39	2	1.5	**150**	45	35	45	2.5	2
19	**95**	**130**	22	—	23	23	18	23	1.5	1.5	**145**	32	24	32	39	32.5	39	2	1.5	**160**	49	38	49	2.5	2
20	**100**	**140**	24	—	25	25	20	25	1.5	1.5	**150**	32	24	32	39	32.5	39	2	1.5	**165**	52	40	52	2.5	2
21	**105**	**145**	24	—	25	25	20	25	1.5	1.5	**160**	35	26	35	43	34	43	2.5	2	**175**	56	44	56	2.5	2
22	**110**	**150**	24	—	25	25	20	25	1.5	1.5	**170**	38	29	38	47	37	47	2.5	2	**180**	56	43	56	2.5	2
24	**120**	**165**	27	—	29	29	23	29	1.5	1.5	**180**	38	29	38	48	38	48	2.5	2	**200**	62	48	62	2.5	2
26	**130**	**180**	30	—	32	32	25	32	2	1.5	**200**	45	34	45	55	43	55	2.5	2	—	—	—	—	—	—
28	**140**	**190**	30	—	32	32	25	32	2	1.5	**210**	45	34	45	56	44	56	2.5	2	—	—	—	—	—	—
30	**150**	**210**	36	—	38	38	30	38	2.5	2	**225**	48	36	48	59	46	59	3	2.5	—	—	—	—	—	—
32	**160**	**220**	36	—	38	38	30	38	2.5	2	**240**	51	38	51	—	—	—	3	2.5	—	—	—	—	—	—
34	**170**	**230**	36	—	38	38	30	38	2.5	2	**260**	57	43	57	—	—	—	3	2.5	—	—	—	—	—	—
36	**180**	**250**	42	—	45	45	34	45	2.5	2	**280**	64	48	64	—	—	—	3	2.5	—	—	—	—	—	—
38	**190**	**260**	42	—	45	45	34	45	2.5	2	**290**	64	48	64	—	—	—	3	2.5	—	—	—	—	—	—
40	**200**	**280**	48	—	51	51	39	51	3	2.5	**310**	70	53	70	—	—	—	3	2.5	—	—	—	—	—	—
44	**220**	**300**	48	—	51	51	39	51	3	2.5	**340**	76	57	76	—	—	—	4	3	—	—	—	—	—	—
48	**240**	**320**	48	—	51	51	39	51	3	2.5	**360**	76	57	76	—	—	—	4	3	—	—	—	—	—	—
52	**260**	**360**	—	—	—	63.5	48	63.5	3	2.5	**400**	87	65	87	—	—	—	5	4	—	—	—	—	—	—
56	**280**	**380**	—	—	—	63.5	48	63.5	3	2.5	**420**	87	65	87	—	—	—	5	4	—	—	—	—	—	—
60	**300**	**420**	—	—	—	76	57	76	4	3	**460**	100	74	100	—	—	—	5	4	—	—	—	—	—	—
64	**320**	**440**	—	—	—	76	57	76	4	3	**480**	100	74	100	—	—	—	5	4	—	—	—	—	—	—
68	**340**	**460**	—	—	—	76	57	76	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
72	**360**	**480**	—	—	—	76	57	76	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Remarks
1. Other series not conforming to this table are also specified by ISO.
2. In the Dimension Series of Diameter Series 9, Classification I is those specified by the old standard, Classification II is those specified by the ISO.
2. Dimension Series not classified conform to dimensions (D, B, C, T) specified by ISO.
3. The chamfer dimensions listed are the minimum permissible dimensions specified by ISO. They do not apply to chamfers on the front face.

302				322			332					303 or 303D					313			323					Tapered Roller Brgs.	
Diameter Series 2												Diameter Series 3														
	Dimension Series 02			Dimension Series 22			Dimension Series 32			Chamfer Dimension			Dimension Series 03				Dimension Series 13			Dimension Series 23			Chamfer Dimension			
										Cone	Cup												Cone	Cup		
D	*B*	*C*	*T*	*B*	*C*	*T*	*B*	*C*	*T*	*r* (min.)		*D*	*B*	*C*	*C* (1)	*T*	*B*	*C*	*T*	*B*	*C*	*T*	*r* (min.)		*d*	Bore Number
30	9	—	9.7	14	—	14.7	—	—	—	0.6	0.6	**35**	11	—	—	11.9	—	—	—	17	—	17.9	0.6	0.6	**10**	**00**
32	10	9	10.75	14	—	14.75	—	—	—	0.6	0.6	**37**	12	—	—	12.9	—	—	—	17	—	17.9	1	1	**12**	**01**
35	11	10	11.75	14	—	14.75	—	—	—	0.6	0.6	**42**	13	11	—	14.25	—	—	—	17	14	18.25	1	1	**15**	**02**
40	12	11	13.25	16	14	17.25	—	—	—	1	1	**47**	14	12	—	15.25	—	—	—	19	16	20.25	1	1	**17**	**03**
47	14	12	15.25	18	15	19.25	—	—	—	1	1	**52**	15	13	—	16.25	—	—	—	21	18	22.25	1.5	1.5	**20**	**04**
50	14	12	15.25	18	15	19.25	—	—	—	1	1	**56**	16	14	—	17.25	—	—	—	21	18	22.25	1.5	1.5	**22**	**/22**
52	15	13	16.25	18	15	19.25	22	18	22	1	1	**62**	17	15	13	18.25	—	—	—	24	20	25.25	1.5	1.5	**25**	**05**
58	16	14	17.25	19	16	20.25	24	19	24	1	1	**68**	18	15	14	19.75	—	—	—	24	20	25.75	1.5	1.5	**28**	**/28**
62	16	14	17.25	20	17	21.25	25	19.5	25	1	1	**72**	19	16	14	20.75	—	—	—	27	23	28.75	1.5	1.5	**30**	**06**
65	17	15	18.25	21	18	22.25	26	20.5	26	1	1	**75**	20	17	15	21.75	—	—	—	28	24	29.75	1.5	1.5	**32**	**/32**
72	17	15	18.25	23	19	24.25	28	22	28	1.5	1.5	**80**	21	18	15	22.75	—	—	—	31	25	32.75	2	1.5	**35**	**07**
80	18	16	19.75	23	19	24.75	32	25	32	1.5	1.5	**90**	23	20	17	25.25	—	—	—	33	27	35.25	2	1.5	**40**	**08**
85	19	16	20.75	23	19	24.75	32	25	32	1.5	1.5	**100**	25	22	18	27.25	—	—	—	36	30	38.25	2	1.5	**45**	**09**
90	20	17	21.75	23	19	24.75	32	24.5	32	1.5	1.5	**110**	27	23	19	29.25	—	—	—	40	33	42.25	2.5	2	**50**	**10**
100	21	18	22.75	25	21	26.75	35	27	35	2	1.5	**120**	29	25	21	31.5	—	—	—	43	35	45.5	2.5	2	**55**	**11**
110	22	19	23.75	28	24	29.75	38	29	38	2	1.5	**130**	31	26	22	33.5	—	—	—	46	37	48.5	3	2.5	**60**	**12**
120	23	20	24.75	31	27	32.75	41	32	41	2	1.5	**140**	33	28	23	36	—	—	—	48	39	51	3	2.5	**65**	**13**
125	24	21	26.25	31	27	33.25	41	32	41	2	1.5	**150**	35	30	25	38	—	—	—	51	42	54	3	2.5	**70**	**14**
130	25	22	27.25	31	27	33.25	41	31	41	2	1.5	**160**	37	31	26	40	—	—	—	55	45	58	3	2.5	**75**	**15**
140	26	22	28.25	33	28	35.25	46	35	46	2.5	2	**170**	39	33	27	42.5	—	—	—	58	48	61.5	3	2.5	**80**	**16**
150	28	24	30.5	36	30	38.5	49	37	49	2.5	2	**180**	41	34	28	44.5	—	—	—	60	49	63.5	4	3	**85**	**17**
160	30	26	32.5	40	34	42.5	55	42	55	2.5	2	**190**	43	36	30	46.5	—	—	—	64	53	67.5	4	3	**90**	**18**
170	32	27	34.5	43	37	45.5	58	44	58	3	2.5	**200**	45	38	32	49.5	—	—	—	67	55	71.5	4	3	**95**	**19**
180	34	29	37	46	39	49	63	48	63	3	2.5	**215**	47	39	—	51.5	51	35	56.5	73	60	77.5	4	3	**100**	**20**
190	36	30	39	50	43	53	68	52	68	3	2.5	**225**	49	41	—	53.5	53	36	58	77	63	81.5	4	3	**105**	**21**
200	38	32	41	53	46	56	—	—	—	3	2.5	**240**	50	42	—	54.5	57	38	63	80	65	84.5	4	3	**110**	**22**
215	40	34	43.5	58	50	61.5	—	—	—	3	2.5	**260**	55	46	—	59.5	62	42	68	86	69	90.5	4	3	**120**	**24**
230	40	34	43.75	64	54	67.75	—	—	—	4	3	**280**	58	49	—	63.75	66	44	72	93	78	98.75	5	4	**130**	**26**
250	42	36	45.75	68	58	71.75	—	—	—	4	3	**300**	62	53	—	67.75	70	47	77	102	85	107.75	5	4	**140**	**28**
270	45	38	49	73	60	77	—	—	—	4	3	**320**	65	55	—	72	75	50	82	108	90	114	5	4	**150**	**30**
290	48	40	52	80	67	84	—	—	—	4	3	**340**	68	58	—	75	79	—	87	114	95	121	5	4	**160**	**32**
310	52	43	57	86	71	91	—	—	—	5	4	**360**	72	62	—	80	84	—	92	120	100	127	5	4	**170**	**34**
320	52	43	57	86	71	91	—	—	—	5	4	**380**	75	64	—	83	88	—	97	126	106	134	5	4	**180**	**36**
340	55	46	60	92	75	97	—	—	—	5	4	**400**	78	65	—	86	92	—	101	132	109	140	6	5	**190**	**38**
360	58	48	64	98	82	104	—	—	—	5	4	**420**	80	67	—	89	97	—	107	138	115	146	6	5	**200**	**40**
400	65	54	72	108	90	114	—	—	—	5	4	**460**	88	73	—	97	106	—	117	145	122	154	6	5	**220**	**44**
440	72	60	79	120	100	127	—	—	—	5	4	**500**	95	80	—	105	114	—	125	155	132	165	6	5	**240**	**48**
480	80	67	89	130	106	137	—	—	—	6	5	**540**	102	85	—	113	123	—	135	165	136	176	6	6	**260**	**52**
500	80	67	89	130	106	137	—	—	—	6	5	**580**	108	90	—	119	132	—	145	175	145	187	6	6	**280**	**56**
540	85	71	96	140	115	149	—	—	—	6	5	—	—	—	—	—	—	—	—	—	—	—	—	—	**300**	**60**
580	92	75	104	150	125	159	—	—	—	6	5	—	—	—	—	—	—	—	—	—	—	—	—	—	**320**	**64**
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	**340**	**68**
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	**360**	**72**

Note (1) Regarding steep-slope bearing 303D, in DIN, the one corresponding to 303D of JIS is numbered 313. For bearings with bore diameters larger than 100 mm, those of dimension series 13 are numbered 313.

Table 7. 3 Boundary Dimensions of Thrust Bearings (Flat Seats) — 1 —

Units: mm

Bore Number	d	Diameter Series 0 D	Dimension Series 70 T	90 T	10 T	r (min.)	Diameter Series 1 D	Dimension Series 71 T	91 T	11 T	r (min.)	Diameter Series 2 D	Dimension Series 72 T	92 T	12 T	22 T	22 Central Washer d_2	22 Central Washer B	r (min.)	r_1 (min.)
Thrust Ball Brgs.										511					512	522				
Spherical Thrust Roller Brgs.														292						
4	**4**	**12**	4	—	6	0.3	—	—	—	—	—	**16**	6	—	8	—	—	—	0.3	—
6	**6**	**16**	5	—	7	0.3	—	—	—	—	—	**20**	6	—	9	—	—	—	0.3	—
8	**8**	**18**	5	—	7	0.3	—	—	—	—	—	**22**	6	—	9	—	—	—	0.3	—
00	**10**	**20**	5	—	7	0.3	**24**	6	—	9	0.3	**26**	7	—	11	—	—	—	0.6	—
01	**12**	**22**	5	—	7	0.3	**26**	6	—	9	0.3	**28**	7	—	11	—	—	—	0.6	—
02	**15**	**26**	5	—	7	0.3	**28**	6	—	9	0.3	**32**	8	—	12	22	10	5	0.6	0.3
03	**17**	**28**	5	—	7	0.3	**30**	6	—	9	0.3	**35**	8	—	12	—	—	—	0.6	—
04	**20**	**32**	6	—	8	0.3	**35**	7	—	10	0.3	**40**	9	—	14	26	15	6	0.6	0.3
05	**25**	**37**	6	—	8	0.3	**42**	8	—	11	0.6	**47**	10	—	15	28	20	7	0.6	0.3
06	**30**	**42**	6	—	8	0.3	**47**	8	—	11	0.6	**52**	10	—	16	29	25	7	0.6	0.3
07	**35**	**47**	6	—	8	0.3	**52**	8	—	12	0.6	**62**	12	—	18	34	30	8	1	0.3
08	**40**	**52**	6	—	9	0.3	**60**	9	—	13	0.6	**68**	13	—	19	36	30	9	1	0.6
09	**45**	**60**	7	—	10	0.3	**65**	9	—	14	0.6	**73**	13	—	20	37	35	9	1	0.6
10	**50**	**65**	7	—	10	0.3	**70**	9	—	14	0.6	**78**	13	—	22	39	40	9	1	0.6
11	**55**	**70**	7	—	10	0.3	**78**	10	—	16	0.6	**90**	16	21	25	45	45	10	1	0.6
12	**60**	**75**	7	—	10	0.3	**85**	11	—	17	1	**95**	16	21	26	46	50	10	1	0.6
13	**65**	**80**	7	—	10	0.3	**90**	11	—	18	1	**100**	16	21	27	47	55	10	1	0.6
14	**70**	**85**	7	—	10	0.3	**95**	11	—	18	1	**105**	16	21	27	47	55	10	1	1
15	**75**	**90**	7	—	10	0.3	**100**	11	—	19	1	**110**	16	21	27	47	60	10	1	1
16	**80**	**95**	7	—	10	0.3	**105**	11	—	19	1	**115**	16	21	28	48	65	10	1	1
17	**85**	**100**	7	—	10	0.3	**110**	11	—	19	1	**125**	18	24	31	55	70	12	1	1
18	**90**	**105**	7	—	10	0.3	**120**	14	—	22	1	**135**	20	27	35	62	75	14	1.1	1
20	**100**	**120**	9	—	14	0.6	**135**	16	21	25	1	**150**	23	30	38	67	85	15	1.1	1
22	**110**	**130**	9	—	14	0.6	**145**	16	21	25	1	**160**	23	30	38	67	95	15	1.1	1
24	**120**	**140**	9	—	14	0.6	**155**	16	21	25	1	**170**	23	30	39	68	100	15	1.1	1.1
26	**130**	**150**	9	—	14	0.6	**170**	18	24	30	1	**190**	27	36	45	80	110	18	1.5	1.1
28	**140**	**160**	9	—	14	0.6	**180**	18	24	31	1	**200**	27	36	46	81	120	18	1.5	1.1
30	**150**	**170**	9	—	14	0.6	**190**	18	24	31	1	**215**	29	39	50	89	130	20	1.5	1.1
32	**160**	**180**	9	—	14	0.6	**200**	18	24	31	1	**225**	29	39	51	90	140	20	1.5	1.1
34	**170**	**190**	9	—	14	0.6	**215**	20	27	34	1.1	**240**	32	42	55	97	150	21	1.5	1.1
36	**180**	**200**	9	—	14	0.6	**225**	20	27	34	1.1	**250**	32	42	56	98	150	21	1.5	2
38	**190**	**215**	11	—	17	1	**240**	23	30	37	1.1	**270**	36	48	62	109	160	24	2	2
40	**200**	**225**	11	—	17	1	**250**	23	30	37	1.1	**280**	36	48	62	109	170	24	2	2
44	**220**	**250**	14	—	22	1	**270**	23	30	37	1.1	**300**	36	48	63	110	190	24	2	2
48	**240**	**270**	14	—	22	1	**300**	27	36	45	1.5	**340**	45	60	78	—	—	—	2.1	—
52	**260**	**290**	14	—	22	1	**320**	27	36	45	1.5	**360**	45	60	79	—	—	—	2.1	—
56	**280**	**310**	14	—	22	1	**350**	32	42	53	1.5	**380**	45	60	80	—	—	—	2.1	—
60	**300**	**340**	18	24	30	1	**380**	36	48	62	2	**420**	54	73	95	—	—	—	3	—
64	**320**	**360**	18	24	30	1	**400**	36	48	63	2	**440**	54	73	95	—	—	—	3	—

Diameter Series 3 D	Dimension Series 73 T	93 T	13 T	23 T	23 Central Washer d_2	23 Central Washer B	r (min.)	r_1 (min.)	Diameter Series 4 D	Dimension Series 74 T	94 T	14 T	24 T	24 Central Washer d_2	24 Central Washer B	r (min.)	r_1 (min.)	Diameter Series 5 D	Dimension Series 95 T	r (min.)	d	Bore Number
			513	523								514	524									Thrust Ball Brgs.
		293									294											Spherical Thrust Roller Brgs.
20	7	—	11	—	—	—	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	**4**	**4**
24	8	—	12	—	—	—	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	**6**	**6**
26	8	—	12	—	—	—	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	**8**	**8**
30	9	—	14	—	—	—	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	**10**	**00**
32	9	—	14	—	—	—	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	**12**	**01**
37	10	—	15	—	—	—	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	**15**	**02**
40	10	—	16	—	—	—	0.6	—	—	—	—	—	—	—	—	—	—	**52**	21	1	**17**	**03**
47	12	—	18	—	—	—	1	—	—	—	—	—	—	—	—	—	—	**60**	24	1	**20**	**04**
52	12	—	18	34	20	8	1	0.3	**60**	16	21	24	45	15	11	1	0.6	**73**	29	1.1	**25**	**05**
60	14	—	21	38	25	9	1	0.3	**70**	18	24	28	52	20	12	1	0.6	**85**	34	1.1	**30**	**06**
68	15	—	24	44	30	10	1	0.3	**80**	20	27	32	59	25	14	1.1	0.6	**100**	39	1.1	**35**	**07**
78	17	22	26	49	30	12	1	0.6	**90**	23	30	36	65	30	15	1.1	0.6	**110**	42	1.5	**40**	**08**
85	18	24	28	52	35	12	1	0.6	**100**	25	34	39	72	35	17	1.1	0.6	**120**	45	2	**45**	**09**
95	20	27	31	58	40	14	1.1	0.6	**110**	27	36	43	78	40	18	1.5	0.6	**135**	51	2	**50**	**10**
105	23	30	35	64	45	15	1.1	0.6	**120**	29	39	48	87	45	20	1.5	0.6	**150**	58	2.1	**55**	**11**
110	23	30	35	64	50	15	1.1	0.6	**130**	32	42	51	93	50	21	1.5	0.6	**160**	60	2.1	**60**	**12**
115	23	30	36	65	55	15	1.1	0.6	**140**	34	45	56	101	50	23	2	1	**170**	63	2.1	**65**	**13**
125	25	34	40	72	55	16	1.1	1	**150**	36	48	60	107	55	24	2	1	**180**	67	3	**70**	**14**
135	27	36	44	79	60	18	1.5	1	**160**	38	51	65	115	60	26	2	1	**190**	69	3	**75**	**15**
140	27	36	44	79	65	18	1.5	1	**170**	41	54	68	120	65	27	2.1	1	**200**	73	3	**80**	**16**
150	29	39	49	87	70	19	1.5	1	**180**	42	58	72	128	65	29	2.1	1.1	**215**	78	4	**85**	**17**
155	29	39	50	88	75	19	1.5	1	**190**	45	60	77	135	70	30	2.1	1.1	**225**	82	4	**90**	**18**
170	32	42	55	97	85	21	1.5	1	**210**	50	67	85	150	80	33	3	1.1	**250**	90	4	**100**	**20**
190	36	48	63	110	95	24	2	1	**230**	54	73	95	166	90	37	3	1.1	**270**	95	5	**110**	**22**
210	41	54	70	123	100	27	2.1	1.1	**250**	58	78	102	177	95	40	4	1.5	**300**	109	5	**120**	**24**
225	42	58	75	130	110	30	2.1	1.1	**270**	63	85	110	192	100	42	4	2	**320**	115	5	**130**	**26**
240	45	60	80	140	120	31	2.1	1.1	**280**	63	85	112	196	110	44	4	2	**340**	122	5	**140**	**28**
250	45	60	80	140	130	31	2.1	1.1	**300**	67	90	120	209	120	46	4	2	**360**	125	6	**150**	**30**
270	50	67	87	153	140	33	3	1.1	**320**	73	95	130	226	130	50	5	2	**380**	132	6	**160**	**32**
280	50	67	87	153	150	33	3	1.1	**340**	78	103	135	236	135	50	5	2.1	**400**	140	6	**170**	**34**
300	54	73	95	165	150	37	3	2	**360**	82	109	140	245	140	52	5	3	**420**	145	6	**180**	**36**
320	58	78	105	183	160	40	4	2	**380**	85	115	150	—	—	—	5	—	**440**	150	6	**190**	**38**
340	63	85	110	192	170	42	4	2	**400**	90	122	155	—	—	—	5	—	**460**	155	7.5	**200**	**40**
360	63	85	112	—	—	—	4	—	**420**	90	122	160	—	—	—	6	—	**500**	170	7.5	**220**	**44**
380	63	85	112	—	—	—	4	—	**440**	90	122	160	—	—	—	6	—	**540**	180	7.5	**240**	**48**
420	73	95	130	—	—	—	5	—	**480**	100	132	175	—	—	—	6	—	**580**	190	9.5	**260**	**52**
440	73	95	130	—	—	—	5	—	**520**	109	145	190	—	—	—	6	—	**620**	206	9.5	**280**	**56**
480	82	109	140	—	—	—	5	—	**540**	109	145	190	—	—	—	6	—	**670**	224	9.5	**300**	**60**
500	82	109	140	—	—	—	5	—	**580**	118	155	205	—	—	—	7.5	—	**710**	236	9.5	**320**	**64**

Remarks
1. Dimension Series 22, 23, and 24 are double direction bearings.
2. The maximum permissible outside diameter of shaft and central washers and minimum permissible bore diameter of housing washers are omitted here. (Refer to the bearing tables for Thrust Bearings).

Table 7. 3 Boundary Dimensions of Thrust Bearings (Flat Seats) — 2 —

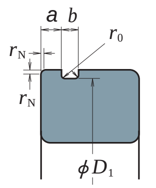
Units: mm

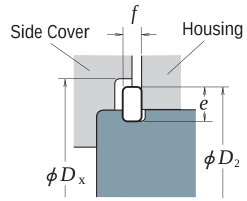
Thrust Ball Brgs.										511					512	522				
Spherical Thrust Roller Brgs.														292						
		Diameter Series 0					Diameter Series 1					Diameter Series 2								
			Dimension Series					Dimension Series					Dimension Series							
			70	90	10			71	91	11			72	92	12	22	22			
Bore Number	d	D	T			r (min.)	D	T			r (min.)	D	T				Central Washer d_2	Central Washer B	r (min.)	r_1 (min.)
68	340	380	18	24	30	1	420	36	48	64	2	460	54	73	96	—	—	—	3	—
72	360	400	18	24	30	1	440	36	48	65	2	500	63	85	110	—	—	—	4	—
76	380	420	18	24	30	1	460	36	48	65	2	520	63	85	112	—	—	—	4	—
80	400	440	18	24	30	1	480	36	48	65	2	540	63	85	112	—	—	—	4	—
84	420	460	18	24	30	1	500	36	48	65	2	580	73	95	130	—	—	—	5	—
88	440	480	18	24	30	1	540	45	60	80	2.1	600	73	95	130	—	—	—	5	—
92	460	500	18	24	30	1	560	45	60	80	2.1	620	73	95	130	—	—	—	5	—
96	480	520	18	24	30	1	580	45	60	80	2.1	650	78	103	135	—	—	—	5	—
/500	500	540	18	24	30	1	600	45	60	80	2.1	670	78	103	135	—	—	—	5	—
/530	530	580	23	30	38	1.1	640	50	67	85	3	710	82	109	140	—	—	—	5	—
/560	560	610	23	30	38	1.1	670	50	67	85	3	750	85	115	150	—	—	—	5	—
/600	600	650	23	30	38	1.1	710	50	67	85	3	800	90	122	160	—	—	—	5	—
/630	630	680	23	30	38	1.1	750	54	73	95	3	850	100	132	175	—	—	—	6	—
/670	670	730	27	36	45	1.5	800	58	78	105	4	900	103	140	180	—	—	—	6	—
/710	710	780	32	42	53	1.5	850	63	85	112	4	950	109	145	190	—	—	—	6	—
/750	750	820	32	42	53	1.5	900	67	90	120	4	1000	112	150	195	—	—	—	6	—
/800	800	870	32	42	53	1.5	950	67	90	120	4	1060	118	155	205	—	—	—	7.5	—
/850	850	920	32	42	53	1.5	1000	67	90	120	4	1120	122	160	212	—	—	—	7.5	—
/900	900	980	36	48	63	2	1060	73	95	130	5	1180	125	170	220	—	—	—	7.5	—
/950	950	1030	36	48	63	2	1120	78	103	135	5	1250	136	180	236	—	—	—	7.5	—
/1000	1000	1090	41	54	70	2.1	1180	82	109	140	5	1320	145	190	250	—	—	—	9.5	—
/1060	1060	1150	41	54	70	2.1	1250	85	115	150	5	1400	155	206	265	—	—	—	9.5	—
/1120	1120	1220	45	60	80	2.1	1320	90	122	160	5	1460	—	206	—	—	—	—	9.5	—
/1180	1180	1280	45	60	80	2.1	1400	100	132	175	6	1520	—	206	—	—	—	—	9.5	—
/1250	1250	1360	50	67	85	3	1460	—	—	175	6	1610	—	216	—	—	—	—	9.5	—
/1320	1320	1440	—	—	95	3	1540	—	—	175	6	1700	—	228	—	—	—	—	9.5	—
/1400	1400	1520	—	—	95	3	1630	—	—	180	6	1790	—	234	—	—	—	—	12	—
/1500	1500	1630	—	—	105	4	1750	—	—	195	6	1920	—	252	—	—	—	—	12	—
/1600	1600	1730	—	—	105	4	1850	—	—	195	6	2040	—	264	—	—	—	—	15	—
/1700	1700	1840	—	—	112	4	1970	—	—	212	7.5	2160	—	276	—	—	—	—	15	—
/1800	1800	1950	—	—	120	4	2080	—	—	220	7.5	2280	—	288	—	—	—	—	15	—
/1900	1900	2060	—	—	130	5	2180	—	—	220	7.5	—	—	—	—	—	—	—	—	—
/2000	2000	2160	—	—	130	5	2300	—	—	236	7.5	—	—	—	—	—	—	—	—	—
/2120	2120	2300	—	—	140	5	2430	—	—	243	7.5	—	—	—	—	—	—	—	—	—
/2240	2240	2430	—	—	150	5	2570	—	—	258	9.5	—	—	—	—	—	—	—	—	—
/2360	2360	2550	—	—	150	5	2700	—	—	265	9.5	—	—	—	—	—	—	—	—	—
/2500	2500	2700	—	—	160	5	2850	—	—	272	9.5	—	—	—	—	—	—	—	—	—

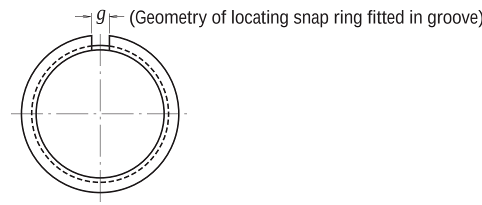
Thrust Ball Brgs.				513	523								514	524									
Spherical Thrust Roller Brgs.			293									294											
		Diameter Series 3									Diameter Series 4									Diameter Series 5			
			Dimension Series									Dimension Series									Dimension Series		
			73	93	13	23	23					74	94	14	24	24					95		
Bore Number	d	D	T				Central Washer d_2	Central Washer B	r (min.)	r_1 (min.)	D	T				Central Washer d_2	Central Washer B	r (min.)	r_1 (min.)	D	T	r (min.)	
68	340	540	90	122	160	—	—	—	5	—	620	125	170	220	—	—	—	7.5	—	750	243	12	
72	360	560	90	122	160	—	—	—	5	—	640	125	170	220	—	—	—	7.5	—	780	250	12	
76	380	600	100	132	175	—	—	—	6	—	670	132	175	224	—	—	—	7.5	—	820	265	12	
80	400	620	100	132	175	—	—	—	6	—	710	140	185	243	—	—	—	7.5	—	850	272	12	
84	420	650	103	140	180	—	—	—	6	—	730	140	185	243	—	—	—	7.5	—	900	290	15	
88	440	680	109	145	190	—	—	—	6	—	780	155	206	265	—	—	—	9.5	—	950	308	15	
92	460	710	112	150	195	—	—	—	6	—	800	155	206	265	—	—	—	9.5	—	980	315	15	
96	480	730	112	150	195	—	—	—	6	—	850	165	224	290	—	—	—	9.5	—	1000	315	15	
/500	500	750	112	150	195	—	—	—	6	—	870	165	224	290	—	—	—	9.5	—	1060	335	15	
/530	530	800	122	160	212	—	—	—	7.5	—	920	175	236	308	—	—	—	9.5	—	1090	335	15	
/560	560	850	132	175	224	—	—	—	7.5	—	980	190	250	335	—	—	—	12	—	1150	355	15	
/600	600	900	136	180	236	—	—	—	7.5	—	1030	195	258	335	—	—	—	12	—	1220	375	15	
/630	630	950	145	190	250	—	—	—	9.5	—	1090	206	280	365	—	—	—	12	—	1280	388	15	
/670	670	1000	150	200	258	—	—	—	9.5	—	1150	218	290	375	—	—	—	15	—	1320	388	15	
/710	710	1060	160	212	272	—	—	—	9.5	—	1220	230	308	400	—	—	—	15	—	1400	412	15	
/750	750	1120	165	224	290	—	—	—	9.5	—	1280	236	315	412	—	—	—	15	—	—	—	—	
/800	800	1180	170	230	300	—	—	—	9.5	—	1360	250	335	438	—	—	—	15	—	—	—	—	
/850	850	1250	180	243	315	—	—	—	12	—	1440	—	354	—	—	—	—	15	—	—	—	—	
/900	900	1320	190	250	335	—	—	—	12	—	1520	—	372	—	—	—	—	15	—	—	—	—	
/950	950	1400	200	272	355	—	—	—	12	—	1600	—	390	—	—	—	—	15	—	—	—	—	
/1000	1000	1460	—	276	—	—	—	—	12	—	1670	—	402	—	—	—	—	15	—	—	—	—	
/1060	1060	1540	—	288	—	—	—	—	15	—	1770	—	426	—	—	—	—	15	—	—	—	—	
/1120	1120	1630	—	306	—	—	—	—	15	—	1860	—	444	—	—	—	—	15	—	—	—	—	
/1180	1180	1710	—	318	—	—	—	—	15	—	1950	—	462	—	—	—	—	19	—	—	—	—	
/1250	1250	1800	—	330	—	—	—	—	19	—	2050	—	480	—	—	—	—	19	—	—	—	—	
/1320	1320	1900	—	348	—	—	—	—	19	—	2160	—	505	—	—	—	—	19	—	—	—	—	
/1400	1400	2000	—	360	—	—	—	—	19	—	2280	—	530	—	—	—	—	19	—	—	—	—	
/1500	1500	2140	—	384	—	—	—	—	19	—	—	—	—	—	—	—	—	—	—	—	—	—	
/1600	1600	2270	—	402	—	—	—	—	19	—	—	—	—	—	—	—	—	—	—	—	—	—	
/1700	1700	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
/1800	1800	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
/1900	1900	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
/2000	2000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
/2120	2120	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
/2240	2240	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
/2360	2360	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
/2500	2500	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	

Remarks
1. Dimension Series 22, 23, and 24 are double direction bearings.
2. The maximum permissible outside diameter of shaft and central washers and minimum permissible bore diameter of housing washers are omitted here. (Refer to the bearings tables for Thrust Bearings).

Table 7. 4 Dimensions of Snap Ring Grooves and Locating Snap Rings — (1)
Bearings of Dimension Series 18 and 19







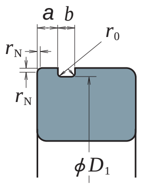
Units: mm

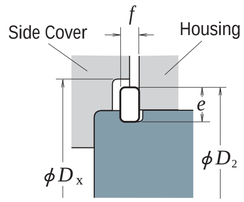
Applicable Bearings			Snap Ring Groove								
d		D	Snap Ring Groove Diameter D_1		Snap Ring Groove Position a				Snap Ring Groove Width b		Radius of Bottom Corners r_0
Dimension Series					Bearing Dimension Series 18		Bearing Dimension Series 19				
18	19		max.	min.	max.	min.	max.	min.	max.	min.	max.
—	10	**22**	20.8	20.5	—	—	1.05	0.9	1.05	0.8	0.2
—	12	**24**	22.8	22.5	—	—	1.05	0.9	1.05	0.8	0.2
—	15	**28**	26.7	26.4	—	—	1.3	1.15	1.2	0.95	0.25
—	17	**30**	28.7	28.4	—	—	1.3	1.15	1.2	0.95	0.25
20	—	**32**	30.7	30.4	1.3	1.15	—	—	1.2	0.95	0.25
22	—	**34**	32.7	32.4	1.3	1.15	—	—	1.2	0.95	0.25
25	20	**37**	35.7	35.4	1.3	1.15	1.7	1.55	1.2	0.95	0.25
—	22	**39**	37.7	37.4	—	—	1.7	1.55	1.2	0.95	0.25
28	—	**40**	38.7	38.4	1.3	1.15	—	—	1.2	0.95	0.25
30	25	**42**	40.7	40.4	1.3	1.15	1.7	1.55	1.2	0.95	0.25
32	—	**44**	42.7	42.4	1.3	1.15	—	—	1.2	0.95	0.25
—	28	**45**	43.7	43.4	—	—	1.7	1.55	1.2	0.95	0.25
35	30	**47**	45.7	45.4	1.3	1.15	1.7	1.55	1.2	0.95	0.25
40	32	**52**	50.7	50.4	1.3	1.15	1.7	1.55	1.2	0.95	0.25
—	35	**55**	53.7	53.4	—	—	1.7	1.55	1.2	0.95	0.25
45	—	**58**	56.7	56.4	1.3	1.15	—	—	1.2	0.95	0.25
—	40	**62**	60.7	60.3	—	—	1.7	1.55	1.2	0.95	0.25
50	—	**65**	63.7	63.3	1.3	1.15	—	—	1.2	0.95	0.25
—	45	**68**	66.7	66.3	—	—	1.7	1.55	1.2	0.95	0.25
55	50	**72**	70.7	70.3	1.7	1.55	1.7	1.55	1.2	0.95	0.25
60	—	**78**	76.2	75.8	1.7	1.55	—	—	1.6	1.3	0.4
—	55	**80**	77.9	77.5	—	—	2.1	1.9	1.6	1.3	0.4
65	60	**85**	82.9	82.5	1.7	1.55	2.1	1.9	1.6	1.3	0.4
70	65	**90**	87.9	87.5	1.7	1.55	2.1	1.9	1.6	1.3	0.4
75	—	**95**	92.9	92.5	1.7	1.55	—	—	1.6	1.3	0.4
80	70	**100**	97.9	97.5	1.7	1.55	2.5	2.3	1.6	1.3	0.4
—	75	**105**	102.6	102.1	—	—	2.5	2.3	1.6	1.3	0.4
85	80	**110**	107.6	107.1	2.1	1.9	2.5	2.3	1.6	1.3	0.4
90	—	**115**	112.6	112.1	2.1	1.9	—	—	1.6	1.3	0.4
95	85	**120**	117.6	117.1	2.1	1.9	3.3	3.1	1.6	1.3	0.4
100	90	**125**	122.6	122.1	2.1	1.9	3.3	3.1	1.6	1.3	0.4
105	95	**130**	127.6	127.1	2.1	1.9	3.3	3.1	1.6	1.3	0.4
110	100	**140**	137.6	137.1	2.5	2.3	3.3	3.1	2.2	1.9	0.6
—	105	**145**	142.6	142.1	—	—	3.3	3.1	2.2	1.9	0.6
120	110	**150**	147.6	147.1	2.5	2.3	3.3	3.1	2.2	1.9	0.6
130	120	**165**	161.8	161.3	3.3	3.1	3.7	3.5	2.2	1.9	0.6
140	—	**175**	171.8	171.3	3.3	3.1	—	—	2.2	1.9	0.6
—	130	**180**	176.8	176.3	—	—	3.7	3.5	2.2	1.9	0.6
150	140	**190**	186.8	186.3	3.3	3.1	3.7	3.5	2.2	1.9	0.6
160	—	**200**	196.8	196.3	3.3	3.1	—	—	2.2	1.9	0.6

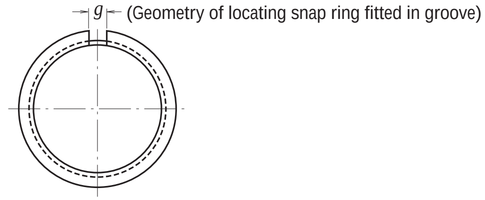
Locating Snap Ring							Side Cover
Locating Snap Ring Number	Cross Sectional Height e		Thickness f		Geometry of snap ring fitted in groove (Reference)		Stepped Bore Diameter (Reference) D_X
					Slit Width g	Snap Ring Outside Diameter D_2	
	max.	min.	max.	min.	approx.	max.	min.
NR 1022	2.0	1.85	0.7	0.6	2	24.8	25.5
NR 1024	2.0	1.85	0.7	0.6	2	26.8	27.5
NR 1028	2.05	1.9	0.85	0.75	3	30.8	31.5
NR 1030	2.05	1.9	0.85	0.75	3	32.8	33.5
NR 1032	2.05	1.9	0.85	0.75	3	34.8	35.5
NR 1034	2.05	1.9	0.85	0.75	3	36.8	37.5
NR 1037	2.05	1.9	0.85	0.75	3	39.8	40.5
NR 1039	2.05	1.9	0.85	0.75	3	41.8	42.5
NR 1040	2.05	1.9	0.85	0.75	3	42.8	43.5
NR 1042	2.05	1.9	0.85	0.75	3	44.8	45.5
NR 1044	2.05	1.9	0.85	0.75	4	46.8	47.5
NR 1045	2.05	1.9	0.85	0.75	4	47.8	48.5
NR 1047	2.05	1.9	0.85	0.75	4	49.8	50.5
NR 1052	2.05	1.9	0.85	0.75	4	54.8	55.5
NR 1055	2.05	1.9	0.85	0.75	4	57.8	58.5
NR 1058	2.05	1.9	0.85	0.75	4	60.8	61.5
NR 1062	2.05	1.9	0.85	0.75	4	64.8	65.5
NR 1065	2.05	1.9	0.85	0.75	4	67.8	68.5
NR 1068	2.05	1.9	0.85	0.75	5	70.8	72
NR 1072	2.05	1.9	0.85	0.75	5	74.8	76
NR 1078	3.25	3.1	1.12	1.02	5	82.7	84
NR 1080	3.25	3.1	1.12	1.02	5	84.4	86
NR 1085	3.25	3.1	1.12	1.02	5	89.4	91
NR 1090	3.25	3.1	1.12	1.02	5	94.4	96
NR 1095	3.25	3.1	1.12	1.02	5	99.4	101
NR 1100	3.25	3.1	1.12	1.02	5	104.4	106
NR 1105	4.04	3.89	1.12	1.02	5	110.7	112
NR 1110	4.04	3.89	1.12	1.02	5	115.7	117
NR 1115	4.04	3.89	1.12	1.02	5	120.7	122
NR 1120	4.04	3.89	1.12	1.02	7	125.7	127
NR 1125	4.04	3.89	1.12	1.02	7	130.7	132
NR 1130	4.04	3.89	1.12	1.02	7	135.7	137
NR 1140	4.04	3.89	1.7	1.6	7	145.7	147
NR 1145	4.04	3.89	1.7	1.6	7	150.7	152
NR 1150	4.04	3.89	1.7	1.6	7	155.7	157
NR 1165	4.85	4.7	1.7	1.6	7	171.5	173
NR 1175	4.85	4.7	1.7	1.6	10	181.5	183
NR 1180	4.85	4.7	1.7	1.6	10	186.5	188
NR 1190	4.85	4.7	1.7	1.6	10	196.5	198
NR 1200	4.85	4.7	1.7	1.6	10	206.5	208

Remarks The minimum permissible chamfer dimensions r_N on the snap-ring-groove side of the outer rings are as follows:
Dimension series 18 : For outside diameters of 78mm and less, use 0.3mm chamfer.
For all others exceeding 78mm, use 0.5mm chamfer.
Dimension series 19 : For outside diameters of 24mm and less, use 0.2mm chamfer.
For 47mm and less, use 0.3mm chamfer.
For all others exceeding 47mm, use 0.5mm chamfer (However, for an outside diameter of 68 mm, use a 0.3 mm chamfer, which is not compliant with ISO 15).

Table 7. 4 Dimensions of Snap Ring Grooves and Locating Snap Rings — (2)
Bearing of Diameter Series 0, 2, 3, and 4







Units: mm

Applicable Bearings					Snap Ring Groove									Locating Snap Ring							Side Cover
d				D	Snap Ring Groove Diameter D_1		Snap Ring Groove Position a				Snap Ring Groove Width b		Radius of Bottom Corners r_0	Locating Snap Ring Number	Cross Sectional Height e		Thickness f		Geometry of snap ring fitted in groove (Reference)		Stepped Bore Diameter (Reference) D_X
Diameter Series							Bearing Diameter Series														
							0		2, 3, 4										Slit Width g	Snap Ring Outside Diameter D_2	
0	2	3	4		max.	min.	max.	min.	max.	min.	max.	min.	max.		max.	min.	max.	min.	approx.	max.	min.
10	—	—	—	**26**	24.5	24.25	1.35	1.19	—	—	1.17	0.87	0.2	**NR 26** (1)	2.06	1.91	0.84	0.74	3	28.7	29.4
12	—	—	—	**28**	26.5	26.25	1.35	1.19	—	—	1.17	0.87	0.2	**NR 28** (1)	2.06	1.91	0.84	0.74	3	30.7	31.4
—	10	9	8	**30**	28.17	27.91	—	—	2.06	1.9	1.65	1.35	0.4	**NR 30**	3.25	3.1	1.12	1.02	3	34.7	35.5
15	12	—	9	**32**	30.15	29.9	2.06	1.9	2.06	1.9	1.65	1.35	0.4	**NR 32**	3.25	3.1	1.12	1.02	3	36.7	37.5
17	15	10	—	**35**	33.17	32.92	2.06	1.9	2.06	1.9	1.65	1.35	0.4	**NR 35**	3.25	3.1	1.12	1.02	3	39.7	40.5
—	—	12	10	**37**	34.77	34.52	—	—	2.06	1.9	1.65	1.35	0.4	**NR 37**	3.25	3.1	1.12	1.02	3	41.3	42
—	17	—	—	**40**	38.1	37.85	—	—	2.06	1.9	1.65	1.35	0.4	**NR 40**	3.25	3.1	1.12	1.02	3	44.6	45.5
20	—	15	12	**42**	39.75	39.5	2.06	1.9	2.06	1.9	1.65	1.35	0.4	**NR 42**	3.25	3.1	1.12	1.02	3	46.3	47
22	—	—	—	**44**	41.75	41.5	2.06	1.9	—	—	1.65	1.35	0.4	**NR 44**	3.25	3.1	1.12	1.02	3	48.3	49
25	20	17	—	**47**	44.6	44.35	2.06	1.9	2.46	2.31	1.65	1.35	0.4	**NR 47**	4.04	3.89	1.12	1.02	4	52.7	53.5
—	22	—	—	**50**	47.6	47.35	—	—	2.46	2.31	1.65	1.35	0.4	**NR 50**	4.04	3.89	1.12	1.02	4	55.7	56.5
28	25	20	15	**52**	49.73	49.48	2.06	1.9	2.46	2.31	1.65	1.35	0.4	**NR 52**	4.04	3.89	1.12	1.02	4	57.9	58.5
30	—	—	—	**55**	52.6	52.35	2.08	1.88	—	—	1.65	1.35	0.4	**NR 55**	4.04	3.89	1.12	1.02	4	60.7	61.5
—	—	22	—	**56**	53.6	53.35	—	—	2.46	2.31	1.65	1.35	0.4	**NR 56**	4.04	3.89	1.12	1.02	4	61.7	62.5
32	28	—	—	**58**	55.6	55.35	2.08	1.88	2.46	2.31	1.65	1.35	0.4	**NR 58**	4.04	3.89	1.12	1.02	4	63.7	64.5
35	30	25	17	**62**	59.61	59.11	2.08	1.88	3.28	3.07	2.2	1.9	0.6	**NR 62**	4.04	3.89	1.7	1.6	4	67.7	68.5
—	32	—	—	**65**	62.6	62.1	—	—	3.28	3.07	2.2	1.9	0.6	**NR 65**	4.04	3.89	1.7	1.6	4	70.7	71.5
40	—	28	—	**68**	64.82	64.31	2.49	2.29	3.28	3.07	2.2	1.9	0.6	**NR 68**	4.85	4.7	1.7	1.6	5	74.6	76
—	35	30	20	**72**	68.81	68.3	—	—	3.28	3.07	2.2	1.9	0.6	**NR 72**	4.85	4.7	1.7	1.6	5	78.6	80
45	—	32	—	**75**	71.83	71.32	2.49	2.29	3.28	3.07	2.2	1.9	0.6	**NR 75**	4.85	4.7	1.7	1.6	5	81.6	83
50	40	35	25	**80**	76.81	76.3	2.49	2.29	3.28	3.07	2.2	1.9	0.6	**NR 80**	4.85	4.7	1.7	1.6	5	86.6	88
—	45	—	—	**85**	81.81	81.31	—	—	3.28	3.07	2.2	1.9	0.6	**NR 85**	4.85	4.7	1.7	1.6	5	91.6	93
55	50	40	30	**90**	86.79	86.28	2.87	2.67	3.28	3.07	3	2.7	0.6	**NR 90**	4.85	4.7	2.46	2.36	5	96.5	98
60	—	—	—	**95**	91.82	91.31	2.87	2.67	—	—	3	2.7	0.6	**NR 95**	4.85	4.7	2.46	2.36	5	101.6	103
65	55	45	35	**100**	96.8	96.29	2.87	2.67	3.28	3.07	3	2.7	0.6	**NR 100**	4.85	4.7	2.46	2.36	5	106.5	108
70	60	50	40	**110**	106.81	106.3	2.87	2.67	3.28	3.07	3	2.7	0.6	**NR 110**	4.85	4.7	2.46	2.36	5	116.6	118
75	—	—	—	**115**	111.81	111.3	2.87	2.67	—	—	3	2.7	0.6	**NR 115**	4.85	4.7	2.46	2.36	5	121.6	123
—	65	55	45	**120**	115.21	114.71	—	—	4.06	3.86	3.4	3.1	0.6	**NR 120**	7.21	7.06	2.82	2.72	7	129.7	131.5
80	70	—	—	**125**	120.22	119.71	2.87	2.67	4.06	3.86	3.4	3.1	0.6	**NR 125**	7.21	7.06	2.82	2.72	7	134.7	136.5
85	75	60	50	**130**	125.22	124.71	2.87	2.67	4.06	3.86	3.4	3.1	0.6	**NR 130**	7.21	7.06	2.82	2.72	7	139.7	141.5
90	80	65	55	**140**	135.23	134.72	3.71	3.45	4.9	4.65	3.4	3.1	0.6	**NR 140**	7.21	7.06	2.82	2.72	7	149.7	152
95	—	—	—	**145**	140.23	139.73	3.71	3.45	—	—	3.4	3.1	0.6	**NR 145**	7.21	7.06	2.82	2.72	7	154.7	157
100	85	70	60	**150**	145.24	144.73	3.71	3.45	4.9	4.65	3.4	3.1	0.6	**NR 150**	7.21	7.06	2.82	2.72	7	159.7	162
105	90	75	65	**160**	155.22	154.71	3.71	3.45	4.9	4.65	3.4	3.1	0.6	**NR 160**	7.21	7.06	2.82	2.72	7	169.7	172
110	95	80	—	**170**	163.65	163.14	3.71	3.45	5.69	5.44	3.8	3.5	0.6	**NR 170**	9.6	9.45	3.1	3	10	182.9	185
120	100	85	70	**180**	173.66	173.15	3.71	3.45	5.69	5.44	3.8	3.5	0.6	**NR 180**	9.6	9.45	3.1	3	10	192.9	195
—	105	90	75	**190**	183.64	183.13	—	—	5.69	5.44	3.8	3.5	0.6	**NR 190**	9.6	9.45	3.1	3	10	202.9	205
130	110	95	80	**200**	193.65	193.14	5.69	5.44	5.69	5.44	3.8	3.5	0.6	**NR 200**	9.6	9.45	3.1	3	10	212.9	215

Note (1) The locating snap rings and snap ring grooves of these bearings are not specified by ISO.

Remarks 1. The dimensions of these snap ring grooves are not applicable to bearings of dimension series 00, 82, and 83.
2. The minimum permissible chamfer dimension r_N on the snap-ring side of outer rings is 0.5mm. However, for bearings of diameter series 0 having outside diameters 35mm and below, it is 0.3mm.

7.2 Formulation of Bearing Numbers

Bearing numbers are alphanumeric combinations that indicate the bearing type, boundary dimensions, dimensional and running accuracies, internal clearance, and other related specifications. They consist of basic numbers and supplementary symbols. The boundary dimensions of commonly used bearings mostly conform to the organizational concept of ISO, and the bearing numbers of these standard bearings are specified by JIS B 1513 (Bearing Numbers for Rolling Bearings). Due to a need for more detailed classification, NSK uses auxiliary symbols other than those specified by JIS.

Bearing numbers consist of a basic number and supplementary symbols. The basic number indicates the bearing series(type) and the width and diameter series as shown in Table 7.5. Basic numbers, supplementary symbols, and the meanings of common numbers and symbols are listed in Table 7.6 (Pages A56 and A57). The contact angle symbols and other supplementary designations are shown in successive columns from left to right in Table 7.6. For reference, some examples of bearing designations are shown here:

(Example 1) 6 3 0 8 ZZ C3

- Radial Clearance **C3** (Internal Clearance Symbol)
- Shields on Both Sides (Shield Symbol)
- Bearing Bore **40mm** (Bore Number)
- Diameter Series **3** } Bearing Series Symbol
- Single-Row Deep Groove Ball Bearing } Bearing Series Symbol

(Example 2) 7 2 2 0 A DB C3

- Axial Clearance **C3**
- Back-to-Back Arrangement
- Contact Angle **30°**
- Bearing Bore **100mm**
- Diameter Series **2**
- Single-Row Angular Contact Ball Bearing

(Example 3) 1 2 0 6 K +H206X

- Adapter with **25mm** Bore
- Tapered Bore (Taper **1:12**)
- Bearing Bore **30mm**
- Diameter Series **2**
- Self-Aligning Ball Bearing

(Example 4) NU 3 1 8 M CM

- Radial Clearance for Electric-Motor Bearings **CM**
- Machined Brass Cage
- Bearing Bore **90mm**
- Diameter Series **3**
- **NU** Type Cylindrical Roller Bearing

(Example 5) NN 3 0 1 7 K CC1 P4

- Accuracy of ISO **Class 4**
- Radial Clearance in Non-Interchangeable Cylindrical Roller Bearings **CC1**
- Tapered Bore (Taper **1:12**)
- Bearing Bore **85mm**
- Diameter Series **0**
- Width Series **3**
- **NN** Type Cylindrical Roller Bearing

(Example 6) HR 3 0 2 0 7 J

- Small Diameter of Cup Raceway and Contact Angle Conform to ISO
- Bearing Bore **35mm**
- Diameter Series **2**
- Width Series **0**
- Tapered Roller Bearing
- High Capacity Bearing

(Example 7) 2 4 0 /1000 M K30 E4 C3

- Radial Clearance **C3**
- Outer Ring with Oil Groove and Oil Holes
- Tapered Bore (Taper **1:30**)
- Machined Brass Cage
- Bearing Bore **1000mm**
- Diameter Series **0**
- Width Series **4**
- Spherical Roller Bearing

(Example 8) 5 1 2 1 5

- Bearing Bore **75mm**
- Diameter Series **2**
- Height Series **1**
- Thrust Ball Bearing

Table 7. 5 Bearing Series Symbols

Bearing Type	Bearing Series Symbols	Type Symbols	Dimension Symbols: Width Symbols	Dimension Symbols: Diameter Symbols
Single-Row Deep Groove Ball Bearings	**68**	6	(1)	8
	69	6	(1)	9
	60	6	(1)	0
	62	6	(0)	2
	63	6	(0)	3
Single-Row Angular Contact Ball Bearings	**79**	7	(1)	9
	70	7	(1)	0
	72	7	(0)	2
	73	7	(0)	3
Self-Aligning Ball Bearings	**12**	1	(0)	2
	13	1	(0)	3
	22	(1)	2	2
	23	(1)	2	3
Single-Row Cylindrical Roller Bearings	**NU10**	NU	1	0
	NU2	NU	(0)	2
	NU22	NU	2	2
	NU3	NU	(0)	3
	NU23	NU	2	3
	NU4	NU	(0)	4
	NJ2	NJ	(0)	2
	NJ22	NJ	2	2
	NJ3	NJ	(0)	3
	NJ23	NJ	2	3
	NJ4	NJ	(0)	4
	NUP2	NUP	(0)	2
	NUP22	NUP	2	2
	NUP3	NUP	(0)	3
	NUP23	NUP	2	3
	NUP4	NUP	(0)	4
	N10	N	1	0
	N2	N	(0)	2
	N3	N	(0)	3
	N4	N	(0)	4
	NF2	NF	(0)	2
	NF3	NF	(0)	3
	NF4	NF	(0)	4

Bearing Type	Bearing Series Symbols	Type Symbols	Dimension Symbols: Width Symbols or Height Symbols	Dimension Symbols: Diameter Symbols
Double-Row Cylindrical Roller Bearings	**NNU49**	NNU	4	9
	NN30	NN	3	0
Needle Roller Bearings	**NA48**	NA	4	8
	NA49	NA	4	9
	NA59	NA	5	9
	NA69	NA	6	9
Tapered Roller Bearings	**329**	3	2	9
	320	3	2	0
	330	3	3	0
	331	3	3	1
	302	3	0	2
	322	3	2	2
	332	3	3	2
	303	3	0	3
	323	3	2	3
Spherical Roller Bearings	**230**	2	3	0
	231	2	3	1
	222	2	2	2
	232	2	3	2
	213 (1)	2	0	3
	223	2	2	3
Thrust Ball Bearings with Flat Seats	**511**	5	1	1
	512	5	1	2
	513	5	1	3
	514	5	1	4
	522	5	2	2
	523	5	2	3
	524	5	2	4
Spherical Thrust Roller Bearings	**292**	2	9	2
	293	2	9	3
	294	2	9	4

Note (1) Bearing Series Symbol 213 should logically be 203, but customarily it is numbered 213.

Remarks Numbers in ( ) in the column of width symbols are usually omitted from the bearing number.

Table 7. 6 Formulation of Bearing Numbers

Basic Numbers

Bearing Series Symbols (1)

Symbol	Meaning
68, 69, 60, :	Single-Row Deep Groove Ball Bearings
70, 72, 73, :	Single-Row Angular Contact Ball Bearings
12, 13, 22, :	Self-Aligning Ball Bearings
NU10, NJ 2, N 3, NN 30, :	Cylindrical Roller Bearings
NA48, NA49, NA69, :	Needle Roller Bearings
320, 322, 323, :	Tapered Roller Bearings (2)
230, 222, 223, :	Spherical Roller Bearings
511, 512, 513, :	Thrust Ball Bearing with Flat Seats
292, 293, 294, :	Thrust Spherical Roller Bearings
HR(4)	High Capacity Tapered Roller Bearings, and others

Bore Number

Symbol	Meaning
1	Bearing Bore 1mm
2	2
3	3
⋮	⋮
9	9
00	10
01	12
02	15
03	17
/22	22
/28	28
/32	32
04(3)	20
05	25
06	30
⋮	⋮
88	440
92	460
96	480
/500	500
/530	530
/560	560
⋮	⋮
/2 360	2 360
/2 500	2 500

Contact Angle Symbol

Symbol	Meaning
	(Angular Contact Ball Bearings)
A	Standard Contact Angle of 30°
A5	Standard Contact Angle of 25°
B	Standard Contact Angle of 40°
C	Standard Contact Angle of 15°
	(Tapered Roller Bearings)
Omitted	Contact Angle Less than 17°
C	Contact Angle about 20°
D	Contact Angle about 28°

Basic Numbers: Symbols and Numbers Conform to JIS(5) — Marked on Bearings

Auxiliary Symbols

Internal Design Symbol

Symbol	Meaning
A	Internal Design Differs from Standard One
J	Smaller Diameter of Outer Ring Raceway, Contact Angle, and Outer Ring Width of Tapered Roller Bearings Conform to ISO 355
	(For High Capacity Bearings)
C, CA, CD, EA	Spherical Roller Bearings
E	Cylindrical Roller Bearings
E	Spherical Thrust Roller Bearings

Material Symbol

Symbol	Meaning
g	Case-Hardened Steel Used in Rings, Rolling Elements
h	Stainless Steel Used in Rings, Rolling Elements

Cage Symbol

Symbol	Meaning
M	Machined Brass Cage
W	Pressed Steel Cage
T	Synthetic Resin Cage
V	Without Cage

Internal Design, Material and Cage Symbols: NSK Symbol. Internal Design and Material Symbols: Marked on Bearings; Cage Symbol: Not Marked on Bearings

External Features — Seals, Shields Symbol

Symbol	Meaning
Z, ZS	Shield on One Side Only
ZZ, ZZS	Shields on Both Sides
DU	Contact Rubber Seal on One Side Only
DDU	Contact Rubber Seals on Both Sides
V	Non-Contact Rubber Seal on One Side Only
VV	Non-Contact Rubber Seals on Both Sides

Seals, Shields Symbol: NSK Symbol

Symbol for Design of Rings

Symbol	Meaning
K	Tapered Bore of Inner Ring (Taper 1:12)
K30	Tapered Bore of Inner Ring (Taper 1:30)
E	Notch or Lubricating Groove in Ring
E4	Lubricating Groove in Outside Surface and Holes in Outer Ring
N	Snap Ring Groove in Outer Ring
NR	Snap Ring Groove with Snap Ring in Outer Ring

Symbol for Design of Rings: Partially the same as JIS(5)

Arrangement Symbol

Symbol	Meaning
DB	Back-to-Back Arrangement
DF	Face-to-Face Arrangement
DT	Tandem Arrangement

Arrangement Symbol: Same as JIS(5)

Internal Clearance Symbol / Preload Symbol

Symbol	Meaning (radial clearance)
	For All Radial Brgs.
C1	Clearance Less than C2
C2	Clearance Less than CN
Omitted	CN Clearance
C3	Clearance Greater than CN
C4	Clearance Greater than C3
C5	Clearance Greater than C4
	For Non-Interchangeable Cylindrical Roller Brgs.
CC1	Clearance Less than CC2
CC2	Clearance Less than CC
CC	Normal Clearance
CC3	Clearance Greater than CC
CC4	Clearance Greater than CC3
CC5	Clearance Greater than CC4
	For Extra-Small and Miniature Ball Brgs.
MC1	Clearance Less than MC2
MC2	Clearance Less than MC3
MC3	Normal Clearance
MC4	Clearance Greater than MC3
MC5	Clearance Greater than MC4
MC6	Clearance Greater than MC5
CM	Clearance in Deep Groove Ball Bearings for Electric Motors
CT, CM	Clearance in Cylindrical Roller Bearings for Electric Motors
	(Preload of Angular Contact Ball Bearing)
EL	Extra light Preload
L	Light Preload
M	Medium Preload
H	Heavy Preload

Internal Clearance Symbol / Preload Symbol: NSK Symbol; Partially the same as JIS(5)/BAS(6)

Tolerance Class Symbol

Symbol	Meaning
Omitted	ISO Normal
P6	ISO Class 6
P6X	ISO Class 6X
P5	ISO Class 5
P4	ISO Class 4
P2	ISO Class 2
	(ABMA(7) Tapered roller bearing)
Omitted	Class 4
PN2	Class 2
PN3	Class 3
PN0	Class 0
PN00	Class 00

Tolerance Class Symbol: Same as JIS(5)

Special Specification Symbol

Symbol	Meaning
	(Bearings treated for Dimensional Stabilization)
X26	Working Temperature Lower than 150 °C
X28	Working Temperature Lower than 200 °C
X29	Working Temperature Lower than 250 °C
	(Spherical Roller Bearings)
S11	Dimensional Stabilizing Treatment Working Temperature Lower than 200°C

Spacer or Sleeve Symbol

Symbol	Meaning
+K	Bearings with Outer Ring Spacers
+L	Bearings with Inner Ring Spacers
+KL	Bearings with Both Inner and Outer Ring Spacers
H	Adapter Designation
AH	Withdrawal Sleeve Designation
HJ	Thrust Collar Designation

Grease Symbol

Symbol	Meaning
AS2	SHELL ALVANIA GREASE S2
ENS	ENS GREASE
NS7	NS HI-LUBE
PS2	MULTEMP PS No. 2

Special Specification, Spacer or Sleeve, and Grease Symbols: NSK Symbol, Partially the same as JIS(5)

Symbol for Design of Rings through Special Specification Symbol: In Principle, Marked on Bearings. Spacer or Sleeve and Grease Symbols: Not Marked on Bearings

Notes (1) Bearing Series Symbols conform to Table 7.5.
(2) For basic numbers of tapered roller bearings in ISO's new series, refer to Page B111.
(3) For Bearing Bore Numbers 04 through 96, five times the bore number gives the bore size (mm) (except double-direction thrust ball bearings).
(4) HR is prefix to bearing series symbols and it is NSK's original prefix.

Notes (5) JIS : Japanese Industrial Standards.
(6) BAS : The Japan Bearing Industrial Association Standard.
(7) ABMA : The American Bearing Manufacturers Association.

8. BEARING TOLERANCES

8.1 Bearing Tolerance Standards

The tolerances for the boundary dimensions and running accuracy of rolling bearings are specified by ISO 492/199/582 (Accuracies of Rolling Bearings). Tolerances are specified for the following items:

Regarding bearing accuracy classes, besides ISO normal accuracy, as the accuracy improves there are Class 6X (for tapered roller bearings), Class 6, Class 5, Class 4, and Class 2, with Class 2 being the highest in ISO. The applicable accuracy classes for each bearing type and the correspondence of these classes are shown in Table 8.1.

Accuracy of Rolling Bearings

- Tolerances for Dimensions (Items necessary to mount bearings on shafts or in housings)
  - Tolerances for bore and outside diameters, ring width and bearing width
  - Tolerances for inscribed and circumscribed circle diameters of rollers
  - Tolerances for chamfer dimensions
  - Tolerances for width variation
  - Tolerances for tapered bore diameters
- Running Accuracy (Items necessary to specify the runout of rotating machine parts)
  - Permissible radial runout of inner and outer rings
  - Permissible face runout with raceway inner and outer rings
  - Permissible inner ring face runout with bore
  - Permissible outer ring variation of outside surface generatrix inclination with face
  - Permissible raceway to back face thickness variation of thrust bearings

Table 8. 1 Bearing Types and Tolerance Classes

Bearing Types		Applicable Tolerance Classes					Applicable Tables	Reference Pages
Deep Groove Ball Bearings		Normal	Class 6	Class 5	Class 4	Class 2	Table 8.2	A60 to A63
Angular Contact Ball Bearings		Normal	Class 6	Class 5	Class 4	Class 2		
Self-Aligning Ball Bearings		Normal	Class 6 equivalent	Class 5 equivalent	—	—		
Cylindrical Roller Bearings		Normal	Class 6	Class 5	Class 4	Class 2		
Needle Roller Bearings (solid type)		Normal	Class 6	Class 5	Class 4	—		
Spherical Roller Bearings		Normal	Class 6	Class 5	—	—		
Tapered Roller Bearings	Metric Design	Normal Class 6X	—	Class 5	Class 4	—	Table 8.3	A64 to A67
	Inch Design	ANSI/ABMA CLASS 4	ANSI/ABMA CLASS 2	ANSI/ABMA CLASS 3	ANSI/ABMA CLASS 0	ANSI/ABMA CLASS 00	Table 8.4	A68 and A69
Magneto Bearings		Normal	Class 6	Class 5	—	—	Table 8.5	A70 and A71
Thrust Ball Bearings		Normal	Class 6	Class 5	Class 4	—	Table 8.4	A72 to A74
Thrust Spherical Roller Bearings		Normal	—	—	—	—	Table 8.7	A75
Equivalent standards (Reference) JIS(1)		Class 0	Class 6	Class 5	Class 4	Class 2	—	—
DIN(2)		P0	P6	P5	P4	P2	—	—
ANSI/ABMA(3)	Ball Bearings	ABEC 1	ABEC 3	ABEC 5 (CLASS 5P)	ABEC 7 (CLASS 7P)	ABEC 9 (CLASS 9P)	Table 8.2	A60 to A63
	Roller Bearings	RBEC 1	RBEC 3	RBEC 5	—	—	[Table 8.8]	(A76 and A77)
	Tapered Roller Bearings	CLASS 4	CLASS 2	CLASS 3	CLASS 0	CLASS 00	[Table 8.4]	(A68 and A69)

Notes (1) JIS : Japanese Industrial Standards (2) DIN : Deutsch Industrie Norm
(3) ANSI/ABMA : The American Bearing Manufacturers Association

Remarks The permissible limit of chamfer dimensions shall conform to Table 8.9 (Page A78), and the tolerances and permissible tapered bore diameters shall conform to Table 8.10 (Page A80).

(Reference) Rough definitions of the items listed for Running Accuracy and their measuring methods are shown in Fig. 8.1, and they are described in detail in ISO 5593 (Rolling Bearings-Vocabulary) and JIS B 1515 (Rolling Bearings-Tolerances) and elsewhere.

Supplementary Table

Running Accuracy	Inner Ring	Outer Ring	Dial Gauge
K_{ia}	Rotating	Stationary	A
K_{ea}	Stationary	Rotating	A
S_{ia}	Rotating	Stationary	B_1
S_{ea}	Stationary	Rotating	B_2
S_d	Rotating	Stationary	C
S_D	—	Rotating	D
S_i , S_e	Only the shaft or housing or central washer is to be rotated.		E

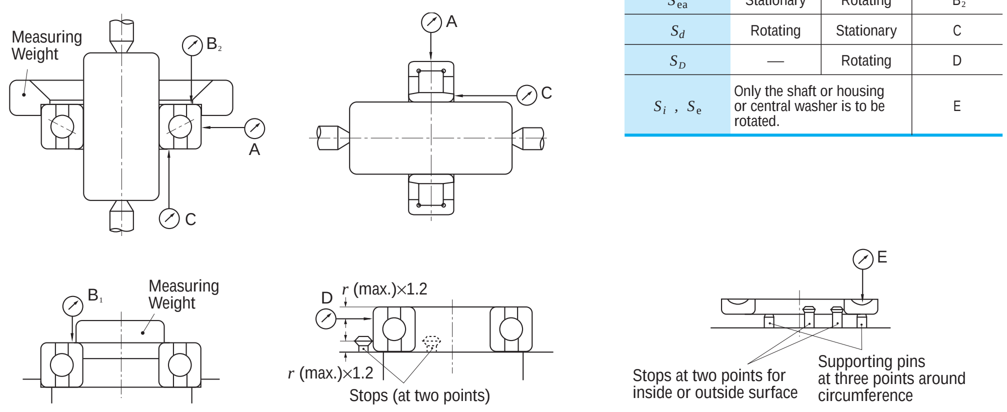


Fig. 8.1 Measuring Methods for Running Accuracy (summarized)

Symbols for Boundary Dimensions and Running Accuracy

d	Brg bore dia., nominal
Δ_{ds}	Deviation of a single bore dia.
Δ_{dmp}	Single plane mean bore dia. deviation
V_{dp}	Bore dia. Variation in a single radial plane
V_{dmp}	Mean bore dia. Variation
B	Inner ring width, nominal
Δ_{Bs}	Deviation of a single inner ring width
V_{Bs}	Inner ring width variation
K_{ia}	Radial runout of assembles brg inner ring
S_d	inner ring reference face (backface, where applicable) runout with bore
S_{ia}	Assembled brg inner ring face (back face) runout with raceway
S_i, S_e	Raceway to backface thickness variation of thrust brg
T	Brg width, nominal
Δ_{Ts}	Deviation of the actual brg width
D	Brg outside dia., nominal
Δ_{Ds}	Deviation of a single outside dia.
Δ_{Dmp}	Single plane mean outside dia. Deviation
V_{Dp}	Outside dia. Variation in a single radial plane
V_{Dmp}	Mean outside dia. Variation
C	Outer ring width, nominal
Δ_{Cs}	Deviation of a single outer ring width
V_{Cs}	Outer ring width variation
K_{ea}	Radial runout of assembled brg outer ring
S_D	Variation of brg outside surface generatrix inclination with outer ring reference face (backface)
S_{ea}	Assembled brg outer ring face (backface) runout with raceway

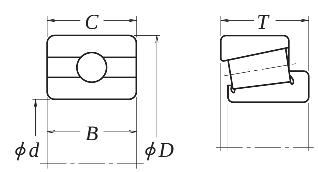


Table 8. 2 Tolerances for Radial Bearings (excluding Tapered Roller Bearings)

Table 8. 2. 1 Tolerances for Inner Rings and Widths of Outer Rings

Nominal Bore Diameter d (mm)		Δ_{dmp} (2)										Δ_{ds} (2)			
		Normal		Class 6		Class 5		Class 4		Class 2		Class 4 Diameter Series 0, 1, 2, 3, 4		Class 2	
over	incl.	high	low	high	low	high	low	high	low	high	low	high	low	high	low
0.6(1)	**2.5**	0	− 8	0	− 7	0	− 5	0	− 4	0	−2.5	0	− 4	0	−2.5
2.5	**10**	0	− 8	0	− 7	0	− 5	0	− 4	0	−2.5	0	− 4	0	−2.5
10	**18**	0	− 8	0	− 7	0	− 5	0	− 4	0	−2.5	0	− 4	0	−2.5
18	**30**	0	− 10	0	− 8	0	− 6	0	− 5	0	−2.5	0	− 5	0	−2.5
30	**50**	0	− 12	0	−10	0	− 8	0	− 6	0	−2.5	0	− 6	0	−2.5
50	**80**	0	− 15	0	−12	0	− 9	0	− 7	0	−4	0	− 7	0	−4
80	**120**	0	− 20	0	−15	0	−10	0	− 8	0	−5	0	− 8	0	−5
120	**150**	0	− 25	0	−18	0	−13	0	−10	0	−7	0	−10	0	−7
150	**180**	0	− 25	0	−18	0	−13	0	−10	0	−7	0	−10	0	−7
180	**250**	0	− 30	0	−22	0	−15	0	−12	0	−8	0	−12	0	−8
250	**315**	0	− 35	0	−25	0	−18	−	−	−	−	−	−	−	−
315	**400**	0	− 40	0	−30	0	−23	−	−	−	−	−	−	−	−
400	**500**	0	− 45	0	−35	−	−	−	−	−	−	−	−	−	−
500	**630**	0	− 50	0	−40	−	−	−	−	−	−	−	−	−	−
630	**800**	0	− 75	−	−	−	−	−	−	−	−	−	−	−	−
800	**1 000**	0	−100	−	−	−	−	−	−	−	−	−	−	−	−
1 000	**1 250**	0	−125	−	−	−	−	−	−	−	−	−	−	−	−
1 250	**1 600**	0	−160	−	−	−	−	−	−	−	−	−	−	−	−
1 600	**2 000**	0	−200	−	−	−	−	−	−	−	−	−	−	−	−

Nominal Bore Diameter d (mm)		V_{dp} (2)											V_{dmp} (2)				
		Normal Diameter Series			Class 6 Diameter Series			Class 5 Diameter Series		Class 4 Diameter Series		Class 2 Diameter Series	Normal	Class 6	Class 5	Class 4	Class 2
		9	0, 1	2, 3, 4	9	0, 1	2, 3, 4	9	0,1,2,3,4	9	0,1,2,3,4	0,1,2,3,4					
over	incl.	max.			max.			max.		max.		max.	max.	max.	max.	max.	max.
0.6(1)	**2.5**	10	8	6	9	7	5	5	4	4	3	2.5	6	5	3	2	1.5
2.5	**10**	10	8	6	9	7	5	5	4	4	3	2.5	6	5	3	2	1.5
10	**18**	10	8	6	9	7	5	5	4	4	3	2.5	6	5	3	2	1.5
18	**30**	13	10	8	10	8	6	6	5	5	4	2.5	8	6	3	2.5	1.5
30	**50**	15	12	9	13	10	8	8	6	6	5	2.5	9	8	4	3	1.5
50	**80**	19	19	11	15	15	9	9	7	7	5	4	11	9	5	3.5	2
80	**120**	25	25	15	19	19	11	10	8	8	6	5	15	11	5	4	2.5
120	**150**	31	31	19	23	23	14	13	10	10	8	7	19	14	7	5	3.5
150	**180**	31	31	19	23	23	14	13	10	10	8	7	19	14	7	5	3.5
180	**250**	38	38	23	28	28	17	15	12	12	9	8	23	17	8	6	4
250	**315**	44	44	26	31	31	19	18	14	−	−	−	26	19	9	−	−
315	**400**	50	50	30	38	38	23	23	18	−	−	−	30	23	12	−	−
400	**500**	56	56	34	44	44	26	−	−	−	−	−	34	26	−	−	−
500	**630**	63	63	38	50	50	30	−	−	−	−	−	38	30	−	−	−
630	**800**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
800	**1 000**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
1 000	**1 250**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
1 250	**1 600**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
1 600	**2 000**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−

Units : μm

Nominal Bore Diameter d (mm)		Δ_{Bs} (or Δ_{Cs})(3)												V_{Bs} (or V_{Cs})				
		Single Bearing						Combined Bearings (4)						Inner Ring (or Outer Ring) (3)		Inner Ring		
		Normal Class 6		Class 5 Class 4		Class 2		Normal Class 6		Class 5 Class 4		Class 2		Normal	Class 6	Class 5	Class 4	Class 2
over	incl.	high	low	high	low	high	low	high	low	high	low	high	low	max.	max.	max.	max.	max.
0.6(1)	**2.5**	0	− 40	0	− 40	0	− 40	—	—	0	−250	0	−250	12	12	5	2.5	1.5
2.5	**10**	0	− 120	0	− 40	0	− 40	0	−250	0	−250	0	−250	15	15	5	2.5	1.5
10	**18**	0	− 120	0	− 80	0	− 80	0	−250	0	−250	0	−250	20	20	5	2.5	1.5
18	**30**	0	− 120	0	−120	0	−120	0	−250	0	−250	0	−250	20	20	5	2.5	1.5
30	**50**	0	− 120	0	−120	0	−120	0	−250	0	−250	0	−250	20	20	5	3	1.5
50	**80**	0	− 150	0	−150	0	−150	0	−380	0	−250	0	−250	25	25	6	4	1.5
80	**120**	0	− 200	0	−200	0	−200	0	−380	0	−380	0	−380	25	25	7	4	2.5
120	**150**	0	− 250	0	−250	0	−250	0	−500	0	−380	0	−380	30	30	8	5	2.5
150	**180**	0	− 250	0	−250	0	−250	0	−500	0	−380	0	−380	30	30	8	5	4
180	**250**	0	− 300	0	−300	0	−300	0	−500	0	−500	0	−500	30	30	10	6	5
250	**315**	0	− 350	0	−350	−	−	0	−500	0	−500	−	−	35	35	13	−	−
315	**400**	0	− 400	0	−400	−	−	0	−630	0	−630	−	−	40	40	15	−	−
400	**500**	0	− 450	−	−	−	−	−	−	−	−	−	−	50	45	−	−	−
500	**630**	0	− 500	−	−	−	−	−	−	−	−	−	−	60	50	−	−	−
630	**800**	0	− 750	−	−	−	−	−	−	−	−	−	−	70	−	−	−	−
800	**1 000**	0	−1 000	−	−	−	−	−	−	−	−	−	−	80	−	−	−	−
1 000	**1 250**	0	−1 250	−	−	−	−	−	−	−	−	−	−	100	−	−	−	−
1 250	**1 600**	0	−1 600	−	−	−	−	−	−	−	−	−	−	120	−	−	−	−
1 600	**2 000**	0	−2 000	−	−	−	−	−	−	−	−	−	−	140	−	−	−	−

Nominal Bore Diameter d (mm)		K_{ia}					S_d			S_{ia} (5)		
over	incl.	Normal	Class 6	Class 5	Class 4	Class 2	Class 5	Class 4	Class 2	Class 5	Class 4	Class 2
		max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.
0.6(1)	**2.5**	10	5	4	2.5	1.5	7	3	1.5	7	3	1.5
2.5	**10**	10	6	4	2.5	1.5	7	3	1.5	7	3	1.5
10	**18**	10	7	4	2.5	1.5	7	3	1.5	7	3	1.5
18	**30**	13	8	4	3	2.5	8	4	1.5	8	4	2.5
30	**50**	15	10	5	4	2.5	8	4	1.5	8	4	2.5
50	**80**	20	10	5	4	2.5	8	5	1.5	8	5	2.5
80	**120**	25	13	6	5	2.5	9	5	2.5	9	5	2.5
120	**150**	30	18	8	6	2.5	10	6	2.5	10	7	2.5
150	**180**	30	18	8	6	5	10	6	4	10	7	5
180	**250**	40	20	10	8	5	11	7	5	13	8	5
250	**315**	50	25	13	−	−	13	−	−	15	−	−
315	**400**	60	30	15	−	−	15	−	−	20	−	−
400	**500**	65	35	−	−	−	−	−	−	−	−	−
500	**630**	70	40	−	−	−	−	−	−	−	−	−
630	**800**	80	−	−	−	−	−	−	−	−	−	−
800	**1 000**	90	−	−	−	−	−	−	−	−	−	−
1 000	**1 250**	100	−	−	−	−	−	−	−	−	−	−
1 250	**1 600**	120	−	−	−	−	−	−	−	−	−	−
1 600	**2 000**	140	−	−	−	−	−	−	−	−	−	−

Notes
(1) 0.6mm is included in the group.
(2) Applicable to bearings with cylindrical bores.
(3) Tolerance for width deviation and tolerance limits for the width variation of the outer ring should be the same bearing. Tolerances for the width variation of the outer ring of Class 5, 4, and 2 are shown in Table 8.2.2.
(4) Applicable to individual rings manufactured for combined bearings.
(5) Applicable to ball bearings such as deep groove ball bearings, angular contact ball bearings, etc.

Remarks
1. The cylindrical bore diameter "no-go side" tolerance limit (high) specified in this table does not necessarily apply within a distance of 1.2 times the chamfer dimension r (max.) from the ring face.
2. ABMA Std 20-1996: ABEC1·RBEC1, ABEC3·RBEC3, ABEC5·RBEC5, ABEC7·RBEC7, and ABEC9·RBEC9 are equivalent to Classes Normal, 6, 5, 4, and 2 respectively.

Table 8. 2 Tolerances for Radial Bearings (excluding Tapered Roller Bearings)

Table 8. 2. 2 Tolerances for Outer Rings

Units : μm

Nominal Outside Diameter D (mm)		Δ_{Dmp}										Δ_{Ds}			
		Normal		Class 6		Class 5		Class 4		Class 2		Class 4 (Diameter Series 0, 1, 2, 3, 4)		Class 2	
over	incl.	high	low	high	low	high	low	high	low	high	low	high	low	high	low
2.5(1)	**6**	0	− 8	0	− 7	0	− 5	0	− 4	0	− 2.5	0	− 4	0	− 2.5
6	**18**	0	− 8	0	− 7	0	− 5	0	− 4	0	− 2.5	0	− 4	0	− 2.5
18	**30**	0	− 9	0	− 8	0	− 6	0	− 5	0	− 4	0	− 5	0	− 4
30	**50**	0	− 11	0	− 9	0	− 7	0	− 6	0	− 4	0	− 6	0	− 4
50	**80**	0	− 13	0	−11	0	− 9	0	− 7	0	− 4	0	− 7	0	− 4
80	**120**	0	− 15	0	−13	0	−10	0	− 8	0	− 5	0	− 8	0	− 5
120	**150**	0	− 18	0	−15	0	−11	0	− 9	0	− 5	0	− 9	0	− 5
150	**180**	0	− 25	0	−18	0	−13	0	−10	0	− 7	0	−10	0	− 7
180	**250**	0	− 30	0	−20	0	−15	0	−11	0	− 8	0	−11	0	− 8
250	**315**	0	− 35	0	−25	0	−18	0	−13	0	− 8	0	−13	0	− 8
315	**400**	0	− 40	0	−28	0	−20	0	−15	0	−10	0	−15	0	−10
400	**500**	0	− 45	0	−33	0	−23	−	−	−	−	−	−	−	−
500	**630**	0	− 50	0	−38	0	−28	−	−	−	−	−	−	−	−
630	**800**	0	− 75	0	−45	0	−35	−	−	−	−	−	−	−	−
800	**1 000**	0	−100	0	−60	−	−	−	−	−	−	−	−	−	−
1 000	**1 250**	0	−125	−	−	−	−	−	−	−	−	−	−	−	−
1 250	**1 600**	0	−160	−	−	−	−	−	−	−	−	−	−	−	−
1 600	**2 000**	0	−200	−	−	−	−	−	−	−	−	−	−	−	−
2 000	**2 500**	0	−250	−	−	−	−	−	−	−	−	−	−	−	−

Nominal Outside Diameter D (mm)		V_{Dp} (2)													V_{Dmp} (2)				
		Normal				Class 6				Class 5		Class 4		Class 2	Normal	Class 6	Class 5	Class 4	Class 2
		Open Type			Shielded Sealed	Open Type			Shielded Sealed	Open Type		Open Type		Open Type					
		Diameter Series				Diameter Series				Diameter Series		Diameter Series		Diameter Series					
		9	0, 1	2, 3, 4	2, 3, 4	9	0, 1	2, 3, 4	0,1,2,3,4	9	0,1,2,3,4	9	0,1,2,3,4	0,1,2,3,4					
over	incl.	max.				max.				max.		max.		max.	max.	max.	max.	max.	max.
2.5(1)	**6**	10	8	6	10	9	7	5	9	5	4	4	3	2.5	6	5	3	2	1.5
6	**18**	10	8	6	10	9	7	5	9	5	4	4	3	2.5	6	5	3	2	1.5
18	**30**	12	9	7	12	10	8	6	10	6	5	5	4	4	7	6	3	2.5	2
30	**50**	14	11	8	16	11	9	7	13	7	5	6	5	4	8	7	4	3	2
50	**80**	16	13	10	20	14	11	8	16	9	7	7	5	4	10	8	5	3.5	2
80	**120**	19	19	11	26	16	16	10	20	10	8	8	6	5	11	10	5	4	2.5
120	**150**	23	23	14	30	19	19	11	25	11	8	9	7	5	14	11	6	5	2.5
150	**180**	31	31	19	38	23	23	14	30	13	10	10	8	7	19	14	7	5	3.5
180	**250**	38	38	23	−	25	25	15	−	15	11	11	8	8	23	15	8	6	4
250	**315**	44	44	26	−	31	31	19	−	18	14	13	10	8	26	19	9	7	4
315	**400**	50	50	30	−	35	35	21	−	20	15	15	11	10	30	21	10	8	5
400	**500**	56	56	34	−	41	41	25	−	23	17	−	−	−	34	25	12	−	−
500	**630**	63	63	38	−	48	48	29	−	28	21	−	−	−	38	29	14	−	−
630	**800**	94	94	55	−	56	56	34	−	35	26	−	−	−	55	34	18	−	−
800	**1 000**	125	125	75	−	75	75	45	−	−	−	−	−	−	75	45	−	−	−
1 000	**1 250**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
1 250	**1 600**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
1 600	**2 000**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
2 000	**2 500**	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−

K_{ea}					S_D			S_{ea} (3)			V_{Cs} (4)			Nominal Outside Diameter D (mm)	
Normal	Class 6	Class 5	Class 4	Class 2	Class 5	Class 4	Class 2	Class 5	Class 4	Class 2	Class 5	Class 4	Class 2		
max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	over	incl.
15	8	5	3	1.5	8	4	1.5	8	5	1.5	5	2.5	1.5	**2.5** (1)	**6**
15	8	5	3	1.5	8	4	1.5	8	5	1.5	5	2.5	1.5	**6**	**18**
15	9	6	4	2.5	8	4	1.5	8	5	2.5	5	2.5	1.5	**18**	**30**
20	10	7	5	2.5	8	4	1.5	8	5	2.5	5	2.5	1.5	**30**	**50**
25	13	8	5	4	8	4	1.5	10	5	4	6	3	1.5	**50**	**80**
35	18	10	6	5	9	5	2.5	11	6	5	8	4	2.5	**80**	**120**
40	20	11	7	5	10	5	2.5	13	7	5	8	5	2.5	**120**	**150**
45	23	13	8	5	10	5	2.5	14	8	5	8	5	2.5	**150**	**180**
50	25	15	10	7	11	7	4	15	10	7	10	7	4	**180**	**250**
60	30	18	11	7	13	8	5	18	10	7	11	7	5	**250**	**315**
70	35	20	13	8	13	10	7	20	13	8	13	8	7	**315**	**400**
80	40	23	−	−	15	−	−	23	−	−	15	−	−	**400**	**500**
100	50	25	−	−	18	−	−	25	−	−	18	−	−	**500**	**630**
120	60	30	−	−	20	−	−	30	−	−	20	−	−	**630**	**800**
140	75	−	−	−	−	−	−	−	−	−	−	−	−	**800**	**1 000**
160	−	−	−	−	−	−	−	−	−	−	−	−	−	**1 000**	**1 250**
190	−	−	−	−	−	−	−	−	−	−	−	−	−	**1 250**	**1 600**
220	−	−	−	−	−	−	−	−	−	−	−	−	−	**1 600**	**2 000**
250	−	−	−	−	−	−	−	−	−	−	−	−	−	**2 000**	**2 500**

Notes (1) 2.5mm is included in the group.
(2) Applicable only when a locating snap ring is not used.
(3) Applicable to ball bearings such as deep groove ball bearings and angular contact ball bearings.
(4) The tolerances for outer ring width variation of bearings of Classes Normal and 6 are shown in Table 8.2.1.

Remarks
1. The outside diameter "no-go side" tolerances (low) specified in this table do not necessarily apply within a distance of 1.2 times the chamfer dimension r (max.) from the ring face.
2. ABMA Std 20-1996: ABEC1·RBEC1, ABEC3·RBEC3, ABEC5·RBEC5, ABEC7·RBEC7, and ABEC9· RBEC9 are equivalent to Classes Normal, 6, 5, 4, and 2 respectively.

Table 8. 3 Tolerances for Metric Design Tapered Roller Bearings

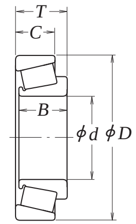
Table 8. 3. 1 Tolerances for Inner Ring Bore Diameter and Running Accuracy

Units : μm

Nominal Bore Diameter d (mm)		Δ_{dmp}						Δ_{ds}		V_{dp}				V_{dmp}			
		Normal Class 6X		Class 6 Class 5		Class 4		Class 4		Normal Class 6X	Class 6	Class 5	Class 4	Normal Class 6X	Class 6	Class 5	Class 4
over	incl.	high	low	high	low	high	low	high	low	max.	max.	max.	max.	max.	max.	max.	max.
10	18	0	−8	0	−7	0	−5	0	−5	8	7	5	4	6	5	5	4
18	30	0	−10	0	−8	0	−6	0	−6	10	8	6	5	8	6	5	4
30	50	0	−12	0	−10	0	−8	0	−8	12	10	8	6	9	8	5	5
50	80	0	−15	0	−12	0	−9	0	−9	15	12	9	7	11	9	6	5
80	120	0	−20	0	−15	0	−10	0	−10	20	15	11	8	15	11	8	5
120	180	0	−25	0	−18	0	−13	0	−13	25	18	14	10	19	14	9	7
180	250	0	−30	0	−22	0	−15	0	−15	30	22	17	11	23	16	11	8
250	315	0	−35	0	−25	0	−18	0	−18	35	−	−	−	26	−	−	−
315	400	0	−40	0	−30	0	−23	0	−23	40	−	−	−	30	−	−	−
400	500	0	−45	0	−35	0	−27	0	−27	−	−	−	−	−	−	−	−
500	630	0	−50	0	−40	−	−	−	−	−	−	−	−	−	−	−	−
630	800	0	−75	0	−60	−	−	−	−	−	−	−	−	−	−	−	−

Nominal Bore Diameter d (mm)		K_{ia}				S_d		S_{ia}
		Normal Class 6X	Class 6	Class 5	Class 4	Class 5	Class 4	Class 4
over	incl.	max.	max.	max.	max.	max.	max.	max.
10	18	15	7	3.5	2.5	7	3	3
18	30	18	8	4	3	8	4	4
30	50	20	10	5	4	8	4	4
50	80	25	10	5	4	8	5	4
80	120	30	13	6	5	9	5	5
120	180	35	18	8	6	10	6	7
180	250	50	20	10	8	11	7	8
250	315	60	25	13	10	13	8	10
315	400	70	30	15	12	15	10	14
400	500	70	35	18	14	19	13	17
500	630	85	40	20	−	22	−	−
630	800	100	45	22	−	27	−	−

Remarks 1. The bore diameter "no-go side" tolerances (high) specified in this table do not necessarily apply within a distance of 1.2 times the chamfer dimension r (max.) from the ring face.
2. Some of these tolerances conform to the NSK Standard.



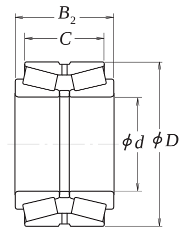


Table 8. 3. 2 Tolerances for Outer Ring Outside Diameter and Running Accuracy

Units : μm

Nominal Outside Diameter D (mm)		Δ_{Dmp}						Δ_{Ds}		V_{Dp}				V_{Dmp}			
		Normal Class 6X		Class 6 Class 5		Class 4		Class 4		Normal Class 6X	Class 6	Class 5	Class 4	Normal Class 6X	Class 6	Class 5	Class 4
over	incl.	high	low	high	low	high	low	high	low	max.	max.	max.	max.	max.	max.	max.	max.
18	30	0	− 9	0	− 8	0	− 6	0	− 6	9	8	6	5	7	6	5	4
30	50	0	− 11	0	− 9	0	− 7	0	− 7	11	9	7	5	8	7	5	5
50	80	0	− 13	0	−11	0	− 9	0	− 9	13	11	8	7	10	8	6	5
80	120	0	− 15	0	−13	0	−10	0	−10	15	13	10	8	11	10	7	5
120	150	0	− 18	0	−15	0	−11	0	−11	18	15	11	8	14	11	8	6
150	180	0	− 25	0	−18	0	−13	0	−13	25	18	14	10	19	14	9	7
180	250	0	− 30	0	−20	0	−15	0	−15	30	20	15	11	23	15	10	8
250	315	0	− 35	0	−25	0	−18	0	−18	35	25	19	14	26	19	13	9
315	400	0	− 40	0	−28	0	−20	0	−20	40	28	22	15	30	21	14	10
400	500	0	− 45	0	−33	0	−23	0	−23	45	−	−	−	34	−	−	−
500	630	0	− 50	0	−38	0	−28	0	−28	50	−	−	−	38	−	−	−
630	800	0	− 75	0	−45	−	−	−	−	−	−	−	−	−	−	−	−
800	1 000	0	−100	0	−60	−	−	−	−	−	−	−	−	−	−	−	−

Nominal Outside Diameter D (mm)		K_{ea}				S_D		S_{ea}
		Normal Class 6X	Class 6	Class 5	Class 4	Class 5	Class 4	Class 4
over	incl.	max.	max.	max.	max.	max.	max.	max.
18	30	18	9	6	4	8	4	5
30	50	20	10	7	5	8	4	5
50	80	25	13	8	5	8	4	5
80	120	35	18	10	6	9	5	6
120	150	40	20	11	7	10	5	7
150	180	45	23	13	8	10	5	8
180	250	50	25	15	10	11	7	10
250	315	60	30	18	11	13	8	10
315	400	70	35	20	13	13	10	13
400	500	80	40	23	15	15	11	15
500	630	100	50	25	18	18	13	18
630	800	120	60	30	−	20	−	−
800	1 000	120	75	35	−	23	−	−

Remarks 1. The outside diameter "no-go side" tolerances (low) specified in this table do not necessarily apply within a distance of 1.2 times the chamfer dimension r (max.) from the ring face.
2. Some of these tolerances conform to the NSK Standard.

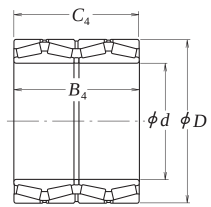


Table 8. 3 Tolerances for Metric Design Tapered Roller Bearings

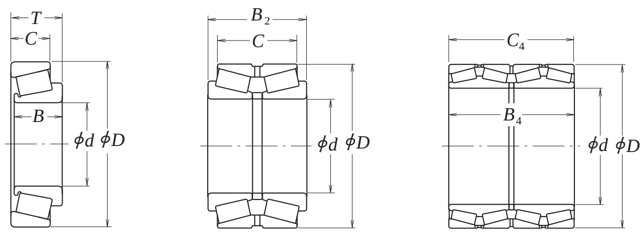
Table 8. 3. 3 Tolerances for Width, Overall Bearing Width, and Combined Bearing Width

Units : μm

Nominal Bore Diameter d (mm)		Δ_{Bs}						Δ_{Cs}						Δ_{Ts}					
		Normal Class 6		Class 6X		Class 5 Class 4		Normal Class 6		Class 6X		Class 5 Class 4		Normal Class 6		Class 6X		Class 5 Class 4	
over	incl.	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low	high	low
10	**18**	0	−120	0	−50	0	−200	0	−120	0	−100	0	−200	+200	0	+100	0	+200	−200
18	**30**	0	−120	0	−50	0	−200	0	−120	0	−100	0	−200	+200	0	+100	0	+200	−200
30	**50**	0	−120	0	−50	0	−240	0	−120	0	−100	0	−240	+200	0	+100	0	+200	−200
50	**80**	0	−150	0	−50	0	−300	0	−150	0	−100	0	−300	+200	0	+100	0	+200	−200
80	**120**	0	−200	0	−50	0	−400	0	−200	0	−100	0	−400	+200	−200	+100	0	+200	−200
120	**180**	0	−250	0	−50	0	−500	0	−250	0	−100	0	−500	+350	−250	+150	0	+350	−250
180	**250**	0	−300	0	−50	0	−600	0	−300	0	−100	0	−600	+350	−250	+150	0	+350	−250
250	**315**	0	−350	0	−50	0	−700	0	−350	0	−100	0	−700	+350	−250	+200	0	+350	−250
315	**400**	0	−400	0	−50	0	−800	0	−400	0	−100	0	−800	+400	−400	+200	0	+400	−400
400	**500**	0	−450	–	–	0	−800	0	−450	–	–	0	−800	+400	−400	–	–	+400	−400
500	**630**	0	−500	–	–	0	−800	0	−500	–	–	0	−800	+500	−500	–	–	+500	−500
630	**800**	0	−750	–	–	0	−800	0	−750	–	–	0	−800	+600	−600	–	–	+600	−600

Ring Width with Rollers Δ_{T1s}				Outer Ring Effective Width Deviation Δ_{T2s}				Overall Combined Bearing Width Deviation				Nominal Bore Diameter d (mm)	
								Δ_{B2s}		Δ_{B4s}, Δ_{C4s}			
Normal		Class 6X		Normal		Class 6X		All classes of double-row bearings		All classes of four-row bearings			
high	low	high	low	high	low	high	low	high	low	high	low	over	incl.
+100	0	+ 50	0	+100	0	+ 50	0	+ 200	− 200	–	–	**10**	**18**
+100	0	+ 50	0	+100	0	+ 50	0	+ 200	− 200	–	–	**18**	**30**
+100	0	+ 50	0	+100	0	+ 50	0	+ 200	− 200	–	–	**30**	**50**
+100	0	+ 50	0	+100	0	+ 50	0	+ 300	− 300	+ 300	− 300	**50**	**80**
+100	−100	+ 50	0	+100	−100	+ 50	0	+ 300	− 300	+ 400	− 400	**80**	**120**
+150	−150	+ 50	0	+200	−100	+100	0	+ 400	− 400	+ 500	− 500	**120**	**180**
+150	−150	+ 50	0	+200	−100	+100	0	+ 450	− 450	+ 600	− 600	**180**	**250**
+150	−150	+100	0	+200	−100	+100	0	+ 550	− 550	+ 700	− 700	**250**	**315**
+200	−200	+100	0	+200	−200	+100	0	+ 600	− 600	+ 800	− 800	**315**	**400**
–	–	–	–	–	–	–	–	+ 700	− 700	+ 900	− 900	**400**	**500**
–	–	–	–	–	–	–	–	+ 800	− 800	+1 000	−1 000	**500**	**630**
–	–	–	–	–	–	–	–	+1 200	−1 200	+1 500	−1 500	**630**	**800**

Remarks The effective width of an inner ring with rollers T_1 is defined as the overall bearing width of an inner ring with rollers combined with a master outer ring.
The effective width of an outer ring T_2 is defined as the overall bearing width of an outer ring combined with a master inner ring with rollers.



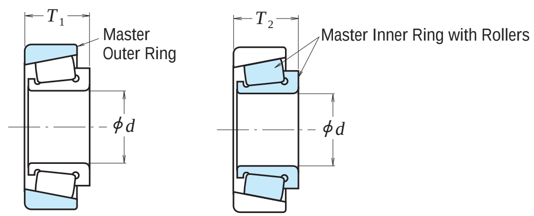


Table 8. 4 Tolerances for Inch Design Tapered Roller Bearings

(Refer to page A58 Table 8. 1 for the tolerance class "CLASS ⁎⁎ " that is the tolerance classes of ANSI/ABMA.)

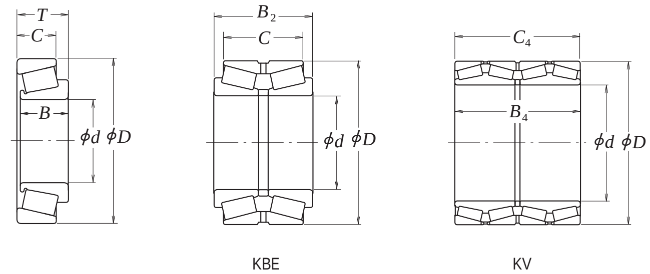


Table 8. 4. 1 Tolerances for Inner Ring Bore Diameter

Units : μm

Nominal Bore Diameter d				Δ_{ds}					
over		incl.		CLASS 4, 2		CLASS 3, 0		CLASS 00	
(mm)	1/25.4	(mm)	1/25.4	high	low	high	low	high	low
–	–	**76.200**	3.0000	+ 13	0	+13	0	+8	0
76.200	3.0000	**266.700**	10.5000	+ 25	0	+13	0	+8	0
266.700	10.5000	**304.800**	12.0000	+ 25	0	+13	0	–	–
304.800	12.0000	**609.600**	24.0000	+ 51	0	+25	0	–	–
609.600	24.0000	**914.400**	36.0000	+ 76	0	+38	0	–	–
914.400	36.0000	**1 219.200**	48.0000	+102	0	+51	0	–	–
1 219.200	48.0000	–	–	+127	0	+76	0	–	–

Table 8. 4. 2 Tolerances for Outer Ring Outside Diameter and Radial Runout of Inner and Outer Rings

Units : μm

Nominal Outside Diameter D				Δ_{Ds}						K_{ia}, K_{ea}				
over		incl.		CLASS 4, 2		CLASS 3, 0		CLASS 00		CLASS 4	CLASS 2	CLASS 3	CLASS 0	CLASS 00
(mm)	1/25.4	(mm)	1/25.4	high	low	high	low	high	low	max.	max.	max.	max.	max.
–	–	**266.700**	10.5000	+ 25	0	+13	0	+8	0	51	38	8	4	2
266.700	10.5000	**304.800**	12.0000	+ 25	0	+13	0	+8	0	51	38	8	4	2
304.800	12.0000	**609.600**	24.0000	+ 51	0	+25	0	–	–	51	38	18	–	–
609.600	24.0000	**914.400**	36.0000	+ 76	0	+38	0	–	–	76	51	51	–	–
914.400	36.0000	**1 219.200**	48.0000	+102	0	+51	0	–	–	76	–	76	–	–
1 219.200	48.0000	–	–	+127	0	+76	0	–	–	76	–	76	–	–

Table 8. 4. 3 Tolerances for Overall Width and Combined Width

Units : μm

Nominal Bore Diameter d				Δ_{Ts}									
over		incl.		CLASS 4		CLASS 2		CLASS 3 D≦508.000 (mm)		CLASS 3 D>508.000 (mm)		CLASS 0, 00	
(mm)	1/25.4	(mm)	1/25.4	high	low	high	low	high	low	high	low	high	low
–	–	**101.600**	4.0000	+203	0	+203	0	+203	−203	+203	−203	+203	−203
101.600	4.0000	**304.800**	12.0000	+356	−254	+203	0	+203	−203	+203	−203	+203	−203
304.800	12.0000	**609.600**	24.0000	+381	−381	+381	−381	+203	−203	+381	−381	–	–
609.600	24.0000	–	–	+381	−381	–	–	+381	−381	+381	−381	–	–

Nominal Bore Diameter d				Double-Row Bearings (KBE Type) Δ_{B2s}										Four-Row Bearings (KV Type) Δ_{B4s}, Δ_{C4s}	
over		incl.		CLASS 4		CLASS 2		CLASS 3 D≦508.000 (mm)		CLASS 3 D>508.000 (mm)		CLASS 0,00		CLASS 4, 3	
(mm)	1/25.4	(mm)	1/25.4	high	low	high	low	high	low	high	low	high	low	high	low
–	–	**101.600**	4.0000	+406	0	+406	0	+406	−406	+406	−406	+406	−406	+1 524	−1 524
101.600	4.0000	**304.800**	12.0000	+711	−508	+406	−203	+406	−406	+406	−406	+406	−406	+1 524	−1 524
304.800	12.0000	**609.600**	24.0000	+762	−762	+762	−762	+406	−406	+762	−762	–	–	+1 524	−1 524
609.600	24.0000	–	–	+762	−762	–	–	+762	−762	+762	−762	–	–	+1 524	−1 524

Table 8. 5 Tolerances for Magneto Bearings

Table 8. 5. 1 Tolerances for Inner Rings and Width of Outer Rings

Units : μm

Nominal Bore Diameter d (mm)		Δ_{dmp}						V_{dp}			V_{dmp}			Δ_{Bs} (or Δ_{Cs}) (1)			
		Normal		Class 6		Class 5		Normal	Class 6	Class 5	Normal	Class 6	Class 5	Normal Class 6		Class 5	
over	incl.	high	low	high	low	high	low	max.	max.	max.	max.	max.	max.	high	low	high	low
2.5	10	0	− 8	0	−7	0	−5	6	5	4	6	5	3	0	−120	0	− 40
10	18	0	− 8	0	−7	0	−5	6	5	4	6	5	3	0	−120	0	− 80
18	30	0	−10	0	−8	0	−6	8	6	5	8	6	3	0	−120	0	−120

Nominal Bore Diameter d (mm)		V_{Bs} (or V_{Cs}) (1)		Δ_{Ts}		K_{ia}			S_d	S_{ia}
		Normal Class 6	Class 5	Normal Class 6 Class 5		Normal	Class 6	Class 5	Class 5	Class 5
over	incl.	max.	max.	high	low	max.	max.	max.	max.	max.
2.5	10	15	5	+120	−120	10	6	4	7	7
10	18	20	5	+120	−120	10	7	4	7	7
18	30	20	5	+120	−120	13	8	4	8	8

Note (1) The width deviation and width variation of an outer ring is determined according to the inner ring of the same bearing.

Remarks The bore diameter "no-go side" tolerances (high) specified in this table do not necessarily apply within a distance of 1.2 times the chamfer dimension r (max.) from the ring face.

Table 8. 5. 2 Tolerances for Outer Rings

Units : μm

Nominal Outside Diameter D (mm)		Δ_{Dmp}												V_{Dp}			V_{Dmp}			K_{ea}			S_{ea}	S_D
		Bearing Series E						Bearing Series EN																
		Normal		Class 6		Class 5		Normal		Class 6		Class 5		Normal	Class 6	Class 5	Normal	Class 6	Class 5	Normal	Class 6	Class 5	Class 5	Class 5
over	incl.	high	low	high	low	high	low	high	low	high	low	high	low	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.
6	18	+ 8	0	+7	0	+5	0	0	− 8	0	−7	0	−5	6	5	4	6	5	3	15	8	5	8	8
18	30	+ 9	0	+8	0	+6	0	0	− 9	0	−8	0	−6	7	6	5	7	6	3	15	9	6	8	8
30	50	+11	0	+9	0	+7	0	0	−11	0	−9	0	−7	8	7	5	8	7	4	20	10	7	8	8

Remarks The outside diameter "no-go side" tolerances (low) do not necessarily apply within a distance of 1.2 times the chamfer dimension r (max.) from the ring face.

Table 8. 6 Tolerances for Thrust Ball Bearings

Table 8. 6. 1 Tolerances for Shaft Washer Bore Diameter and Running Accuracy

Units : μm

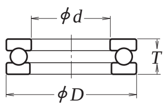
Nominal Bore Diameter d or d_2 (mm)		Δ_{dmp} or Δ_{d2mp}				V_{dp} or V_{d2p}		S_i or S_e (1)			
		Normal Class 6 Class 5		Class 4		Normal Class 6 Class 5	Class 4	Normal	Class 6	Class 5	Class 4
over	incl.	high	low	high	low	max.	max.	max.	max.	max.	max.
–	**18**	0	− 8	0	− 7	6	5	10	5	3	2
18	**30**	0	− 10	0	− 8	8	6	10	5	3	2
30	**50**	0	− 12	0	−10	9	8	10	6	3	2
50	**80**	0	− 15	0	−12	11	9	10	7	4	3
80	**120**	0	− 20	0	−15	15	11	15	8	4	3
120	**180**	0	− 25	0	−18	19	14	15	9	5	4
180	**250**	0	− 30	0	−22	23	17	20	10	5	4
250	**315**	0	− 35	0	−25	26	19	25	13	7	5
315	**400**	0	− 40	0	−30	30	23	30	15	7	5
400	**500**	0	− 45	0	−35	34	26	30	18	9	6
500	**630**	0	− 50	0	−40	38	30	35	21	11	7
630	**800**	0	− 75	0	−50	–	–	40	25	13	8
800	**1 000**	0	−100	–	–	–	–	45	30	15	–
1 000	**1 250**	0	−125	–	–	–	–	50	35	18	–

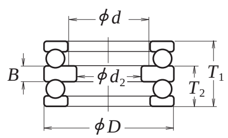
Note (1) For double-direction bearings, the thickness variation doesn't depend on the bore diameter d_2 , but on d for single-direction bearings with the same D in the same diameter series.
The thickness variation of housing washers, S_e, applies only to flat-seat thrust bearings.

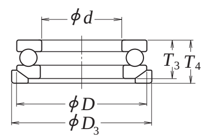
Table 8. 6. 2 Tolerances for Outside Diameter of Housing Washers and Aligning Seat Washers

Units : μm

Nominal Outside Diameter of Bearing or Aligning Seat Washer D or D_3 (mm)		Δ_{Dmp}						V_{Dp}		Aligning Seat Washer Outside Diameter Deviation Δ_{D3s}	
		Flat Seat Type				Aligning Seat Washer Type					
		Normal Class 6 Class 5		Class 4		Normal Class 6		Normal Class 6 Class 5	Class 4	Normal Class 6	
over	incl.	high	low	high	low	high	low	max.	max.	high	low
10	**18**	0	− 11	0	− 7	0	− 17	8	5	0	− 25
18	**30**	0	− 13	0	− 8	0	− 20	10	6	0	− 30
30	**50**	0	− 16	0	− 9	0	− 24	12	7	0	− 35
50	**80**	0	− 19	0	−11	0	− 29	14	8	0	− 45
80	**120**	0	− 22	0	−13	0	− 33	17	10	0	− 60
120	**180**	0	− 25	0	−15	0	− 38	19	11	0	− 75
180	**250**	0	− 30	0	−20	0	− 45	23	15	0	− 90
250	**315**	0	− 35	0	−25	0	− 53	26	19	0	−105
315	**400**	0	− 40	0	−28	0	− 60	30	21	0	−120
400	**500**	0	− 45	0	−33	0	− 68	34	25	0	−135
500	**630**	0	− 50	0	−38	0	− 75	38	29	0	−180
630	**800**	0	− 75	0	−45	0	−113	55	34	0	−225
800	**1 000**	0	−100	–	–	–	–	75	–	–	–
1 000	**1 250**	0	−125	–	–	–	–	–	–	–	–
1 250	**1 600**	0	−160	–	–	–	–	–	–	–	–







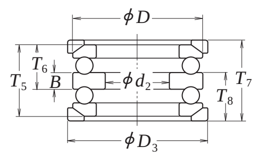


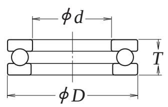
Table 8. 6. 3 Tolerances for Thrust Ball Bearing Height and Central Washer Height

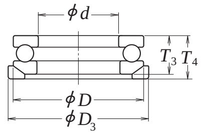
Units : μm

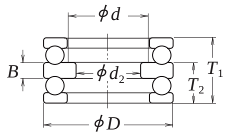
Nominal Bore Diameter d (1) (mm)		Flat Seat Type				Aligning Seat Washer Type				With Aligning Seat Washer				Height Deviation of Central Washer	
		Δ_{Ts} or Δ_{T2s}		Δ_{T1s}		Δ_{T3s} or Δ_{T6s}		Δ_{T5s}		Δ_{T4s} or Δ_{T8s}		Δ_{T7s}		Δ_{Bs}	
		Normal, Class 6 Class 5, Class 4		Normal, Class 6 Class 5, Class 4		Normal Class 6		Normal Class 6		Normal Class 6		Normal Class 6		Normal, Class 6 Class 5, Class 4	
over	incl.	high	low	high	low	high	low	high	low	high	low	high	low	high	low
–	**30**	0	− 75	+ 50	−150	0	− 75	+ 50	−150	+ 50	− 75	+150	−150	0	− 50
30	**50**	0	−100	+ 75	−200	0	−100	+ 75	−200	+ 50	−100	+175	−200	0	− 75
50	**80**	0	−125	+100	−250	0	−125	+100	−250	+ 75	−125	+250	−250	0	−100
80	**120**	0	−150	+125	−300	0	−150	+125	−300	+ 75	−150	+275	−300	0	−125
120	**180**	0	−175	+150	−350	0	−175	+150	−350	+100	−175	+350	−350	0	−150
180	**250**	0	−200	+175	−400	0	−200	+175	−400	+100	−200	+375	−400	0	−175
250	**315**	0	−225	+200	−450	0	−225	+200	−450	+125	−225	+450	−450	0	−200
315	**400**	0	−300	+250	−600	0	−300	+250	−600	+150	−275	+550	−550	0	−250

Note (1) For double-direction bearings, its classification depends on d for single-direction bearings with the same D in the same diameter series.

Remarks Δ_{Ts} in the table is the deviation in the respective heights T in figures below.







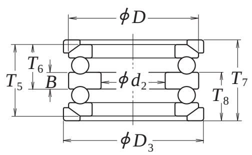


Table 8. 7 Tolerances for Thrust Spherical Roller Bearings

Table 8. 7. 1 Tolerances for Bore Diameters of Shaft Rings and Height (Class Normal)

Units : μm

Nominal Bore Diameter d (mm)		Δ_{dmp}		V_{dp}	Reference		
					S_d	Δ_{Ts}	
over	incl.	high	low	max.	max.	high	low
50	**80**	0	−15	11	25	+150	−150
80	**120**	0	−20	15	25	+200	−200
120	**180**	0	−25	19	30	+250	−250
180	**250**	0	−30	23	30	+300	−300
250	**315**	0	−35	26	35	+350	−350
315	**400**	0	−40	30	40	+400	−400
400	**500**	0	−45	34	45	+450	−450

Remarks The bore diameter "no-go side" tolerances (high) specified in this table do not necessarily apply within a distance of 1.2 times the chamfer dimension r (max.) from the ring face.

Table 8. 7. 2 Tolerances for Housing Ring Diameter (Class Normal)

Units : μm

Nominal Outside Diameter D (mm)		Δ_{Dmp}	
over	incl.	high	low
120	**180**	0	− 25
180	**250**	0	− 30
250	**315**	0	− 35
315	**400**	0	− 40
400	**500**	0	− 45
500	**630**	0	− 50
630	**800**	0	− 75
800	**1 000**	0	−100

Remarks The outside diameter "no-go side" tolerances (low) specified in this table do not necessarily apply within a distance of 1.2 times the chamfer dimension r (max.) from the ring face.

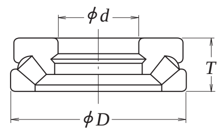


Table 8. 8 Tolerances of Instrument Ball Bearings (Inch design)

CLASS 5P, CLASS 7P, and CLASS 9P (ANSI/ABMA Equivalent)

(1) Tolerances for Inner Rings and Width of Outer Rings

Units : μm

Nominal Bore Diameter d (mm)		Δ_{dmp}				Δ_{ds}				V_{dp}		V_{dmp}		Δ_{Bs}	
		CLASS 5P CLASS 7P		CLASS 9P		CLASS 5P CLASS 7P		CLASS 9P		CLASS 5P CLASS 7P	CLASS 9P	CLASS 5P CLASS 7P	CLASS 9P	Single Brgs CLASS 5P CLASS 7P CLASS 9P	
over	incl.	high	low	high	low	high	low	high	low	max.	max.	max.	max.	high	low
–	10	0	−5.1	0	−2.5	0	−5.1	0	−2.5	2.5	1.3	2.5	1.3	0	−25.4
10	18	0	−5.1	0	−2.5	0	−5.1	0	−2.5	2.5	1.3	2.5	1.3	0	−25.4
18	30	0	−5.1	0	−2.5	0	−5.1	0	−2.5	2.5	1.3	2.5	1.3	0	−25.4

Nominal Bore Diameter d (mm)		(or Δ_{Cs})		V_{Bs}			K_{ia}			S_{ia}			S_d		
		Combined Brgs (1) CLASS 5P CLASS 7P CLASS 9P		CLASS 5P	CLASS 7P	CLASS 9P	CLASS 5P	CLASS 7P	CLASS 9P	CLASS 5P	CLASS 7P	CLASS 9P	CLASS 5P	CLASS 7P	CLASS 9P
over	incl.	high	low	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.
–	10	0	−400	5.1	2.5	1.3	3.8	2.5	1.3	7.6	2.5	1.3	7.6	2.5	1.3
10	18	0	−400	5.1	2.5	1.3	3.8	2.5	1.3	7.6	2.5	1.3	7.6	2.5	1.3
18	30	0	−400	5.1	2.5	1.3	3.8	3.8	2.5	7.6	3.8	1.3	7.6	3.8	1.3

Note (1) Applicable to bearings for which the axial clearance (preload) is to be adjusted by combining two selected bearings.
Remarks For the CLASS 3P and the tolerances of Metric design Instrument Ball Bearings, it is advisable to consult NSK.

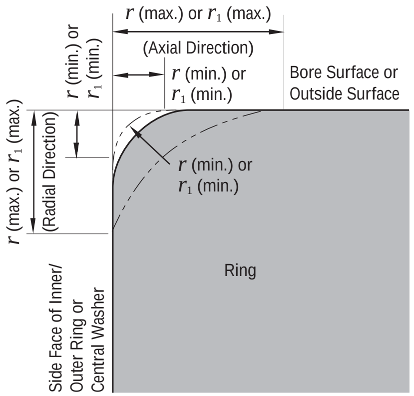
(2) Tolerances for Outer Rings

Units : μm

Nominal Outside Diameter D (mm)		Δ_{Dmp}				Δ_{Ds}						V_{Dp}			V_{Dmp}		
		CLASS 5P CLASS 7P		CLASS 9P		CLASS 5P CLASS 7P				CLASS 9P		CLASS 5P CLASS 7P		CLASS 9P	CLASS 5P CLASS 7P		CLASS 9P
						Open		Shielded Sealed		Open		Open	Shielded Sealed	Open	Open	Shielded Sealed	Open
over	incl.	high	low	high	low	high	low	high	low	high	low	max.	max.	max.	max.	max.	max.
–	18	0	−5.1	0	−2.5	0	−5.1	+1	−6.1	0	−2.5	2.5	5.1	1.3	2.5	5.1	1.3
18	30	0	−5.1	0	−3.8	0	−5.1	+1	−6.1	0	−3.8	2.5	5.1	2	2.5	5.1	2
30	50	0	−5.1	0	−3.8	0	−5.1	+1	−6.1	0	−3.8	2.5	5.1	2	2.5	5.1	2

Nominal Outside Diameter D (mm)		V_{Cs} (1)			S_D			K_{ea}			S_{ea}			Deviation of Flange Outside Diameter Δ_{D1s}		Deviation of Flange Width Δ_{C1s}		Flange Backface Runout with Raceway (2) S_{ea1}
		CLASS 5P	CLASS 7P	CLASS 9P	CLASS 5P	CLASS 7P	CLASS 9P	CLASS 5P	CLASS 7P	CLASS 9P	CLASS 5P	CLASS 7P	CLASS 9P	CLASS 5P CLASS 7P		CLASS 5P CLASS 7P		CLASS 5P CLASS 7P
over	incl.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	high	low	high	low	max.
–	18	5.1	2.5	1.3	7.6	3.8	1.3	5.1	3.8	1.3	7.6	5.1	1.3	0	−25.4	0	−50.8	7.6
18	30	5.1	2.5	1.3	7.6	3.8	1.3	5.1	3.8	2.5	7.6	5.1	2.5	0	−25.4	0	−50.8	7.6
30	50	5.1	2.5	1.3	7.6	3.8	1.3	5.1	5.1	2.5	7.6	5.1	2.5	0	−25.4	0	−50.8	7.6

Notes (1) Applicable to flange width variation for flanged bearings.
(2) Applicable to flange back face.



r : Chamfer Dimension of Inner/Outer Ring

r_1 : Chamfer Dimension of Inner/Outer Ring (Front Side) or of Central Washer of Thrust Ball Bearings

Remarks The precise shape of chamfer surfaces has not been specified but its profile in the axial plane shall not intersect an arc of radius r (min.) or r_1 (min.) touching the side face of an inner ring or central washer and bore surface, or the side face of an outer ring and outside surface.

Table 8. 9 Chamfer Dimension Limits (for Metric Design Bearings)

Table 8. 9. 1 Chamfer Dimension Limits for Radial Bearings (excluding Tapered Roller Bearings)

Units : mm

Permissible Chamfer Dimension for Inner/ Outer Rings r (min.) or r_1 (min.)	Nominal Bore Diameter d		Permissible Chamfer Dimension for Inner/Outer Rings r (max.) or r_1 (max.)		Reference Corner Radius of Shaft or Housing r_a
	over	incl.	Radial Direction	Axial Direction	max.
0.05	–	–	0.1	0.2	0.05
0.08	–	–	0.16	0.3	0.08
0.1	–	–	0.2	0.4	0.1
0.15	–	–	0.3	0.6	0.15
0.2	–	–	0.5	0.8	0.2
0.3	–	40	0.6	1	0.3
	40	–	0.8	1	
0.6	–	40	1	2	0.6
	40	–	1.3	2	
1	–	50	1.5	3	1
	50	–	1.9	3	
1.1	–	120	2	3.5	1
	120	–	2.5	4	
1.5	–	120	2.3	4	1.5
	120	–	3	5	
2	–	80	3	4.5	2
	80	220	3.5	5	
	220	–	3.8	6	
2.1	–	280	4	6.5	2
	280	–	4.5	7	
2.5	–	100	3.8	6	2
	100	280	4.5	6	
	280	–	5	7	
3	–	280	5	8	2.5
	280	–	5.5	8	
4	–	–	6.5	9	3
5	–	–	8	10	4
6	–	–	10	13	5
7.5	–	–	12.5	17	6
9.5	–	–	15	19	8
12	–	–	18	24	10
15	–	–	21	30	12
19	–	–	25	38	15

Remarks For bearings with nominal widths less than 2mm, the value of r (max.) in the axial direction is the same as that in the radial direction.

Table 8. 9. 2 Chamfer Dimension Limits for Tapered Roller Bearings

Units : mm

Permissible Chamfer Dimension for Inner/ Outer Rings r (min.)	Nominal Bore or Nominal Outside Diameter (1) d or D		Permissible Chamfer Dimension for Inner/ Outer Rings r (max.)		Reference Corner Radius of Shaft or Housing r_a
	over	incl.	Radial Direction	Axial Direction	max.
0.15	–	–	0.3	0.6	0.15
0.3	–	40	0.7	1.4	0.3
	40	–	0.9	1.6	
0.6	–	40	1.1	1.7	0.6
	40	–	1.3	2	
1	–	50	1.6	2.5	1
	50	–	1.9	3	
1.5	–	120	2.3	3	1.5
	120	250	2.8	3.5	
	250	–	3.5	4	
2	–	120	2.8	4	2
	120	250	3.5	4.5	
	250	–	4	5	
2.5	–	120	3.5	5	2
	120	250	4	5.5	
	250	–	4.5	6	
3	–	120	4	5.5	2.5
	120	250	4.5	6.5	
	250	400	5	7	
	400	–	5.5	7.5	
4	–	120	5	7	3
	120	250	5.5	7.5	
	250	400	6	8	
	400	–	6.5	8.5	
5	–	180	6.5	8	4
	180	–	7.5	9	
6	–	180	7.5	10	5
	180	–	9	11	

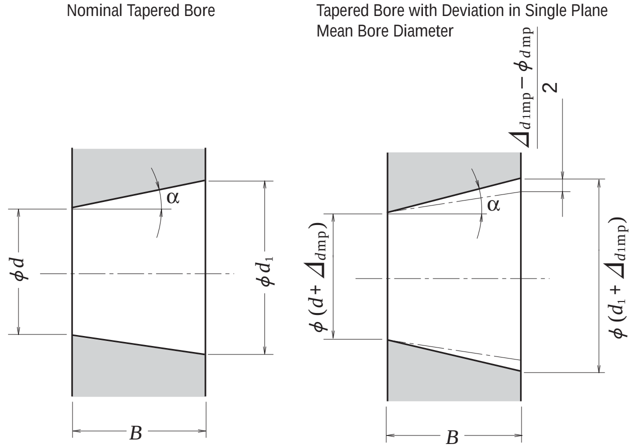
Note (1) Inner Rings are classified by d and Outer Rings by D.

Table 8. 9. 3 Chamfer Dimension Limits for Thrust Bearings

Units : mm

Permissible Chamfer Dimension for Shaft (or Central)/Housing Washers r (min.) or r_1 (min.)	Permissible Chamfer Dimension for Shaft (or Central)/Housing Washers r (max.) or r_1 (max.)	Reference Corner Radius of Shaft or Housing r_a
	Radial or Axial Direction	max.
0.05	0.1	0.05
0.08	0.16	0.08
0.1	0.2	0.1
0.15	0.3	0.15
0.2	0.5	0.2
0.3	0.8	0.3
0.6	1.5	0.6
1	2.2	1
1.1	2.7	1
1.5	3.5	1.5
2	4	2
2.1	4.5	2
3	5.5	2.5
4	6.5	3
5	8	4
6	10	5
7.5	12.5	6
9.5	15	8
12	18	10
15	21	12
19	25	15

Table 8.10 Tolerances for Tapered Bores (Class Normal)



d : Nominal Bore Diameter
d_1 : Theoretical Diameter of Larger End of Tapered Bore
Taper 1:12 $d_1 = d + 1/12\ B$ Taper 1:30 $d_1 = d + /30\ B$
Δ_{dmp} : Single Plane Mean Bore Diameter Deviation in Theoretical Diameter of Smaller End of Bore
Δ_{d1mp} : Single Plane Mean Bore Diameter Deviation in Theoretical Diameter of Larger End of Bore
V_{dp} : Bore diameter variation in a single radial plane
B : Nominal Inner Ring width
α : Half of Taper Angle of Tapered Bore

Taper 1:12
α =2°23´9.4
=2.38594°
=0.041643 rad

Taper 1:30
α =57´17.4
=0.95484°
=0.016665 rad

Taper 1 : 12

Units : μm

Nominal Bore Diameter d (mm)		Δ_{dmp}		$\Delta_{d1mp} - \Delta_{dmp}$		V_{dp} (1) (2)
over	incl.	high	low	high	low	max.
18	**30**	+33	0	+21	0	13
30	**50**	+39	0	+25	0	16
50	**80**	+46	0	+30	0	19
80	**120**	+54	0	+35	0	22
120	**180**	+63	0	+40	0	40
180	**250**	+72	0	+46	0	46
250	**315**	+81	0	+52	0	52
315	**400**	+89	0	+57	0	57
400	**500**	+97	0	+63	0	63
500	**630**	+110	0	+70	0	70
630	**800**	+125	0	+80	0	–
800	**1 000**	+140	0	+90	0	–
1 000	**1 250**	+165	0	+105	0	–
1 250	**1 600**	+195	0	+125	0	–

Notes (1) Applicable to all radial planes of tapered bores.
(2) Not applicable to diameter series 7 and 8.

Taper 1 : 30

Units : μm

Nominal Bore Diameter d (mm)		Δ_{dmp}		$\Delta_{d1mp} - \Delta_{dmp}$		V_{dp} (1) (2)
over	incl.	high	low	high	low	max.
80	**120**	+20	0	+35	0	22
120	**180**	+25	0	+40	0	40
180	**250**	+30	0	+46	0	46
250	**315**	+35	0	+52	0	52
315	**400**	+40	0	+57	0	57
400	**500**	+45	0	+63	0	63
500	**630**	+50	0	+70	0	70

Notes (1) Applicable to all radial planes of tapered bores.
(2) Not applicable to diameter series 7 and 8.
Remarks For a value exceeding 630 mm, please contact NSK.

8.2 Selection of Accuracy Classes

For general applications, Class Normal tolerances are adequate in nearly all cases for satisfactory performance, but for the following applications, bearings having an accuracy class of 5,4 or higher are more suitable.
For reference, in Table 8.11, examples of applications and appropriate tolerance classes are listed for various bearing requirements and operating conditions.

Table 8. 11 Typical Tolerance Classes for Specific Applications (Reference)

Bearing Requirement, Operating Conditions	Examples of Applications	Tolerance Classes
High running accuracy is required	VTR Drum Spindles	P5
	Magnetic Disk Spindles for Computers	P5, P4, P2
	Machine-Tool Main Spindles	P5, P4, P2
	Rotary Printing Presses	P5
	Rotary Tables of Vertical Presses, etc.	P5, P4
	Roll Necks of Cold Rolling Mill Backup Rolls	Higher than P4
	Slewing Bearings for Parabolic Antennas	Higher than P4
Extra high speed is required	Dental Drills	CLASS 7P, CLASS 5P
	Gyroscopes	CLASS 7P, P4
	High Frequency Spindles	CLASS 7P, P4
	Superchargers	P5, P4
	Centrifugal Separators	P5, P4
	Main Shafts of Jet Engines	Higher than P4
Low torque and low torque variation are required	Gyroscope Gimbals	CLASS 7P, P4
	Servomechanisms	CLASS 7P, CLASS 5P
	Potentiometric Controllers	CLASS 7P

9. FITS AND INTERNAL CLEARANCES

9.1 Fits

9.1.1 Importance of Proper Fits

In the case of a rolling bearing with the inner ring fitted to the shaft with only slight interference, a harmful circumferential slipping may occur between the inner ring and shaft. This slipping of the inner ring, which is called “creep”, results in a circumferential displacement of the ring relative to the shaft if the interference fit is not sufficiently tight. When creep occurs, the fitted surfaces become abraded, causing wear and considerable damage to the shaft. Abnormal heating and vibration may also occur due to abrasive metallic particles entering the interior of the bearing.
It is important to prevent creep by having sufficient interference to firmly secure that ring which rotates to either the shaft or housing. Creep cannot always be eliminated using only axial tightening through the bearing ring faces. Generally, it is not necessary, however, to provide interference for rings subjected only to stationary loads. Fits are sometimes made without any interference for either the inner or outer ring, to accommodate certain operating conditions, or to facilitate mounting and dismounting. In this case, to prevent damage to the fitting surfaces due to creep, lubrication of other applicable methods should be considered.

9.1.2 Selection of Fit

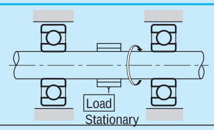
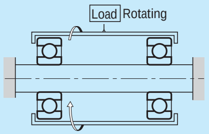
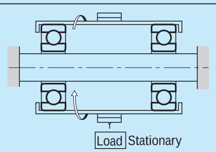
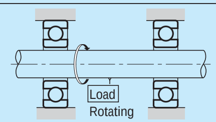
(1) Load Conditions and Fit
The proper fit may be selected from Table 9.1 based on the load and operating conditions.

(2) Magnitude of Load and Interference
The interference of the inner ring is slightly reduced by the bearing load; therefore, the loss of interference should be estimated using the following equations:

$$\left.\begin{aligned} \varDelta d_F &= 0.08\sqrt{\frac{d}{B}F_r}\times 10^{-3}\ \dots\dots\dots\ (\mathrm{N}) \\ \varDelta d_F &= 0.25\sqrt{\frac{d}{B}F_r}\times 10^{-3}\ \dots\dots\ \{\mathrm{kgf}\} \end{aligned}\right\}\ \dots\ \mathbf{(9.1)}$$

where $\varDelta d_F$: Interference decrease of inner ring (mm)
d : Bearing bore diameter (mm)
B : Nominal inner ring width (mm)
F_r : Radial load applied on bearing (N), {kgf}

Table 9.1 Loading Conditions and Fits

Load Application	Bearing Operation		Load Conditions	Fitting	
	Inner Ring	Outer Ring		Inner Ring	Outer Ring
	Rotating	Stationary	Rotating Inner Ring Load	Tight Fit	Loose Fit
	Stationary	Rotating	Stationary Outer Ring Load		
	Stationary	Rotating	Rotating Outer Ring Load	Loose Fit	Tight Fit
	Rotating	Stationary	Stationary Inner Ring Load		
Direction of load indeterminate due to variation of direction or unbalanced load	Rotating or Stationary	Rotating or Stationary	Direction of Load Indeterminate	Tight Fit	Tight Fit

Therefore, the effective interference $\varDelta d$ should be larger than the interference given by Equation (9.1).
However, in the case of heavy loads where the radial load exceeds 20% of the basic static load rating C_{0r}, under the operating condition, interference often becomes shortage. Therefore, interference should be estimated using Equation (9.2):

$$\left.\begin{aligned} \varDelta d &\geqq 0.02\,\frac{F_r}{B}\times 10^{-3}\ \dots\dots\dots\ (\mathrm{N}) \\ \varDelta d &\geqq 0.2\,\frac{F_r}{B}\times 10^{-3}\ \dots\dots\dots\ \{\mathrm{kgf}\} \end{aligned}\right\}\ \dots\dots\ \mathbf{(9.2)}$$

where $\varDelta d$: Effective interference (mm)
F_r : Radial load applied on bearing (N), {kgf}
B : Nominal inner ring width (mm)

(3) Interference Variation Caused by Temperature Difference between Bearing and Shaft or Housing
The effective interference decreases due to the increasing bearing temperature during operation. If the temperature difference between the bearing and housing is $\varDelta T$ (°C), then the temperature difference between the fitted surfaces of the shaft and inner ring is estimated to be about (0.1~0.15) $\varDelta T$ in case that the shaft is cooled. The decrease in the interference of the inner ring due to this temperature difference $\varDelta d_T$ may be calculated using Equation (9.3):

$$\begin{aligned} \varDelta d_T &= (0.10 \text{ to } 0.15)\times \varDelta T\cdot\alpha\cdot d \\ &\fallingdotseq 0.0015\varDelta T\cdot d\times 10^{-3}\ \dots\dots\dots\dots\dots\dots\ \mathbf{(9.3)} \end{aligned}$$

where $\varDelta d_T$: Decrease in interference of inner ring due to temperature difference (mm)
$\varDelta T$: Temperature difference between bearing interior and surrounding parts (°C)
α : Coefficient of linear expansion of bearing steel=12.5×10^{-6} (1/°C)
d : Bearing nominal bore diameter (mm)

In addition, depending on the temperature difference between the outer ring and housing, or difference in their coefficients of linear expansion, the interference may increase.

(4) Effective Interference and Finish of Shaft and Housing
Since the roughness of fitted surfaces is reduced during fitting, the effective interference becomes less than the apparent interference. The amount of this interference decrease varies depending on the roughness of the surfaces and may be estimated using the following equations:

For ground shafts $$\varDelta d = \frac{d}{d+2}\varDelta d_a\ \dots\dots\dots\dots\ \mathbf{(9.4)}$$

For machined shafts $$\varDelta d = \frac{d}{d+3}\varDelta d_a\ \dots\dots\dots\dots\ \mathbf{(9.5)}$$

where $\varDelta d$: Effective interference (mm)
$\varDelta d_a$: Apparent interference (mm)
d : Bearing nominal bore diameter (mm)

According to Equations (9.4) and (9.5), the effective interference of bearings with a bore diameter of 30 to 150 mm is about 95% of the apparent interference.

(5) Fitting Stress and Ring Expansion and Contraction
When bearings are mounted with interference on a shaft or in a housing, the rings either expand or contract and stress is produced. Excessive interference may damage the bearings; therefore, as a general guide, the maximum interference should be kept under approximately 7/10 000 of the shaft diameter.
The pressure between fitted surfaces, expansion or contraction of the rings, and circumferential stress may be calculated using the equations in Section **15.2**, Fitting(1) (Pages A130 and A131).

9.1.3 Recommended Fits

As described previously, many factors, such as the characteristics and magnitude of bearing load, temperature differences, means of bearing mounting and dismounting, must be considered when selecting the proper fit.
If the housing is thin or the bearing is mounted on a hollow shaft, a tighter than usual fit is necessary. A split housing often deforms the bearing into an oval shape; therefore, a split housing should be avoided when a tight fit with the outer ring is required.
The fits of both the inner and outer rings should be tight in applications where the shaft is subjected to considerable vibration.
The recommended fits for some common applications are shown in Table 9.2 to 9.7. In the case of unusual operating conditions, it is advisable to consult NSK. For the accuracy and surface finish of shafts and housings, please refer to Section **11.1** (Page A100).

Table 9.2 Fits of Radial Bearings with Shafts

Load Conditions		Examples	Shaft Diameter (mm) Ball Brgs	Cylindrical Roller Brgs, Tapered Roller Brgs	Spherical Roller Brgs	Tolerance of Shaft	Remarks
Radial Bearings with Cylindrical Bores							
Rotating Outer Ring Load	Easy axial displacement of inner ring on shaft desirable.	Wheels on Stationary Axles	All Shaft Diameters			g6	Use g5 and h5 where accuracy is required. In case of large bearings, f6 can be used to allow easy axial movement.
	Easy axial displacement of inner ring on shaft unnecessary	Tension Pulleys Rope Sheaves				h6	
Rotating Inner Ring Load or Direction of Load Indeterminate	Light Loads or Variable Loads ($<0.06C_r$[1])	Electrical Home Appliances Pumps, Blowers, Transport Vehicles, Precision Machinery, Machine Tools	<18	—	—	js5	
			18 to 100	<40	—	js6(j6)	
			100 to 200	40 to 140	—	k6	
			—	140 to 200	—	m6	
	Normal Loads (0.06 to $0.13C_r$[1])	General Bearing Applications, Medium and Large Motors[3], Turbines, Pumps, Engine Main Bearings, Gears, Woodworking Machines	<18	—	—	js5 or js6 (j5 or j6)	k6 and m6 can be used for single-row tapered roller bearings and single-row angular contact ball bearings instead of k5 and m5.
			18 to 100	<40	<40	k5 or k6	
			100 to 140	40 to 100	40 to 65	m5 or m6	
			140 to 200	100 to 140	65 to 100	m6	
			200 to 280	140 to 200	100 to 140	n6	
			—	200 to 400	140 to 280	p6	
			—	—	280 to 500	r6	
			—	—	over 500	r7	
	Heavy Loads or Shock Loads ($>0.13C_r$[1])	Railway Axleboxes, Industrial Vehicles, Traction Motors, Construction Equipment, Crushers	—	50 to 140	50 to 100	n6	More than CN bearing internal clearance is necessary.
			—	140 to 200	100 to 140	p6	
			—	over 200	140 to 200	r6	
			—	—	200 to 500	r7	
Axial Loads Only			All Shaft Diameters			js6 (j6)	—
Radial Bearings with Tapered Bores and Sleeves							
All Types of Loading		General bearing Applications, Railway Axleboxes	All Shaft Diameters			h9/IT5[2]	IT5 and IT7 mean that the deviation of the shaft from its true geometric form, e. g. roundness and cylindricity should be within the tolerances of IT5 and IT7 respectively.
		Transmission Shafts, Woodworking Spindles				h10/IT7[2]	

Notes (1) C_r represents the basic load rating of the bearing.
(2) Refer to Appendix Table 11 on page C22 for the values of standard tolerance grades IT.
(3) Refer to Tables 9.13.1 and 9.13.2 for the recommended fits of shafts used in electric motors for deep groove ball bearings with bore diameters ranging from 10 mm to 160 mm, and for cylindrical roller bearings with bore diameters ranging from 24 mm to 200 mm.

Remarks This table is applicable only to solid steel shafts.

Table 9.3 Fits of Thrust Bearings with Shafts

Load Conditions		Examples	Shaft Diameter (mm)	Tolerance of Shaft	Remarks
Central Axial Load Only		Main Shafts of Lathes	All Shaft Diameters	h6 or js6 (j6)	—
Combined Radial and Axial Loads (Spherical Thrust Roller Bearings)	Stationary Inner Ring Load	Cone Crushers	All Shaft Diameters	js6 (j6)	
	Rotating Inner Ring Load or Direction of Load Indeterminate	Paper Pulp Refiners, Plastic Extruders	<200	k6	
			200 to 400	m6	
			over 400	n6	

Table 9.4 Fits of Radial Bearings with Housings

Load Conditions			Examples	Tolerances for Housing Bores	Axial Displacement of Outer Ring	Remarks
Solid Housings	Rotating Outer Ring Load	Heavy Loads on Bearing in Thin-Walled Housing or Heavy Shock Loads	Automotive Wheel Hubs (Roller Bearings) Crane Travelling Wheels	P7	Impossible	—
		Normal or Heavy Loads	Automotive Wheel Hubs (Ball Bearings) Vibrating Screens	N7		
		Light or Variable Loads	Conveyor Rollers Rope Sheaves Tension Pulleys	M7		
	Direction of Load Indeterminate	Heavy Shock Loads	Traction Motors			
		Normal or Heavy Loads	Pumps Crankshaft Main Bearings Medium and Large Motors[1]	K7	Generally Impossible	If axial displacement of the outer ring is not required.
Solid or Split Housings		Normal or Light Loads		JS7 (J7)	Possible	Axial displacement of outer ring is necessary.
	Rotating Inner Ring Load	Loads of All kinds	General Bearing Applications, Railway Axleboxes	H7	Easily possible	—
		Normal or Light Loads	Plummer Blocks	H8		
		High Temperature Rise of Inner Ring Through Shaft	Paper Dryers	G7		
Solid Housing		Accurate Running Desirable under Normal or Light Loads	Grinding Spindle Rear Ball Bearings High Speed Centrifugal Compressor Free Bearings	JS6 (J6)	Possible	—
	Direction of Load Indeterminate		Grinding Spindle Front Ball Bearings High Speed Centrifugal Compressor Fixed Bearings	K6	Generally Impossible	For heavy loads, interference fit tighter than K is used. When high accuracy is required, very strict tolerances should be used for fitting.
	Rotating Inner Ring Load	Accurate Running and High Rigidity Desirable under Variable Loads	Cylindrical Roller Bearings for Machine Tool Main Spindle	M6 or N6	Impossible	
		Minimum noise is required.	Electrical Home Appliances	H6	Easily Possible	—

Note (1) Refer to Tables 9.13.1 and 9.13.2 for the recommended fits of housing bores of deep groove ball bearings and cylindrical roller bearings for electric motors.

Remarks 1. This table is applicable to cast iron and steel housings. For housings made of light alloys, the interference should be tighter than those in this table.
2. Refer to the introductory section of the bearing dimension tables (blue pages) for special fits such as drawn cup needle roller bearings.

Table 9.5 Fits of Thrust Bearings with Housings

Load Conditions		Bearing Types	Tolerances for Housing Bores	Remarks
Axial Loads Only		Thrust Ball Bearings	Clearance over 0.25mm	For General Applications
			H8	When precision is required
		Spherical Thrust Roller Bearings Steep Angle Tapered Roller Bearings	Outer ring has radial clearance.	When radial loads are sustained by other bearings.
Combined Radial and Axial Loads	Stationary Outer Ring Loads	Spherical Thrust Roller Bearings	H7 or JS7 (J7)	—
	Rotating Outer Ring Loads or Direction of Load Indeterminate		K7	Normal Loads
			M7	Relatively Heavy Radial Loads

Table 9.6 Fits of Inch Design Tapered Roller Bearings with Shafts

(1) Bearings of Precision Classes 4 and 2

Units : μm

Operating Conditions		Nominal Bore Diameters d over (mm)	over 1/25.4	incl. (mm)	incl. 1/25.4	Bore Diameter Tolerances Δ_{ds} high	low	Shaft Diameter Tolerances high	low	Remarks
Rotating Inner Ring Loads	Normal Loads	—		76.200	3.0000	+13	0	+ 38	+ 25	For bearings with $d \leq 152.4$ mm, clearance is usually larger than CN.
		76.200	3.0000	304.800	12.0000	+25	0	+ 64	+ 38	
		304.800	12.0000	609.600	24.0000	+51	0	+127	+ 76	
		609.600	24.0000	914.400	36.0000	+76	0	+190	+114	
	Heavy Loads Shock Loads High Speeds	—		76.200	3.0000	+13	0	+ 64	+ 38	In general, bearings with a clearance larger than CN are used. ※ means that the average interference is about 0.0005 d.
		76.200	3.0000	304.800	12.0000	+25	0	※		
		304.800	12.0000	609.600	24.0000	+51	0	※		
		609.600	24.0000	914.400	36.0000	+76	0	+381	+305	
Rotating Outer Ring Loads	Normal Loads without Shocks	—		76.200	3.0000	+13	0	+ 13	0	The inner ring cannot be displaced axially. When heavy or shock loads exist, the figures in the above (Rotating inner ring loads, heavy or shock loads) apply.
		76.200	3.0000	304.800	12.0000	+25	0	+ 25	0	
		304.800	12.0000	609.600	24.0000	+51	0	+ 51	0	
		609.600	24.0000	914.400	36.0000	+76	0	+ 76	0	
		—		76.200	3.0000	+13	0	0	− 13	The inner ring can be displaced axially.
		76.200	3.0000	304.800	12.0000	+25	0	0	− 25	
		304.800	12.0000	609.600	24.0000	+51	0	0	− 51	
		609.600	24.0000	914.400	36.0000	+76	0	0	− 76	

(2) Bearings of Precision Classes 3 and 0 (1)

Units : μm

Operating Conditions		Nominal Bore Diameters d over (mm)	over 1/25.4	incl. (mm)	incl. 1/25.4	Bore Diameter Tolerances Δ_{ds} high	low	Shaft Diameter Tolerances high	low	Remarks
Rotating Inner Ring Loads	Precision Machine-Tool Main Spindles	—		76.200	3.0000	+13	0	+ 30	+18	—
		76.200	3.0000	304.800	12.0000	+13	0	+ 30	+18	
		304.800	12.0000	609.600	24.0000	+25	0	+ 64	+38	
		609.600	24.0000	914.400	36.0000	+38	0	+102	+64	
	Heavy Loads Shock Loads High Speeds	—		76.200	3.0000	+13	0	—		A minimum interference of about 0.00025 d is used.
		76.200	3.0000	304.800	12.0000	+13	0	—		
		304.800	12.0000	609.600	24.0000	+25	0	—		
		609.600	24.0000	914.400	36.0000	+38	0	—		
Rotating Outer Ring Loads	Precision Machine-Tool Main Spindles	—		76.200	3.0000	+13	0	+ 30	+18	—
		76.200	3.0000	304.800	12.0000	+13	0	+ 30	+18	
		304.800	12.0000	609.600	24.0000	+25	0	+ 64	+38	
		609.600	24.0000	914.400	36.0000	+38	0	+102	+64	

Note (1) For bearings with d greater than 304.8 mm, Class 0 does not exist.

Table 9.7 Fits of Inch Design Tapered Roller Bearings with Housings

(1) Bearings of Precision Classes 4 and 2

Units : μm

Operating Conditions		Nominal Outside Diameters D over (mm)	over 1/25.4	incl. (mm)	incl. 1/25.4	Outside Diameter Tolerances Δ_{Ds} high	low	Housing Bore Diameter Tolerances high	low	Remarks
Rotating Inner Ring Loads	Used either on free-end or fixed-end	—		76.200	3.0000	+25	0	+ 76	+ 51	The outer ring can be easily displaced axially.
		76.200	3.0000	127.000	5.0000	+25	0	+ 76	+ 51	
		127.000	5.0000	304.800	12.0000	+25	0	+ 76	+ 51	
		304.800	12.0000	609.600	24.0000	+51	0	+152	+102	
		609.600	24.0000	914.400	36.0000	+76	0	+229	+152	
	The outer ring position can be adjusted axially.	—		76.200	3.0000	+25	0	+ 25	0	The outer ring can be displaced axially.
		76.200	3.0000	127.000	5.0000	+25	0	+ 25	0	
		127.000	5.0000	304.800	12.0000	+25	0	+ 51	0	
		304.800	12.0000	609.600	24.0000	+51	0	+ 76	+ 25	
		609.600	24.0000	914.400	36.0000	+76	0	+127	+ 51	
	The outer ring position cannot be adjusted axially.	—		76.200	3.0000	+25	0	− 13	− 38	Generally, the outer ring is fixed axially.
		76.200	3.0000	127.000	5.0000	+25	0	− 25	− 51	
		127.000	5.0000	304.800	12.0000	+25	0	− 25	− 51	
		304.800	12.0000	609.600	24.0000	+51	0	− 25	− 76	
		609.600	24.0000	914.400	36.0000	+76	0	− 25	−102	
Rotating Outer Ring Loads	Normal Loads The outer ring position cannot be adjusted axially.	—		76.200	3.0000	+25	0	− 13	− 38	The outer ring is fixed axially.
		76.200	3.0000	127.000	5.0000	+25	0	− 25	− 51	
		127.000	5.0000	304.800	12.0000	+25	0	− 25	− 51	
		304.800	12.0000	609.600	24.0000	+51	0	− 25	− 76	
		609.600	24.0000	914.400	36.0000	+76	0	− 25	−102	

(2) Bearings of Precision Classes 3 and 0 (1)

Units : μm

Operating Conditions		Nominal Outside Diameters D over (mm)	over 1/25.4	incl. (mm)	incl. 1/25.4	Outside Diameter Tolerances Δ_{Ds} high	low	Housing Bore Diameter Tolerances high	low	Remarks
Rotating Inner Ring Loads	Used on free-end	—		152.400	6.0000	+13	0	+38	+25	The outer ring can be easily displaced axially.
		152.400	6.0000	304.800	12.0000	+13	0	+38	+25	
		304.800	12.0000	609.600	24.0000	+25	0	+64	+38	
		609.600	24.0000	914.400	36.0000	+38	0	+89	+51	
	Used on fixed-end	—		152.400	6.0000	+13	0	+25	+13	The outer ring can be displaced axially.
		152.400	6.0000	304.800	12.0000	+13	0	+25	+13	
		304.800	12.0000	609.600	24.0000	+25	0	+51	+25	
		609.600	24.0000	914.400	36.0000	+38	0	+76	+38	
	The outer ring position can be adjusted axially.	—		152.400	6.0000	+13	0	+13	0	Generally, the outer ring is fixed axially.
		152.400	6.0000	304.800	12.0000	+13	0	+25	0	
		304.800	12.0000	609.600	24.0000	+25	0	+25	0	
		609.600	24.0000	914.400	36.0000	+38	0	+38	0	
	The outer ring position cannot be adjusted axially.	—		152.400	6.0000	+13	0	0	−13	The outer ring is fixed axially.
		152.400	6.0000	304.800	12.0000	+13	0	0	−25	
		304.800	12.0000	609.600	24.0000	+25	0	0	−25	
		609.600	24.0000	914.400	36.0000	+38	0	0	−38	
Rotating Outer Ring Loads	Normal Loads The outer ring position cannot be adjusted axially.	—		76.200	3.0000	+13	0	−13	−25	The outer ring is fixed axially.
		76.200	3.0000	152.400	6.0000	+13	0	−13	−25	
		152.400	6.0000	304.800	12.0000	+13	0	−13	−38	
		304.800	12.0000	609.600	24.0000	+25	0	−13	−38	
		609.600	24.0000	914.400	36.0000	+38	0	−13	−51	

Note (1) For bearings with D greater than 304.8 mm, Class 0 does not exist.

9.2 Bearing Internal Clearances

9.2.1 Internal Clearances and Their Standards

The internal clearance in rolling bearings in operation greatly influences bearing performance including fatigue life, vibration, noise, heat-generation, etc. Consequently, the selection of the proper internal clearance is one of the most important tasks when choosing a bearing after the type and size have been determined.

This bearing internal clearance is the combined clearances between the inner/outer rings and rolling elements. The radial and axial clearances are defined as the total amount that one ring can be displaced relative to the other in the radial and axial directions respectively (Fig. 9.1).

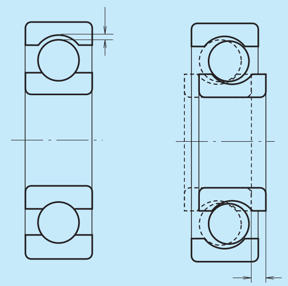


Table 9.8 Bearing Internal Clearance

To obtain accurate measurements, the clearance is generally measured by applying a specified measuring load on the bearing; therefore, the measured clearance (sometimes called “measured clearance” to make a distinction) is always slightly larger than the theoretical internal clearance (called “geometrical clearance” for radial bearings) by the amount of elastic deformation caused by the measuring load.

Therefore, the theoretical internal clearance may be obtained by correcting the measured clearance by the amount of elastic deformation. However, in the case of roller bearings this elastic deformation is negligibly small.

Usually the clearance before mounting is the one specified as the theoretical internal clearance.

In Table 9.8, reference table and page numbers are listed by bearing types.

Table 9.8 Index for Radial Internal Clearances by Bearing Types

Bearing Types		Table Number	Page Number
Deep Groove Ball Bearings		9.9	A89
Extra Small and Miniature Ball Bearings		9.10	A89
Magneto Bearings		9.11	A89
Self-Aligning Ball Bearings		9.12	A90
Deep Groove Ball Bearings	For Motors	9.13.1	A90
Cylindrical Roller Bearings	For Motors	9.13.2	A90
Cylindrical Roller Bearings	With Cylindrical Bores With Cylindrical Bores (Matched) With Tapered Bores (Matched)	9.14	A91
Spherical Roller Bearings	With Cylindrical Bores With Tapered Bores	9.15	A92
Double-Row and Combined Tapered Roller Bearings		9.15	A93
Combined Angular Contact Ball Bearings ([1])		9.17	A94
Four-Point Contact Ball Bearings ([1])		9.18	A94

Note ([1]) Values given are axial clearances.

Table 9.9 Radial Internal Clearances in Deep Groove Ball Bearings

Units : μm

Nominal Bore Diameter *d* (mm) over	incl.	C2 min.	C2 max.	CN min.	CN max.	C3 min.	C3 max.	C4 min.	C4 max.	C5 min.	C5 max.
10 only		0	7	2	13	8	23	14	29	20	37
10	**18**	0	9	3	18	11	25	18	33	25	45
18	**24**	0	10	5	20	13	28	20	36	28	48
24	**30**	1	11	5	20	13	28	23	41	30	53
30	**40**	1	11	6	20	15	33	28	46	40	64
40	**50**	1	11	6	23	18	36	30	51	45	73
50	**65**	1	15	8	28	23	43	38	61	55	90
65	**80**	1	15	10	30	25	51	46	71	65	105
80	**100**	1	18	12	36	30	58	53	84	75	120
100	**120**	2	20	15	41	36	66	61	97	90	140
120	**140**	2	23	18	48	41	81	71	114	105	160
140	**160**	2	23	18	53	46	91	81	130	120	180
160	**180**	2	25	20	61	53	102	91	147	135	200
180	**200**	2	30	25	71	63	117	107	163	150	230
200	**225**	2	35	25	85	75	140	125	195	175	265
225	**250**	2	40	30	95	85	160	145	225	205	300
250	**280**	2	45	35	105	90	170	155	245	225	340
280	**315**	2	55	40	115	100	190	175	270	245	370
315	**355**	3	60	45	125	110	210	195	300	275	410
355	**400**	3	70	55	145	130	240	225	340	315	460
400	**450**	3	80	60	170	150	270	250	380	350	510
450	**500**	3	90	70	190	170	300	280	420	390	570
500	**560**	10	100	80	210	190	330	310	470	440	630
560	**630**	10	110	90	230	210	360	340	520	490	690
630	**710**	20	130	110	260	240	400	380	570	540	760
710	**800**	20	140	120	290	270	450	430	630	600	840

Remarks To obtain the measured values, use the clearance correction for radial clearance increase caused by the measuring load in the table below.

For the C2 clearance class, the smaller value should be used for bearings with minimum clearance and the larger value for bearings near the maximum clearance range.

Units : μm

Nominal Bore Dia. *d* (mm) over	incl.	Measuring Load (N)	{kgf}	Radial Clearance Correction Amount C2	CN	C3	C4	C5
10 (incl)	**18**	24.5	{2.5}	3 to 4	4	4	4	4
18	**50**	49	{5}	4 to 5	5	6	6	6
50	**280**	147	{15}	6 to 8	8	9	9	9

Remarks For values exceeding 280 mm, please contact NSK.

Table 9.10 Radial Internal Clearances in Extra Small and Miniature Ball Bearings

Units : μm

Clear-ance Symbol	MC1 min.	MC1 max.	MC2 min.	MC2 max.	MC3 min.	MC3 max.	MC4 min.	MC4 max.	MC5 min.	MC5 max.	MC6 min.	MC6 max.
Clear-ance	0	5	3	8	5	10	8	13	13	20	20	28

Remarks 1. The standard clearance is MC3.
2. To obtain the measured value, add correction amount in the table below.

Units : μm

Clearance Symbol	MC1	MC2	MC3	MC4	MC5	MC6
Clearance Correction Value	1	1	1	1	2	2

The measuring loads are as follows :

For miniature ball bearings∗ 2.5N {0.25kgf}

For extra small ball bearings∗ 4.4N {0.45kgf}

∗For their classification, refer to Table 1 on Page B 31.

Table 9.11 Radial Internal Clearances in Magneto Bearings

Units : μm

Nominal Bore Diameter *d* (mm) over	incl.	Bearing Series	Clearance min.	max.
2.5	**30**	EN	10	50
		E	30	60

Table 9.12 Radial Internal Clearances in Self-Aligning Ball Bearings

Units : μm

Nominal Bore Dia. *d* (mm)		Clearance in Bearings with Cylindrical Bores										Clearance in Bearings with Tapered Bores									
		C2		CN		C3		C4		C5		C2		CN		C3		C4		C5	
over	incl.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
2.5	**6**	1	8	5	15	10	20	15	25	21	33	—	—	—	—	—	—	—	—	—	—
6	**10**	2	9	6	17	12	25	19	33	27	42	—	—	—	—	—	—	—	—	—	—
10	**14**	2	10	6	19	13	26	21	35	30	48	—	—	—	—	—	—	—	—	—	—
14	**18**	3	12	8	21	15	28	23	37	32	50	—	—	—	—	—	—	—	—	—	—
18	**24**	4	14	10	23	17	30	25	39	34	52	7	17	13	26	20	33	28	42	37	55
24	**30**	5	16	11	24	19	35	29	46	40	58	9	20	15	28	23	39	33	50	44	62
30	**40**	6	18	13	29	23	40	34	53	46	66	12	24	19	35	29	46	40	59	52	72
40	**50**	6	19	14	31	25	44	37	57	50	71	14	27	22	39	33	52	45	65	58	79
50	**65**	7	21	16	36	30	50	45	69	62	88	18	32	27	47	41	61	56	80	73	99
65	**80**	8	24	18	40	35	60	54	83	76	108	23	39	35	57	50	75	69	98	91	123
80	**100**	9	27	22	48	42	70	64	96	89	124	29	47	42	68	62	90	84	116	109	144
100	**120**	10	31	25	56	50	83	75	114	105	145	35	56	50	81	75	108	100	139	130	170
120	**140**	10	38	30	68	60	100	90	135	125	175	40	68	60	98	90	130	120	165	155	205
140	**160**	15	44	35	80	70	120	110	161	150	210	45	74	65	110	100	150	140	191	180	240

Table 9.13 Radial Internal Clearances in Bearings for Electric Motors

Table 9.13. 1 Deep Groove Ball Bearings for Electric Motors

Units : μm

Nominal Bore Dia. *d* (mm)		Clearance		Remarks	
		CM		Recommended fit	
over	incl.	min.	max.	Shaft	Housing Bore
10 (incl)	**18**	4	11	js5 (j5)	H6, H7(1) or JS6, JS7 (J6, J7)(2)
18	**30**	5	12	k5	
30	**50**	9	17		
50	**80**	12	22		
80	**100**	18	30		
100	**120**	18	30	m5	
120	**160**	24	38		

Notes (1) Applicable to outer rings that require movement in the axial direction.
(2) Applicable to outer rings that do not require movement in the axial direction.

Remarks The radial clearance increase caused by the measuring load is equal to the correction amount for CN clearance in the remarks under Table 9.9.

Table 9.13.2 Cylindrical Roller Bearings for Electric Motors

Units : μm

Nominal Bore Dia. *d* (mm)		Clearance				Remarks	
		Interchangeable CT		Non-Interchangeable CM		Recommended Fit	
over	incl.	min.	max.	min.	max.	Shaft	Housing Bore
24	**40**	15	35	15	30	k5	JS6, JS7 (J6, J7)(1) or K6, K7(2)
40	**50**	20	40	20	35	m5	
50	**65**	25	45	25	40		
65	**80**	30	50	30	45		
80	**100**	35	60	35	55		
100	**120**	35	65	35	60		
120	**140**	40	70	40	65		
140	**160**	50	85	50	80		
160	**180**	60	95	60	90	n6	
180	**200**	65	105	65	100		

Notes (1) Applicable to outer rings that require movement in the axial direction.
(2) Applicable to outer rings that do not require movement in the axial direction.

Table 9.14 Radial Internal Clearances in Cylindrical Roller Bearings and Solid-Type Needle Roller Bearings

Units : μm

Nominal Bore Dia. *d* (mm)		Clearances in Bearings with Cylindrical Bores										Clearances in Non-Interchangeable Bearings with Cylindrical Bores											
		C2		CN		C3		C4		C5		CC1		CC2		CC (1)		CC3		CC4		CC5	
over	incl.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
—	**10**	0	25	20	45	35	60	50	75	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10	**24**	0	25	20	45	35	60	50	75	65	90	5	15	10	20	20	30	35	45	45	55	65	75
24	**30**	0	25	20	45	35	60	50	75	70	95	5	15	10	25	25	35	40	50	50	60	70	80
30	**40**	5	30	25	50	45	70	60	85	80	105	5	15	12	25	25	40	45	55	55	70	80	95
40	**50**	5	35	30	60	50	80	70	100	95	125	5	18	15	30	30	45	50	65	65	80	95	110
50	**65**	10	40	40	70	60	90	80	110	110	140	5	20	15	35	35	50	55	75	75	90	110	130
65	**80**	10	45	40	75	65	100	90	125	130	165	10	25	20	40	40	60	70	90	90	110	130	150
80	**100**	15	50	50	85	75	110	105	140	155	190	10	30	25	45	45	70	80	105	105	125	155	180
100	**120**	15	55	50	90	85	125	125	165	180	220	10	30	25	50	50	80	95	120	120	145	180	205
120	**140**	15	60	60	105	100	145	145	190	200	245	10	35	30	60	60	90	105	135	135	160	200	230
140	**160**	20	70	70	120	115	165	165	215	225	275	10	35	35	65	65	100	115	150	150	180	225	260
160	**180**	25	75	75	125	120	170	170	220	250	300	10	40	35	75	75	110	125	165	165	200	250	285
180	**200**	35	90	90	145	140	195	195	250	275	330	15	45	40	80	80	120	140	180	180	220	275	315
200	**225**	45	105	105	165	160	220	220	280	305	365	15	50	45	90	90	135	155	200	200	240	305	350
225	**250**	45	110	110	175	170	235	235	300	330	395	15	50	50	100	100	150	170	215	215	265	330	380
250	**280**	55	125	125	195	190	260	260	330	370	440	20	55	55	110	110	165	185	240	240	295	370	420
280	**315**	55	130	130	205	200	275	275	350	410	485	20	60	60	120	120	180	205	265	265	325	410	470
315	**355**	65	145	145	225	225	305	305	385	455	535	20	65	65	135	135	200	225	295	295	360	455	520
355	**400**	100	190	190	280	280	370	370	460	510	600	25	75	75	150	150	225	255	330	330	405	510	585
400	**450**	110	210	210	310	310	410	410	510	565	665	25	85	85	170	170	255	285	370	370	455	565	650
450	**500**	110	220	220	330	330	440	440	550	625	735	25	95	95	190	190	285	315	410	410	505	625	720

Note (1) CC denotes normal clearance for non-Interchangeable cylindrical roller bearings and solid-type needle roller bearings.

Units : μm

Nominal Bore Dia. *d* (mm)		Clearances in Non-Interchangeable Bearings with Tapered Bores															
		CC9 (1)		CC0		CC1		CC2		CC (2)		CC3		CC4		CC5	
over	incl.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
10	**24**	5	10	—	—	10	20	20	30	35	45	45	55	55	65	75	85
24	**30**	5	10	8	15	10	25	25	35	40	50	50	60	60	70	80	95
30	**40**	5	12	8	15	12	25	25	40	45	55	55	70	70	80	95	110
40	**50**	5	15	10	20	15	30	30	45	50	65	65	80	80	95	110	125
50	**65**	5	15	10	20	15	35	35	50	55	75	75	90	90	110	130	150
65	**80**	10	20	15	30	20	40	40	60	70	90	90	110	110	130	150	170
80	**100**	10	25	20	35	25	45	45	70	80	105	105	125	125	150	180	205
100	**120**	10	25	20	35	25	50	50	80	95	120	120	145	145	170	205	230
120	**140**	15	30	25	40	30	60	60	90	105	135	135	160	160	190	230	260
140	**160**	15	35	30	50	35	65	65	100	115	150	150	180	180	215	260	295
160	**180**	15	35	30	50	35	75	75	110	125	165	165	200	200	240	285	320
180	**200**	20	40	30	50	40	80	80	120	140	180	180	220	220	260	315	355
200	**225**	20	45	35	60	45	90	90	135	155	200	200	240	240	285	350	395
225	**250**	25	50	40	65	50	100	100	150	170	215	215	265	265	315	380	430
250	**280**	25	55	40	70	55	110	110	165	185	240	240	295	295	350	420	475
280	**315**	30	60	—	—	60	120	120	180	205	265	265	325	325	385	470	530
315	**355**	30	65	—	—	65	135	135	200	225	295	295	360	360	430	520	585
355	**400**	35	75	—	—	75	150	150	225	255	330	330	405	405	480	585	660
400	**450**	40	85	—	—	85	170	170	255	285	370	370	455	455	540	650	735
450	**500**	45	95	—	—	95	190	190	285	315	410	410	505	505	600	720	815

Notes (1) Clearance CC9 is applicable to cylindrical roller bearings with tapered bores in ISO Tolerance Classes 5 and 4.
(2) CC denotes normal clearance for non-Interchangeable cylindrical roller bearings and solid-type needle roller bearings.

Table 9.15 Radial Internal Clearances in Spherical Roller Bearings

Units : μm

Nominal Bore Dia. d (mm)		Clearance in Bearings with Cylindrical Bores										Clearance in Bearings with Tapered Bores									
		C2		CN		C3		C4		C5		C2		CN		C3		C4		C5	
over	incl.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
24	30	15	25	25	40	40	55	55	75	75	95	20	30	30	40	40	55	55	75	75	95
30	40	15	30	30	45	45	60	60	80	80	100	25	35	35	50	50	65	65	85	85	105
40	50	20	35	35	55	55	75	75	100	100	125	30	45	45	60	60	80	80	100	100	130
50	65	20	40	40	65	65	90	90	120	120	150	40	55	55	75	75	95	95	120	120	160
65	80	30	50	50	80	80	110	110	145	145	180	50	70	70	95	95	120	120	150	150	200
80	100	35	60	60	100	100	135	135	180	180	225	55	80	80	110	110	140	140	180	180	230
100	120	40	75	75	120	120	160	160	210	210	260	65	100	100	135	135	170	170	220	220	280
120	140	50	95	95	145	145	190	190	240	240	300	80	120	120	160	160	200	200	260	260	330
140	160	60	110	110	170	170	220	220	280	280	350	90	130	130	180	180	230	230	300	300	380
160	180	65	120	120	180	180	240	240	310	310	390	100	140	140	200	200	260	260	340	340	430
180	200	70	130	130	200	200	260	260	340	340	430	110	160	160	220	220	290	290	370	370	470
200	225	80	140	140	220	220	290	290	380	380	470	120	180	180	250	250	320	320	410	410	520
225	250	90	150	150	240	240	320	320	420	420	520	140	200	200	270	270	350	350	450	450	570
250	280	100	170	170	260	260	350	350	460	460	570	150	220	220	300	300	390	390	490	490	620
280	315	110	190	190	280	280	370	370	500	500	630	170	240	240	330	330	430	430	540	540	680
315	355	120	200	200	310	310	410	410	550	550	690	190	270	270	360	360	470	470	590	590	740
355	400	130	220	220	340	340	450	450	600	600	750	210	300	300	400	400	520	520	650	650	820
400	450	140	240	240	370	370	500	500	660	660	820	230	330	330	440	440	570	570	720	720	910
450	500	140	260	260	410	410	550	550	720	720	900	260	370	370	490	490	630	630	790	790	1 000
500	560	150	280	280	440	440	600	600	780	780	1 000	290	410	410	540	540	680	680	870	870	1 100
560	630	170	310	310	480	480	650	650	850	850	1 100	320	460	460	600	600	760	760	980	980	1 230
630	710	190	350	350	530	530	700	700	920	920	1 190	350	510	510	670	670	850	850	1 090	1 090	1 360
710	800	210	390	390	580	580	770	770	1 010	1 010	1 300	390	570	570	750	750	960	960	1 220	1 220	1 500
800	900	230	430	430	650	650	860	860	1 120	1 120	1 440	440	640	640	840	840	1 070	1 070	1 370	1 370	1 690
900	1 000	260	480	480	710	710	930	930	1 220	1 220	1 570	490	710	710	930	930	1 190	1 190	1 520	1 520	1 860
1 000	1 120	290	530	530	780	780	1 020	1 020	1 330	—	—	530	770	770	1 030	1 030	1 300	1 300	1 670	—	—
1 120	1 250	320	580	580	860	860	1 120	1 120	1 460	—	—	570	830	830	1 120	1 120	1 420	1 420	1 830	—	—
1 250	1 400	350	640	640	950	950	1 240	1 240	1 620	—	—	620	910	910	1 230	1 230	1 560	1 560	2 000	—	—

Table 9.16 Radial Internal Clearances in Double-Row and Combined Tapered Roller Bearings

Units : μm

Nominal Bore Dia. d (mm)		Clearance											
Cylindrical Bore		C1		C2		CN		C3		C4		C5	
Tapered Bore		—		C1		C2		CN		C3		C4	
over	incl.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
—	18	0	10	10	20	20	30	35	45	50	60	65	75
18	24	0	10	10	20	20	30	35	45	50	60	65	75
24	30	0	10	10	20	20	30	40	50	50	60	70	80
30	40	0	12	12	25	25	40	45	60	60	75	80	95
40	50	0	15	15	30	30	45	50	65	65	80	95	110
50	65	0	15	15	35	35	55	60	80	80	100	110	130
65	80	0	20	20	40	40	60	70	90	90	110	130	150
80	100	0	25	25	50	50	75	80	105	105	130	155	180
100	120	5	30	30	55	55	80	90	115	120	145	180	210
120	140	5	35	35	65	65	95	100	130	135	165	200	230
140	160	10	40	40	70	70	100	110	140	150	180	220	260
160	180	10	45	45	80	80	115	125	160	165	200	250	290
180	200	10	50	50	90	90	130	140	180	180	220	280	320
200	225	20	60	60	100	100	140	150	190	200	240	300	340
225	250	20	65	65	110	110	155	165	210	220	270	330	380
250	280	20	70	70	120	120	170	180	230	240	290	370	420
280	315	30	80	80	130	130	180	190	240	260	310	410	460
315	355	30	80	80	130	140	190	210	260	290	350	450	510
355	400	40	90	90	140	150	200	220	280	330	390	510	570
400	450	45	95	95	145	170	220	250	310	370	430	560	620
450	500	50	100	100	150	190	240	280	340	410	470	620	680
500	560	60	110	110	160	210	260	310	380	450	520	700	770
560	630	70	120	120	170	230	290	350	420	500	570	780	850
630	710	80	130	130	180	260	310	390	470	560	640	870	950
710	800	90	140	150	200	290	340	430	510	630	710	980	1 060
800	900	100	150	160	210	320	370	480	570	700	790	1 100	1 200
900	1 000	120	170	180	230	360	410	540	630	780	870	1 200	1 300
1 000	1 120	130	190	200	260	400	460	600	700	—	—	—	—
1 120	1 250	150	210	220	280	450	510	670	770	—	—	—	—
1 250	1 400	170	240	250	320	500	570	750	870	—	—	—	—

Remarks Axial internal clearance $\Delta_a = \Delta_r \cot\alpha \fallingdotseq \frac{1.5}{e}\Delta_r$

where Δ_r : Radial internal clearance
α : Contact angle
e : Constant (Listed in bearing tables)

Table 9.17 Axial Internal Clearances in Combined Angular Contact Ball Bearings (Measured Clearance)

Units : μm

Nominal Bore Diameter. d (mm)		Axial Internal Clearance											
		Contact Angle 30°						Contact Angle 40°					
		CN		C3		C4		CN		C3		C4	
over	incl.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
—	10	9	29	29	49	49	69	6	26	26	46	46	66
10	18	10	30	30	50	50	70	7	27	27	47	47	67
18	24	19	39	39	59	59	79	13	33	33	53	53	73
24	30	20	40	40	60	60	80	14	34	34	54	54	74
30	40	26	46	46	66	66	86	19	39	39	59	59	79
40	50	29	49	49	69	69	89	21	41	41	61	61	81
50	65	35	60	60	85	85	110	25	50	50	75	75	100
65	80	38	63	63	88	88	115	27	52	52	77	77	100
80	100	49	74	74	99	99	125	35	60	60	85	85	110
100	120	72	97	97	120	120	145	52	77	77	100	100	125
120	140	85	115	115	145	145	175	63	93	93	125	125	155
140	160	90	120	120	150	150	180	66	96	96	125	125	155
160	180	95	125	125	155	155	185	68	98	98	130	130	160
180	200	110	140	140	170	170	200	80	110	110	140	140	170

Remarks This table is applicable to bearings in Tolerance Classes Normal and 6. For internal axial clearances in bearings in tolerance classes better than 5 and contact angles of 15° and 25°, it is advisable to consult NSK.

Table 9.18 Axial Internal Clearance in Four-Point Contact Ball Bearings (Measured Clearances)

Units : μm

Nominal Bore Dia. d (mm)		Axial Internal Clearance							
		C2		CN		C3		C4	
over	incl.	min.	max.	min.	max.	min.	max.	min.	max.
10	18	15	55	45	85	75	125	115	165
18	40	26	66	56	106	96	146	136	186
40	60	36	86	76	126	116	166	156	206
60	80	46	96	86	136	126	176	166	226
80	100	56	106	96	156	136	196	186	246
100	140	66	126	116	176	156	216	206	266
140	180	76	156	136	196	176	246	226	296
180	220	96	176	156	226	206	276	256	326
220	260	115	196	175	245	225	305	285	365
260	300	135	215	195	275	255	335	315	395
300	350	155	235	215	305	275	365	345	425
350	400	175	265	245	335	315	405	385	475
400	500	205	305	285	385	355	455	435	525

9.2.2 Selection of Bearing Internal Clearances

Among the bearing internal clearances listed in the tables, the CN Clearance is adequate for standard operating conditions. The clearance becomes progressively smaller from C2 to C1 and larger from C3 to C5.

Standard operating conditions are defined as those where the inner ring speed is less than approximately 50% of the limiting speed listed in the bearing tables, the load is less than normal ($P \fallingdotseq 0.1C_r$), and the bearing is tight-fitted on the shaft.

As a measure to reduce bearing noise for electric motors, the radial clearance range is narrower than the normal class and the values are somewhat smaller for deep groove ball bearings and cylindrical roller bearings for electric motors. (Refer to Table 9.13.1 and 9.13.2)

Internal clearance varies with the fit and temperature differences in operation. The changes in radial clearance in a roller bearing are shown in Fig. 9.2.

(1) Decrease in Radial Clearance Caused by Fitting and Residual Clearance

When the inner ring or the outer ring is tight-fitted on a shaft or in a housing, a decrease in the radial internal clearance is caused by the expansion or contraction of the bearing rings. The decrease varies according to the bearing type and size and design of the shaft and housing. The amount of this decrease is approximately 70 to 90% of the interference (refer to Section **15.2**, Fits (1), Pages A130 to A133). The internal clearance after subtracting this decrease from the theoretical internal clearance Δ_0 is called the residual clearance, Δ_f.

(2) Decrease in Radial Internal Clearance Caused by Temperature Differences between Inner and Outer Rings and Effective Clearance

The frictional heat generated during operation is conducted away through the shaft and housing. Since housings generally conduct heat better than shafts, the temperature of the inner ring and the rolling elements is usually higher than that of the outer ring by 5 to 10°C. If the shaft is heated or the housing is cooled, the difference in temperature between the inner and outer rings is greater. The radial clearance decreases due to the thermal expansion caused by the temperature difference between the inner and outer rings. The amount of this decrease can be calculated using the following equations:

$$\delta_t \fallingdotseq \alpha \Delta_t D_e \quad \cdots\cdots \textbf{(9.6)}$$

where δ_t : Decrease in radial clearance due to temperature difference between inner and outer rings (mm)
α : Coefficient of linear expansion of bearing steel $\fallingdotseq 12.5 \times 10^{-6}$ (1/°C)
Δ_t : Temperature difference between inner and outer rings (°C)
D_e : Outer ring raceway diameter (mm)

For ball bearings

$$D_e \fallingdotseq \frac{1}{5}(4D+d) \quad \cdots\cdots \textbf{(9.7)}$$

For roller bearings

$$D_e \fallingdotseq \frac{1}{4}(3D+d) \quad \cdots\cdots \textbf{(9.8)}$$

The clearance after substracting this δ_t from the residual clearance, Δ_f is called the effective clearance, Δ. Theoretically, the longest life of a bearing can be expected when the effective clearance is slightly negative. However, it is difficult to achieve such an ideal condition, and an excessive negative clearance will greatly shorten the bearing life. Therefore, a clearance of zero or a slightly positive amount, instead of a negative one, should be selected. When single-row angular contact ball bearings or tapered roller bearings are used facing each other, there should be a small effective clearance, unless a preload is required. When two cylindrical roller bearings with a rib on one side are used facing each other, it is necessary to provide adequate axial clearance to allow for shaft elongation during operation.

The radial clearances used in some specific applications are given in Table9.19. Under special operating conditions, it is advisable to consult NSK.

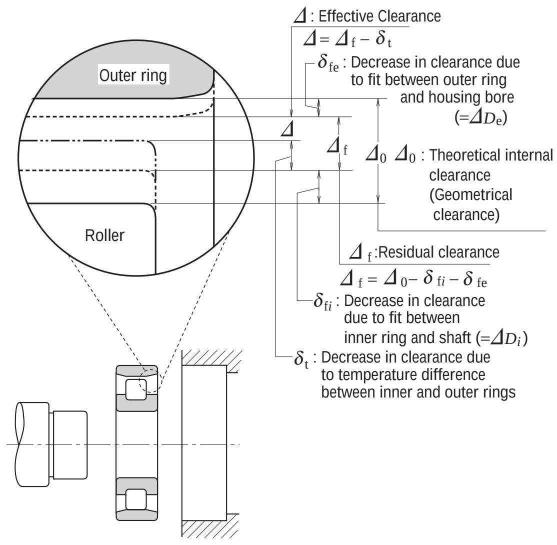


Fig. 9.2 Changes in Radial Internal Clearance of Bearings

Table 9. 19 Examples of Clearances for Specific Applications

Operating Conditions	Examples	Internal Clearance
When shaft deflection is large.	Semi-floating rear wheels of automobiles	C5 or equivalent
When steam passes through hollow shafts or roller shafts are heated.	Dryers in paper making machines	C3, C4
	Table rollers for rolling mills	C3
When impact loads and vibration are severe or when both the inner and outer rings are tight-fitted.	Traction motors for railways	C4
	Vibrating screens	C3, C4
	Fluid couplings	C4
	Final reduction gears for tractors	C4
When both the inner and outer rings are loose-fitted	Rolling mill roll necks	C2 or equivalent
When noise and vibration restrictions are severe	Small motors with special specifications	C1, C2, CM
When clearance is adjusted after mounting to prevent shaft deflection, etc.	Main shafts of lathes	CC9, CC1

10. PRELOAD

Rolling bearings usually retain some internal clearance while in operation. In some cases, however, it is desirable to provide a negative clearance to keep them internally stressed. This is called “preloading”. A preload is usually applied to bearings in which the clearance can be adjusted during mounting, such as angular contact ball bearings or tapered roller bearings. Usually, two bearings are mounted face-to-face or back-to-back to form a duplex set with a preload.

10.1 Purpose of Preload

The main purposes and some typical applications of preloaded bearings are as follows:

(1) To maintain the bearings in exact position both radially and axially and to maintain the running accuracy of the shaft.
...Main shafts of machine tools, precision instruments, etc.
(2) To increase bearing rigidity
...Main shafts of machine tools, pinion shafts of final drive gears of automobiles, etc.
(3) To minimize noise due to axial vibration and resonance
...Small electric motors, etc.
(4) To prevent sliding between the rolling elements and raceways due to gyroscopic moments
...High speed or high acceleration applications of angular contact ball bearings, and thrust ball bearings
(5) To maintain the rolling elements in their proper position with the bearing rings
...Thrust ball bearings and spherical thrust roller bearings mounted on a horizontal shaft

10.2 Preloading Methods

10.2.1 Position Preload

A position preload is achieved by fixing two axially opposed bearings in such a way that a preload is imposed on them. Their position, once fixed, remain unchanged while in operation.
In practice, the following three methods are generally used to obtain a position preload.

(1) By installing a duplex bearing set with previously adjusted stand-out dimensions (see Page A7, Fig. 1.1) and axial clearance.
(2) By using a spacer or shim of proper size to obtain the required spacing and preload. (Refer to Fig. 10.1)
(3) By utilizing bolts or nuts to allow adjustment of the axial preload. In this case, the starting torque should be measured to verify the proper preload.

10.2.2 Constant-Pressure Preload

A constant pressure preload is achieved using a coil or leaf spring to impose a constant preload. Even if the relative position of the bearings changes during operation, the magnitude of the preload remains relatively constant (refer to Fig. 10.2)

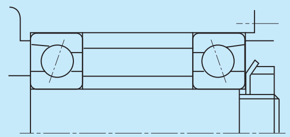


Fig. 10.1 Position Preload

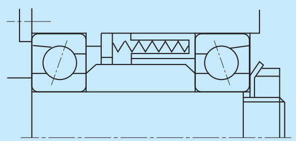


Fig. 10.2 Constant-Pressure Preload

10.3 Preload and Rigidity

10.3.1 Position Preload and Rigidity

When the inner rings of the duplex bearings shown in Fig.10.3 are fixed axially, bearings A and B are displaced δ_{a0} and axial space $2\delta_{a0}$ between the inner rings is eliminated. With this condition, a preload F_{a0} is imposed on each bearing. A preload diagram showing bearing rigidity, that is the relation between load and displacement with a given axial load F_a imposed on a duplex set, is shown in Fig. 10.4.

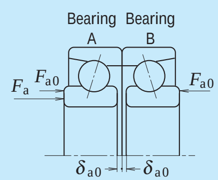


Fig. 10.3 Back-to-Back Duplex Bearing Preload

10.3.2 Constant-Pressure Preload and Rigidity

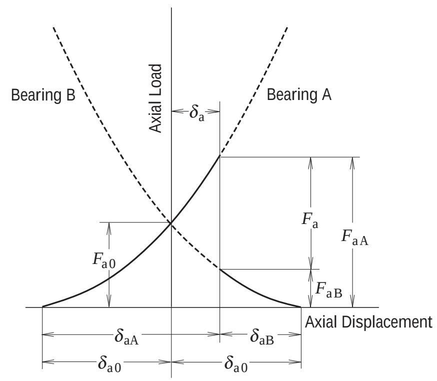
A preload diagram for duplex bearings under a constant-pressure preload is shown in Fig. 10.5. The deflection curve of the spring is nearly parallel to the horizontal axis because the rigidity of springs is lower than that of the bearing. As a result, the rigidity under a constant-pressure preload is approximately equal to that for a single bearing with a preload F_{a0} applied to it. Fig. 10.6 presents a comparison of the rigidity of a bearing with a position preload and one with a constant-pressure preload.

10.4 Selection of Preloading Method and Amount of Preload

10.4.1 Comparison of Preloading Methods

A comparison of the rigidity using both preloading methods is shown in Fig. 10.6. The position preload and constant-pressure preload may be compared as follows:

(1) When both of the preloads are equal, the position preload provides greater bearing rigidity, in other words, the deflection due to external loads is less for bearings with a position preload.
(2) In the case of a position preload, the preload varies depending on such factors as a difference in axial expansion due to a temperature difference between the shaft and housing, a difference in radial expansion due to a temperature difference between the inner and outer rings, deflection due to load, etc.



F_a : Axial load applied from outside
F_{aA}: Axial load imposed on Bearing A
F_{aB}: Axial load imposed on Bearing B
δ_a : Displacement of duplex bearing set
δ_{aA} : Displacement of Bearing A
δ_{aB} : Displacement of Bearing B

Fig. 10.4 Axial Displacement with Position Preload

In the case of a constant-pressure preload, it is possible to minimize any change in the preload because the variation of the spring load with shaft expansion and contraction is negligible. From the foregoing explanation, it is seen that position preloads are generally preferred for increasing rigidity and constant-pressure preloads are more suitable for high speed applications, for prevention of axial vibration, for use with thrust bearings on horizontal shafts, etc.

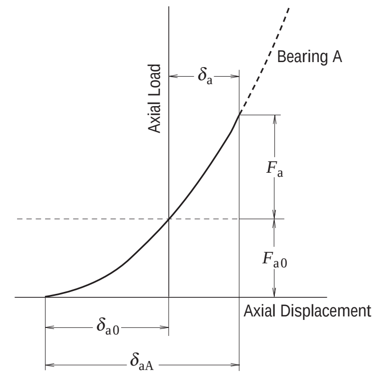


Fig. 10.5 Axial Displacement with Constant-Pressure Preload

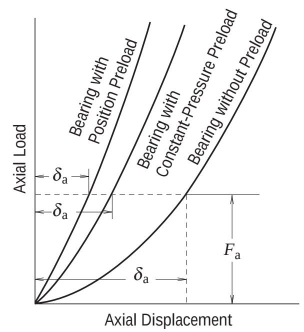


Fig. 10.6 Comparison of Rigidities and Preloading Methods

10.4.2 Amount of Preload

If the preload is larger than necessary, abnormal heart generation, increased frictional torque, reduced fatigue life, etc. may occur. The amount of the preload should be carefully determined considering the operating conditions and the purpose of the preload.

(1) Preloading of Duplex Angular Contact Ball Bearings

Average preloads for duplex angular contact ball bearings (contact angle of 15°) with precision better than P5 class, which are used on the main shafts of machine tools, are listed in Table 10.2.

The recommended fitting between the shaft and inner ring and between the housing and outer ring are listed in Table 10.1. In the case of fits with housings, the lower limit of the fitting range should be selected for fixed-end bearings and the upper limit for free-end bearings.

As a general rule, an extra light or light preload should be selected for grinding spindles and the main shafts of machining centers, while a medium preload should be adopted for the main shafts of lathes requiring rigidity.

When speeds result in a value of $D_{pw} \times n$ ($d_m n$ value) higher than 500000, the preload should be very carefully studied and selected. In such a case, please consult with NSK beforehand.

Table 10. 1 Recommended Fitting for High Accuracy Duplex Angular Contact Ball Bearings with Preload

Units : μm

Nominal Bore Dia. d (mm) over	Nominal Bore Dia. d (mm) incl.	Target Shaft Interference	Nominal Outside Dia. D (mm) over	Nominal Outside Dia. D (mm) incl.	Target Housing Clearance
—	18	0 to 2	—	18	—
18	30	0 to 2.5	18	30	2 to 6
30	50	0 to 2.5	30	50	2 to 6
50	80	0 to 3	50	80	3 to 8
80	120	0 to 4	80	120	3 to 9
120	150	—	120	150	4 to 12
150	180	—	150	180	4 to 12
180	250	—	180	250	5 to 15

(2) Preload of Thrust Ball Bearings

When the balls in thrust ball bearings rotate at relatively high speeds, sliding due to gyroscopic moments on the balls may occur. The larger of the two values obtained from Equations(10.1) and (10.2) below should be adopted as the minimum axial load in order to prevent such sliding

$$F_{a\,min} = \frac{C_{0a}}{100}\left(\frac{n}{N_{max}}\right)^2 \quad \cdots\cdots\cdots\cdots (10.1)$$

$$F_{a\,min} = \frac{C_{0a}}{1000} \quad \cdots\cdots\cdots\cdots (10.2)$$

where $F_{a\,min}$: Minimum axial load (N), {kgf}
n : Speed (min^{-1})
C_{0a} : Basic static load rating (N), {kgf}
N_{max} : Limiting speed (oil lubrication) (min^{-1})

(3) Preload of Spherical Thrust Roller Bearings

When spherical thrust roller bearings are used, damage such as scoring may occur due to sliding between the rollers and outer ring raceway. The minimum axial load $F_{a\,min}$ necessary to prevent such sliding is obtained from the following equation:

$$F_{a\,min} = \frac{C_{0a}}{1000} \quad \cdots\cdots\cdots\cdots (10.3)$$

Table 10. 2 Preloads for Duplex Angular Contact Ball Bearings

Table 10. 2. 1 Duplex Bearings of Series 79

Units : N

Bearing No.	Preloads: Extra light Preload EL	Light Preload L	Medium Preload M	Heavy Preload H
7900 C	7	15	29	59
7901 C	8.6	15	39	78
7902 C	12	25	49	100
7903 C	12	25	59	120
7904 C	19	39	78	150
7905 C	19	39	100	200
7906 C	24	49	100	200
7907 C	34	69	150	290
7908 C	39	78	200	390
7909 C	50	100	200	390
7910 C	50	100	250	490
7911 C	60	120	290	590
7912 C	60	120	290	590
7913 C	75	150	340	690
7914 C	100	200	490	980
7915 C	100	200	490	980
7916 C	100	200	490	980
7917 C	145	290	640	1 270
7918 C	145	290	740	1 470
7919 C	145	290	780	1 570
7920 C	195	390	880	1 770

Table 10. 2. 2 Duplex Bearings of Series 70

Units : N

Bearing No.	Preloads: Extra light Preload EL	Light Preload L	Medium Preload M	Heavy Preload H
7000 C	12	25	49	100
7001 C	12	25	59	120
7002 C	14	29	69	150
7003 C	14	29	69	150
7004 C	24	49	120	250
7005 C	29	59	150	290
7006 C	39	78	200	390
7007 C	60	120	250	490
7008 C	60	120	290	590
7009 C	75	150	340	690
7010 C	75	150	390	780
7011 C	100	200	490	980
7012 C	100	200	540	1 080
7013 C	125	250	540	1 080
7014 C	145	290	740	1 470
7015 C	145	290	780	1 570
7016 C	195	390	930	1 860
7017 C	195	390	980	1 960
7018 C	245	490	1 180	2 350
7019 C	270	540	1 180	2 350
7020 C	270	540	1 270	2 550

Table 10. 2. 3 Duplex Bearings of Series 72

Units : N

Bearing No.	Preloads: Extra light Preload EL	Light Preload L	Medium Preload M	Heavy Preload H
7200 C	14	29	69	150
7201 C	19	39	100	200
7202 C	19	39	100	200
7203 C	24	49	150	290
7204 C	34	69	200	390
7205 C	39	78	200	390
7206 C	60	120	290	590
7207 C	75	150	390	780
7208 C	100	200	490	980
7209 C	125	250	540	1 080
7210 C	125	250	590	1 180
7211 C	145	290	780	1 570
7212 C	195	390	930	1 860
7213 C	220	440	1 080	2 160
7214 C	245	490	1 180	2 350
7215 C	270	540	1 230	2 450
7216 C	295	590	1 370	2 750
7217 C	345	690	1 670	3 330
7218 C	390	780	1 860	3 730
7219 C	440	880	2 060	4 120
7220 C	490	980	2 350	4 710

11. DESIGN OF SHAFTS AND HOUSINGS

11.1 Accuracy and Surface Finish of Shafts and Housings

If the accuracy of a shaft or housing does not meet the specification, the performance of the bearings will be affected and they will not provide their full capability. For example, inaccuracy in the squareness of the shaft shoulder may cause misalignment of the bearing inner and outer rings, which may reduce the bearing fatigue life by adding an edge load in addition to the normal load. Cage fracture and seizure sometimes occur for this same reason. Housings should be rigid in order to provide firm bearing support. High rigidity housings are advantageous also from he standpoint of noise, load distribution, etc.
For normal operating conditions, a turned finish or smooth bored finish is sufficient for the fitting surface; however, a ground finish is necessary for applications where vibration and noise must be low or where heavy loads are applied.
In cases where two or more bearings are mounted in one single-piece housing, the fitting surfaces of the housing bore should be designed so both bearing seats may be finished together with one operation such as in -line boring. In the case of split housings, care must be taken in the fabrication of the housing so the outer ring will not become deformed during installation. The accuracy and surface finish of shafts and housings are listed in Table 11.1 for normal operating conditions.

Table 11. 1 Accuracy and Roughness of Shaft and Housing

Item	Class of Bearings	Shaft	Housing Bore
Tolerance for Out-of-roundness	Normal, Class 6	$\frac{IT3}{2}$ to $\frac{IT4}{2}$	$\frac{IT4}{2}$ to $\frac{IT5}{2}$
	Class 5, Class 4	$\frac{IT2}{2}$ to $\frac{IT3}{2}$	$\frac{IT2}{2}$ to $\frac{IT3}{2}$
Tolerance for Cylindricality	Normal, Class 6	$\frac{IT3}{2}$ to $\frac{IT4}{2}$	$\frac{IT4}{2}$ to $\frac{IT5}{2}$
	Class 5, Class 4	$\frac{IT2}{2}$ to $\frac{IT3}{2}$	$\frac{IT2}{2}$ to $\frac{IT3}{2}$
Tolerance for Shoulder Runout	Normal, Class 6	IT3	IT3 to IT4
	Class 5, Class 4	IT3	IT3
Roughness of Fitting Surfaces R_a	Small Bearings	0.8	1.6
	Large Bearings	1.6	3.2

Remarks This table is for general recommendation using radius measuring method, the basic tolerance (IT) class should be selected in accordance with the bearing precision class. Regarding the figures of IT, please refer to the Appendix Table 11 (page C22).
In cases that the outer ring is mounted in the housing bore with interference or that a thin cross-section bearing is mounted on a shaft and housing, the accuracy of the shaft and housing should be higher since this affects the bearing raceway directly.

11.2 Shoulder and Fillet Dimensions

The shoulders of the shaft or housing in contact with the face of a bearing must be perpendicular to the shaft center line. (Refer to Table 11.1) The front face side shoulder bore of the housing for a tapered roller bearing should be parallel with the bearing axis in order to avoid interference with the cage.
The fillets of the shaft and housing should not come in contact with the bearing chamfer; therefore, the fillet radius r_a must be smaller than the minimum bearing chamfer dimension r or r_1.

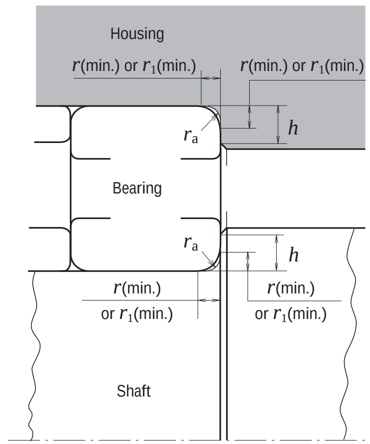


Fig. 11.1 Chamfer Dimensions, Fillet Radius of Shaft and Housing, and Shoulder Height

The shoulder heights for both shafts and housings for radial bearings should be sufficient to provide good support over the face of the bearings, but enough face should extend beyond the shoulder to permit use of special dismounting tools. The recommended minimum shoulder heights for metric series radial bearings are listed in Table 11.2
Nominal dimensions associated with bearing mounting are listed in the bearing tables including the proper shoulder diameters. Sufficient shoulder height is particularly important for supporting the side ribs of tapered roller bearings and cylindrical roller bearings subjected to high axial loads.
The values of h and r_a in Table 11.2 should be adopted in those cases where the fillet radius of the shaft or housing is as shown in Fig. 11.2 (a), while the values in Table 11.3 are generally used with an undercut fillet radius produced when grinding the shaft as shown in Fig. 11.2 (b).

Table 11. 2 Recommended Minimum Shoulder Heights for Use with Metric Series Radial Bearings

Units : mm

Nominal Chamfer Dimensions r (min.) or r_1 (min.)	Shaft or Housing		
	Fillet Radius r_a (max.)	Minimun Shoulder Heights h (min.)	
		Deep Groove Ball Bearings, Self-Aligning Ball Bearings, Cylindrical Roller Bearings, Solid Needle Roller Bearings	Angular Contact Ball Bearings, Tapered Roller Bearings, Spherical Roller Bearings
0.05	0.05	0.2	—
0.08	0.08	0.3	—
0.1	0.1	0.4	—
0.15	0.15	0.6	—
0.2	0.2	0.8	—
0.3	0.3	1	1.25
0.6	0.6	2	2.5
1	1	2.5	3
1.1	1	3.25	3.5
1.5	1.5	4	4.5
2	2	4.5	5
2.1	2	5.5	6
2.5	2	—	6
3	2.5	6.5	7
4	3	8	9
5	4	10	11
6	5	13	14
7.5	6	16	18
9.5	8	20	22
12	10	24	27
15	12	29	32
19	15	38	42

Remarks
1. When heavy axial loads are applied, the shoulder height must be sufficiently higher than the values listed.
2. The fillet radius of the corner is also applicable to thrust bearings.
3. The shoulder diameter is listed instead of shoulder height in the bearing tables.

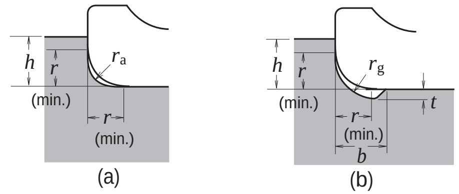


Fig. 11. 2 Chamfer Dimensions, Fillet Radius, and Shoulder Height

Table 11. 3 Shaft Undercut

Units : mm

Chamfer Dimensions of Inner and Outer Rings r (min.) or r_1 (min.)	Undercut Dimensions		
	t	r_g	b
1	0.2	1.3	2
1.1	0.3	1.5	2.4
1.5	0.4	2	3.2
2	0.5	2.5	4
2.1	0.5	2.5	4
2.5	0.5	2.5	4
3	0.5	3	4.7
4	0.5	4	5.9
5	0.6	5	7.4
6	0.6	6	8.6
7.5	0.6	7	10

For thrust bearings, the squareness and contact area of the supporting face for the bearing rings must be adequate. In the case of thrust ball bearings, the housing shoulder diameter D_a should be less than the pitch circle diameter of the balls, and the shaft shoulder diameter d_a should be greater than the pitch circle diameter of the balls (Fig. 11.3).
For thrust roller bearings, it is advisable for the full contact length between rollers and rings to be supported by the shaft and housing shoulder (Fig. 11.4).
These diameters d_a and D_a are listed in the bearing tables.

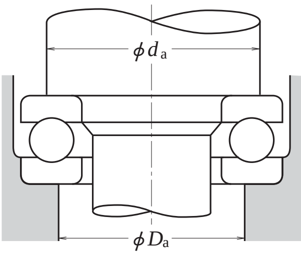


Fig. 11.3 Face Supporting Diameters for Thrust Ball Bearings

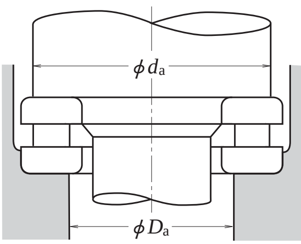


Fig. 11.4 Face Supporting Diameters for Thrust Roller Bearings

11.3 Bearing Seals

To insure the longest possible life of a bearing, it may be necessary to provide seals to prevent leakage of lubricant and entry of dust, water and other harmful material like metallic particles. The seals must be free from excessive running friction and the probability of seizure. They should also be easy to assemble and disassemble. It is necessary to select a suitable seal for each application considering the lubricating method.

11.3.1 Non-Contact Type Seals

Various sealing devices that do not contact the shaft, such as oil grooves, flingers, and labyrinths, are available. Satisfactory sealing can usually be obtained with such seals because of their close running clearance. Centrifugal force may also assist in preventing internal contamination and leakage of the lubricant.

(1) Oil Groove Seals

The effectiveness of oil groove seals is obtained by means of the small gap between the shaft and housing bore and by multiple grooves on either or both of the housing bore and shaft surface (Fig. 11.5 (a), (b)).
Since the use of oil grooves alone is not completely effective, except at low speeds, a flinger or labyrinth type seal is often combined with an oil groove seal (Fig. 11.5 (c)). The entry of dust is impeded by packing grease with a consistency of about 200 into the grooves.
The smaller the gap between the shaft and housing, the greater the sealing effect; however, the shaft and housing must not come in contact while running. The recommended gaps are given in Table 11.4.
The recommended groove width is approximately 3 to 5mm, with a depth of about 4 to 5mm. In the case of sealing methods using grooves only, there should be three or more grooves.

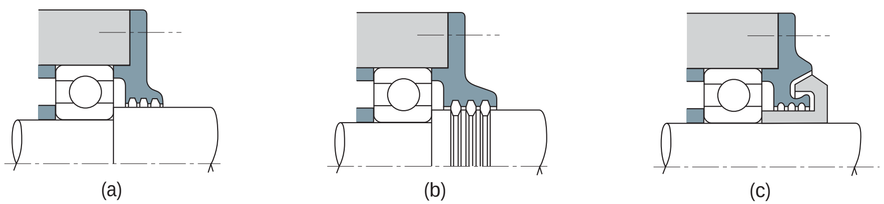


Fig. 11.5 Examples of Oil Grooves

(2) Flinger (Slinger) Type Seals

A flinger is designed to force water and dust away by means of the centrifugal force acting on any contaminants on the shaft. Sealing mechanisms with flingers inside the housing as shown in Fig. 11.6 (a), (b) are mainly intended to prevent oil leakage, and are used in environments with relatively little dust. Dust and moisture are prevented from entering by the centrifugal force of flingers shown in Figs 11.6 (c), (d).

(3) Labyrinth Seals

Labyrinth seals are formed by interdigitated segments attached to the shaft and housing that are separated by a very small gap. They are particularly suitable for preventing oil leakage from the shaft at high speeds.
The type shown in Fig. 11.7 (a) is widely used because of its ease of assembly, but those shown in Fig. 11.7 (b), (c) have better seal effectiveness.

Table 11. 4 Gaps between Shafts and Housings for Oil-Groove Type Seals

Units : mm

Nominal Shaft Diameter	Radial Gap
Under 50	0.25 to 0.4
50-200	0.5 to 1.5

Table 11. 5 Labyrinth Seal Gaps

Units : mm

Nominal Shaft Diameter	Labyrinth Gaps	
	Radial Gap	Axiall Gap
Under 50	0.25 to 0.4	1 to 2
50-200	0.5 to 1.5	2 to 5

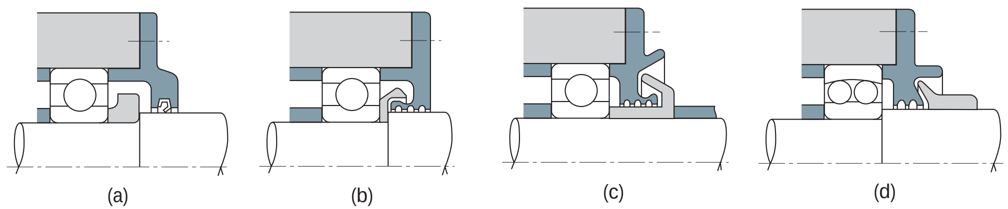


Fig. 11.6 Examples of Flinger Configurations

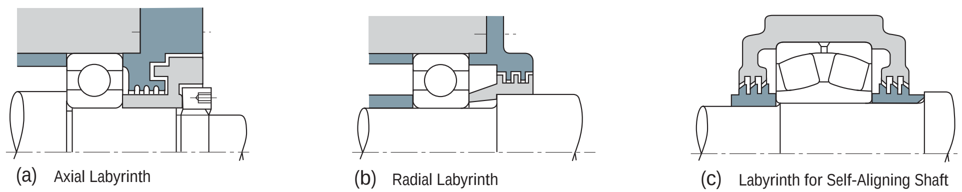


Fig. 11.7 Examples of Labyrinth Designs

11.3.2 Contact Type Seals

The effectiveness of contact seals is achieved by the physical contact between the shaft and seal, which may be made of synthetic rubber, synthetic resin, felt, etc. Oil seals with synthetic rubber lips are most frequently used.

(1) Oil Seals

Many types of oil seals are used to prevent lubricant from leaking out as well as to prevent dust, water, and other foreign matter from entering (Figs. 11.8 and 11.9)
In Japan, such oil seals are standardized (Refer to JIS B 2402) on the basis of type and size. Since many oil seals are equipped with circumferential springs to maintain adequate contact force, oil seals can follow the non-uniform rotational movement of a shaft to some degree.
Seal lip materials are usually synthetic rubber including nitrile, acrylate, silicone, and fluorine. Tetrafluoride ethylene is also used. The maximum allowable operating temperature for each material increases in this same order.
Synthetic rubber oil seals may cause trouble such as overheating, wear, and seizure, unless there is an oil film between the seal lip and shaft. Therefore, some lubricant should be applied to the seal lip when the seals are installed. It is also desirable for the lubricant inside the housing to spread a little between the sliding surfaces. However, please be aware that ester-based grease will cause acrylic rubber material to swell. Also, low aniline point mineral oil, silicone-based grease,and silicon-based oil will cause silicone-based material to swell. Moreover, urea-based grease will cause fluorine-based material to deteriorate.
The permissible circumferential speed for oil seals varies depending on the type, the finish of the shaft surface, liquid to be sealed, temperature, shaft eccentricity, etc. The temperature range for oil seals is restricted by the lip material. Approximate circumferential surface speeds and temperature permitted under favorable conditions are listed in Table 11.6.
When oil seals are used at high circumferential surface speed or under high internal pressure, the contact surface of the shaft must be smoothly finished and the shaft eccentricity should be less than 0.02 to 0.05 mm.
The hardness of the shaft's contact surface should be made higher than HRC40 by means of heat treatment or hard chrome plating in order to gain abrasion resistance. If possible, a hardness of more than HRC 55 is recommended.
The approximate level of contact surface finish required for several shaft circumferential surface speeds is given in Table 11.7.

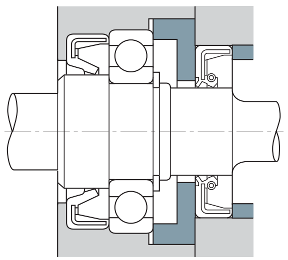


Fig. 11.8 Example of Application of Oil Seal (1)

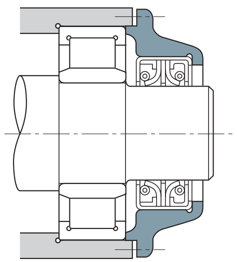


Fig. 11.9 Example of Application of Oil Seal (2)

Table 11. 6 Permissible Circumferential Surface Speeds and Temperature Range for Oil Seals

Seal Materials		Permissible Circumferential Speeds(m/sec)	Operating Temperature Range(°C)(1)
Synthetic Rubber	Nitrile Rubber	Under 16	−25 to +100
	Acrylic Rubber	Under 25	−15 to +130
	Silicone Rubber	Under 32	−70 to +200
	Fluorine-containes Rubber	Under 32	−30 to +200
Tetrafluoride Ethylene Resin		Under 15	−50 to +220

Note (1) The upper limit of the temperature range may be raised about 20 °C for operation for short intervais.

Table 11. 7 Shaft Circumferential Surface Speeds and Finish of Contact Surfaces

Circumferential Surface Speeds(m/s)	Surface Finish R_a (μm)
Under 5	0.8
5 to 10	0.4
Over 10	0.2

(2) Felt Seals

Felt seals are one of the simplest and most common seals being used for transmission shafts, etc.
However, since oil permeation and leakage are unavoidable if oil is used, this type of seal is used only for grease lubrication, primarily to prevent dust and other foreign matter from entering. Felt seals are not suitable for circumferential surface speeds exceeding 4 m/sec; therefore, it is preferable to replace them with synthetic rubber seals depending on the application.

12. LUBRICATION

12.1 Purposes of Lubrication

The main purposes of lubrication are to reduce friction and wear inside the bearings 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 components 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 Frictional Heat and Cooling
Circulation lubrication may be used to carry away frictional heat or heat transferred from the outside to prevent the bearing from overheating and the oil from deteriorating.
(4) Others
Adequate lubrication also helps to prevent foreign material from entering the bearings and guards against corrosion or rusting.

12.2 Lubricating Methods

The various lubricating methods are first divided into either grease or oil lubrication. Satisfactory bearing performance can be achieved by adopting the lubricating method which is most suitable for the particular application and operating condition.
In general, oil offers superior lubrication; however, grease lubrication allows a simpler structure around the bearings. A comparison of grease and oil lubrication is given in Table 12.1.

Table 12. 1 Comparison of Grease and Oil Lubrication

Item	Grease Lubrication	Oil Lubrication
Housing Structure and Sealing Method	Simple	May be complex, Careful maintenance required.
Speed	Limiting speed is 65% to 80% of that with oil lubrication.	Higher limiting speed.
Cooling Effect	Poor	Heat transter is possible using forced oil circulation.
Fluidity	Poor	Good
Full Lubricant Replacement	Sometimes difficult	Easy
Removal of Foreign Matter	Removal of particles from grese is impossible.	Easy
External Contamination due to Leakage	Surroundings seldom contaminated by leakage.	Often leaks without proper countermeasures. Not suitable if external contamination must be avoided.

12.2.1 Grease Lubrication

(1) Grease Quantity

The quantity of grease to be packed in a housing depends on the housing design and free space, grease characteristics, and ambient temperature. For example, the bearings for the main shafts of machine tools, where the accuracy may be impaired by a small temperature rise, require only a small amount of grease. The quantity of grease for ordinary bearings is determined as follows.
Sufficient grease must be packed inside the bearing including the cage guide face. The available space inside the housing to be packed with grease depends on the speed as follows:
1/2 to 2/3 of the space … When the speed is less than 50% of the limiting speed.
1/3 to 1/2 of the space … When the speed is more than 50% of the limiting speed.

(2) Replacement of Grease

Grease, once packed, usually need not be replenished for a long time; however, for severe operating conditions, grease should be frequently replenished or replaced. In such cases, the bearing housing should be designed to facilitate grease replenishment and replacement.

When replenishment intervals are short, provide replenishment and discharge ports at appropriate positions so deteriorated grease is replaced by fresh grease. For example, the housing space on the grease supply side can be divided into several sections with partitions. The grease on the partitioned side gradually passes through the bearings and old grease forced from the bearing is discharged through a grease valve (Fig. 12.1). If a grease valve is not used, the space on the discharge side is made larger than the partitioned side so it can retain the old grease, which is removed periodically by removing the cover.

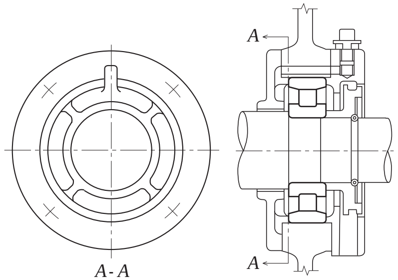


Fig. 12.1 Combination of Partitioned Grease Reservoir and Grease Valve

(3) Replenishing Interval

Even if high-quality grease is used, there is deterioration of its properties with time; therefore, periodic replenishment is required. Figs 12.2 (1) and (2) show the replenishment time intervals for various bearing types running at different speeds. Figs.12.2 (1) and (2) apply for the condition of high-quality lithium soap-mineral oil grease, bearing temperature of 70°C, and normal load (P/C=0.1).

· Temperature

If the bearing temperature exceeds 70°C, the replenishment time interval must be reduced by half for every 15°C temperature rise of the bearings.

· Grease

In case of ball bearings especially, the replenishing time interval can be extended depending on used grease type. (For example, high-quality lithium soap-synthetic oil grease may extend about two times of replenishing time interval shown in Fig.12.2 (1). If the temperature of the bearings is less than 70°C, the usage of lithium soap-mineral oil grease or lithium soap-synthetic oil grease is appropriate.)

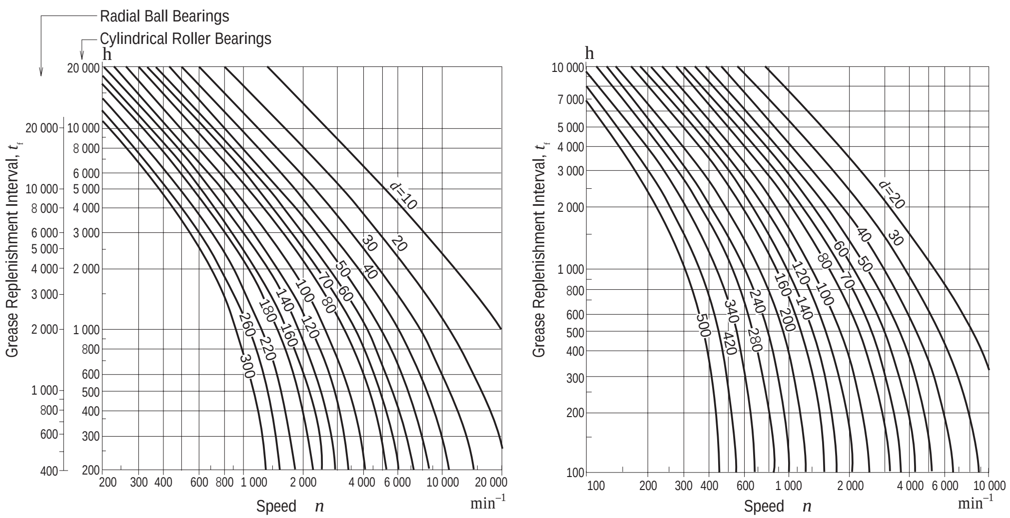
It is advisable to consult NSK.

· Load

The replenishing time interval depends on the magnitude of the bearing load.

Please refer to Fig.12.2 (3).

If P/C exceeds 0.16, it is advisable to consult NSK.



(1) Radial Ball Bearings, Cylindrical Roller Bearings

(2) Tapered Roller Bearings, Spherical Roller Bearings

(3) Load factor

P/C	≦0.06	0.1	0.13	0.16
Load factor	1.5	1	0.65	0.45

Fig. 12.2 Grease Replenishment Intervals

(4) Grease Life of Sealed Ball Bearings

When grease is packed into single-row deep groove ball bearings, the grease life may be estimated using Equation (12.1) or (12.2) or Fig. 12.3:

(General purpose grease (1))

$$\log t = 6.54 - 2.6\frac{n}{N_{max}} - \left(0.025 - 0.012\frac{n}{N_{max}}\right)T \quad \text{………………}(12.1)$$

(Wide-range grease (2))

$$\log t = 6.12 - 1.4\frac{n}{N_{max}} - \left(0.018 - 0.006\frac{n}{N_{max}}\right)T \quad \text{………………}(12.2)$$

where t : Average grease life, (h)
n : Speed (min^{-1})
N_{max} : Limiting speed with grease lubrication (min^{-1})
(values for ZZ and VV types listed in the bearing tables)
T : Operating temperature °C

Equations (12.1) and (12.2) and Fig. 12.3 apply under the following conditions:

(a) Speed, n

$$0.25 \leqq \frac{n}{N_{max}} \leqq 1$$

$$\text{when } \frac{n}{N_{max}} < 0.25, \text{ assume } \frac{n}{N_{max}} = 0.25$$

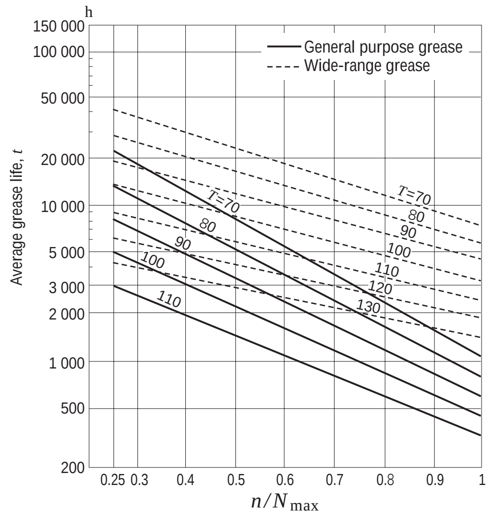


Fig. 12.3 Grease Life of Sealed Ball Bearings

(b) Operating Temperature, T

For general purpose grease (1)

$$70\ °C \leqq T \leqq 110\ °C$$

For wide-range grease (2)

$$70\ °C \leqq T \leqq 130\ °C$$

When $T < 70$ °C assume $T = 70$ °C

(c) Bearing Loads

The bearing loads should be about 1/10 or less of the basic load rating C_r.

Notes (1) Mineral-oil base greases (e.g. lithium soap base grease) which are often used over a temperature range of around – 10 to 110 °C.
(2) Synthetic-oil base greases are usable over a wide temperature range of around – 40 to 130 °C.

12.2.2 Oil Lubrication

(1) Oil Bath Lubrication

Oil bath lubrication is a widely used with low or medium speeds. The oil level should be at the center of the lowest rolling element. It is desirable to provide a sight gauge so the proper oil level may be maintained (Fig. 12.4)

(2) Drip-Feed Lubrication

Drip feed lubrication is widely used for small ball bearings operated at relatively high speeds. As shown in Fig. 12.5, oil is stored in a visible oiler. The oil drip rate is controlled with the screw in the top.

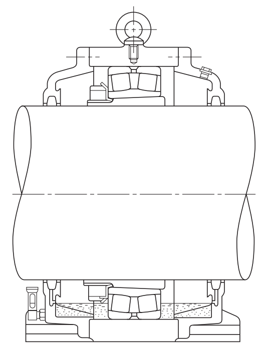


Fig. 12.4 Oil Bath Lubrication

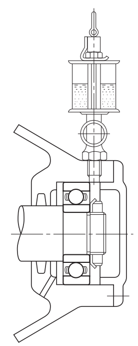


Fig. 12.5 Drip Feed Lubrication

(3) Splash Lubrication

With this lubricating method, oil is splashed onto the bearings by gears or a simple rotating disc installed near bearings without submerging the bearings in oil.
It is commonly used in automobile transmissions and final drive gears. Fig. 12.6 shows this lubricating method used on a reduction gear.

(4) Circulating Lubrication

Circulating lubrication is commonly used for high speed operation requiring bearing cooling and for bearings used at high temperatures. As shown in Fig. 12.7 (a), oil is supplied by the pipe on the right side, it travels through the bearing, and drains out through the pipe on the left. After being cooled in a reservoir, it returns to the bearing through a pump and filter.
The oil discharge pipe should be larger than the supply pipe so an excessive amount of oil will not back up in the housing.

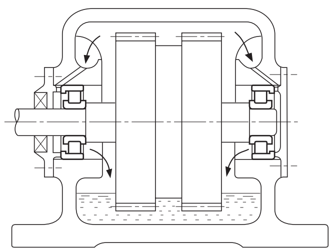


Fig. 12.6 Splash Lubrication

(5) Jet Lubrication

Jet lubrication is often used for ultra high speed bearings, such as the bearings in jet engines with a $d_m n$ valve (d_m: pitch diameter of rolling element set in mm; n: rotational speed in min^{-1}) exceeding one million. Lubricating oil is sprayed under pressure from one or more nozzles directly into the bearing.
Fig. 12.8 shows an example of ordinary jet lubrication. The lubricating oil is sprayed on the inner ring and cage guide face. In the case of high speed operation, the air surrounding the bearing rotates with it causing the oil jet to be deflected. The jetting speed of the oil from the nozzle should be more than 20 % of the circumferential speed of the inner ring outer surface (which is also the guide face for the cage).
More uniform cooling and a better temperature distribution is achieved using more nozzles for a given amount of oil. It is desirable for the oil to be forcibly discharged so the agitating resistance of the lubricant can be reduced and the oil can effectively carry away the heat.

(6) Oil Mist Lubrication

Oil mist lubrication, also called oil fog lubrication, utilizes an oil mist sprayed into a bearing. This method has the following advantages:
(a) Because of the small quantity of oil required, the oil agitation resistance is small, and higher speeds are possible.
(b) Contamination of the vicinity around the bearing is slight because the oil leakage is small.
(c) It is relatively easy to continuously supply fresh oil; therefore, the bearing life is extended.

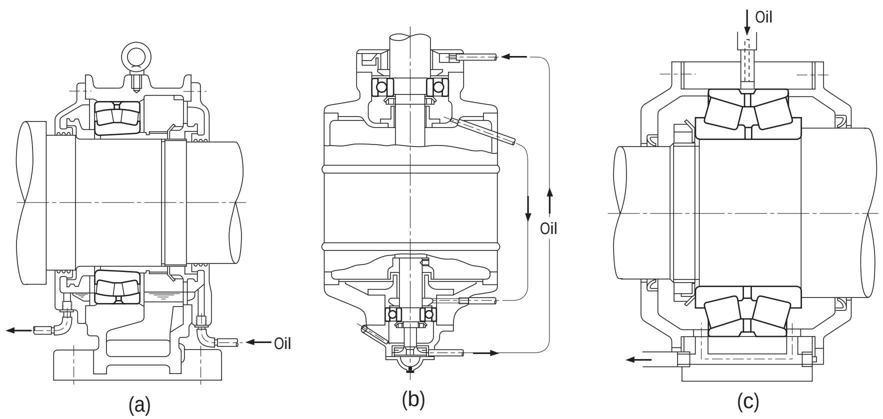


Fig. 12.7 Circulating Lubrication

This lubricating method is used in bearings for the high speed spindles of machine tools, high speed pumps, roll necks of rolling mills, etc (Fig. 12.9).
For oil mist lubrication of large bearings, it is advisable to consult NSK.

(7) Oil/Air Lubricating Method

Using the oil/air lubricating method, a very small amount of oil is discharged intermittently by a constant-quantity piston into a pipe carrying a constant flow of compressed air. The oil flows along the wall of the pipe and approaches a constant flow rate.
The major advantages of oil/air lubrication are:
(a) Since the minimum necessary amount of oil is supplied, this method is suitable for high speeds because less heat is generated.
(b) Since the minimum amount of oil is fed continuously, bearing temperature remains stable. Also, because of the small amount of oil, there is almost no atmospheric pollution.
(c) Since only fresh oil is fed to the bearings, oil deterioration need not be considered.
(d) Since compressed air is always fed to the bearings, the internal pressure is high, so dust, cutting fluid, etc. cannot enter.
For these reasons, this method is used in the main spindles of machine tools and other high speed applications (Fig. 12.10).

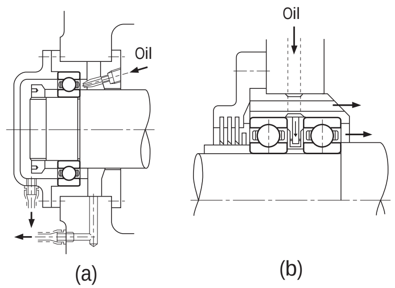


Fig. 12.8 Jet Lubrication

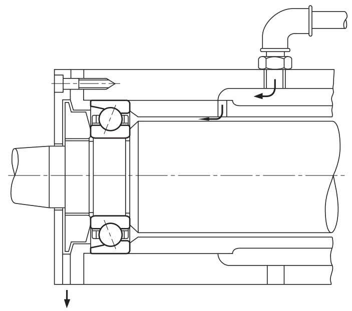


Fig. 12.9 Oil Mist Lubrication

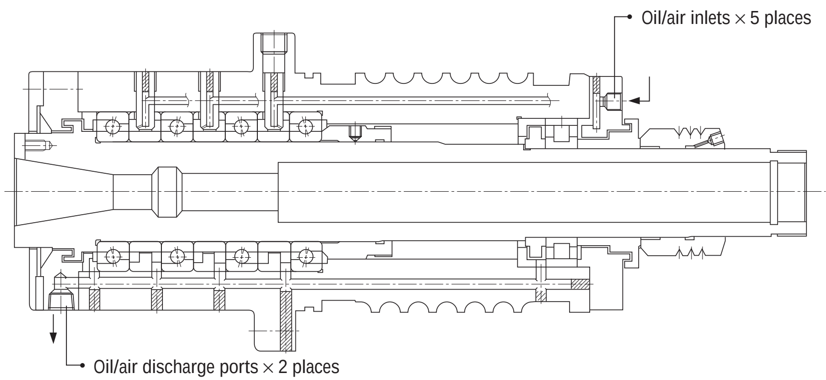


Fig. 12.10 Oil/Air Lubrication

12.3 Lubricants

12.3.1 Lubricating Grease

Grease is a semi-solid lubricant consisting of base oil, a thickener and additives. The main types and general properties of grease are shown in Table 12.2. It should be remembered that different brands of the same type of grease may have different properties.

(1) Base Oil

Mineral oils or synthetic oils such as silicone or diester oil are mainly used as the base oil for grease. The lubricating properties of grease depend mainly on the characteristics of its base oil. Therefore, the viscosity of the base oil is just as important when selecting grease as when selecting an oil. Usually, grease made with low viscosity base oils is more suitable for high speeds and low temperatures, while greases made with high viscosity base oils are more suited for high temperatures and heavy loads.
However, the thickener also influences the lubricating properties of grease; therefore, the selection criteria for grease is not the same as for lubricating oil. Moreover, please be aware that ester-based grease will cause acrylic rubber material to swell, and that silicone-based grease will cause silicone-based material to swell.

(2) Thickener

As thickeners for lubricating grease, there are several types of metallic soaps, inorganic thickeners such as silica gel and bentonite, and heat resisting organic thickeners such as polyurea and fluoric compounds.
The type of thickener is closely related to the grease dropping point (1); generally, grease with a high dropping point also has a high temperature capability during operation. However, this type of grease does not have a high working temperature unless the base oil is heat-resistant. The highest possible working temperature for grease should be determined considering the heat resistance of the base oil.
The water resistance of grease depends upon the type of thickener. Sodium soap grease or compound grease containing sodium soap emulsifies when exposed to water or high humidity, and therefore, cannot be used where moisture is prevalent. Moreover, please be aware that urea-based grease will cause fluorine-based material to deteriorate.

Note (1) The grease dropping point is that temperature at which a grease heated in a specified small container becomes sufficiently fluid to drip.

Table 12.2 Grease Properties

Name (Popular name)	Lithium Grease			Sodium Grease (Fiber Grease)	Calcium Grease (Cup Grease)	Mixed Base Grease	Complex Base Grease (Complex Grease)	Non-Soap Base Grease (Non-Soap Grease)	
Thickener	Li Soap			Na Soap	Ca Soap	Na + Ca Soap, Li + Ca Soap, etc.	Ca Complex Soap, Al Complex Soap, Li Complex Soap, etc.	Urea, Bentonite, Carbon Black, Fluoric Compounds, Heat Resistant Organic Compound, etc.	
Base Oil / Properties	Mineral Oil	Diester Oil, Polyatomic Ester Oil	Silicone Oil	Mineral Oil	Mineral Oil	Mineral Oil	Mineral Oil	Mineral Oil	Synthetic Oil (Ester Oil, Polyatomic Ester Oil, Synthetic Hydrocarbon Oil, Silicone Oil, Fluoric Based Oil)
Dropping Point, ˚C	170 to 195	170 to 195	200 to 210	170 to 210	70 to 90	160 to 190	180 to 300	> 230	> 230
Working Temperatures, ˚C	–20 to +110	–50 to +130	–50 to +160	–20 to +130	–20 to +60	–20 to +80	–20 to +130	–10 to +130	< +220
Working Speed, %(1)	70	100	60	70	40	70	70	70	40 to 100
Mechanical Stability	Good	Good	Good	Good	Poor	Good	Good	Good	Good
Pressure Resistance	Fair	Fair	Poor	Fair	Poor	Fair to Good	Fair to Good	Fair	Fair
Water Resistance	Good	Good	Good	Poor	Good	Poor for Na Soap Grease	Good	Good	Good
Rust Prevention	Good	Good	Poor	Poor to Good	Good	Fair to Good	Fair to Good	Fair to Good	Fair to Good
Remarks	General purpose grease used for numerous applications	Good low temperature and torque characteristics. Often used for small motors and instrument bearings. Pay attention to rust caused by insulation varnish.	Mainly for high temperature applications. Unsuitable for bearings for high and low speeds or heavy loads or those having numerous sliding-contact areas (roller bearings, etc.)	Long and short fiber types are available. Long fiber grease is unsuitable for high speeds. Attention to water and high temperature is requred.	Extreme pressure grease containing high viscosity mineral oil and extreme pressure additive (Pb soap, etc.) has high pressure resistance.	Often used for roller bearings and large ball bearing.	Suitable for extreme pressures mechanically stable	Mineral oil base grease is middle and high temperature purpose lubricant. Synthetic oil base grease is recommended for low or high temperature. Some silicone and fluoric oil based grease have poor rust prevention and noise.	

Note (1) The values listed are percentages of the limiting speeds given in the bearing tables.

Remarks The grease properties shown here can vary between brands.

(3) Additives

Grease often contains various additives such as antioxidants, corrosion inhibitors, and extreme pressure additives to give it special properties. It is recommended that extreme pressure additives be used in heavy load applications. For long use without replenishment, an antioxidant should be added.

(4) Consistency

Consistency indicates the “softness” of grease. Table 12.3 shows the relation between consistency and working conditions.

Table 12.3 Consistency and Working Conditions

Consistency Number	0	1	2	3	4
Consistency(1) 1/10 mm	355 to 385	310 to 340	265 to 295	220 to 250	175 to 205
Working Conditions (Application)	·For centralized oiling ·When fretting is likely to occur	·For centralized oiling ·When fretting is likely to occur ·For low temperatures	·For general use ·For sealed ball bearings	·For general use ·For sealed ball bearings ·For high temperatures	·For high temperatures ·For grease seals

Note (1) Consistency: The depth to which a cone descends into grease when a specified weight is applied, indicated in units of 1/10mm. The larger the value, the softer the grease.

(5) Mixing Different Types of Grease

In general, different brands of grease must not be mixed. Mixing grease with different types of thickneners may destroy its composition and physical properties. Even if the thickeners are of the same type, possible differences in the additive may cause detrimental effects.

12.3.2 Lubricating Oil

The lubricating oils used for rolling bearings are usually highly refined mineral oil or synthetic oil that have a high oil film strength and superior oxidation and corrosion resistance. When selecting a lubricating oil, the viscosity at the operating conditions is important. If the viscosity is too low, a proper oil film is not formed and abnormal wear and seizure may occur. On the other hand, if the viscosity is too high, excessive viscous resistance may cause heating or large power loss. In general, low viscosity oils should be used at high speed; however, the viscosity should increase with increasing bearing load and size.

Table 12.4 gives generally recommended viscosities for bearings under normal operating conditions.

For use when selecting the proper lubricating oil, Fig. 12.11 shows the relationship between oil temperature and viscosity, and examples of selection are shown in Table 12.5.

Table 12. 4 Bearing Types and Proper Viscosity of Lubricating Oils

Bearing Type	Proper Viscosity at Operating Temperature
Ball Bearings and Cylindrical Roller Bearings	Higher than 13mm²/s
Tapered Roller Bearings and Spherical Roller Bearings	Higher than 20mm²/s
Spherical Thrust Roller Bearings	Higher than 32mm²/s

Remarks 1mm²/s=1cSt (centistokes)

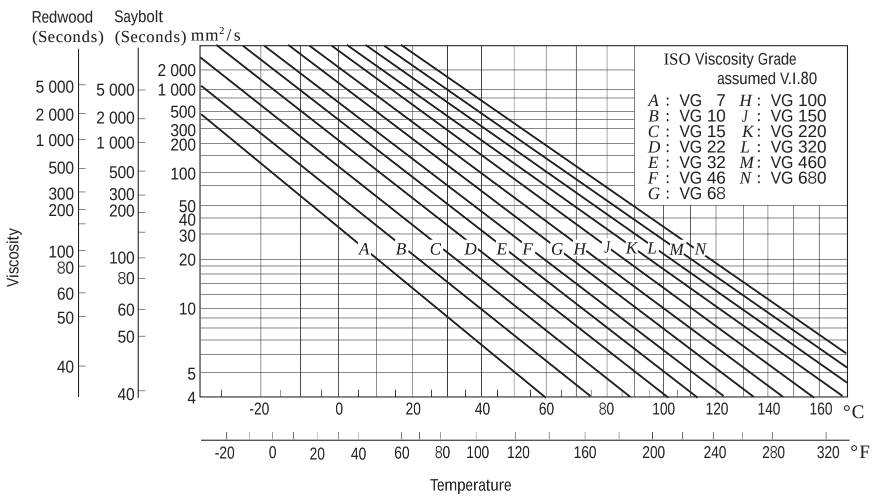


Fig. 12.11 Temperature-Viscosity Chart

Oil Replacement Intervals

Oil replacement intervals depend on the operating conditions and oil quantity.

In those cases where the operating temperature is less than 50˚C, and the environmental conditions are good with little dust, the oil should be replaced approximately once a year. However, in cases where the oil temperature is about 100˚C, the oil must be changed at least once every three months.

If moisture may enter or if foreign matter may be mixed in the oil, then the oil replacement interval must be shortened.

Mixing different brands of oil must be prevented for the same reason given previously for grease.

Table 12. 5 Examples of Selection Lubricating Oils

Operating Temperature	Speed	Light or normal Load	Heavy or Shock Load
−30 to 0 °C	Less than limiting speed	ISO VG 15, 22, 32 (refrigerating machine oil)	–
0 to 50 °C	Less than 50% of limiting speed	ISO VG 32, 46, 68 (bearing oil, turbine oil)	ISO VG 46, 68, 100 (bearing oil, turbine oil)
	50 to 100% of limiting speed	ISO VG 15, 22, 32 (bearing oil, turbine oil)	ISO VG 22, 32, 46 (bearing oil, turbine oil)
	More than limiting speed	ISO VG 10, 15, 22 (bearing oil)	–
50 to 80 °C	Less than 50% of limiting speed	ISO VG 100, 150, 220 (bearings oil)	ISO VG 150, 220, 320 (bearing oil)
	50 to 100% of limiting speed	ISO VG 46, 68, 100 (bearing oil, turbine oil)	ISO VG 68, 100, 150 (bearing oil, turbine oil)
	More than limiting speed	ISO VG 32, 46, 68 (bearing oil, turbine oil)	–
80 to 110 °C	Less than 50% of limiting speed	ISO VG 320, 460 (bearing oil)	ISO VG 460, 680 (bearing oil, gear oil)
	50 to 100% of limiting speed	ISO VG 150, 220 (bearing oil)	ISO VG 220, 320 (bearing oil)
	More than limiting speed	ISO VG 68, 100 (bearing oil, turbine oil)	–

Remarks
1. For the limiting speed, use the values listed in the bearing tables.
2. Refer to Refrigerating Machine Oils (JIS K 2211), Bearing Oils (JIS K 2239), Turbine Oils (JIS K 2213), Gear Oils (JIS K 2219).
3. If the operating temperature is near the high end of the temperature range listed in the left column, select a high viscosity oil.
4. If the operating temperature is lower than -30°C or higher than 110°C , it is advisable to consult NSK.

13. BEARING MATERIALS

The bearing rings and rolling elements of rolling bearings are subjected to repetitive high pressure with a small amount of sliding. The cages are subjected to tension and compression and sliding contact with the rolling elements and either or both of the bearing rings.
Therefore, the materials used for the rings, rolling elements, and cages require the following characteristics:

Material characteristics required for bearing rings and rolling elements:
- High rolling contact fatigue strength
- High hardness
- High wear resistance
- High dimensional stability
- High mechanical strength

Characteristics required for cage material:
- High wear resistance
- High dimensional stability
- High mechanical strength

Other necessary characteristics, such as easy production, shock and heat resistance, and corrosion resistance, are required depending on individual applications.

13.1 Materials for Bearing Rings and Rolling Elements

Primarily, high carbon chromium bearing steel (Table 13.1) is used for the bearing rings and rolling elements. Most NSK bearings are made of SUJ2 among the JIS steel types listed in Table 13.1, while the larger bearings generally use SUJ3. The chemical composition of SUJ2 is approximately the same as AISI 52100 specified in the USA, DIN 100 Cr6 in Germany, and BS 535A99 in England.
For bearings that are subjected to very severe shock loads, carburized low-carbon alloy steels such as chrome steel, chrome molybdenum steel, nickel chrome molybdenum steel, etc. are often used. Such steels, when they are carburized to the proper depth and have sufficient surface hardness, are more shock resistant than normal, through-hardened bearing steels because of the softer energy-absorbing core. The chemical composition of common carburized bearing steels is listed in Table 13.2.

Table 13. 1 Chemical Composition of High-Carbon Chromium Bearing Steel (Major Elements)

Standard	Symbols	Chemical Composition (%)						
		C	Si	Mn	P	S	Cr	Mo
JIS G 4805	SUJ 2	0.95 to 1.10	0.15 to 0.35	Less than 0.50	Less than 0.025	Less than 0.025	1.30 to 1.60	—
	SUJ 3	0.95 to 1.10	0.40 to 0.70	0.90 to 1.15	Less than 0.025	Less than 0.025	0.90 to 1.20	—
	SUJ 4	0.95 to 1.10	0.15 to 0.35	Less than 0.50	Less than 0.025	Less than 0.025	1.30 to 1.60	0.10 to 0.25
ASTM A 295	52100	0.93 to 1.05	0.15 to 0.35	0.25 to 0.45	Less than 0.025	Less than 0.015	1.35 to 1.60	Less than 0.10

Table 13. 2 Chemical Composition of Carburizing Bearing Steels (Major Elements)

Standard	Symbols	Chemical Composition (%)							
		C	Si	Mn	P	S	Ni	Cr	Mo
JIS G 4052	SCr 420 H	0.17 to 0.23	0.15 to 0.35	0.55 to 0.95	Less than 0.030	Less than 0.030	Less than 0.25	0.85 to 1.25	—
	SCM 420 H	0.17 to 0.23	0.15 to 0.35	0.55 to 0.95	Less than 0.030	Less than 0.030	Less than 0.25	0.85 to 1.25	0.15 to 0.35
	SNCM 220 H	0.17 to 0.23	0.15 to 0.35	0.60 to 0.95	Less than 0.030	Less than 0.030	0.35 to 0.75	0.35 to 0.65	0.15 to 0.30
	SNCM 420 H	0.17 to 0.23	0.15 to 0.35	0.40 to 0.70	Less than 0.030	Less than 0.030	1.55 to 2.00	0.35 to 0.65	0.15 to 0.30
JIS G 4053	SNCM 815	0.12 to 0.18	0.15 to 0.35	0.30 to 0.60	Less than 0.030	Less than 0.030	4.00 to 4.50	0.70 to 1.00	0.15 to 0.30
ASTM A 534	8620 H	0.17 to 0.23	0.15 to 0.35	0.60 to 0.95	Less than 0.025	Less than 0.015	0.35 to 0.75	0.35 to 0.65	0.15 to 0.25
	4320 H	0.17 to 0.23	0.15 to 0.35	0.40 to 0.70	Less than 0.025	Less than 0.015	1.55 to 2.00	0.35 to 0.65	0.20 to 0.30
	9310 H	0.07 to 0.13	0.15 to 0.35	0.40 to 0.70	Less than 0.025	Less than 0.015	2.95 to 3.55	1.00 to 1.40	0.08 to 0.15

Table 13. 3 Chemical Composition of High Speed Steel for Bearings Used at High Temperatures

Standard	Symbols	Chemical Composition (%)											
		C	Si	Mn	P	S	Cr	Mo	V	Ni	Cu	Co	W
AISI	M50	0.77 to 0.85	Less than 0.25	Less than 0.35	Less than 0.015	Less than 0.015	3.75 to 4.25	4.00 to 4.50	0.90 to 1.10	Less than 0.10	Less than 0.10	Less than 0.25	Less than 0.25

NSK uses highly pure vacuum-degassed bearing steel containing a minimum of oxygen, nitrogen, and hydrogen compound impurities. The rolling fatigue life of bearings has been remarkably improved using this material combined with the appropriate heat treatment.
For special purpose bearings, high temperature bearing steel, which has superior heat resistance, and stainless steel having good corrosion resistance may be used. The chemical composition of these special materials are given in Tables 13.3 and 13.4.

13.2 Cage Materials

The low carbon steels shown in Table 13.5 are the main ones for the pressed cages for bearings. Depending on the purpose, brass or stainless steel may be used. For machined cages, high strength brass (Table 13.6) or carbon steel (Table 13.5) is used. Sometimes synthetic resin is also used.

Table 13. 4 Chemical Composition of Stainless Steel for Rolling Bearing (Major Elements)

Standard	Symbols	Chemical Composition (%)						
		C	Si	Mn	P	S	Cr	Mo
JIS G 4303	SUS 440 C	0.95 to 1.20	Less than 1.00	Less than 1.00	Less than 0.040	Less than 0.030	16.00 to 18.00	Less than 0.75
SAE J 405	51440 C	0.95 to 1.20	Less than 1.00	Less than 1.00	Less than 0.040	Less than 0.030	16.00 to 18.00	Less than 0.75

Table 13. 5 Chemical Composition of Steel sheet and Carbon Steel for Cages (Major Elements)

Classification	Standard	Symbols	Chemical Composition (%)				
			C	Si	Mn	P	S
Steel sheet and strip for pressed cages	JIS G 3141	SPCC	Less than 0.12	—	Less than 0.50	Less than 0.04	Less than 0.045
	BAS 361	SPB 2	0.13 to 0.20	Less than 0.30	0.25 to 0.60	Less than 0.03	Less than 0.030
	JIS G 3311	S 50 CM	0.47 to 0.53	0.15 to 0.35	0.60 to 0.90	Less than 0.03	Less than 0.035
Carbon steel for machined cages	JIS G 4051	S 25 C	0.22 to 0.28	0.15 to 0.35	0.30 to 0.60	Less than 0.03	Less than 0.035

Remarks BAS is Japanese Bearing Association Standard.

Table 13. 6 Chemical Composition of High Strength Brass for Machined Cages

Standard	Symbols	Chemical Composition (%)								
		Cu	Zn	Mn	Fe	Al	Sn	Ni	Impurities	
									Pb	Si
JIS H 5120	CAC301 (HBsC 1)	55.0 to 60.0	33.0 to 42.0	0.1 to 1.5	0.5 to 1.5	0.5 to 1.5	Less than 1.0	Less than 1.0	Less than 0.4	Less than 0.1
JIS H 3250	C 6782	56.0 to 60.5	Residual	0.5 to 2.5	0.1 to 1.0	0.2 to 2.0	—	—	Less than 0.5	—

Remarks Improved HBsC 1 is also used.

14. BEARING HANDLING

14.1 Precautions for Proper Handling of Bearings

Since rolling bearings are high precision machine parts, they must be handled accordingly. Even if high quality bearings are used, their expected performance cannot be achieved if they are not handled properly.
The main precautions to be observed are as follows:

(1) Keep Bearings and Surrounding Area Clean

Dust and dirt, even if invisible to the naked eye, have harmful effects on bearings. It is necessary to prevent the entry of dust and dirt by keeping the bearings and their environment as clean as possible.

(2) Careful Handling

Heavy shocks during handling may cause bearings to be scratched or otherwise damaged possibly resulting in their failure. Excessively strong impacts may cause brinelling, breaking, or cracking.

(3) Use Proper Tools

Always use the proper equipment when handling bearings and avoid general purpose tools.

(4) Prevent Corrosion

Since perspiration on the hands and various other contaminants may cause corrosion, keep the hands clean when handling bearings. Wear gloves if possible. Pay attention to rust of bearing caused by corrosive gasses.

14.2 Mounting

The method of mounting rolling bearings strongly affects their accuracy, life, and performance, so their mounting deserves careful attention. Their characteristics should first be thoroughly studied, and then they should be mounted in the proper manner. It is recommended that the handling procedures for bearings be fully investigated by the design engineers and that standards be established with respect to the following items:

(1) Cleaning the bearings and related parts.
(2) Checking the dimensions and finish of related parts.
(3) Mounting
(4) Inspection after mounting.
(5) Supply of lubricants.

Bearings should not be unpacked until immediately before mounting. When using ordinary grease lubrication, the grease should be packed in the bearings without first cleaning them. Even in the case of ordinary oil lubrication, cleaning the bearings is not required. However, bearings for instruments or for high speed operation must first be cleaned with clean filtered oil in order to remove the anti-corrosion agent.
After the bearings are cleaned with filtered oil, they should be protected to prevent corrosion.
Prelubricated bearings must be used without cleaning.
Bearing mounting methods depend on the bearing type and type of fit. As bearings are usually used on rotating shafts, the inner rings require a tight fit.
Bearings with cylindrical bores are usually mounted by pressing them on the shafts (press fit) or heating them to expand their diameter (shrink fit). Bearings with tapered bores can be mounted directly on tapered shafts or cylindrical shafts using tapered sleeves.
Bearings are usually mounted in housings with a loose fit. However, in cases where the outer ring has an interference fit, a press may be used. Bearings can be interference-fitted by cooling them before mounting using dry ice. In this case, a rust preventive treatment must be applied to the bearing because moisture in the air condenses on its surface.

14.2.1 Mounting of Bearings with Cylindrical Bores

(1) Press Fits

Fitting with a press is widely used for small bearings. A mounting tool is placed on the inner ring as shown in Fig. 14.1 and the bearing is slowly pressed on the shaft with a press until the side of the inner ring rests against the shoulder of the shaft. The mounting tool must not be placed on the outer ring for press mounting, since the bearing may be damaged. Before mounting, applying oil to the fitted shaft surface is recommended for smooth insertion. The mounting method using a hammer should only be used for small ball bearings with minimally tight fits and when a press is not available. In the case of tight interference fits or for medium and large bearings, this method should not be used. Any time a hammer is used, a mounting tool must be placed on the inner ring.
When both the inner and outer rings of non-separable bearings, such as deep groove ball bearings, require tight-fit, a mounting tool is placed on both rings as shown in Fig. 14.2, and both rings are fitted at the same time using a screw or hydraulic press. Since the outer ring of self-aligning ball bearings may deflect a mounting tool such as that shown in Fig. 14.2 should always be used for mounting them.
In the case of separable bearings, such as cylindrical roller bearings and tapered roller bearings, the inner and outer rings may be mounted separately. Assembly of the inner and outer rings, which were previously mounted separately, should be done carefully to align the inner and outer rings correctly. Careless or forced assembly may cause scratches on the rolling contact surfaces.

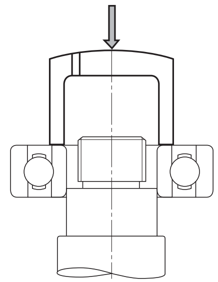


Fig. 14.1 Press Fitting Inner Ring

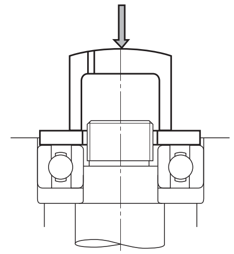


Fig. 14.2 Simultaneous Press Fitting of Inner and Outer Rings

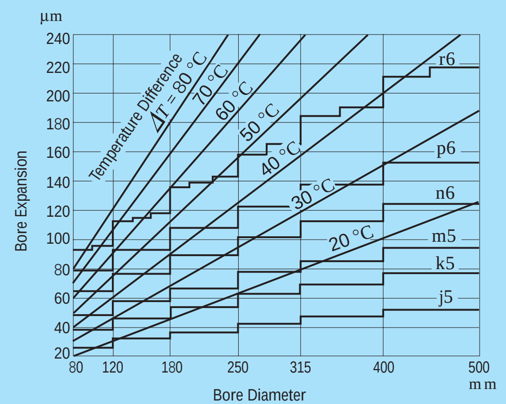


Fig. 14.3 Temperature and Thermal Expansion of Inner Ring

(2) Shrink Fits

Since press fitting large bearings requires a large force, a shrink fit is widely used. The bearings are first heated in oil to expand them before mounting.
This method prevents an excessive force from being imposed on the bearings and allows mounting them in a short time.
The expansion of the inner ring for various temperature differences and bearing sizes is shown in Fig. 14.3.
The precautions to follow when making shrink fits are as follows:

(a) Do not heat bearings to more than 120°C.
(b) Put the bearings on a wire net or suspend them in an oil tank in order to prevent them from touching the tank's bottom directly.
(c) Heat the bearings to a temperature 20 to 30°C higher than the lowest temperature required for mounting without interference since the inner ring will cool a little during mounting.
(d) After mounting, the bearings will shrink in the axial direction as well as the radial direction while cooling. Therefore, press the bearing firmly against the shaft shoulder using locating methods to avoid a clearance between the bearing and shoulder.

NSK Bearing Induction Heaters

Besides heating in oil, NSK Bearing Heaters, which use electromagnetic induction to heat bearings, are widely used. (Refer to Page C7.)
In NSK Bearing Heaters, electricity (AC) in a coil produces a magnetic field that induces a current inside the bearing that generates heat. Consequently, without using flames or oil uniform heating in a short time is possible, making bearing shrink fitting efficient and clean.
In the case of relatively frequent mounting and dismounting such as cylindrical roller bearings for roll necks of rolling mills and for railway journal boxes, induction heating should be used for mounting and dismounting inner rings.

14.2.2 Mounting of Bearings with Tapered Bores

Bearings with tapered bores are mounted on tapered shafts directly or on cylindrical shafts with adapters or withdrawal sleeves (Figs. 14.4 and 14.5). Large spherical roller bearings are often mounted using hydraulic pressure. Fig. 14.6 shows a bearing mounting utilizing a sleeve and hydraulic nut. Fig. 14.7 shows another mounting method. Holes are drilled in the sleeve which are used to feed oil under pressure to the bearing seat. As the bearing expands radially, the sleeve is inserted axially with adjusting bolts.
Spherical roller bearings should be mounted while checking their radial-clearance reduction and referring to the push-in amounts listed in Table 14.1. The radial clearance must be measured using clearance gauges.
In this measurement, as shown in Fig. 14.8, the clearance for both rows of rollers must be measured simultaneously, and these two values should be kept roughly the same by adjusting the relative position of the outer and inner rings.
When a large bearing is mounted on a shaft, the outer ring may be deformed into an oval shape by its own weight. If the clearance is measured at the lowest part of the deformed bearing, the measured value may be bigger than the true value. If an incorrect radial internal clearance is obtained in this manner and the values in Table 14.1 are used, then the interference fit may become too tight and the true residual clearance may become too small. In this case, as shown in Fig. 14.9. one half of the total clearance at points a and b (which are on a horizontal line passing through the bearing center) and c (which is at the lowest position of the bearing) may be used as the residual clearance.
When a self-aligning ball bearing is mounted on a shaft with an adapter, be sure that the residual clearance does not become too small. Sufficient clearance for easy alignment of the outer ring must be allowed.

14.3 Operation Inspection

After the mounting has been completed, a running test should be conducted to determine if the bearing has been mounted correctly. Small machines may be manually operated to assure that they rotate smoothly. Items to be checked include sticking due to foreign matter or visible flaws, uneven torque caused by improper mounting or an improper mounting surface, and excessive torque caused by an inadequate clearance, mounting error, or seal friction. If there are no abnormalities, powered operation may be started.

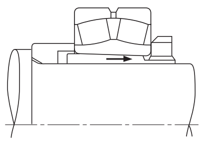


Fig. 14.4 Mounting with Adapter

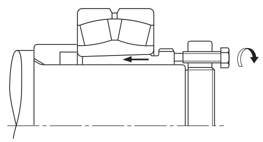


Fig. 14.5 Mounting with Withdrawal Sleeve

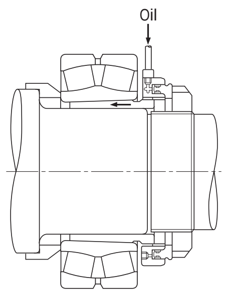


Fig. 14.6 Mounting with Hydraulic Nut

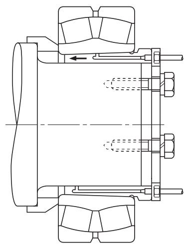


Fig. 14.7 Mounting with Special Sleeve and Hydraulic Pressure

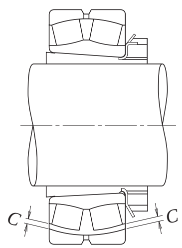


Fig. 14.8 Clearance Measurement of Spherical Roller Bearing

Table 14.1 Mounting of Spherical Roller Bearings with Tapered Bores

Units : mm

Bearing Bore Diameter d		Reduction in Radial Clearance		Push-in amount in axial direction				Minimum Permissible Residual Clearance	
				Taper 1 : 12		Taper 1 : 30			
over	incl.	min.	max.	min.	max.	min.	max.	CN	C3
30	**40**	0.025	0.030	0.40	0.45	—	—	0.010	0.025
40	**50**	0.030	0.035	0.45	0.55	—	—	0.015	0.030
50	**65**	0.030	0.035	0.45	0.55	—	—	0.025	0.035
65	**80**	0.040	0.045	0.60	0.70	—	—	0.030	0.040
80	**100**	0.045	0.055	0.70	0.85	1.75	2.15	0.035	0.050
100	**120**	0.050	0.060	0.75	0.90	1.9	2.25	0.045	0.065
120	**140**	0.060	0.070	0.90	1.1	2.25	2.75	0.055	0.080
140	**160**	0.065	0.080	1.0	1.3	2.5	3.25	0.060	0.100
160	**180**	0.070	0.090	1.1	1.4	2.75	3.5	0.070	0.110
180	**200**	0.080	0.100	1.3	1.6	3.25	4.0	0.070	0.110
200	**225**	0.090	0.110	1.4	1.7	3.5	4.25	0.080	0.130
225	**250**	0.100	0.120	1.6	1.9	4.0	4.75	0.090	0.140
250	**280**	0.110	0.140	1.7	2.2	4.25	5.5	0.100	0.150
280	**315**	0.120	0.150	1.9	2.4	4.75	6.0	0.110	0.160
315	**355**	0.140	0.170	2.2	2.7	5.5	6.75	0.120	0.180
355	**400**	0.150	0.190	2.4	3.0	6.0	7.5	0.130	0.200
400	**450**	0.170	0.210	2.7	3.3	6.75	8.25	0.140	0.220
450	**500**	0.190	0.240	3.0	3.7	7.5	9.25	0.160	0.240
500	**560**	0.210	0.270	3.4	4.3	8.5	11.0	0.170	0.270
560	**630**	0.230	0.300	3.7	4.8	9.25	12.0	0.200	0.310
630	**710**	0.260	0.330	4.2	5.3	10.5	13.0	0.220	0.330
710	**800**	0.280	0.370	4.5	5.9	11.5	15.0	0.240	0.390
800	**900**	0.310	0.410	5.0	6.6	12.5	16.5	0.280	0.430
900	**1 000**	0.340	0.460	5.5	7.4	14.0	18.5	0.310	0.470
1 000	**1 120**	0.370	0.500	5.9	8.0	15.0	20.0	0.360	0.530

Remarks The values for reduction in radial internal clearance are for bearings with CN clearance. For bearing with C3 Clearance,the maximum values listed should be used for the reduction in radial internal clearance.

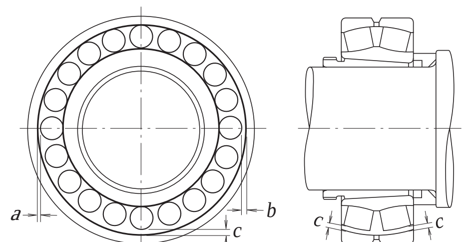


Fig. 14.9 Measuring Clearance in Large Spherical Roller Bearing

Large machines, which cannot be turned by hand, can be started after examination with no load, and the power immediately cutoff and the machine allowed to coast to a stop. Confirm that there is no abnormality such as vibration, noise, contact of rotating parts, etc.
Powered operation should be started slowly without load and the operation should be observed carefully until it is determined that no abnormalities exist, then gradually increase the speed, load, etc. to their normal levels. Items to be checked during the test operation include the existence of abnormal noise, excessive rise of bearing temperature, leakage and contamination of lubricants, etc. If any abnormality is found during the test operation, it must be stopped immediately and the machine should be inspected. If necessary, the bearing should be dismounted for examination.

Although the bearing temperature can generally be estimated by the temperature of the outside surface of the housing, it is more desirable to directly measure the temperature of the outer ring using oil holes for access.
The bearing temperature should rise gradually to the steady state level within one to two hours after the operation starts. If the bearing or its mounting is improper, the bearing temperature may increase rapidly and become abnormally high. The cause of this abnormal temperature may be an excessive amount of lubricant, insufficient bearing clearance, incorrect mounting, or excessive friction of the seals.
In the case of high speed operation, an incorrect selection of bearing type or lubricating method may also cause an abnormal temperature rise.
The sound of a bearing may be checked with a noise locater or other instruments. Abnormal conditions are indicated by a loud metallic sound, or other irregular noise, and the possible cause may include incorrect lubrication, poor alignment of the shaft and housing, or the entry of foreign matter into the bearing. The possible causes and measures for irregularities are listed in Table 14.2.

Table 14. 2 Causes of and Measures for Operating Irregularities

Irregularities		Possible Causes	Measures
Noise	Loud Metallic Sound (1)	Abnormal Load	Improve the fit, internal clearance, preload, position of housing shoulder, etc.
		Incorrect mounting	Improve the machining accuracy and alignment of shaft and housing, accuracy of mounting method.
		Insufficient or improper Lubricant	Replenish the lubricant or select another lubricant.
		Contact of rotating parts	Modify the labyrinth seal, etc.
	Loud Regular Sound	Flaws,corrosion,or scratches on raceways	Replace or clean the bearing, improve the seals, and use clean lubricant.
		Brinelling	Replace the bearing and use care when handling bearings.
		Flaking on raceway	Replace the bearing.
	Irregular Sound	Excessive clearance	Improve the fit, clearance and preload.
		Penetration of foreign particles	Replace or clean the bearing, improve the seals, and use clean lubricant.
		Flaws or flaking on balls	Replace the bearing.
Abnormal Temperature Rise		Excessive amount of lubricant	Reduce amount of lubricant, select stiffer grease.
		Insufficient or improper lubricant	Replenish lubricant or select a better one.
		Abnormal load	Improve the fit, internal clearance, preload, position of housing shoulder.
		Incorrect mounting	Improve the machining accuracy and alignment of shaft and housing, accuracy of mounting, or mounting method.
		Creep on fitted surface, excessive seal friction	Correct the seals, replace the bearing, correct the fitting or mounting.
Vibration (Axial runout)		Brinelling	Replace the bearing and use care when handling bearings.
		Flaking	Replace the bearing.
		Incorrect mounting	Correct the squareness between the shaft and housing shoulder or side of spacer.
		Penetration of foreign particles	Replace or clean the bearing, improve the seals.
Leakage or Discoloration of Lubricant		Too much lubricant, Penetration by foreign matter or abrasion chips	Reduce the amount of lubricant, select a stiffer grease. Replace the bearing or lubricant. Clean the housing and adjacent parts.

Note (1) Intermittent squeal or high-pitch noise may be heard in medium- to large-sized cylindrical roller bearings or ball bearings that are operating under grease lubrication in low-temperature environments. Under such low-temperature conditions, bearing temperature will not rise resulting in fatigue nor is grease performance affected. Although intermittent squeal or high-pitch noise may occur under these conditions, the bearing is fully functional and can continue to be used. In the event that greater noise reduction or quieter running properties are needed, please contact your nearest NSK branch office.

14.4 Dismounting

A bearing may be removed for periodic inspection or for other reasons. If the removed bearing is to be used again or it is removed only for inspection, it should be dismounted as carefully as when it was mounted. If the bearing has a tight fit, its removal may be difficult. The means for removal should be considered in the original design of the adjacent parts of the machine. When dismounting, the procedure and sequence of removal should first be studied using the machine drawing and considering the type of mounting fit in order to perform the operation properly.

14.4.1 Dismounting of Outer Rings

In order to remove an outer ring that is tightly fitted, first place bolts in the push-out holes in the housing at several locations on its circumference as shown in Fig. 14.10, and remove the outer ring by uniformly tightening the bolts. These bolt holes should always be fitted with blank plugs when not being used for dismounting. In the case of separable bearings, such as tapered roller bearings, some notches should be made at several positions in the housing shoulder, as shown in Fig. 14.11, so the outer ring may be pressed out using a dismounting tool or by tapping it.

14.4.2 Dismounting of Bearings with Cylindrical Bores

If the mounting design allows space to press out the inner ring, this is an easy and fast method. In this case, the withdrawal force should be imposed only on the inner ring (Fig. 14.12). Withdrawal tools like those shown in Figs. 14.13 and 14.14 are often used.

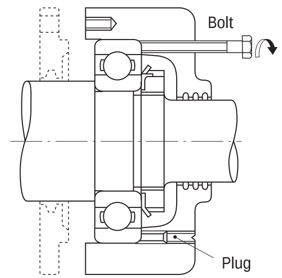


Fig. 14.10 Removal of Outer Ring with Dismounting Bolts

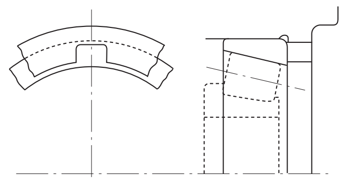


Fig. 14.11 Removal Notches

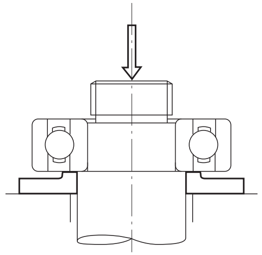


Fig. 14.12 Removal of Inner Ring Using a Press

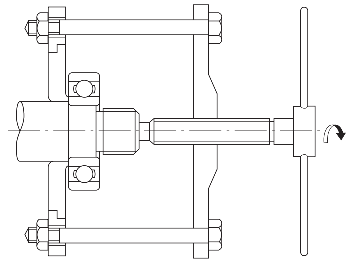


Fig. 14.13 Removal of Inner Ring Using Withdrawal Tool (1)

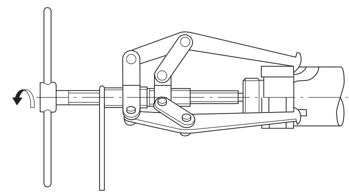


Fig. 14.14 Removal of Inner Ring Using Withdrawal Tool (2)

In both cases, the claws of the tools must substantially engage the face of the inner ring; therefore, it is advisable to consider the size of the shaft shoulder or to cut grooves in the shoulder to accommodate the withdrawal tools (Fig. 14.14).
The oil injection method is usually used for the withdrawal of large bearings. The withdrawal is achieved easily by mean of oil pressure applied through holes in the shaft. In the case of extra wide bearings, the oil injection method is used together with a withdrawal tool.
Induction heating is used to remove the inner rings of NU and NJ types of cylindrical roller bearings. The inner rings are expanded by brief local heating, and then withdrawn (Fig. 14.15). Induction heating is also used to mount several bearings of these types on a shaft.

14.4.3 Dismounting of Bearings with Tapered Bores

When dismounting relatively small bearings with adapters, the inner ring is held by a stop fastened to the shaft and the nut is loosened several turns. This is followed by hammering on the sleeve using a suitable tool as shown in Fig. 14.18. Fig. 14.16 shows one procedure for dismounting a withdrawal sleeve by tightening the removal nut. If this procedure is difficult, it may be possible to drill and tap bolt holes in the nut and withdraw the sleeve by tightening the bolts as shown in Fig. 14.17.
Large bearings may be withdrawn easily using oil pressure. Fig. 14.19 illustrates the removal of a bearing by forcing oil under pressure through a hole and groove in a tapered shaft to expand the inner ring. The bearing may suddenly move axially when the interference is relieved during this procedure so a stop nut is recommended for protection. Fig. 14.20 shows a withdrawal using a hydraulic nut.

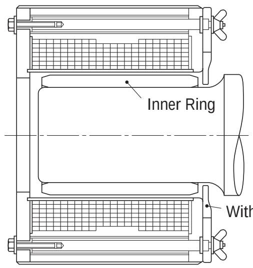


Fig. 14.15 Removal of Inner Ring Using Induction Heater

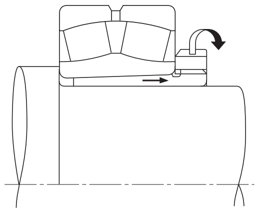


Fig. 14.16 Removal of Withdrawal Sleeve Using Withdrawal Nut (1)

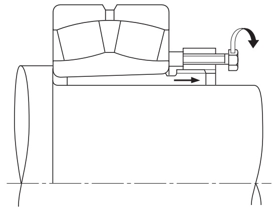


Fig. 14.17 Removal of Withdrawal Sleeve Using Withdrawal Nut (2)

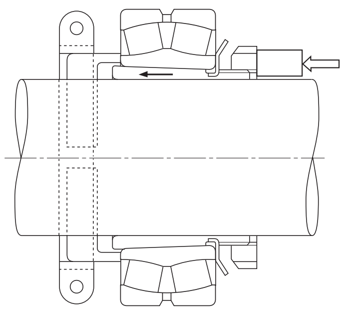


Fig. 14.18 Removal of Adapter with Stop and Axial Pressure

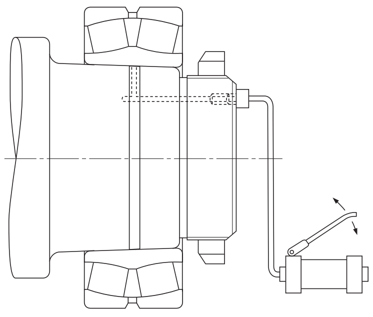


Fig. 14.19 Removal Using Oil Injection Hydraulic Pump

14.5 Inspection of Bearings

14.5.1 Bearing Cleaning

When bearings are inspected, the appearance of the bearings should first be recorded and the amount and condition of the residual lubricant should be checked.
After the lubricant has been sampled for examination, the bearings should be cleaned. In general, light oil or kerosene may be used as a cleaning solution.
Dismounted bearings should first be given a preliminary cleaning followed by a finishing rinse. Each bath should be provided with a metal net to support the bearings in the oil without touching the sides or bottom of the tank. If the bearings are rotated with foreign matter in them during preliminary cleaning, the raceways may be damaged. The lubricant and other deposits should be removed in the oil bath during the initial rough cleaning with a brush or other means. After the bearing is relatively clean, it is given the finishing rinse. The finishing rinse should be done carefully with the bearing being rotated while immersed in the rinsing oil. It is necessary to always keep the rinsing oil clean.

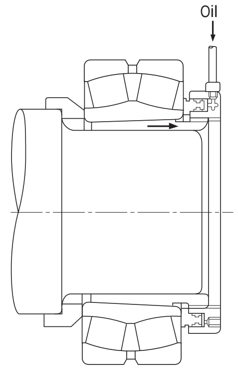


Fig. 14.20 Removal Using Hydraulic Nut

14.5.2 Inspection and Evaluation of Bearings

After being thoroughly cleaned, bearings should be examined for the condition of their raceways and external surfaces, the amount of cage wear, the increase in internal clearance, and degradation of tolerances. These should be carefully checked, in addition to examination for possible damage or other abnormalities, in order to determine the possibility for its reuse.
In the case of small non-separable ball bearings, hold the bearing horizontally in one hand, and then rotate the outer ring to confirm that it turns smoothly.
Separable bearings such as tapered roller bearings may be checked by individually examining their rolling elements and the outer ring raceway.
Large bearings cannot be rotated manually; however, the rolling elements, raceway surfaces, cages, and contact surface of the ribs should be carefully examined visually. The more important a bearing is, the more carefully it should be inspected.
The determination to reuse a bearing should be made only after considering the degree of bearing wear, the function of the machine, the importance of the bearings in the machine, operating conditions, and the time until the next inspection. However, if any of the following defects exist, reuse is impossible and replacement is necessary.

(a) When there are cracks in the inner or outer rings, rolling elements, or cage.
(b) When there is flaking of the raceway or rolling elements.
(c) When there is significant smearing of the raceway surfaces, ribs, or rolling elements.
(d) When the cage is significantly worn or rivets are loose.
(e) When there is rust or scoring on the raceway surfaces or rolling elements.
(f) When there are any significant impact or brinell traces on the raceway surfaces or rolling elements.
(g) When there is significant evidence of creep on the bore or the periphery of the outer ring.
(h) When discoloration by heat is evident.
(i) When significant damage to the seals or shields of grease sealed bearings has occurred.

14.6 Maintenance and Inspection

14.6.1 Detecting and Correcting Irregularities

In order to maintain the original performance of a bearing for as long as possible, proper maintenance and inspection should be performed. If proper procedures are used, many bearing problems can be avoided and the reliability, productivity, and operating costs of the equipment containing the bearings are all improved. It is suggested that periodic maintenance be done following the procedure specified. This periodic maintenance encompasses the supervision of operating conditions, the supply or replacement of lubricants, and regular periodic inspection. Items that should be regularly checked during operation include bearing noise, vibration, temperature, and lubrication.
If an irregularity is found during operation, the cause should be determined and the proper corrective actions should be taken after referring to Table 14.2.
If necessary, the bearing should be dismounted and examined in detail. As for the procedure for dismounting and inspection, refer to Section 14.5, Inspection of Bearings.

NSK BEARING MONITOR (Bearing Abnormality Detector)

It is important during operation to detect signs of irregularities early before damage becomes severe.
The NSK Bearing Monitor (see Page C5) is an instrument that checks the condition of bearings and gives a warning of any abnormality, or it stops a machine automatically in order to prevent serious trouble. In addition, it helps to improve maintenance and reduce its cost.

14.6.2 Bearing Failures and Measures

In general, if rolling bearings are used correctly they will survive to their predicted fatigue life. However, they often fail prematurely due to avoidable mistakes.
In contrast to fatigue life, this premature failure is caused by improper mounting, handling, or lubrication, entry of foreign matter, or abnormal heat generation.
For instance, the causes of rib scoring, as one example of premature failure, may include insufficient lubrication, use of improper lubricant, faulty lubrication system, entry of foreign matter, bearing mounting error, excessive deflection of the shaft, or any combination of these. Thus, it is difficult to determine the real cause of some premature failures.
If all the conditions at the time of failure and previous to the time of failure are known, including the application, the operating conditions, and environment; then by studying the nature of the failure and its probable causes, the possibility of similar future failures can be reduced. The most frequent types of bearing failure, along with their causes and corrective actions, are listed in Table 14.3.

Table 14.3 Causes and Measures for Bearing Failures

Type of Failure	Probable Causes	Measures
Flaking		
Flaking of one-side of the raceway of radial bearing.	Abnomal axial load.	A loose fit should be used when mounting the outer ring of free-end bearings to allow axial expansion of the shaft.
Flaking of the raceway in symmetrical patterm.	Out-of-roundness of the housing bore.	Correct the faulty housing.
Flaking pattern inclined relative to the raceway in radial ball bearings. Flaking near the edge of the raceway and rolling surfaces in roller bearings.	Improper muonting, deflection of shaft, inadequate tolerances for shaft and housing.	Use care in mounting and centering, select a bearing with a large clearance, and correct the shaft and housing shoulder.
Flaking of raceway with same spacing as rolling elements.	Large shock load during mounting, rusting while bearing is out of operation for prolonged period.	Use care in mounting and apply a rust preventive when machine operation is suspended for a long time.
Premature flaking of raceway and rolling elements.	Insufficient clearance, excessive load, improper lubrication, rust, etc.	Select proper fit, bearing clearance, and lubricant.
Premature flaking of duplex bearings.	Excessive preload.	Adjust the preload.
Scoring		
Scoring or smearing between raceway and rolling surfaces.	Inadequate initial lubrication, excessively hard grease and high acceleration when starting.	Use a softer grease and avoid rapid acceleration.
Spiral scoring or smearing of raceway surface of thrust ball bearing.	Raceway rings are not parallel and excessive speed.	Correct the mounting, apply a preload, or select another bearing type.
Scoring or smearing between the end face of the rollers and guide rib.	Inadequate lubrication, incorrect mounting and large axial load.	Select proper lubricant and modify the mounting.
Cracks		
Crack in outer or inner ring.	Excessive shock load, excessive interference in fitting, poor surface cylindricality, improper sleeve taper, large fillet radius, development of thermal cracks and advancement of flaking.	Examine the loading conditions, modify the fit of bearing and sleeve. The fillet radius must be smaller than the bearing chamfer.
Crack in rolling element. Broken rib.	Advancement of flaking, shock applied to the rib during mounting or dropped during handling.	Be carefull in handling and mounting.
Fractured cage.	Abnormal loading of cage due to incorrect mounting and improper lubrication.	Reduce the mounting error and review the lubricating method and lubricant.
Indentations		
Indentations in raceway in same pattern as rolling elements.	Shock load during mounting or excessive load when not rotating.	Use care in handling.
Indentations in raceway and rolling elements.	Foreign matter such as metallic chips or sand.	Clean the housing, improve the seals, and use a clean lubricant.
Abnormal Wear		
False brinelling (phenomenon similar to brinelling)	Vibration of the bearing without rotation during shipment or rocking motion of small amplitude.	Secure the shaft and housing, use oil as a lubricant and reduce vibration by applying a preload.
Fretting	Slight wear of the fitting surface.	Increase interference and apply oil.
Wearing of raceway, rolling elements, rib, and cage.	Penentration by foreign matter, incorrect lubrication, and rust.	Improve the seals, clean the housing, and use a clean lubricant.
Creep	Insufficient interference or insufficient tightening of sleeve.	Modify the fit or tighten the sleeve
Seizure		
Discoloration and melting of raceway, rolling elements, and ribs.	Insufficient clearance, incorrect lubrication, or improper mounting.	Review the internal clearance and bearing fit, supply an adequate amount of the proper lubricant and improve the mounting method and related parts.
Electric Burng		
Fluting or corrugations.	Melting due to electric arcing.	Install a ground wire to stop the flow of electricity or insulate the beaning.
Corrosion & Rust		
Rust and corrosion of fitting surfaces and bearing interior.	Condensation of water from the air, or fretting. Penetration by corrosive substance(especially varnish-gas, etc).	Use care in storing and avoid high temperature and high humidity, treatment for rust prevention is necessary when operation is stopped for long time. Selection of varnish and grease.

15. TECHNICAL DATA

NSK

DEFINIONS OF SYMBOLS AND THEIR UNITS

Symbols	Nomenclature	Units
a	Contact Ellipse Major Axis	(mm)
b	Contact Ellipse Major Axis	(mm)
C_r	Basic Dynamic Load Rating of Radial Bearings	(N){kgf}
C_{0r}	Basic Static Load Radial of Radial Bearings	(N){kgf}
C_a	Basic Dynamic Load Rating of Thrust Bearings	(N){kgf}
C_{0a}	Basic Static Load Rating of Thrust Bearings	(N){kgf}
d	Shaft Diameter, Nominal Bearing Bore Diameter	(mm)
D	Housing Bore Diameter, Nominal Bearing Outside Diameter	(mm)
D_e	Outer Ring Raceway Diameter	(mm)
D_i	Inner Ring Raceway Diameter	(mm)
D_0	Housing Outside Diameter	(mm)
D_{pw}	Rolling Element Pitch Diameter	(mm)
D_w	Nominal Rolling Element Diameter	(mm)
e	Contact Position of Tapered Roller End Face with Rib	(mm)
E	Modulus of Longitudinal Elasticity (Bearing Steel) 208 000 MPa{21 200 kgf/mm²}	
$E(k)$	Complete elliptic integral of the 2nd kind for which the population parameter is $k=\sqrt{1-\left(\frac{b}{a}\right)^2}$	
f_0	factor which depends on the geometry of the bearing components and on the applicable stress level	
$f(\varepsilon)$	Function of ε	
F_a	Axial Load, Preload	(N){kgf}
F_r	Radial Load	(N){kgf}
h	D_e/D	
h_0	D/D_0	
k	d/D_i	
K	Constant Determined by Internal Design of Bearing	
L	Fatigue Life when Effective Clearance is 0	
L_{we}	Effective Leng of Roller	(mm)
L_ε	Fatigue Life when Effective Clearance is Δ	
m_0	Distance between Centers of Curvature of Inner and Outer Rings $r_i+r_e-D_w$	(mm)
M	Frictional Torque	(N·mm){kgf·mm}
M_s	Spin Friction	(N·mm){kgf·mm}

Symbols	Nomenclature	Units
n_a	Rotating Speed of Rolling Elements	(min^{-1})
n_c	Revolving Speed of Rolling Elements (Cape Speed)	(min^{-1})
n_e	Speed of Ouder Ring	(min^{-1})
n_i	Speed of Inner Ring	(min^{-1})
p_m	Surface Pressure on Fitted Surface	(MPa){kgf/mm²}
P	Bearing Load	(N){kgf}
Q	Rolling Element Load	(N){kgf}
r_e	Groove Radius of Outer Ring	(mm)
r_i	Groove Radius of Inner Ring	(mm)
v_a	Circumferential Speed of Rolling Element about Its Center	(m/sec)
v_c	Circumferential Speed of Rolling Element about Beaing Center	(m/sec)
Z	Number of Rolling Elements per Row	
α	Contact Angle (when axial load is applied on Radial Ball Bearning	(°)
α_0	Initial Confact Angle (Geometri) (when inner and outer rings of Angular Contact Ball Bearings are pushed axially)	(°)
α_R	Initial Contact Angle (Geometric) (when inner and outer rings Angular Contact Ball Bearing are pushed radially)	(°)
β	1/2 of Conical Angle of Roller	(°)
δ_a	Relative Axial Displacement of Inner and Outer Rings	(mm)
Δ_a	Axial Internal Clearance	(mm)
Δd	Effective Interference of Inner Ring and Shaft	(mm)
Δ_r	Radial Internal Clearance	(mm)
ΔD	Effective Interference of Outer Ring and Housing	(mm)
ΔD_e	Contraction of Outer Ring Raceway Diameter due to Fit	(mm)
ΔD_i	Expansion of Inner Ring Raceway Diameter dus to Fit	(mm)
ε	Load Factor	
μ	Coefficient of Dynamic Friction of Rolling Bearing	
μ_e	Coefficient of Friction between Roller End Face and Rib	
μ_s	Coefficient of Sliding Friction	
$\sigma_{t\,max}$	Maximum Stress on Fitted Surfaces	(MPa){kgf/mm²}

15. 1 Axial Displacement of Bearings

(1) Contact Angle α and Axial Displacement δ_a of Deep Groove Ball Bearing and Angular Contact Ball Bearings
(Figs. 15.1 to 15.3)

$$\left.\begin{aligned}\delta_a &= \frac{0.00044}{\sin\alpha}\left(\frac{Q^2}{D_w}\right)^{\frac{1}{3}} \;\cdots\cdots\cdots\cdots\; (\mathrm{N})\\ \delta_a &= \frac{0.002}{\sin\alpha}\left(\frac{Q^2}{D_w}\right)^{\frac{1}{3}} \;\cdots\cdots\cdots\cdots\; \{\mathrm{kgf}\}\end{aligned}\right\}(\mathrm{mm})$$

$$Q = \frac{F_a}{Z\sin\alpha} \qquad (\mathrm{N}),\ \{\mathrm{kgf}\}$$

(2) Axial Load F_a and Axial Displacement δ_a of Tapered Roller Bearings
(Fig. 15.4)

$$\left.\begin{aligned}\delta_a &= \frac{0.000077\, F_a^{0.9}}{(\sin\alpha)^{1.9}\, Z^{0.9}\, L_{we}^{0.8}} \;\cdots\cdots\cdots\; (\mathrm{N})\\ \delta_a &= \frac{0.0006\, F_a^{0.9}}{(\sin\alpha)^{1.9}\, Z^{0.9}\, L_{we}^{0.8}} \;\cdots\cdots\cdots\; \{\mathrm{kgf}\}\end{aligned}\right\}(\mathrm{mm})$$

Remarks:
Actual axial displacement may vary depending on the shaft/housing thickness, material, and fitting interference with the bearing. Please contact NSK about such factors of axial displacement which are not discussed in detail in this catalog.

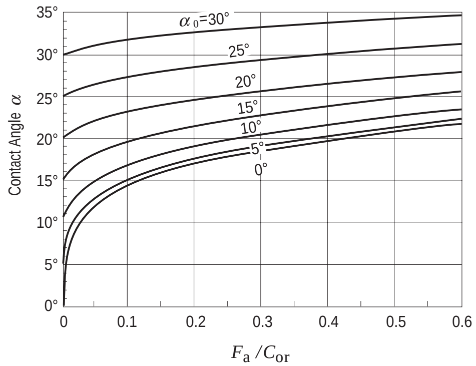


Fig. 15.1 F_a / C_{or} **and Contact Angle of Deep Groove and Angular Contact Ball Bearings**

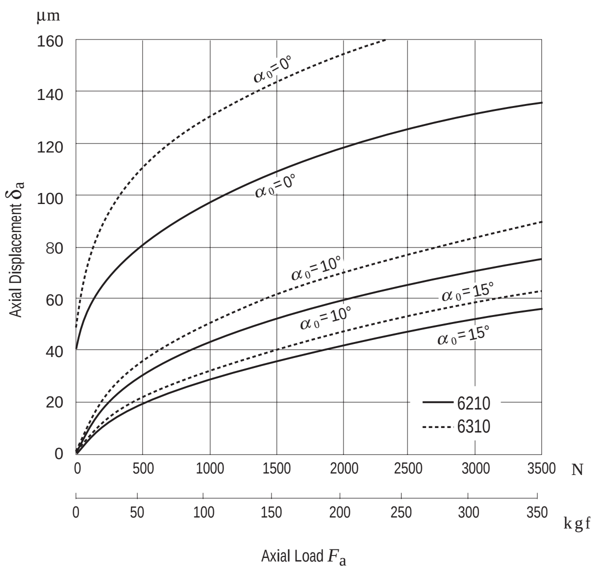


Fig. 15.2 Axial Load and Axial Displacement of Deep Groove Ball Bearings

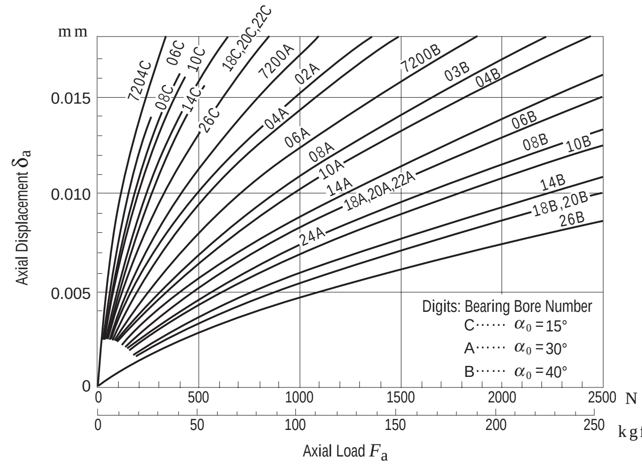


Fig. 15.3 Axial Load and Axial Displacement of Angular Contact Ball Bearings

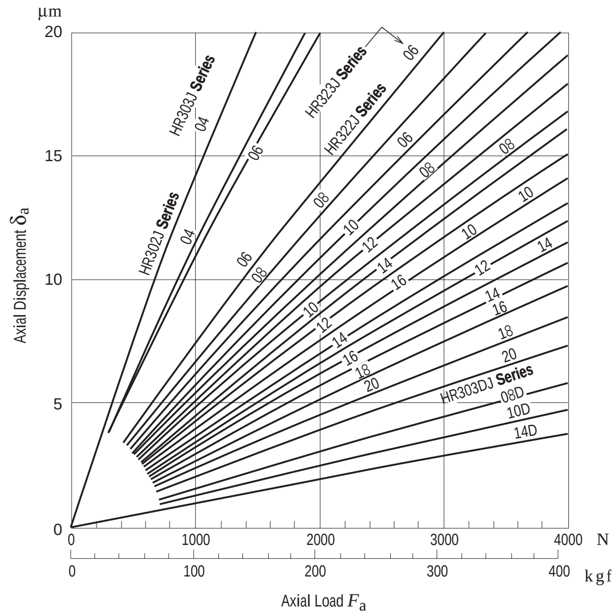


Fig. 15.4 Axial Load and Axial Displacement of Tapered Roller Bearings

15.2 Fits

(1) Surface Pressure p_m, Maximum Stress σ_{tmax} on Fitted Surfaces and Expansion of Inner Ring Raceway Diameter ΔD_i or Contraction of Outer Ring Raceway Diameter ΔD_e (Table 15.1, Figs. 15.5 and 15.6)

(2) Interferences or Clearances of Shafts and Inner Rings (Table 15.2)

(3) Interferences or Clearances of Housing Bores and Outer Rings (Table 15.3)

Table. 15. 1 Surface Pressure, Maximum Stress on Fitted Surfaces and Expansion or Contraction

Items	Shaft & Inner Ring	Housing & Bore & Outer Ring
Surface Pressure p_m (MPa) {kgf/mm²}	(In case of sold shaft) $p_m = \frac{E}{2}\frac{\Delta d}{2}(1-k^2)$	In case of housing outside dia. $D_0 \neq \infty$ $p_m = \frac{E}{2}\frac{\Delta D}{D}\frac{(1-h^2)(1-h_0^2)}{1-h^2 h_0^2}$ In case $D_0 = \infty$ $p_m = \frac{E}{2}\frac{\Delta D}{D}(1-h^2)$
Maximum stress $\sigma_{t\,max}$ (MPa) {kgf/mm²}	Maximum circumferential stress on fitted surface of inner ring bore is $\sigma_{t\,max} = p_m \frac{1+k^2}{1-k^2}$	Maximum circumferential stress on outer ring bore surface is $\sigma_{t\,max} = p_m \frac{2}{1-h^2}$
Expansion of inner ring raceway dia. ΔD_i (mm) Contraction of outer ring raceway dia. ΔD_e (mm)	In case of solid shaft $\Delta D_i = \Delta d \cdot k$	In case $D_0 \neq \infty$ $\Delta D_e = \Delta D \cdot h \frac{1-h_0^2}{1-h^2 h_0^2}$ In case $D_0 = \infty$ $\Delta D_e = \Delta D \cdot h$

Remarks The modulus of longitudinal elasticity and Poisson's ratio for the shaft and housing material are the same as those for inner and outer rings.

Reference 1 MPa=1 N/mm²=0.102 kgf/mm²

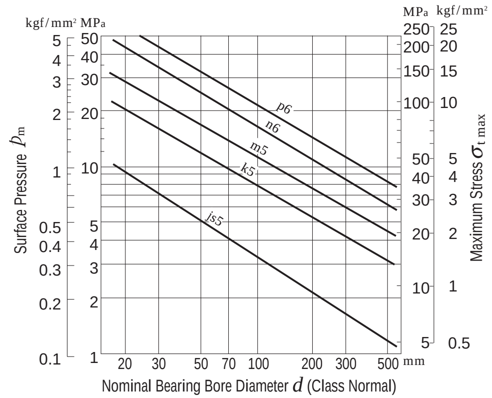


Fig. 15.5 Surface Pressure p_m and Maximum Stress $\sigma_{t\,max}$ for Average Fitting Interference

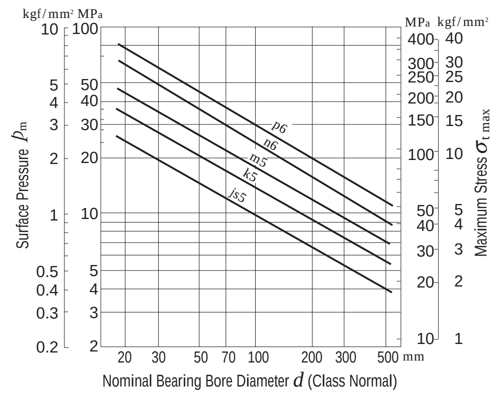


Fig. 15.6 Surface Pressure p_m and Maximum Stress $\sigma_{t\,max}$ for Maximum Fitting Interference

Table 15. 2 Interferences or Clearances of Shafts and Inner Rings

Units : µm

Size Classification (mm)		Single Plane Mean Bore Dia. Deviation (Normal) Δd_{mp}		Interferences or Clearances for Each Fitting Class													
				f6		g5		g6		h5		h6		js5		j5	
				Clearance		Clearance	Interference	Clearance	Interference	Clearance	Interference	Clearance	Interference	Clearance	Interference	Clearance	Interference
over	incl.	high	low	max.	min.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.
3	6	0	− 8	18	2	9	4	12	4	5	8	8	8	—	—	—	—
6	10	0	− 8	22	5	11	3	14	3	6	8	9	8	3	11	2	12
10	18	0	− 8	27	8	14	2	17	2	8	8	11	8	4	12	3	13
18	30	0	−10	33	10	16	3	20	3	9	10	13	10	4.5	14.5	4	15
30	50	0	−12	41	13	20	3	25	3	11	12	16	12	5.5	17.5	5	18
50	65	0	−15	49	15	23	5	29	5	13	15	19	15	6.5	21.5	7	21
65	80	0	−15	49	15	23	5	29	5	13	15	19	15	6.5	21.5	7	21
80	100	0	−20	58	16	27	8	34	8	15	20	22	20	7.5	27.5	9	26
100	120	0	−20	58	16	27	8	34	8	15	20	22	20	7.5	27.5	9	26
120	140	0	−25	68	18	32	11	39	11	18	25	25	25	9	34	11	32
140	160	0	−25	68	18	32	11	39	11	18	25	25	25	9	34	11	32
160	180	0	−25	68	18	32	11	39	11	18	25	25	25	9	34	11	32
180	200	0	−30	79	20	35	15	44	15	20	30	29	30	10	40	13	37
200	225	0	−30	79	20	35	15	44	15	20	30	29	30	10	40	13	37
225	250	0	−30	79	20	35	15	44	15	20	30	29	30	10	40	13	37
250	280	0	−35	88	21	40	18	49	18	23	35	32	35	11.5	46.5	16	42
280	315	0	−35	88	21	40	18	49	18	23	35	32	35	11.5	46.5	16	42
315	355	0	−40	98	22	43	22	54	22	25	40	36	40	12.5	52.5	18	47
355	400	0	−40	98	22	43	22	54	22	25	40	36	40	12.5	52.5	18	47
400	450	0	−45	108	23	47	25	60	25	27	45	40	45	13.5	58.5	20	52
450	500	0	−45	108	23	47	25	60	25	27	45	40	45	13.5	58.5	20	52

js6		j6		k5		k6		m5		m6		n6		p6		r6		Size Classification (mm)	
Clearance	Interference	Clearance	Interference	Interference		Interference		Interference		Interference		Interference		Interference		Interference			
max.	max.	max.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	over	incl.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	6
4.5	12.5	2	15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	10
5.5	13.5	3	16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10	18
6.5	16.5	4	19	2	21	2	25	—	—	—	—	—	—	—	—	—	—	18	30
8	20	5	23	2	25	2	30	9	32	9	37	—	—	—	—	—	—	30	50
9.5	24.5	7	27	2	30	2	36	11	39	11	45	—	—	—	—	—	—	50	65
9.5	24.5	7	27	2	30	2	36	11	39	11	45	20	54	—	—	—	—	65	80
11	31	9	33	3	38	3	45	13	48	13	55	23	65	37	79	—	—	80	100
11	31	9	33	3	38	3	45	13	48	13	55	23	65	37	79	—	—	100	120
12.5	37.5	11	39	3	46	3	53	15	58	15	65	27	77	43	93	63	113	120	140
12.5	37.5	11	39	3	46	3	53	15	58	15	65	27	77	43	93	65	115	140	160
12.5	37.5	11	39	3	46	3	53	15	58	15	65	27	77	43	93	68	118	160	180
14.5	44.5	13	46	4	54	4	63	17	67	17	76	31	90	50	109	77	136	180	200
14.5	44.5	13	46	4	54	4	63	17	67	17	76	31	90	50	109	80	139	200	225
14.5	44.5	13	46	4	54	4	63	17	67	17	76	31	90	50	109	84	143	225	250
16	51	16	51	4	62	4	71	20	78	20	87	34	101	56	123	94	161	250	280
16	51	16	51	4	62	4	71	20	78	20	87	34	101	56	123	98	165	280	315
18	58	18	58	4	69	4	80	21	86	21	97	37	113	62	138	108	184	315	355
18	58	18	58	4	69	4	80	21	86	21	97	37	113	62	138	114	190	355	400
20	65	20	65	5	77	5	90	23	95	23	108	40	125	68	153	126	211	400	450
20	65	20	65	5	77	5	90	23	95	23	108	40	125	68	153	132	217	450	500

Remarks 1. The figures for tolerance classes where stress caused by the fitting of the shaft and inner ring becomes excessive are omitted.
2. The tolerance range js is now recommended instead of j.

Table 15. 3 Interferences or Clearances of Housing Bores and Outer Rings

Units : μm

Size Classification (mm) over	Size Classification (mm) incl.	Single Plane Mean O. D. Deviation (Normal) ΔD_{mp} high	low	G7 Clearance max.	G7 Clearance min.	H6 Clearance max.	H6 Clearance min.	H7 Clearance max.	H7 Clearance min.	H8 Clearance max.	H8 Clearance min.	J6 Clearance max.	J6 Interference max.	JS6 Clearance max.	JS6 Interference max.	J7 Clearance max.	J7 Interference max.
6	**10**	0	– 8	28	5	17	0	23	0	30	0	13	4	12.5	4.5	16	7
10	**18**	0	– 8	32	6	19	0	26	0	35	0	14	5	13.5	5.5	18	8
18	**30**	0	– 9	37	7	22	0	30	0	42	0	17	5	15.5	6.5	21	9
30	**50**	0	– 11	45	9	27	0	36	0	50	0	21	6	19	8	25	11
50	**80**	0	– 13	53	10	32	0	43	0	59	0	26	6	22.5	9.5	31	12
80	**120**	0	– 15	62	12	37	0	50	0	69	0	31	6	26	11	37	13
120	**150**	0	– 18	72	14	43	0	58	0	81	0	36	7	30.5	12.5	44	14
150	**180**	0	– 25	79	14	50	0	65	0	88	0	43	7	37.5	12.5	51	14
180	**250**	0	– 30	91	15	59	0	76	0	102	0	52	7	44.5	14.5	60	16
250	**315**	0	– 35	104	17	67	0	87	0	116	0	60	7	51	16	71	16
315	**400**	0	– 40	115	18	76	0	97	0	129	0	69	7	58	18	79	18
400	**500**	0	– 45	128	20	85	0	108	0	142	0	78	7	65	20	88	20
500	**630**	0	– 50	142	22	94	0	120	0	160	0	—	—	72	22	—	—
630	**800**	0	– 75	179	24	125	0	155	0	200	0	—	—	100	25	—	—
800	**1 000**	0	–100	216	26	156	0	190	0	240	0	—	—	128	28	—	—

JS7 Clearance max.	JS7 Interference max.	K6 Clearance max.	K6 Interference max.	K7 Clearance max.	K7 Interference max.	M6 Clearance max.	M6 Interference max.	M7 Clearance max.	M7 Interference max.	N6 Clearance max.	N6 Interference max.	N7 Clearance max.	N7 Interference max.	P6 Interference max.	P6 Interference max.	P7 Interference min.	P7 Interference max.	Size Classification (mm) over	Size Classification (mm) incl.
15	7	10	7	13	10	5	12	8	15	1	16	4	19	4	21	1	24	**6**	**10**
17	9	10	9	14	12	4	15	8	18	1*	20	3	23	7	26	3	29	**10**	**18**
19	10	11	11	15	15	5	17	9	21	2*	24	2	28	9	31	5	35	**18**	**30**
23	12	14	13	18	18	7	20	11	25	1*	28	3	33	10	37	6	42	**30**	**50**
28	15	17	15	22	21	8	24	13	30	1*	33	4	39	13	45	8	51	**50**	**80**
32	17	19	18	25	25	9	28	15	35	1*	38	5	45	15	52	9	59	**80**	**120**
38	20	22	21	30	28	10	33	18	40	2*	45	6	52	18	61	10	68	**120**	**150**
45	20	29	21	37	28	17	33	25	40	5	45	13	52	11	61	3	68	**150**	**180**
53	23	35	24	43	33	22	37	30	46	8	51	16	60	11	70	3	79	**180**	**250**
61	26	40	27	51	36	26	41	35	52	10	57	21	66	12	79	1	88	**250**	**315**
68	28	47	29	57	40	30	46	40	57	14	62	24	73	11	87	1	98	**315**	**400**
76	31	53	32	63	45	35	50	45	63	18	67	28	80	10	95	0	108	**400**	**500**
85	35	50	44	50	70	24	70	24	96	6	88	6	114	28	122	28	148	**500**	**630**
115	40	75	50	75	80	45	80	45	110	25	100	25	130	13	138	13	168	**630**	**800**
145	45	100	56	100	90	66	90	66	124	44	112	44	146	0	156	0	190	**800**	**1 000**

Note (*) Indicates the minimum interference
Remarks The tolerance range JS is now recommended instead of J.

15.3 Radial and Axial Internal Clearances

(1) Radial Internal Clearance Δ_r and Axial Internal Clearance Δ_a in Single-Row Deep Groove Ball Bearings
(Fig. 15.7)

$$\Delta_a \doteqdot K \Delta_r^{\frac{1}{2}} \qquad \text{(mm)}$$

where

$$K = 2\,(r_e + r_i - D_w)^{\frac{1}{2}}$$

(2) Radial Internal Clearance Δ_r and Axial Internal Clearance Δ_a in Double-Row Angular Contact Ball Bearings
(Fig. 15.8)

$$\Delta_a = 2\sqrt{m_0^2 - \left(m_0 \cos\alpha_R - \frac{\Delta_r}{2}\right)^2} - 2\,m_0 \sin\alpha_R \qquad \text{(mm)}$$

Table 15. 4 Constant *K*

Bore No.	Values of K 160XX	60XX	62XX	63XX
00	—	—	0.93	1.14
01	0.80	0.80	0.93	1.06
02	0.80	0.93	0.93	1.06
03	0.80	0.93	0.99	1.11
04	0.90	0.96	1.06	1.07
05	0.90	0.96	1.06	1.20
06	0.96	1.01	1.07	1.19
07	0.96	1.06	1.25	1.37
08	0.96	1.06	1.29	1.45
09	1.01	1.11	1.29	1.57
10	1.01	1.11	1.33	1.64
11	1.06	1.20	1.40	1.70
12	1.06	1.20	1.50	2.09
13	1.06	1.20	1.54	1.82
14	1.16	1.29	1.57	1.88
15	1.16	1.29	1.57	1.95
16	1.20	1.37	1.64	2.01
17	1.20	1.37	1.70	2.06
18	1.29	1.44	1.76	2.11
19	1.29	1.44	1.82	2.16
20	1.29	1.44	1.88	2.25
21	1.37	1.54	1.95	2.32
22	1.40	1.64	2.01	2.40
24	1.40	1.64	2.06	2.40
26	1.54	1.70	2.11	2.49
28	1.54	1.70	2.11	2.59
30	1.57	1.76	2.11	2.59

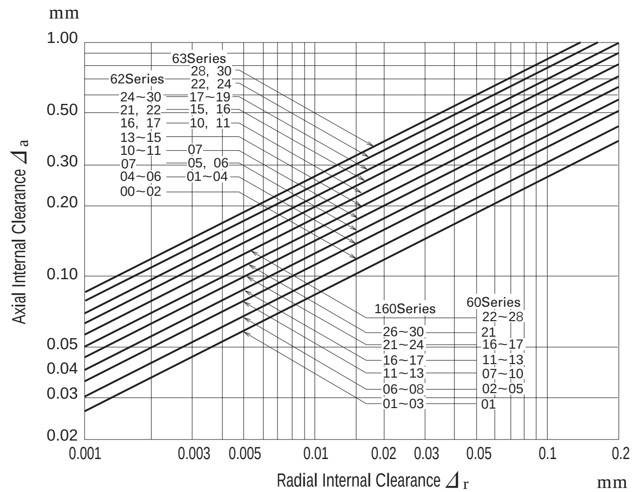


Fig. 15.7 Δ_r **and** Δ_a **in Single-Row Deep Groove Ball Bearings**

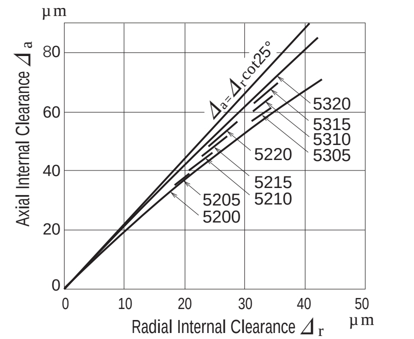


Fig. 15.8 Δ_r **and** Δ_a **in Double-Row Angular Contact Ball Bearings (52, 53 Series)**

15. 4 Preload and Staring Torque

(1) Axial Load F_a and Starting Torque M of Tapered Roller Bearings (Figs. 15.9 and 15.10)

$$M = e\,\mu_e\,F_a \cos\beta \qquad \text{(N·mm), \{kgf·mm\}}$$

where

μ_e : 0.20

When bearings with the same number are used in opposition, the torque M caused by the preload becomes $2M$.

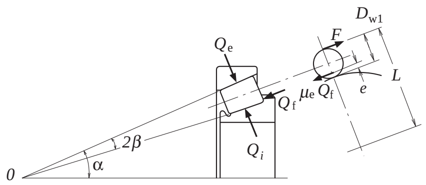


Fig. 15.9 Relation between e and β

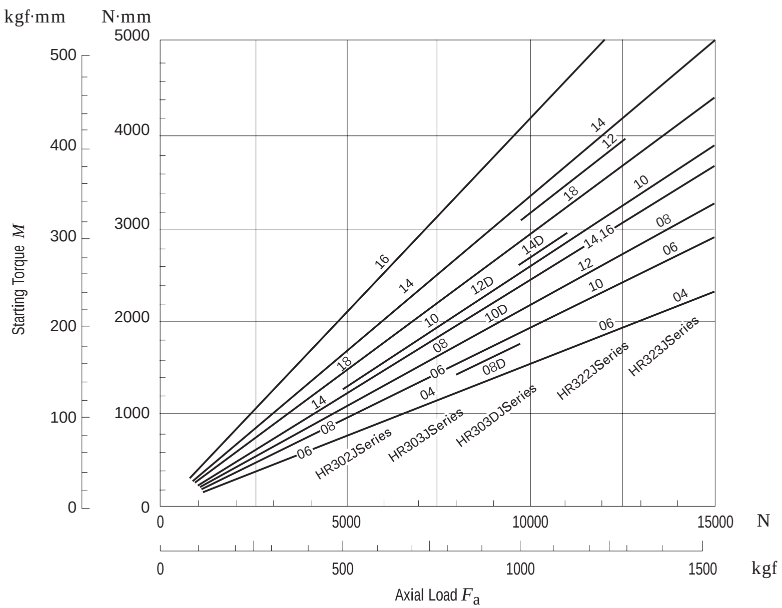


Fig. 15.10 Relation between Axial Load and Starting Torque of Tapered Roller Bearings

(2) Preload F_a and Starting Torque M of Angular Contact Ball Bearings and Double-Direction Angular Contact Thrust Ball Bearings (Figs. 15.11 and 15.12)

$$M = M_s\,Z \sin\alpha \qquad \text{(N·mm), \{kgf·mm\}}$$

where M_S is spin friction

$$M_S = \frac{3}{8}\mu_s\,Q\,a\,E(k) \qquad \text{(N·mm), \{kgf·mm\}}$$

where

μ_s = 0.15

When bearings with the same number are used in opposition, the torque M caused by the preload becomes $2M$.

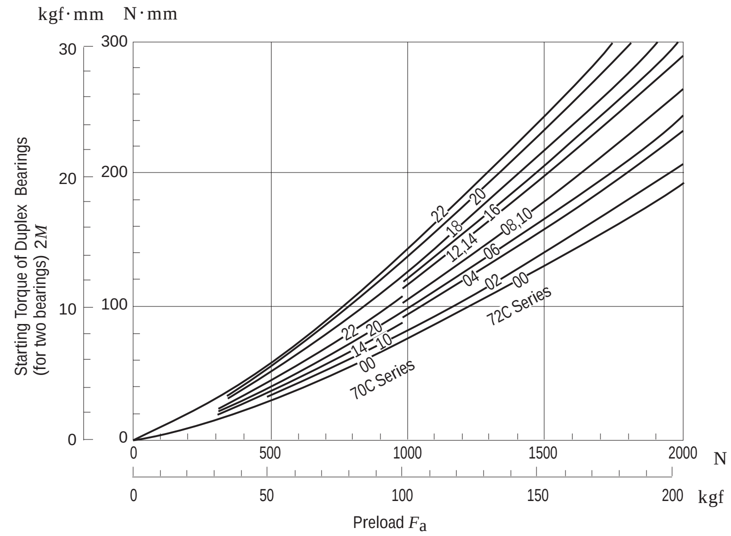


Fig. 15.11 Preload and Starting Torque for Back-to-Back or Face-to-Face Arrangements of Angular Contact Ball Bearings (α =15°)

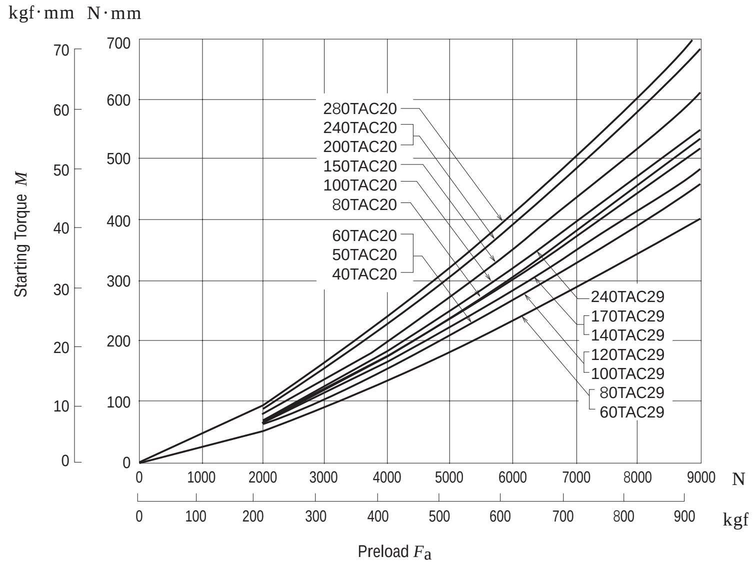


Fig. 15.12 Preload and Starting Torque of Double-Direction Angular Contact Thrust Ball Bearings

15.5 Coefficients of Dynamic Friction and Other Bearing Data

(1) Bearing Types and Their Coefficients of Dynamic Friction μ

$$\mu = \frac{M}{P \cdot \frac{d}{2}}$$

Table 15.5 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

(3) Radial Internal Clearance $\varDelta_r$ and Fatigue Life L (Fig. 15.13)

For the radial internal clearance $\varDelta_r$ and the function $f(\varepsilon)$ of the load factor, the following equations are valid:

For Deep Groove Ball Bearings

$$f(\varepsilon) = \frac{\varDelta_r \cdot D_w^{\frac{1}{3}}}{0.00044 \left(\frac{F_r}{Z}\right)^{\frac{2}{3}}} \text{ ....(N)}$$

$$f(\varepsilon) = \frac{\varDelta_r \cdot D_w^{\frac{1}{3}}}{0.002 \left(\frac{F_r}{Z}\right)^{\frac{2}{3}}} \text{ ....\{kgf\}}$$

For Cylindrical Roller Bearings

$$f(\varepsilon) = \frac{\varDelta_r \cdot L_{we}^{0.8}}{0.000077 \left(\frac{F_r}{Z}\right)^{0.9}} \text{ ....(N)}$$

$$f(\varepsilon) = \frac{\varDelta_r \cdot L_{we}^{0.8}}{0.0006 \left(\frac{F_r}{Z}\right)^{0.9}} \text{ ....\{kgf\}}$$

The relation between the load factor ε and $f(\varepsilon)$ and L_ε / L, when the radial internal clearance is $\varDelta_r$ is as shown in Table 15.7.
From the above equations, first obtain $f(\varepsilon)$ and then ε and L_ε / L can be obtained.

(2) Circumferential Speeds of Rolling Elements about Their Centers and Bearing Center

Table 15.6 Circumferential Speeds of Rolling Elements about Their Centers and Bearing Center

Items	Rotating inner ring, fixed outer ring	Rotating outer ring, fixed inner ring
Ball rotating speed n_a (min^{-1})	$-\left(\frac{D_{pw}}{D_w} - \frac{\cos^2\alpha}{D_{pw}/D_w}\right)\frac{n_i}{2}$	$+\left(\frac{D_{pw}}{D_w} - \frac{\cos^2\alpha}{D_{pw}/D_w}\right)\frac{n_e}{2}$
Cicumferential speed around bearing ball's center υ_a (m/sec)	$-\frac{\pi \cdot D_w}{60\times10^3}\left(\frac{D_{pw}}{D_w} - \frac{\cos^2\alpha}{D_{pw}/D_w}\right)\frac{n_i}{2}$	$+\frac{\pi \cdot D_w}{60\times10^3}\left(\frac{D_{pw}}{D_w} - \frac{\cos^2\alpha}{D_{pw}/D_w}\right)\frac{n_e}{2}$
Revolving speed around bearing center n_c (min^{-1})	$+\left(1-\frac{\cos\alpha}{D_{pw}/D_w}\right)\frac{n_i}{2}$	$+\left(1-\frac{\cos\alpha}{D_{pw}/D_w}\right)\frac{n_e}{2}$
Cicumferential speed around bearing center υ_c (m/sec)	$-\frac{\pi \cdot D_{pw}}{60\times10^3}\left(1-\frac{\cos\alpha}{D_{pw}/D_w}\right)\frac{n_i}{2}$	$+\frac{\pi \cdot D_{pw}}{60\times10^3}\left(1-\frac{\cos\alpha}{D_{pw}/D_w}\right)\frac{n_e}{2}$

Remarks 1. + sign indicates CW rotation and – sign CCW
2. The revolving speed and circumferential speed of the rolling elements are the same as those of the cage.

Table 15. 7 ε and $f(\varepsilon)$, L_ε / L

ε	Deep Groove Ball Bearings $f(\varepsilon)$	Deep Groove Ball Bearings $\frac{L_\varepsilon}{L}$	Cylindrical Roller Bearings $f(\varepsilon)$	Cylindrical Roller Bearings $\frac{L_\varepsilon}{L}$
0.1	33.713	0.294	51.315	0.220
0.2	10.221	0.546	14.500	0.469
0.3	4.045	0.737	5.539	0.691
0.4	1.408	0.889	1.887	0.870
0.5	0	1.0	0	1.0
0.6	– 0.859	1.069	– 1.133	1.075
0.7	– 1.438	1.098	– 1.897	1.096
0.8	– 1.862	1.094	– 2.455	1.065
0.9	– 2.195	1.041	– 2.929	0.968
1.0	– 2.489	0.948	– 3.453	0.805
1.25	– 3.207	0.605	– 4.934	0.378
1.5	– 3.877	0.371	– 6.387	0.196
1.67	– 4.283	0.276	– 7.335	0.133
1.8	– 4.596	0.221	– 8.082	0.100
2.0	– 5.052	0.159	– 9.187	0.067
2.5	– 6.114	0.078	–11.904	0.029
3	– 7.092	0.043	–14.570	0.015
4	– 8.874	0.017	–19.721	0.005
5	–10.489	0.008	–24.903	0.002
10	–17.148	0.001	–48.395	0.0002

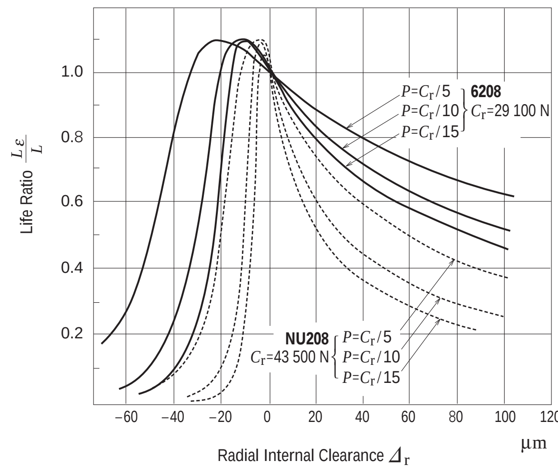


Fig. 15.13 Radial Internal Clearance and Life Ratio

15. 6 BRANDS AND PROPERTIES OF LUBRICATING GREASES

Table 15. 8 Brands of Lubricating Greases and Comparison of Properties

Brands	Thickeners	Base Oils	Dropping Point (˚C)	Consistency	Working Temperature Range(1)(°C)	Pressure Resistance	Usable Limit Compared to Listed Limiting Speed(2)(%)
ADLEX	Lithium	Mineral oil	198	300	0 to +110	Good	70
APOLOIL AUTOLEX A	Lithium	Mineral oil	198	280	−10 to +110	Fair	60
ARAPEN RB 300	Lithium/Calcium	Mineral oil	177	294	−10 to + 80	Fair	70
EA2 GREASE	Urea (3)	Poly-α-olefin oil	≧260	243	−40 to +150	Fair	100
EA3 GREASE	Urea (3)	Poly-α-olefin oil	≧260	230	−40 to +150	Fair	100
EA5 GREASE	Urea (3)	Poly-α-olefin oil	≧260	251	−40 to +160	Good	60
EA7 GREASE	Urea (3)	Poly-α-olefin oil	≧260	243	−40 to +160	Fair	100
ENC GREASE	Urea (3)	Polyol ester oil + Mineral oil (4)	≧260	262	−40 to +160	Fair	70
ENS GREASE	Urea (3)	Polyol ester oil (4)	≧260	264	−40 to +160	Poor	100
ECE GREASE	Lithium	Poly-α-olefin oil	≧260	235	−10 to +120	Fair	100
ISOFLEX NBU 15	Barium Complex	Ester oil + Mineral oil (4)	≧260	280	−30 to +120	Poor	100
ISOFLEX SUPER LDS 18	Lithium	Ester oil (4)	195	280	−50 to +110	Poor	100
ISOFLEX TOPAS NB 52	Barium Complex	Poly-α-olefin oil	≧260	280	−40 to +130	Poor	90
DOW CORNING SH 33 L GREASE	Lithium	Silicone oil (5)	210	310	−60 to +120	Poor	60
DOW CORNING SH 44 M GREASE	Lithium	Silicone oil (5)	210	260	−30 to +130	Poor	60
NS HI-LUBE	Lithium	Polyol ester oil + Diester oil (4)	192	250	−40 to +130	Fair	100
NSC GREASE	Lithium	Alkyldiphenyl ether oil + Polyol ester oil (4)	192	235	−30 to +140	Fair	70
NSK CLEAN GREASE LG2	Lithium	Poly-α-olefin oil + Mineral oil	201	199	−40 to +130	Poor	100
EMALUBE 8030	Urea (3)	Mineral oil	≧260	280	0 to +130	Good	60
MA8 GREASE	Urea (3)	Alkyldiphenyl ether oil + Poly-α-olefin oil	≧260	283	−30 to +160	Fair	70
KRYTOX GPL-524	PTFE	Perfluoropolyether oil	≧260	265	0 to +200	Fair	70
KP1 GREASE	PTFE	Perfluoropolyether oil	≧260	280	−30 to +200	Fair	60
COSMO WIDE GREASE WR No.3N	Sodium Terephtalamate	Polyol ester oil + Mineral oil (4)	≧230	227	−40 to +130	Poor	100
G-40M	Lithium	Silicone oil (5)	223	252	−30 to +130	Poor	60
SHELL GADUS S2 V220 2	Lithium	Mineral oil	187	276	0 to + 80	Good	60
SHELL ALVANIA GREASE S1	Lithium	Mineral oil	182	323	−10 to +110	Fair	70
SHELL ALVANIA GREASE S2	Lithium	Mineral oil	185	275	−10 to +110	Fair	70
SHELL ALVANIA GREASE S3	Lithium	Mineral oil	185	242	−10 to +110	Fair	70
CASSIDA GREASE RLS 2	Aluminum Complex	Poly-α-olefin oil	≧240	280	0 to +120	Fair	70
SHELL SUNLIGHT GREASE 2	Lithium	Mineral oil	200	274	−10 to +110	Fair	70
WPH GREASE	Urea (3)	Poly-α-olefin oil	259	240	−40 to +150	Fair	70
DEMNUM GREASE L-200	PTFE	Perfluoropolyether oil	≧260	280	−30 to +200	Fair	60
NIGACE WR-S	Urea (3)	Synthetic oil	≧260	230	−30 to +150	Poor	70
NIGLUBE RSH	Sodium Complex	Polyalkylene Glycol oil	≧260	270	−20 to +120	Fair	60

(continued on next page)

Notes (1) If grease will be used at the upper or lower limit sufficient of the temperature range or in a special environment such as vacuum, it is advisable to consult NSK.
(2) For short-term operation or when cooling is grease may be used at speeds exceeding the above limits provided the supply of grease is appropriate.
(3) Urea-based grease causes fluorine-based material to deteriorate.
(4) Ester-based grease causes acrylic rubber material to swell.
(5) Silicone-based grease causes silicone-based material to swell.

Brands	Thickeners	Base Oils	Dropping Point (°C)	Consistency	Working Temperature Range(1)(°C)	Pressure Resistance	Usable Limit Compared to Listed Limiting Speed(2)(%)
PALMAX RBG	Lithium Complex	Mineral oil	216	300	−10 to +130	Good	70
BEACON 325	Lithium	Diester oil (4)	190	274	−50 to +100	Poor	100
MULTEMP PS No.2	Lithium	Poly-α-olefin oil + Diester oil (4)	190	275	−50 to +110	Poor	100
MOLYKOTE FS-3451 GREASE	PTFE	Fluorosilicone oil (5)	≧260	285	0 to +180	Fair	70
UME GREASE	Urea	Mineral oil	≧260	268	−10 to +130	Fair	70
RAREMAX AF-1	Urea	Mineral oil	≧260	300	−10 to +130	Fair	70

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