1. Basic Structure and Types of Rolling Bearing

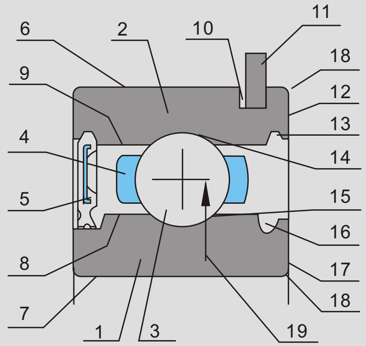
1. 1 Bearing Terms of Rolling Bearing Structure

Radial bearing
Basic terms of radial bearing structure are shown in Fig. 1.1
Thrust bearing
Basic terms of thrust bearing structure are shown in Fig. 1.2
Bearing installment
Basic terms for bearing installment are shown in Fig 1.3

Radial bearing

1. Inner ring
2. Outer ring
3. Rolling element(steel ball, cylindrical roller, needle roller, taper roller, spherical roller)
4. Cage
5. Seal(dustproof) fixture(Including seal ring and shield cover)
6. Outer diameter
7. Inner diameter
8. Outer diameter (flange) of inner ring

Fig1. 1a



Radial bearing

9. Inner diameter (flange)of outer ring
10. Snap groove
11. Snap ring
12. Outer face
13. Seal (dustproof)groove
14. Raceway of outer ring
15. Raceway of inner ring
16. Seal (dustproof)groove
17. Inner face
18. Assembling corner
19. Average diameter of bearing
20. Assembling height
21. Direction flange
22. Flange
23. Contact Angular

Fig1. 1b

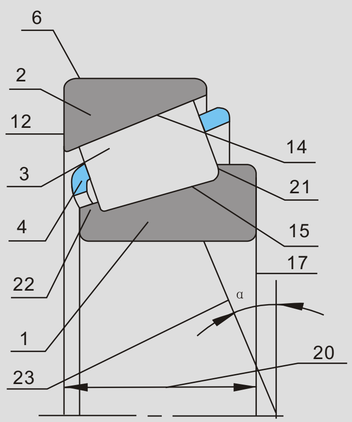
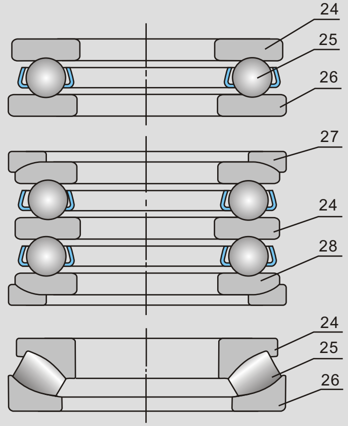


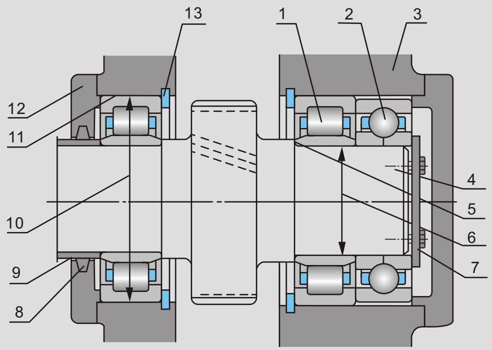
Fig1. 2



Thrust Bearing

24. Shaft washer
25. Rolling element-cage assembly
26. Housing washer
27. Aligning seat washer
28. Aligning housing washer

Fig1. 3



Bearing configure

1. Cylindrical roller bearing
2. Four-point contact ball bearing
3. House
4. Shaft
5. Shaft shoulder
6. Shaft journal
7. Lock plate
8. Radial shaft seal
9. Space ring
10. Aperture
11. House hole
12. Cover
13. Snap ring

1.2 Rolling Bearing Structure

Basic structures of rolling bearing consist of inner ring, outer ring, rolling element and cage.

1.2.1 Structure type of rolling bearing

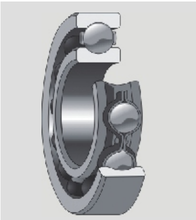
1.2.1.1 As per the shape of rolling element:
- Ball bearing (Figl.4.1)
- Roller bearing (Figl.4.7)

1.2.1.2 As per load direction:
- Radial bearing (Figl.4.1)
- Thrust bearing (Fig.l .4.3)

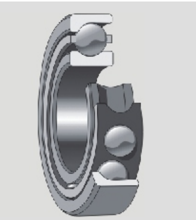
1.2.1.3 As per structure type:
- Deep groove ball bearing (Figl.4.5)
- Self-aligning ball bearing (Figl.4.6)
- Cylindrical roller bearing(Figl.4.7)
- Spherical roller bearing (Figl.4.8)
- Needle roller bearing (Figl.4.9)
- Angular contact ball bearing (Fig.l .4,10)
- Taper roller bearing (Figl.4.11)
- Thrust ball bearing (Fig.l .4.12)
- Thrust roller bearing (Fig.l .4.13)

1.2.1.4 As per the rows of rolling element
- Single row (Fig1.4.14)
- Double-row (Fig1.4.15)
- Multi-row (Fig1.4.16)

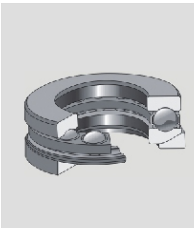
1.2.1.5 As per the component separability
- Separable bearing (Fig1.4.7)
- Non-separable bearing (Fig1.4.1)



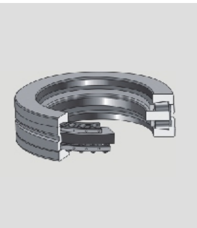
Radial Bearing
Fig1. 4. 1



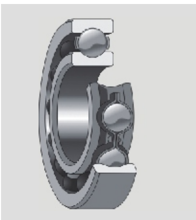
Angular Contact Radial Bearing
Fig1. 4. 2



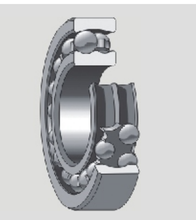
Thrust Bearing
Fig1. 4. 3



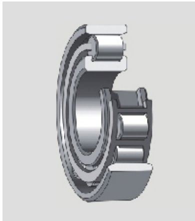
Angular Contact Thrust Bearing
Fig1. 4. 4



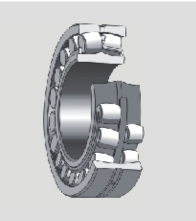
Deep Groove Ball Bearing
Fig1. 4. 5



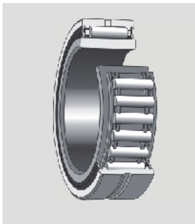
Self-aligning Ball Bearing
Fig1. 4. 6



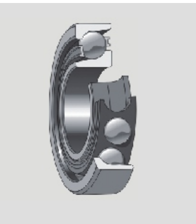
Cylindrical Roller Bearing
Fig1. 4. 7



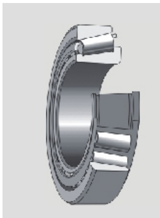
Spherical Roller Bearing
Fig1. 4. 8



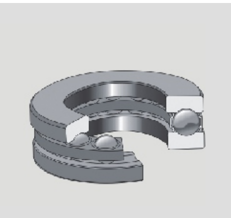
Needle Roller Bearing
Fig1. 4. 9



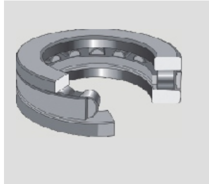
Angular Contact Ball Bearing
Fig1. 4. 10



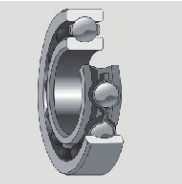
Taper Roller Bearing
Fig1. 4. 11



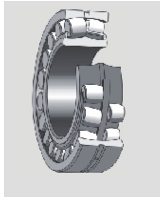
Thrust Ball Bearing
Fig1.4. 12



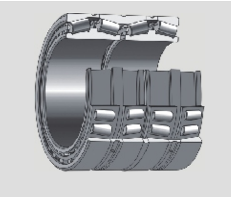
Thrust Roller Bearing
Fig1. 4. 13



Single Row Bearing
Fig1. 4. 14



Double-row Bearing
Fig1. 4. 15



Multi-row Bearing
Fig1. 4. 16

Additionally, some bearings with special structures are designed to meet special requirements of certain machinery application, such as railway bearing, hub bearing, rolling mill bearing, ball screw, linear bearing, bearing without a inner ring or outer ring, bearing with shield cover or seals, split outer ring or split inner ring bearing, and integrated split bearing etc.

Basic structures of LYC bearing as Fig1.5 showing.

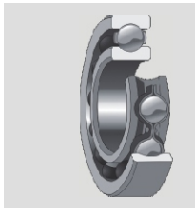


Fig1. 5. 1

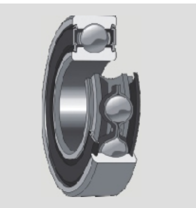


Fig1. 5. 2

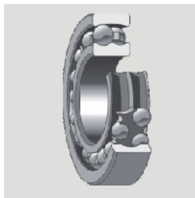
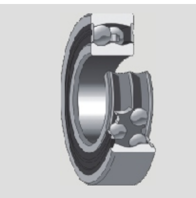


Fig1. 5. 3



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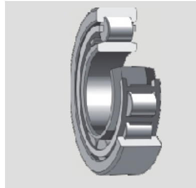

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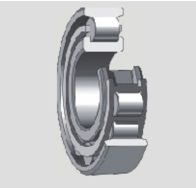

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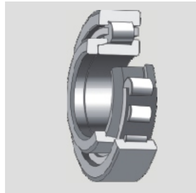

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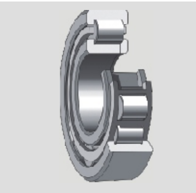

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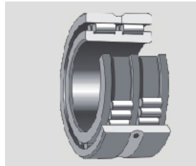

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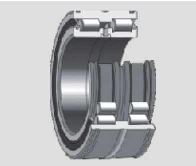

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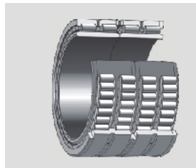
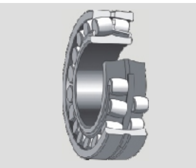


Fig1. 5. 11



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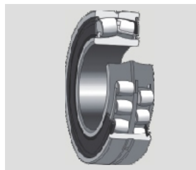

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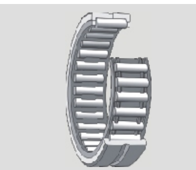

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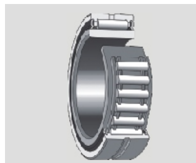

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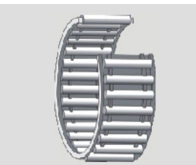

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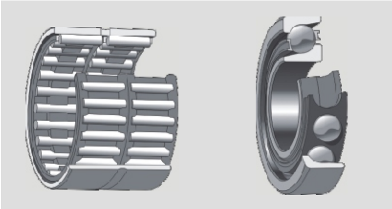


Fig1. 5. 17 Fig1. 5. 18

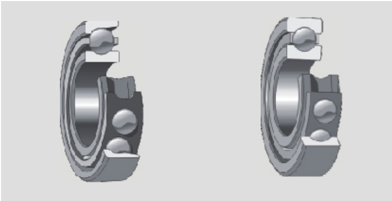
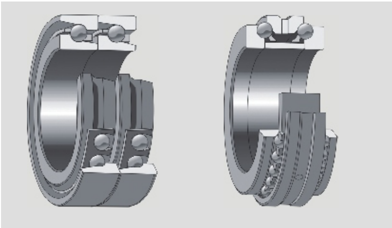


Fig1. 5. 19 Fig1. 5. 20



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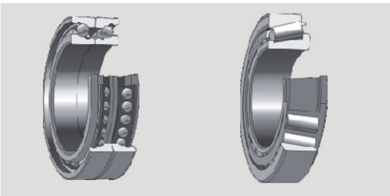


Fig1. 5. 23 Fig1. 5. 24

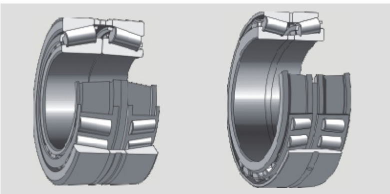


Fig1. 5. 25 Fig1. 5. 26

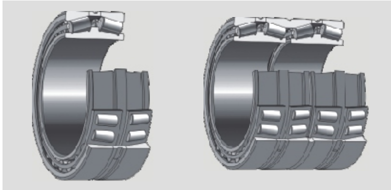


Fig1. 5. 27 Fig1. 5. 28

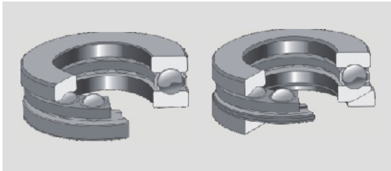


Fig1. 5. 29 Fig1. 5. 30

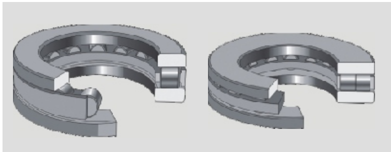


Fig1. 5. 31 Fig1. 5. 32

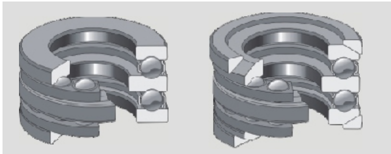


Fig1. 5. 33 Fig1. 5. 34

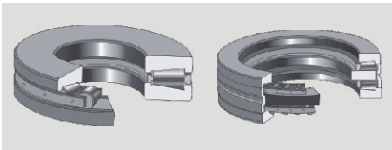


Fig1. 5. 35 Fig1. 5. 36

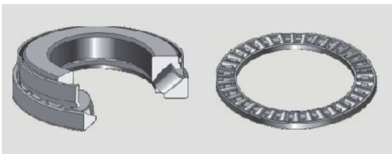


Fig1. 5. 37 Fig1. 5. 38

2. LYC Bearing Designations

2.1 LYC Standard Bearing Designations

LYC's standard bearing designations meet Chinese bearing standard of GB/T272 <Rolling Bearing, Designation Method> and JB/T2974 <Rolling Bearing, Supplementary Rules of Designation Method>

LYC bearing designations consist of the prefix, the bearing basic designation and the suffix.

2.1.1 Basic Designations

The basic designations consist of an identification code of the bearing type, the dimensional series code and the bore diameter code.

Identification code of bearing type is listed in Table 2.1.

The dimensional series code is listed in Table 2.2.

The bore diameter code is listed in Table 2.3.

Table 2. 1

Code	Bearing Type	Code	Bearing Type
0	Double-row angular contact ball bearings	6	Deep groove ball bearings
1	Self-aligning ball bearings	7	Angular contact ball bearings
2	Spherical roller bearings and spherical roller thrust bearings	8	Cylindrical roller thrust bearings
3	Single row taper roller bearings	9	Tapered roller thrust bearings
4	Double-row deep groove ball bearings	N	Cylindrical roller bearings
35	Double-row taper roller bearings	NN	Double-row or multi-row cylindrical roller bearings
38	Four-row tapered roller bearings	QJ	Four-point contact ball bearings
5	Thrust ball bearings		
56	Angular contact thrust ball bearings		

Table 2. 2

Diameter Series Code	Radial Bearing								Thrust Bearing			
	Width Series Code								Height Series Code			
	8	0	1	2	3	4	5	6	7	9	1	2
	Dimensional Series Code											
7	-	-	17	-	37	-	-	-	-	-	-	-
8	-	08	18	28	38	48	58	68	-	-	-	-
9	-	09	19	29	39	49	59	69	-	-	-	-
0	-	00	10	20	30	40	50	60	70	90	10	-
1	-	01	11	21	31	41	51	61	71	91	11	-
2	82	02	12	22	32	42	52	62	72	92	12	22
3	83	03	13	23	33	-	-	-	73	93	13	23
4	-	04	-	24	-	-	-	-	74	94	14	24
5	-	-	-	-	-	-	-	-	-	95	-	-

Table 2. 3

Nominal Bore Diameter (mm)		Bore Diameter Code	Example
0.6 to 10(non-integer)		Directly indicated by the millimeters of nominal bore diameter, separated with dimensional series code by "/"	Deep groove ball bearings 618/2.5 d=2.5mm
1 to 9(integer)		Directly indicated by the millimeters of nominal bore diameter, for the diameter series 7,8,9 of deep groove ball bearings, bore diameter is separated with dimensional series code by "/"	Deep groove ball bearings618/5 d=5 mm
10 to 17	10 12 15 17	00 01 02 03	Deep groove ball bearings 6200 d=10mm
20 to 480 (except 22,28,32)		Indicated by the quotient of dividing bore diameter by 5, if the quotient is single-digit, then add "0" on the left of quotient, e.g. 08	Spherical roller bearings 23208 d=40mm
Equal to or greater than 500, and 22,28,32		Directly indicated by the millimeters of nominal bore diameter, but separated with dimensional series code by "/"	Spherical roller bearings 230/500 d=500mm

Example: cylindrical roller bearing N2210
N- Identification code of the bearing type
22 - dimensional series code
10 - bore diameter code

2.1.2 Prefix Code

The most common used prefix codes in LYC's bearing code system are listed and explained as follows:

L Removable inner or outer ring for a separable bearing
R Bearing without removable inner or outer ring (only suitable for needle roller bearings of type NA)
K Roller and cage assembly
WS Shaft washer of a cylindrical roller thrust bearing
GS Housing washer of a cylindrical roller thrust bearing
KOW Thrust bearing without shaft washer
KIW Thrust bearing without housing washer
LR Bearing with removable inner ring or outer ring and rolling elements assembly

2.1.3 Suffix Code

- **Internal Design**

A, B, C, D, E

1) Deviating or modified internal design
2) Standard type, the design contents can be altered according to different bearing structures, in which:

B indicated nominal contact angle α =40° for angular contact ball bearings; and it indicates the increased contact angle for taper roller bearings;
C indicated nominal contact angle α =15° for angular contact ball bearings;

AC Nominal contact angle α =25° for angular contact ball bearings;
D Split bearings
ZW Needle roller cage assembly, double row

- **Codes of Seals, Shields and External Designs**

K Tapered bore taper 1:12 on diameter
K30 Tapered bore, taper 1:30 on diameter
-2K Double-row tapered bore bearing, taper 1:12 on diameter
R Bearing with flanged outer ring
N Bearing with snap ring groove in outer ring
N1 Bearing with a locating notch in outer ring
N2 Bearing with two or more symmetrical locating notch in outer ring
N4 N+N2, locating notch and snap ring groove are not in the same side
N6 N+N2, locating notch and snap ring groove are in the same side
NR Bearing with snap ring groove in outer ring and snap ring
-RS Embedded case rubber seal at one side of the bearing (contact seal)
-2RS Embedded case rubber seals at both sides of the bearing (contact seal)
-RZ Embedded case rubber seal at one side of the bearing (non-contact seal)
-2RZ Embedded case rubber seals at both sides of the bearing (non-contact seal)
-Z Bearing with shield at one side
-2Z Bearing with shields at both sides
-RSZ Bearing with embedded case rubber seal at one side (contact seal) and shield at the other side
-RZZ Bearing with embedded case rubber seal at one side (non-contact seal) and shield at the other side
-ZN Bearing with shield at one side and snap ring groove at the other side in outer ring
-ZNR Bearing with shield at one side and snap ring groove and snap ring at the other side in outer ring
-ZNB Bearing with shield at one side and snap ring groove at the same side in outer ring
-2ZN Bearing with shields at both sides and snap ring grooves in outer ring
-FS Bearing with felt ring seal at one side
-2FS Bearing with felt ring seals at both sides
-LS Embedded case rubber seal at one side of the bearing (contact seal, without grooves in bearing rings)
-2LS Embedded case rubber seals at both sides of the bearing (contact seal, without grooves in bearing rings)
DC Double-row angular contact ball bearing, double outer rings
D1 Double-row taper roller bearing, without inner spacer, end face polishing
DH One-way thrust bearing with two housing washers
DS One-way thrust bearing with two shaft washers
P Spherical roller bearing with double split outer rings
PR Spherical roller bearing with double split outer rings, spacer ring between the two split outer rings
S 1)Bearing outer ring with spherical surface (except spherical ball bearings)
2) Adjustable clearance (needle roller bearings)
WB Bearing with extended inner ring (double width): WBI single width
WC Bearing with extended outer ring
SC Radial bearing in shell
Z 1) Needle roller combination bearing with shield cover
2) Needle roller and full thrust ball combination bearing in shell (grease lubrication)
ZH Thrust bearing, housing ring with shield cover
ZS Thrust bearing, shaft ring with shield cover
U Thrust ball bearing with spherical washer

- **Bearing Components Materials**

/HE Rings, rolling elements and cages, or only rings and rolling elements, made of electroslag refining bearing steel ZGCr15, ZGCr15SiMn
/HA Rings, rolling elements and cages, or only rings and rolling elements, made of vacuum arc-melted steel
/HU Rings, rolling elements and cages, or only rings and rolling elements, made of unable hardening stainless steel 1Cr18Ni9Ti
/HV Rings, rolling elements and cages, or only rings and rolling elements, made of hardening stainless steel (/HV-9Cr18;/Hv1-9Cr18Mo)
/HN Rings and rolling elements, made of heat-resisting bearing steel (/HN-Cr4Mo4V; /HN1-Cr14Mo4; /HN2-Cr15Mo4V; /Hn3-W18Cr4V)
/HC Rings, rolling elements, or only rings, made of carburized steel (/HC-20Cr2Ni4A; /HC1-20Cr2Mn2MoA; /HC2-15Mn)
/HP Rings and rolling elements, made of beryllium bronze or other anti-magnetic materials
/HQ Rings and rolling elements, made of seldom used materials (/HQ-plastic; /Hq1-ceramal)
/HG Rings, rolling elements, or only rings, made of other bearing steel (/HG-5CrMnMo; /HG1-55SiMoA)
/CS Bearing components are made of carbon steel
F Solid cage made of steel, nodular cast iron or power metallurgy (F1-carbon steel; F2-graphite steel; F3-nodular cast iron; F4V power metallurgy)
Q Bronze solid cage (Q1-ferro-aluminium manganese bronze; Q2-ferro-silicon zinc bronze; Q3-nichrome silicon bronze; Q4-aluminium bronze)
M Brass solid cage
L Light alloy solid cage (L1-LY11CZ; L2-LY12CZ)
T Phenolic pressure piping solid cage
TH Glass-fiber-reinforced phenols resin cage (basket type)
TN Molded cage with engineering plastic (TN1-nylon; TN2-polysulfone; TN3-polyimide; TN4-polycarbonate; Tn5-polyformaldehyde)
J Pressed steel plate cage
Y Pressed brass plate cage
SZ Cage is made of spring steel wire or spring plate
ZA Zinc-aluminum cage
V Full complement bearing(without cage)

- **Tolerance and Clearance**

/P0 Tolerance class conforms to standard group 0, not shown in the bearing code
/P6 Tolerance class conforms to standard group 6
/P6x Tolerance class conforms to standard group 6x
/P5 Tolerance class conforms to standard group 5
/P4 Tolerance class conforms to standard group 4
/P2 Tolerance class conforms to standard group 2
/SP Dimensional precision equal to class P5, rotation precision equal to class P4
/UP Dimensional precision equal to class
/UP Tolerance class conforms to standard P4, rotation precision is above class P4
/CM Internal clearance of deep groove ball bearing for electric motor
/C0 Internal clearance conforms to standard group 0, not shown in the bearing code
/C1 Internal clearance conforms to standard group 1
/C2 Internal clearance conforms to standard group 2
/C3 Internal clearance conforms to standard group 3
/C4 Internal clearance conforms to standard group 4
/C5 Internal clearance conforms to standard group 5
/CM Internal clearance of deep groove ball hearing for electric motor

/C9 Bearing internal clearance differs from the present standard

When tolerance and clearance need to be indicated simultaneously, it can be simply shown as /P3, P43 etc, in which /P3 indicates bearing tolerance class P3 and radial clearance of basic group (group 0), /P43 means bearing tolerance class P4 and radial clearance of group 3.

• Codes of Dimensional Series

XI Outer diameter non-standard

X2 Width (assembling height) non-standard

X3 Outer diameter and width (assembling height) non-standard (inner diameter standard)

• Codes of Bearing Configuration

/DB Back-to-back arrangement

/DF Face-to- face arrangement

/DT Tandem arrangement

• Other Codes of Bearing Features

/Z Limited values of the vibration acceleration level, Ire additional figures indicate the different limited values, asZl,Z2, Z3

/V Limited values of the vibration speed level, the additional figures express the different values, as VI, V2,V3

/SO The bearing ring are high-tempered through heat treatment, and the operating high temperature is up to 150℃

/SI The bearing rings are high-tempered through heat treatment, and the operating high temperature is up to 200℃

/S2 The bearing ring are high-tempered through heat treatment, and the operating high temperature is up to 250℃

/S3 The bearing ring are high-tempered through heat treatment, and the operating high temperature is up to 300℃

/S4 The bearing ring are high-tempered through heat treatment, and the operating high temperature is up to 350℃

/W20 The bearing with three lubrication holes in outer ring

/W26 The bearing with six lubrication holes in outer ring

/W33 The bearing with a lubrication groove and three lubrication holes in outer ring

/W33X The bearing with three lubrication holes and six lubrication holes in outer ring

/AS The bearing with lubrication holes in outer ring, the additional figure shows the numbers of oil hole (used for needle roller bearings)

/IS The bearing with lubrication holes hi inner ring, the additional figure shows the numbers of oil hole (used for needle roller bearings)

When R is added behind AS, IS, they respectively express the inner ring or outer ring with a lubrication hole and groove

/HT The bearing is filled with special grease for high temperature, grease quantities which differ from the standard filling are identified by an additional letter:

A-grease quantity is less than standard filling

B-grease quantity is more than standard filling

C-full quantity of grease

/LT Bearing with the special grease for lower temperature

/MT Bearing with die special grease for medium temperature

/LTH Bearing with the special grease for lower or high temperature

/LHT Bearing with the grease for lower or higher temperature, the additional letter is the same meaning as HT

/Y Combinations of the letter Y with another letter or figure can identify differences from the standard design which are not concluded by other established suffixes

/YA Modification of structures (comprehensive expression)

/YB Alteration of specifications (comprehensive Expression)

Note: If suffix Y with another letter or additional figure are presented hi bearing designations, the product drawings or the supplementary specifications must be looked up from the LYC design department to indentify more information.

2.2 LYC Special Bearing Code

LYC' s standard bearing designations should meet most bearings with standard structure and boundary dimension, but, it is still difficult to attain some individual requirement of special structure or boundary dimension due to the diversity of bearing structures and extensive applications. For this reason, LYC make up special bearing codes to meet the requirement in this part of the bearings. LYC special bearing code consists of our designation "LY", "-" and "serial-number of bearing type", hi which the first letter (or Figure) in the serial number of bearing type symbolizes the code of bearing type, shown in Table 2.1.
The last three Figures constitute the serial number of the bearing. Serial number indicates the sequences of bearing design and manufacture.

e.g. 1:LY-6008
LY-(LYC company code)
6- Bearing series number (deep groove ball bearing)
008- The eighth special bearing designed and produced by LYC in deep groove ball bearing
e.g.2:LY-N1012
LY-(LYC company code)
N- Bearing series number (cylindrical roller bearing)
012-The twelfth special bearing designed and produced by LYC in cylindrical roller bearing.

3. Selection of Bearing Type

It is extremely important to select the correct bearing for the duty that is expected of it, eg: life expectancy and service intervals. You will see within this catalog there are many complex bearing structures that can be applied to an array of various applications. The applications and performance of various bearings are explained; these explanations are only a generalization. For absolute assurance of the correct bearing selection customers should contact the LYC Technical Department for their expertise in bearing selection. The LYC technical staff will request a detailed amount of information regarding the application before they will make a recommendation. Based on many practical experiences of bearing application, theory analysis and research, LYC's technical department suggests: when selecting bearing types or structures, the customer should make comprehensive analysis according to the following aspects, weigh up the pros and cons, choose the bearing type suited to your application.

- Available space
- Bearing load
- Aligning capacity
- Turning speed
- Turning precision
- Stiffness
- Noise and vibration
- Axial displacement
- Frictional moment
- Mounting and dismounting

Besides, additional factors like bearing load capacity, internal clearance, life rating, reliability, preload, lubrication, seal as well as source cost and delivery on-time should be taken into account.

3.1 Available Space

Internal dimension is one of the main principles for bearing selection. During the machinery design, journal dimension is one of the first confirmed parameters through the methods of theoretical calculation or analogy.
Selection of the bearing is always according to the diameter of shaft. Ball bearing or thrust ball bearing can be selected for small diameter shaft, which, usually apply for low load status. Cylindrical bearing, taper roller bearing or spherical roller bearing can be selected for a heavy load or safety consideration.
Normally, the bearing's available space in machinery can be limited. If radial space is limited, the bearing with small radial cross section should be selected (Fig 3.1) such as the kinds of bearings with a diameter series 7, 8, 9. If axial space is limited, the bearing with small axial cross section should be selected (Fig 3.2) such as all kinds of bearings with width series 8, 0, 7, 9.

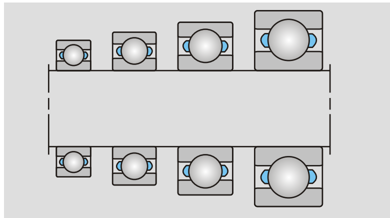


Fig3. 1

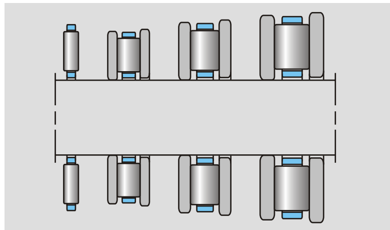


Fig3. 2

3.2 Bearing Load

3.2.1 Load Strength

Load strength on the bearing is very important for bearing selection. Generally speaking, roller bearings can carry heavier loads than ball bearings when with the same boundary dimension, similarly cageless rolling bearings carry heavier loads than bearings with cages. Therefore, ball bearings are fit for low and medium loads, and roller bearings are fit for heavy loads.

3.2.2 Load Direction

When the bearings carry pure radial load, radial bearings should be selected, such as deep groove

ball bearing, cylindrical roller bearing and needle roller bearing etc., shown as Fig 3.3a.
When the bearing carries pure axial load, thrust bearings should be selected, such as thrust ball bearing, cylindrical roller thrust bearing or needle roller thrust bearing etc., shown as Fig 3.3b.
When bearings carry radial and axial (combined loads) , angular contact bearings are generally selected. If the radial load is larger and axial load is smaller, then the angular contact radial bearing should be selected, such as angular contact ball bearing. If the radial load is smaller than axial load in the combined load, then an angular contact thrust bearing should be selected, such as the angular contact thrust ball bearing, shown as Fig 3.3c.
When the load acts eccentrically on the bearing, tilting moments will arise. If moment load is not large, the single row angular contact ball bearings in pair arranged face-to-face or back-to-back as well as single-row taper roller bearings would be more suitable (Fig 3.3d). But, for some larger machinery or an application carrying a large tilting moment, such as crane, mineral machinery,

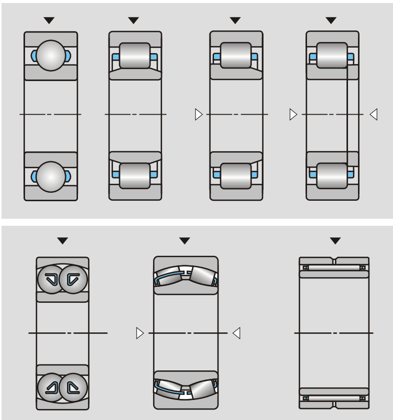


Fig3. 3a

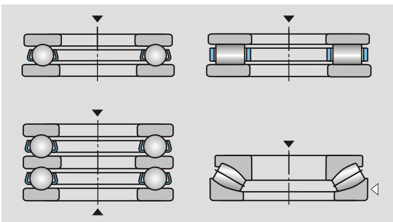


Fig3. 3b

antenna base for radar, rocket launcher etc., then a slewing bearings would be more suitable. Information about slewing bearing can be found in the catalog of <LYC Slewing Bearings>.

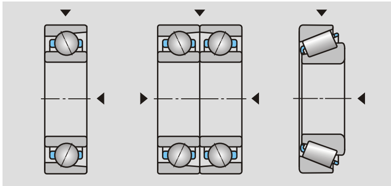


Fig3. 3c

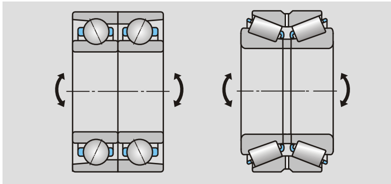


Fig3. 3d

3.3 Aligning Capacity

In normal applications, the shaft deflection would occur due to load, or mounting errors, or components deviation in production, that will make the inner ring and outer ring slant (Fig 3.4) and cause uneven loads on the bearing raceway and generate excessive loads. Severe cases will cause stress concentration, and result in early failure. Therefore, aligning capacity should be considered when selecting bearings.
The bearing deflection within the allowed angle error will not influence the normal working of the bearing; allowed angle error for all kinds of bearing are listed in the Table 3.1.
When selecting bearings, self-aligning ball bearing, spherical roller bearing or thrust spherical roller bearing, pillow block bearing could be selected for the larger deflection situation. The allowed angle errors for self-aligning ball bearing and spherical roller bearing are shown in Table 3.2.

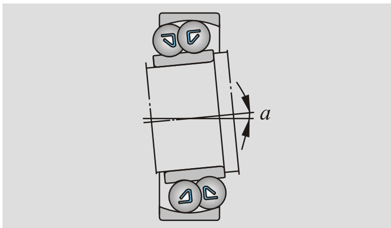


Fig3. 4

Table3. 1

Bearing Type	Angle error allowed
Deep groove ball bearing (clearance group 0)	8'
Deep groove ball bearing (clearance group 3)	12'
Deep groove ball bearing (clearance group 4)	16'
Cylindrical roller bearing (N,NU series)	4'
Cylindrical roller bearing (Other series)	2'
Single row taper roller bearing	2'

Table3. 2

Self-aligning ball bearing		Spherical roller bearing	
Dimension series	Angle error allowed	Dimension series	Angle error allowed
12	2.5°	213	1°
13	3°	222	1.5°
14	3°	223	2°
22	2.5°	230	1.5°
23	3°	231	1.5°
		232	2.5°
		239	1.5°
		240	2°
		241	2.5°

3.4 Turning Speed

The speed will have little influence on the bearing selection when working under the medium and low speed(less than 0.5 times of limiting speed).
However, turning speed must be considered in the case of the higher speed, because the inertia force from rolling elements and cages will have large effect on the load distribution, temperature, and vibration etc. under high speed.
The highest speed of bearing is limited, which is the so-called "limiting speed". "Limiting speed" depends on the working temperature of the bearing, which, depends on the various factors such as structure, material, dimension, precision, clearance, load, lubrication, heat dispersion of the bearing, and cage structure, material, and guiding method etc.
Generally speaking, friction coefficient of ball bearing is lower than that of roller bearing, so the limiting speed of ball bearings are higher than that of roller bearings. The speed of thrust bearing is lower than a radial bearing due to the restriction of the structure. When deep groove ball bearings and cylindrical roller bearings carry pure radial load, they are suitable for high speed applications.
While the single-row angular contact ball bearing carry combined load, it can operate well at high speed.
Additionally, if customers require bearings with higher speed than the limiting speed in the dimension list of LYC catalogue, then please consult the technical department of LYC.

3.5 Running Accuracy

Running accuracy of the bearing is not only related to the parameters of structure, producing precision, clearance and stiffness of bearings, but also related to the supporting structure, material, stiffness, manufacture precision and mounting precision. Therefore, the selection of bearing precision should be considered from both aspects of bearing manufacture and application.
In view of bearing manufacture, all kinds of bearings with normal precision could meet the requirements of most bearing applications. When part of the machinery require strict running accuracy, such as machine tool spindles or high speed shaft applications and the condition of high maintenance and with high reliability, the precision bearings must be selected to satisfy this requirement.
LYC technical department reminds customers: when selecting precision bearings, the manufacturing and mounting precision and rigidity of matched shaft and bearing housing bore should be improved, otherwise, precision bearing would not play its function.
The precision tolerances of all kinds of LYC's bearings are shown in the part of 'General Data' in this catalogue.

3.6 Stiffness

Bearing stiffness refers to the elastic deformation generated from the contacting position of the bearing rings and rolling elements, its deformation degree is also called stiffness. Normally, the elastic deformation of bearing is very small, therefore, it could be ignored in most situations. However, the elastic deformation is of significance in some applications, e.g. machine tool spindle bearing, the requirement of bearing stiffness should have detailed investigation.
Generally, because of the contact conditions between rolling elements and raceways are linear in theory, the roller bearing such as cylindrical roller bearings and taper roller bearings have greater stiffness than theoretical point contact ball bearings.
The stiffness can be enhanced by preloading, but, the preloading amount should be controlled. Suitable preload can improve bearing precision and fatigue life. However, if preloading amount exceeds an optimum value, then the bearing stiffness has increased little; conversely, it will

have destroyed influence on the bearing operation, such as bearing friction and abrasion increasing, the temperature.
The stiffness of the angular contact bearing can be realized by different bearing configuration.

3.7 Noise and Vibration

Bearings can make sounds during their operation. This is the result of vibration, sounds can be classified into acceptable sounds and noise. Acceptable sounds are generated by the rolling of rolling elements on the raceway and are smooth and continuous. However, noise is resulted from a number of abnormal conditions, such as bad component contacts or pore lubrication, foreign matter invasion, damage of bearing working surfaces, dimension error etc., these sounds have characteristics of discontinuity, or regularity, or vibration.
In some applications, such as household appliances, medical appliance, office equipment etc., noise and vibration must be strictly controlled. However, the sounds and vibration of the bearings used for general application are much lower than that of the matched parts, so it is not necessary to control.
Then testing for bearings noise needs to be evaluated. Noise control is usually ensured by testing the vibration value of bearings.
LYC can supply all groups of low-noise bearings.

3.8 Axial Displacement

The turning shaft adopts double support in machinery. Two supports are used for confining radial displacement, while there are three methods to restrict the axial displacement, i.e. support with both ends fixed, one end fixed but the other free and both ends freely.
Bearings used in the fixed end applications are called fixed end bearing. These require to be in an axial location (except where the axial displacement results from the clearance).
Bearings which carry combined load or supply axial orientation together with another bearing such as deep groove ball bearing, angular contact ball bearing, self-aligning (spherical roller) bearing etc. is best suited to be a fixed end bearing.
Bearings used in free end are called wandering end bearing, which, can allow the shaft to displace axially. For example, as the thermal expansion of shaft, the length of shaft will become longer, but, the bearing will not carry exceeding load or jam for this reason through a certain axial displacement.
Needle roller bearing or N, NU series of cylindrical best choice. The NJ series of cylindrical roller bearing can also be used as wandering end bearing. When a shaft needs a larger axial displacement, the clearance fit could be taken into consideration, but, the fit surface should be appropriately lubricated.
If a deep groove ball bearing, self-aligning (spherical roller) bearing must be adopted as wandering end bearing, clearance fit could be considered, but, the fit surface should he appropriately lubricated.

3.9 Fricitional Moment

Friction happens when the bearing running. The frictional force depends on several factors, such as the bearing type, dimension, load, running speed, characteristics of lubricants and lubrication amount.
The summation of all kinds of frictions within bearing could be measured by friction moment In general, frictional resistance of ball bearings is smaller than that of roller bearings. When bearings carry pure radial load, the friction moment of thrust ball bearings is smaller. When bearings carry pure axial load, the friction moment of thrust ball hearings is smaller also. Angular contact bearings, whose load angle is almost the same with contact angle, have the smallest friction moment under the combined load. The relationship of load angle B and contact angle α is shown in Fig. 3.5.
Deep groove ball bearings and cylindrical roller bearings should be a priority selection, when customers need low friction moment bearings. If sealed bearings need to be used in low friction moment, contact sealed bearings should not be selected. All kinds of sealed bearings can be selected in the case of low frictional moment, but It is necessary to notice that bearings with rubbing seal should be avoid.
The feature and volume of lubricant has a certain influence on friction moment, it is suggested to adopt low viscosity (or low consistence) lubricant hi the low friction moment application. Drop lubrication, oil jet lubrication and oil mist lubrication are recommended when using oil lubrication.

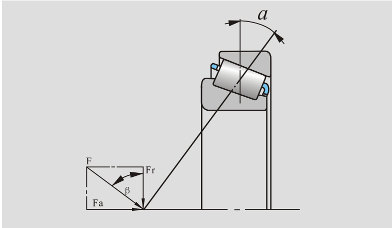


Fig3. 5

3.10 Mounting and Dismounting

- **Cylindrical Bore**

Separable bearings with cylindrical bore, such as angular contact ball bearings, cylindrical roller bearings, needle roller hearings, taper roller bearing and thrust bearings etc., can be mounted on the shaft or into the housing bore independently. If mounting and dismounting are required often hi bearing applications, the bearings mentioned above should be priority selection.

- **Tapered Bore**

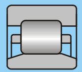
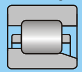
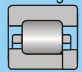
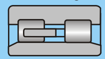
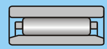
Bearings with tapered bore can be mounted directly on the journal and can be easily mounted on a cylindrical shaft with appropriate adapter or withdrawal sleeve. Self-aligning ball bearings, spherical roller bearings or double row cylindrical roller bearings with tapered bore should be selected.
Bearings with tapered bore also have an effect of adjusting the radial clearance. General selection of bearing type is shown hi Table 3.3.

Table 3. 3

Characteristic \ Bearing Type	Deep Groove Ball Bearings	Angular Contact Ball Bearings	Paired Angular Contact Ball Bearings	Self-aligning Ball Bearings
Load capacity (Radial load / Axial load)				
Speed performance	△△△△[1]	△△△△	△△△	△△
Running accuracy	△△△	△△△	△△△	
Noise and vibration	△△△△	△△△	△	
Frictional moment	△△△△	△△△	△△	△
Stiffness			△△	
Vibration and impact resistance				▲[1]
Deflection allowed for inner ring and outer ring	△			△△△
Aligning performance				☆[2]
Separability of inner ring and outer ring				
Tapered bore of inner ring				☆
Axial fixation	◎[3]	○[3]	◎DB、DF Assembled	◎
Axial movement	○		○DB Assembled	○

Note: 1)The more the symbols△are , the better the features are; symbol▲means unavailable.
2) Symbol☆means applicable.
3) Symbol◎: could make axial bidirectional movement;
Symbol○ : could only move along one direction (axial movement) .

Add table 3. 3

Cylindrical Roller Bearings 	Single Flanged Cylindrical Roller Bearings 	Double Flanged Cylindrical Roller Bearings 	Double-row Cylindrical Roller Bearings 	Needle Roller Bearings 
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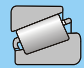
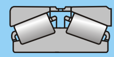
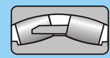
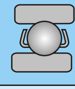
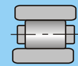
Tapered Roller Bearing 	Two Row, Four Row Tapered Roller Bearings 	Spherical Roller Bearings 	Thrust Ball Bearings 	Thrust Roller Bearings 
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4. Selection of Bearing Size

Selection of bearing sizes is confirmed according to the requirement of bearing load, life and reliability. The bearing basic load rating could be used for calculating the required bearing size when selecting bearing size. For rotating bearing, basic dynamic load rating could be used for calculation. Low speed or static bearing can be calculated according to basic static load rating. Beside, the basic load rating is an important parameter for calculation of bearing life. Dynamic (static) load rating of each size could be found in the dimension table of this catalogue.

4.1 General Definition

4.1.1 Life and Reliability

The life of a single roller bearing means revolutions of one bearing ring (or washer) toward another ring (or washer) before the first fatigue expanding indication appeared on one bearing (or washer) or material of rolling elements.
The bearing reliability refers to the percentages of the bearings, which is up to or exceeding specified life, in a similar group of rolling bearings running under the same condition.

4.1.2 Basic Rating Life

Basic rating life is the life of an individual rolling bearing or a similar group of rolling bearings, which is related with 90% reliability, common used material and processing quality, and normal operating condition. Usually, bearing life refers to the basic rating life of rolling bearings without special instruction.

4.1.3 Basic Dynamic Load Rating

• Basic Dynamic Radial Load Rating

Basic dynamic radial load rating is the constant radial load theoretically carried by a piece of rolling bearing. The basic load rating of bearing is one million revolutions under this load.
For single row angular contact bearings, the load refers to the radial component of the load resulted in the pure radial displacement between the bearing rings.

• Basic Dynamic Axial Load Rating

Basic dynamic axial load rating is the constant central axial load theoretically carried by a piece of rolling bearing. The basic load rating of bearing is one million revolutions under this load.

4.1.4 Basic Static Load Rating

• Static Load

Static load means the load acting on the bearing when the relative speed of the bearing rings is zero (or extremely low)

• Basic Static Radial Load Rating

Basic static radial load rating means a central radial static load equivalent to the following computed stress generated on the contact centre of the rolling elements and raceway under the maximum load.

Self-aligning ball bearings	4600MPa
Other types of radial bearings	4200MPa
Radial roller bearings	4000MPa

For single row angular contact bearings, the load refers to the radial component of the load resulting in the pure radial displacement between the bearing rings.

• Basic Static Axial Load Rating

Basic static axial load rating means a central axial static load equivalent to the following computed stress generated on the contact centre of the rolling elements and raceway under the maximum load.

Thrust ball bearings	4200MPa
Thrust roller bearings	4000MPa

4.1.5 Equivalent Load

• Equivalent Dynamic Load

Radial (axial) equivalent dynamic load is a constant radial (central axial) load, under which rolling bearings have the same life as that under the actual load.

• Equivalent Static Load

Radial (axial) equivalent static load means radial (central axial) static load, which is the same with the contact stress under the actual load, generated from the contact centre of the rolling elements and raceway under the maximum load.

4.1.6 Bearing Life

Practice proves that rolling bearings have the characteristics of randomicity and discreteness. Bearings with the absolutely same dimensions and structures under the exact same working conditions may still have different lives. Therefore, the concept of bearing life must be clearly realized when selecting bearing size.
The basic dynamic load rating calculated by LYC is based on the large enough quantity of bearings with absolutely the same structure and dimension. Among them, 90% life reliability could be reached or exceeded.
In practice, there are many expressions for bearing life. Working life indicates the bearing life before its failure caused by malfunction under the normal working conditions. These breakdowns are component burn, abrasion, components fracture, corrosion, and dimension distortion etc. Although these breakdowns caused by similar reasons lead to bearing failure, these failure modes are

different. Therefore, this should not be mixed with bearing life. The failure mode of bearing life is material fatigue, the bearing life refers to the fatigue life of bearing.
Notice that in view of the extensive application and diverse structures of bearings, there is no effective method at present to exactly predict the specific value of bearing life for an individual bearing, except reinforcing the testing during the application. Bearing life is established on the basis of mathematical statistics towards the bearings with the same structure, dimension and certain reliability (e.g.90%). In other words, bearing life means 90% (reliability) of a great many bearings that could reach the basic dynamic load rating in their applications. So bearing life is not for an individual bearing.
In practice, for the most safety estimating method of bearing life is analogy, i.e. making the optimum choice after analogy with applied and a similar situation according to the actual application of the bearing.

4.2 Selecting Bearing Size According to Basic Static Load Rating

Bearing size should be selected according to the basic static load rating C_0 ,where a bearing is working under the following conditions:

- Bearing is static under continuous or intermittent (impact) load
- Bearing only has slowly repeated swaying or adjustive movement under load
- Bearing is running at slow speed under load, normally n＜10 r/min
- Bearing is rotating, but it carries larger impact load except the normal working load

From the above mentioned conditions, bearing life does not depend on the fatigue life of material at this time, but, the permanent plastic deformation degree of the raceway and rolling elements caused by the load. The load, which is acting on static, slowly running or slowly repeated swaying bearing, may result in flattening of some part of rolling elements or dents on the raceway. The permanent plastic deformation on the working surface of components may also cause a quality problem such as vibration, noise, precision lose, increased friction etc.
When selecting bearing size, if there is any one of the following situations, we not only need to calculate the bearing life, but also to check basic static load rating C_0:

- High reliability
- Low noise or low vibration
- Larger impact or vibrational load

4.2.1 Calculation of Equivalent Static Load

The equivalent static load can be calculated separately by the following formulas, and finally the larger value should be adapted.

$$P_o = X_o F_r + Y_o F_a$$

$$P_o = F_r$$

where

P_o – Equivalent static load, N
F_a – Axial load, N
F_r – Radial load, N
X_o – Radial load coefficient
Y_o – Axial load coefficient

The specific values of Xo, Yo are listed in the bearing dimension table in this catalogue.

4.2.2 Selecting Bearing Size According to Basic Static Load Rating

Selecting bearing size according to basic static load rating, calculating as per the following formula:

$$C_0 = S_0 P_0$$

where

C_0 – Basic static load rating, N
P_0 – Equivalent static load, N
S_0 – Safety factor (Table 4.1)

When selecting bearing size according to basic static load rating, we should also note that the stiffness of the parts matched with bearings should be considered. S_0 should be a larger value if stiffness is weaker, conversely, a smaller value.

Table 4.1

Applications	S_0(≥)
High requirement for rotating accuracy and stability, or carrying impact load	1.2～2.5
Normal Application	0.8～1.2
Low requirement for rotating accuracy and stability, or not carrying impact load	0.5～0.8

Example:
Bearing 6206E is selected for a machine in normal application with low speed. The equivalent static load on the bearing P0=6000N, try to check the safety factor.
After checking the bearing size table in this catalogue, bearing 6206E: C0=11200N.

$$S_0 = \frac{C_o}{P_o} = \frac{11200}{6000} = 1.87$$

According to Table 4.1, bearings for normal application: S_0= 0.8~1.2, the calculated value of S_0 is larger than specified value, so as to meet the requirement.

4.3 Selecting Bearing Size According to Basic Dynamic Load Rating

4.3.1 Calculation of Equivalent Dynamic Load

The load carried by bearings is derived from the weight and acting force of the supported objects, such as rotating shaft, all kinds of components mounted on the rotating shaft, driving force, and the additional load generated by the rotation of all types of components. Some loads can be gained from the theoretical calculation, some loads are difficult to calculate, such as the additional load generated by the rotation of components, impact load resulted from vibration. Therefore, in view of reliability, are usually add load coefficient on the basis of theoretical calculation of the main loads, load coefficient fp is shown in Table 4.2.

Table 4.2

Properties of Bearing Load	fp	Applications
Without or with slight impact	1.0-1.2	Electric motors, steam turbines, ventilator, pumps
Medium impact	1.2-1.8	Vehicles, machine tools, driving device, crane, metallurgical equipment, internal combustion engines, gearbox
Heavy impact	1.8-3.0	Crushers, rolling mills, oil rigs, vibrating screens

For the bearing supported by pure radial or axial loads, the formula of equivalent dynamic load is:

$P = fp \cdot Fa$

$P = fp \cdot Fr$

But, in the actual applications, the bearing has little chance to carry pure radial load or pure axial load, in many cases, bearing simultaneously carries combined forces of radial and axial loads. Therefore, the actual loads must be converted into equivalent dynamic loads when calculating the bearing life, the specific derivation method is:

$P=XFr+YFa$

where

P – Equivalent dynamic load, N
Fr – Radial load, N
Fa – Axial load, N
X – Radial factor
Y – Axial factor

The specific values of coefficient X and Y are listed in the bearing dimension tables of this catalogue.

When considering the working conditions of vibration or impact:

$P = fp\,(XFr + YFa)$

4.3.2 Equivalent Dynamic Load Rating for Face to Face Mounted Angular Contact Bearing

When carrying radial load, interior of angular contact bearing will generate axial force due to its structure. When mounting the angular contact bearings in pairs, in the sight of the balance of axial force series, toward another bearing, the internal axial force of one bearing is part of imposed axial load, so the influence of internal axial force should be considered when calculating the equivalent dynamic load of this type of bearings. Internal axial force is related to radial load of bearing and contact angle, approximate calculation formula of internal axial force is:

$S=1.25Fr \cdot tg\alpha$

where

S – Internal axial force, N
α– Actual contact angle
Fr – Radial load, N

Under different mounting situation, the calculation formula for axial loads FaI, FaII of bearing I, II is shown in the Table 4.3.

4.3.3 Mean Equivalent Dynamic Load

In many applications, bearing loads are not always under constant state, and will have some changes. So mean equivalent dynamic load should be introduced into the equation.

- **Fluctuating Loads and Speeds**

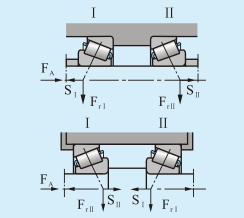
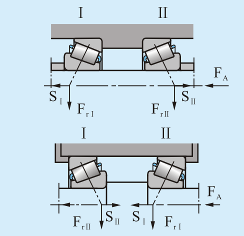
If the bearing is under the effect of P_1, P_2, P_3…, the corresponding speed is n_1, n_2, n_3…, and the rotating time is t_1, t_2, t_3… (Fig. 4.1), and the mean equivalent dynamic load is:

$$P_m=\left(\frac{P_1^{\varepsilon}n_1t_1+P_2^{\varepsilon}n_2t_2+P_3^{\varepsilon}n_3t_3+\cdots}{n_m}\right)^{\frac{1}{\varepsilon}}$$

where

n_m – Average speed, $n_m=n_1+n_2+n_3+$……
ε – Life index, ball bearing ε = 3, roller bearing ε = 10/3

Table 4.3

Mount Sketch	Load Condition	F_{aI}	F_{aII}
	$S_I \leqslant S_{II}$ $F_a \geqslant 0$	$S_{II}+F_A$ S_I	S_{II} S_I-F_A
	$S_I > S_{II}$ $F_a \geqslant S_I-S_{II}$		
	$S_I > S_{II}$ $F_a < S_I-S_{II}$		
	$S_I \geqslant S_{II}$ $F_a \geqslant 0$	S_I $S_{II}-F_A$	S_I+F_A S_{II}
	$S_I < S_{II}$ $F_a \geqslant S_{II}-S_I$		
	$S_I < S_{II}$ $F_a < S_{II}-S_I$		

Note: 1) S_I, S_{II} is the internal axial force for bearing I and bearing II
2) F_{aI}, F_{aII} is the radial load carried by bearing I and bearing II.
3) F_A is the external axial load acted on the shaft series.

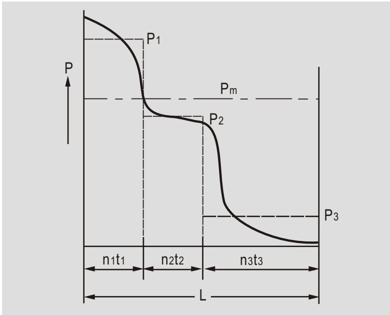


Fig4. 1

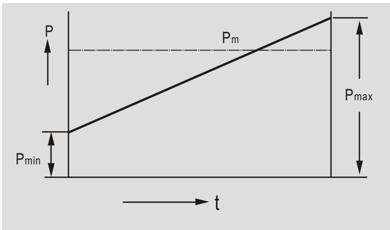


Fig4. 2

- **Constant Speed, Load with Approximating Line Shape Variation**

When bearing speed and load direction are constant, the loads only fluctuate between Pmin and Pmax similar to line shape (Fig. 4.2), the mean equivalent dynamic load is:

$$P_m=\frac{P_{min}+2P_{max}}{3}$$

- **Rotating Load**

As illustrated in Fig.4.3, if the bearings carry combined actions of F1and F2, the load on the bearing consists of load F1 which is constant in magnitude and direction (e.g. the weight of a rotor), and a rotating constant load F2 (e.g. a centrifugal force caused by an unbalanced load), the mean load can be obtained from:

$$F_m=f_m\,(F_1+F_2)$$

Values for the factor fm can be obtained from fig.4.4.

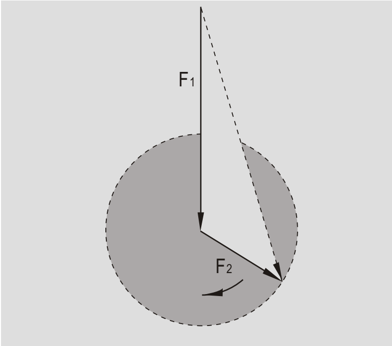


Fig4. 3

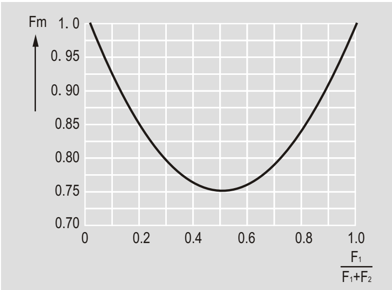


Fig4. 4

4.3.4 Modified Coefficient of Basic Dynamic Load Rating

In actual applications, the working temperature of normal bearings could not be over 120℃ in applications, where bearings operate over this temperature, they should adopt the material with special heat treatment or special material. During high temperature, the hardness of bearing surface will de reduced, consequently the basic dynamic load rating is influenced accordingly. So the temperature factor fT should be brought into this equation for modifying basic dynamic load rating. Basic dynamic load rating after modification:

$$C_T = f_T \cdot C$$

Where

Cr – Basic dynamic load rating when the operating temperature is T℃， N

F_T – Temperature factor, see (Table 4.4)

Table 4. 4

Operating Temperature (℃)	<120	125	150	175	200	225	250	300
f_T	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.60

When the parts surface hardness changes due to some reason, the hardness factor fH should be brought in, and basic dynamic load rating after modification is:

$$C_H = f_H \cdot C$$

Where

C_H –Basic dynamic load rating after the hardness factor modified, N

f_H – Hardness factor

$$f_H = \left(\frac{HRC}{58}\right)^{8.6}$$

Where

HRC is the hardness value from the actual measurement of the bearing.

4.3.5 Selecting Bearing Size According to Basic Dynamic Load Rating

According to the life formula in GB/T6391 <Rolling bearing dynamic load rating and rating life>, for the simplified calculation, take 500 hours as the nominal life and then derive the speed factor fn and life factor f_H

$$f_n = \left(\frac{33\frac{1}{3}}{n}\right)^{1/\varepsilon}$$

$$F_h = \left(\frac{L_{10h}}{500}\right)^{1/\varepsilon}$$

So basic dynamic load rating could be calculated according to the following formula:

$$C = \frac{f_h}{f_n} P$$

Based on this rewritten basic dynamic load rating formula, when the bearing operation speed n and anticipated service life L_{10} are assured, corresponding factor value fh and fn can be obtained by searching in the Table 4.5 and 4.6 according to n, L_{10}. Then introduce the factor value fh and fn into the equation, the basic dynamic load rating value of the candidate bearing can be assured conveniently and accurately, then the bearing size can be selected according to basic dynamic load rating, which can be searched in the dimension table in this catalogue.

Table 4. 5

L_h	f_h		L_h	f_h		L_h	f_h		L_h	f_h	
h	ball bearing	roller bearing	h	ball bearing	roller bearing	h	ball bearing	roller bearing	h	ball bearing	roller bearing
100	0.585	0.617	700	1.12	1.11	4600	2.1	1.95	34000	4.08	3.55
110	0.604	0.635	750	1.14	1.13	4800	2.13	1.97	36000	4.16	3.61
120	0.622	0.652	800	1.17	1.15	5000	2.15	2	38000	4.24	3.67
130	0.639	0.668	850	1.19	1.17	5500	2.22	2.05	40000	4.31	3.72
140	0.654	0.683	900	1.22	1.19	6000	2.29	2.11	42000	4.38	3.78
150	0.67	0.697	950	1.24	1.21	6500	2.35	2.16	44000	4.45	3.83
160	0.684	0.71	1000	1.26	1.23	7000	2.41	2.21	46000	4.51	3.88
170	0.698	0.723	1100	1.3	1.27	7500	2.47	2.25	48000	4.58	3.93
180	0.712	0.736	1200	1.34	1.3	8000	2.52	2.3	50000	4.64	3.98
190	0.724	0.748	1300	1.38	1.33	8500	2.57	2.34	55000	4.79	4.1
200	0.737	0.76	1400	1.41	1.36	9000	2.62	2.38	60000	4.93	4.2
220	0.761	0.782	1500	1.44	1.39	9500	2.67	2.42	65000	5.07	4.31
240	0.783	0.802	1600	1.47	1.42	10000	2.71	2.46	70000	5.19	4.4
260	0.804	0.822	1700	1.5	1.44	11000	2.8	2.53	75000	5.31	4.5
280	0.824	0.84	1800	1.53	1.47	12000	2.88	2.59	80000	5.43	4.58
300	0.843	0.858	1900	1.56	1.49	13000	2.96	2.66	85000	5.54	4.68
320	0.861	0.875	2000	1.59	1.52	14000	3.04	2.72	90000	5.65	4.75
340	0.879	0.891	2200	1.64	1.56	15000	3.11	2.77	100000	5.85	4.9
360	0.896	0.906	2400	1.69	1.6	16000	3.17	2.83			
380	0.913	0.921	2600	1.73	1.64	17000	3.24	2.88			
400	0.928	0.935	2800	1.78	1.68	18000	3.3	2.93			
420	0.944	0.949	3000	1.82	1.71	19000	3.36	2.98			
440	0.959	0.962	3200	1.86	1.75	20000	3.42	3.02			
460	0.973	0.975	3400	1.89	1.78	22000	3.53	3.11			
480	0.987	0.988	3600	1.93	1.81	24000	3.63	3.19			
500	1	1	3800	1.97	1.84	26000	3.37	3.27			
550	1.03	1.03	4000	2	1.87	28000	3.83	3.35			
600	1.06	1.06	4200	2.03	1.89	30000	3.91	3.42			
650	1.09	1.08	4400	2.06	1.92	32000	4	3.48			

Table 4. 6

n	f_n		n	f_n		n	f_n		n	f_n	
r/min	ball bearing	roller bearing	r/min	ball bearing	roller bearing	r/min	ball bearing	roller bearing	r/min	ball bearing	roller bearing
10	1.49	1.44	80	0.747	0.769	600	0.382	0.420	4600	0.194	0.228
11	1.45	1.4	85	0.732	0.755	650	0.372	0.410	4800	0.191	0.225
12	1.41	1.4	90	0.718	0.742	700	0.362	0.401	5000	0.188	0.222
13	1.37	1.33	95	0.705	0.730	750	0.354	0.393	5500	0.182	0.216
14	1.34	1.3	100	0.693	0.719	800	0.347	0.385	6000	0.177	0.211
15	1.31	1.27	110	0.672	0.699	850	0.340	0.378	6500	0.172	0.206
16	1.28	1.25	120	0.652	0.681	900	0.333	0.372	7000	0.168	0.201
17	1.25	1.23	130	0.635	0.665	950	0.327	0.366	7500	0.164	0.197
18	1.23	1.2	140	0.620	0.650	1000	0.322	0.360	8000	0.161	0.193
19	1.21	1.18	150	0.606	0.637	1100	0.312	0.350	8500	0.158	0.190
20	1.19	1.17	160	0.593	0.625	1200	0.303	0.341	9000	0.155	0.186
22	1.15	1.13	170	0.581	0.613	1300	0.2995	0.333	9500	0.152	0.183
24	1.12	1.1	180	0.570	0.603	1400	0.288	0.326	10000	0.149	0.181
26	1.09	1.08	190	0.560	0.593	1500	0.281	0.319	11000	0.145	0.176
28	1.06	1.05	200	0.550	0.584	1600	0.275	0.313	12000	0.141	0.171
30	1.04	1.03	220	0.533	0.568	1700	0.270	0.307	13000	0.137	0.167
32	1.01	1.01	240	0.518	0.553	1800	0.265	0.302	14000	0.134	0.163
34	0.994	0.99	260	0.504	0.540	1900	0.260	0.297	15000	0.131	0.160
36	0.975	0.98	280	0.492	0.528	2000	0.255	0.293	16000	0.128	0.157
38	0.958	0.96	300	0.481	0.517	2200	0.247	0.285	17000	0.125	0.154
40	0.941	0.95	320	0.471	0.507	2400	0.240	0.277	18000	0.123	0.151
42	0.926	0.93	340	0.461	0.498	2600	0.234	0.271	19000	0.121	0.149
44	0.912	0.92	360	0.452	0.490	2800	0.228	0.265	20000	0.119	0.147
46	0.898	0.91	380	0.444	0.482	3000	0.223	0.259	22000	0.115	0.143
48	0.885	0.9	400	0.437	0.475	3200	0.218	0.254	24000	0.112	0.139
50	0.874	0.89	420	0.430	0.468	3400	0.214	0.250	26000	0.109	0.136
55	0.846	0.86	440	0.423	0.461	3600	0.210	0.245	28000	0.106	0.133
60	0.822	0.84	460	0.417	0.455	3800	0.206	0.242	30000	0.104	0.130
65	0.8	0.82	480	0.411	0.449	4000	0203	0.238			
70	0.781	0.800	500	0.405	0.444	4200	0.199	0.234			
75	0.763	0.784	550	0.393	0.431	4400	0.196	0.231			

Example:
Known: The shaft rotating speed of a machine n=5000 r/min, constant (equivalent) radial load carried by bearing P=1000 N, the selected bearing structure is deep groove ball bearing, the anticipated bearing service life is 8000h, try to calculate the size of suitable bearing.
Searching in the Table 4.5 and Table 4.6:
The corresponding speed factor of the deep groove ball bearing 5000r/min, f_n=0.188
The corresponding life factor of deep groove ball bearing 8000h, f_h=2.52
Introduce f_n, f_h into the equation:

$$C=\frac{f_h}{f_n}P=\frac{2.52}{0.188}\times 1000=13404N$$

Searching the deep groove ball bearing size table, bearing 6006E: C=13300N, smaller than calculated value, while bearing 6206E: C=19500N, bigger than calculated value. Considering the reliability of bearing service life, bearing 6206E should be better to choose.

4.4 Calculation of Bearing Life

4.4.1 Bearing Life

It is important for the customers to ensure the bearing service life. The estimation of extra long service life will cause the waste of resources or the increase of dimension; the matched parts dimension will increase accordingly. The estimation of extra short service life will result in changing bearings frequently and unnecessary work and waste of manpower and material; moreover it is harmful to the reliability of bearing service life.
Therefore, before ensuring the bearing service life, comprehensive evaluation should be made for the machinery category, all types of different working conditions and requirement of reliability etc.
The recommended values of service life for all types of machinery under different applications should refer to Table 4.7.

Table 4. 7

Operating Conditions	Operating Hours
Infrequently used instruments and machines	300～3000
Machines used for short periods or intermittently: Electric hand tools, agricultural machines, lifting tackle in workshops, automatic-feeder equipment.	3000～8000
Machines used intermittently, which will have serious result: auxiliary equipment of power plant, flow line driving device, rubber belt conveyor, workshop cranes.	8000～12000
Machines working 8 hours per day but infrequently at full capacity: electric motor, general gearing, crusher, cranes and normal machinery.	10000～25000
Machines working 8 hours per day at full capacity: machine tools, woodworking machinery, printing machinery, centrifuge.	20000～30000
Machines working continuously for 24 hours: compressor, pump, electric motor, rolling mill gearing, textile machinery.	40000～50000
Machines working continuously for 24 hours, intermittently working will have serious results: fiber machinery, paper machinery, primary device of power plant, water equipments, mine pump and ventilating fan.	～100000

4.4.2 Basic Rating Life

According to GB/T6391 <Rolling bearings Basic dynamic load rating and basic rating life>, the basic rating life can be calculated by the following formula:

$$L_{10}=\left(\frac{C}{P}\right)^{\varepsilon}$$

where
L_{10} – Basic rating life, million of revolutions
C – Basic dynamic load rating, N
P – Equivalent dynamic load, N
ε– Exponent of the life equation ε = 3 for ball bearings ε = 10/3 for roller bearings
For bearings operating at constant speed, rating life could be usually indicated by operating hours, and the calculating equation is:

$$L_{10h}=\frac{10^6}{60n}\left(\frac{C}{P}\right)^{\varepsilon}$$

or $$L_{10h}=\frac{10^6}{60n}L_{10}$$

where
L_{10h} – Basic rating life indicated by hours, h
n – Working speed, r/min
The basic rating life of a vehicle bearing is usually indicated by kilometers, the formula of its rating life is:

$$L_{10s}=\frac{\pi D}{1000}L_{10}$$

Where
L_{10s}– Basic rating life indicated by kilometers,km
D – Wheel diameter, m

4.4.3 Modified Calculation of Bearing Life

The calculation precision of basic rating life L10 is satisfied for most applications. However, with the completeness of the bearings lubrication theory, the application of new technique and the improved material quality, there is new method for the calculation of bearing life. The modified calculation formula for bearing life is proposed in the Chinese standard GB/T 6391:

$$L_{na}=a_1a_2a_3L_{10}$$

where
L_{na} – Modified basic rating life with the reliability (100-n) %, special bearing performance and certain operating conditions, N
a_1 – Reliability coefficient, shown in Table 4.8
a_2 – Material coefficient
a_3 – Working condition coefficient
For the bearing made of standard material, a_2=1. For high purity steel or special smelted steel, such as vacuum degassing steel, electroslag remelting steel, a_2>1
For a normal application, a_3=1. When a bearing is lubricated enough, and formed with the flexibility liquid film on the roller contact surface, a_3>1. If a bearing is not lubricated enough, the value of a_3 should be considered less than 1.
Please note, if bearing isn't lubricated enough, it couldn't exert as compensate effect for bearing life due to the improvement of material quality, so under this situation, the value of a_2 should not be more than 1.

Table 4. 8

Reliability S	L_{na}	a_1
90	L_{10}	1
95	L_5	0.62
96	L_4	0.53
97	L_3	0.44
98	L_2	0.33
99	L_1	0.21

5. Friction

Friction still exists, even though the friction of rolling bearing is much lower than that of sliding bearing. Friction is the main reason of bearing heating, friction forms kinetic resistance and creates dimensional variation with in the components. Friction is also one of the key factors which determine the bearing working temperature.
The sum of the friction in rolling bearings is considered as the running resistance of bearings to be measured, which, could be expressed as drag or torque and called friction moment in bearing application.
The total resistance generated from the bearing running is composed of rolling friction and sliding friction. According to its generation mechanism, the main sources of friction can be divided into the following parts:

- Pure rolling friction cause by material elastic hysteresis
- Friction caused by differential sliding on rolling contact surface
- Friction caused by spin sliding
- Friction of sliding contact places
- Viscous friction of lubricants
- Friction caused by slant mounting of bearing axis
- Other frictions

From the generation mechanism of bearing friction, friction moment have the characteristic of multiple-factors and randomicity. The friction moment has changes even though bearings with same structure and size are under the same working condition. The moment needed from static state to running is called starting friction moment. While the friction running under a certain speed after starting is pivoting friction torque, which, is often expressed by average friction torque and max friction torque.

5.1 Friction Moment Calculation

Bearings have different requirements of friction moment under different working conditions. Generally, for the bearing running continuously the smaller of the average friction, this is better for bearings starting frequently or having the requirement of bidirectional rotation, smaller start friction moment is needed. Bearings for instruments with high sensitivity require that the max friction moment should be small and maintain stability.
The friction moment calculation has two methods of proximate calculation and accurate calculation.

5.1.1 Proximate Calculation

The friction was decided by bearing structure, type, load capacity, speed, lubrication performance and volume, proximate calculation of friction moment M can be according to the formula below:

$$M = 0.5\mu Fd$$

where

μ — Coefficient, shown in Table 5.1
F — Bearing load, N
d — Inner diameter of bearing, mm

Table 5. 1

Bearing Type	Friction Coefficient μ
Deep groove ball bearing	0.0015
Angular contact ball bearing	
Single row	0.0020
Double row	0.0024
Four-point contact	0.0024
Self-aligning ball bearing	0.0010
Cylindrical roller bearing	
With cage (F_a=0)	0.0011
Full rollers (F_a=0)	0.0020
Taper roller bearing	0.0018
Spherical roller bearing	0.0018
Thrust ball bearing	0.0013
Thrust cylindrical roller bearing	0.0050
Thrust taper roller bearing	0.0018

The above formula is only suited for the average friction moment calculation under good lubrication, medium load and speed.

5.1.2 Accurate Calculation

Accurate calculation formula:

$$M=M_0+M_1$$

where

M_0 – Friction moment related to bearing type, speed and lubricant, N • mm

M_1 – Friction moment related to bearing load, N • mm

- Calculation for M_0

M_0 reflects the hydrokinetic loss of lubricant, which, could be calculated as the following equation:

when $vn \geq 2000$

$$M_0=f_0(vn)^{2/3}d_m^3 \cdot 10^{-7}$$

when $vn<2000$

$$M_0=160\times10^{-7}f_0 d_m^3$$

where d_m— Bearing average diameter, dm=0.5(d+D),mm

f_0— Coefficient related to the bearing type and lubricant, value of f_0 refers to Table 5.2; select smaller value of f_0 for the light series, and larger value of f_0 for the heavy series

n— Bearing speed, r/min

v— Kinematic viscosity of lubricant under working temperature (grease refer to the viscosity of basic oil), mm^2/s

- Calculation for M_1

M_1 reflects all kinds of friction loss related to loads, which, could be calculated as the following equation:

$$M_1=f_1P_1d_m$$

where f_1— Coefficient related to bearing load, refer to Table 5.3

P_1— Assumed load ensured the bearing friction moment, N refers to Table 5.3

If a cylindrical roller bearing carries the combined effect of radial load and axial load simultaneously, additional friction moment M2 should be considered:

$$M_2=f_2F_ad_m$$

Total friction moment:

$$M=M_0+M_1+M_2$$

where

f_2— Coefficient related to bearing structure and lubrication method, its value is shown in Table 5.4

Fa— Bearing axial load, N

Table 5.2

Bearing Type	Oil Mist Lubrication	Bath Lubrication or Grease Lubrication	Vertical Shaft Bath Lubrication or Oil Jet Lubrication
Single-row deep groove ball bearing	0.7~1	1.5 ~ 2	3~4
Double-row self-aligning ball bearing	0.7~1	1.5~2	3~4
Single-row angular contact ball bearing	1	2	4
Double-row angular contact ball bearing	2	4	8
Cylindrical roller bearing(With cage)	1~1.5	2~3	4~6
Cylindrical roller bearing (full-fill components)	-	2.5~4	-
Spherical roller bearing	2 ~ 3	4~6	8 ~ 12
Taper roller bearing	1.5 ~ 2	3~4	6~8
Thrust ball bearing	0.7~1	1.5~2	3~4
Thrust cylindrical roller bearing	-	2.5	5
Thrust spherical roller bearing	-	3~4	6~8

Table 5.3

Bearing Type	f_1	$P_1$①
Single row deep groove ball bearing	$0.0009 (P_0/C_0)^{0.5}$	3Fa-0.1Fr
Single row angular contact ball bearing	$0.0003 (P_0/C_0)^{0.4}$	1.4yFa-0.1Fr
Double-row angular contact ball bearing	$0.0013 (P_0/C_0)^{0.33}$	Fa-0.IFr
Double-row angular contact point	$0.001 (P_0/C_0)^{0.33}$	1.4Fa-0.1Fr
Cylindrical roller bearing(With cage)	0.00025 ~ 0.0003②	Fr
Cylindrical roller bearing(full-fill components)	0.00045	Fr
Spherical roller bearing	0.0004 ~ 0.0005②	1.2yFa
Taper roller bearing	0.0004 ~ 0.0005②	2yFa
Thrust ball bearing	$0.0012 (P_0/C_0)^{0.33}$	Fa
Thrust cylindrical roller bearing	0.0018	Fa
Thrust spherical roller bearing	0.0004 ~ 0.0006②	Fa (Frmax$\leqslant$0.55 Fa)

Note： ① If P_1< Fr, then P_1=Fr.
② For light series, smaller value should be chosen; for heavy series, bigger value should be chose.
③ In the table above, P_0 is bearing equivalent static load, N.
C_0 is bearing rating static load, N.
y is axial load factor when Fa /Fr >e.

Table 5.4

Bearing Structure	Oil Lubrication	Grease Lubrication
With cage	0. 006	0. 009
Full component roller	0. 003	0. 006

The value of f_2 is fit for Kv=1.5, Kv is the ratio between the chosen lubricant viscosity and the practical viscosity when bearing is operating.

5. 2 Power Consumption

Power consumption caused by friction can be calculated as follows:

$$Q=1.05\times10^{-6}M \cdot n$$

where

Q – Heating value, W
M – Friction moment, N • mm
n – Speed, min/r

When the heating value and output heat reach to a balance, the temperature of bearing maintains stability.

6. Limiting Speed

Limiting speeds of bearings mainly depend on the relation between friction heating (including other outside heat) and discharged heat during rotation. It is not only related to the lubricant and temperature of the bearing components material, but also related to the bearing structures, dimensions, clearances, loads, cage structures, material, guiding methods, lubrication method, volume, and bearing cooling conditions.
The suitable conditions of bearing limiting speeds given in the dimension table in this catalogue are:

- Bearing with standard structure
- Under the temperature 20℃, the temperature rising of bearing is 50℃, i.e. the measured working temperature is 70℃ on the outer ring or housing washer without rotation
- Equivalent dynamic loading P≤0.1C
- The structure of rigidly connected shaft and housing washer
- Open bearing with normal precision, clearance group 0 (basic group)
- Radial bearings only carry radial loads; thrust bearings only carry axial loads
- Sufficient lubricating

For oil lubrication
Lubricant: mineral oil without extreme pressure additives, and kinetic viscosity under 70℃ is:

For axial bearing $v = 12mm^2/s$
For thrust bearing $v = 24mm^2/s$

Lubrication method: bath lubrication, oil level is at the center of lowest Rolling elements

For grease lubrication
Lubricant: Lithium-based oil lubrication, viscosity(40℃) $100 \sim 200mm^2/s$

Filling volume of grease: about 30% of the bearing internal free space.

In practice, working conditions often don't conform to the above conditions, e.g. P>0.1C, or radial bearing carrying combined radial and axial loads, or inadequate lubrication, or excessive lubricants etc. At this time, the actual highest working speed of bearing will be lower than the given (reference) limiting speed in this catalogue, so the speed drop coefficient f_1 and f_2 should be introduced to modify the value of the coefficient could be selected according to Fig 6.1 and Fig 6.2. Modified limiting speed could be calculated according to the following formula:

$$n_a = f_1 \cdot f_2 \cdot n_{limit}$$

where

n_{limit}— Limiting speed given in this catalogue
f_1, f_2— Modified coefficient of limiting speed

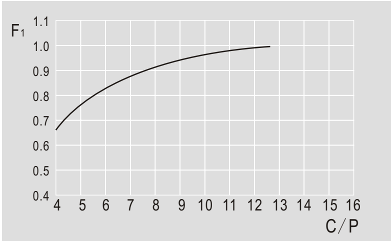


Fig 6.1

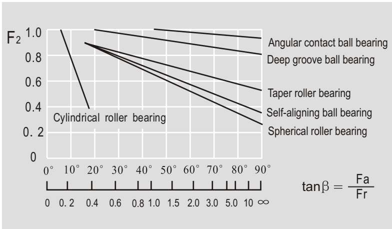


Fig 6. 2

If the limiting speed given in this catalogue could not meet the application requirement, the following methods can be adopted to improve the limiting speed:

- Improve the bearing precision
- Increase the clearance value appropriately
- Adopt cages made by light material or with special designed structure, and adjust the guiding method of the cages
- Improve the lubrication ways, e.g. circular oil lubrication, oil jet or oil mist lubrication
- More efficient cooling

7 . Materials

The basis of bearing quality is material, which, has great influence on bearing performance, life and reliability. The rolling surface of components carries periodical alternating loads during operation, extremely high contact stress (1000~4000MPa) is generated on the contact position due to the small contact area between rolling elements and raceway. The material of components will fatigue under the repeated actions of the stress, which results in the fatigue flake. Meanwhile, both rolling friction and sliding friction exist at the component contact position. Therefore, the bearing material should have the following performances:

- High contact fatigue intensity
- High flexibility limit
- High material purity
- High hardness obtained
- Good abrasion resistance and anticorrosion
- Good structure stability
- Good machining property
- Good impact resistance

To ensure LYC's bearings with perfect performance and reliability, the bearings are made of various high quality steels.
The main bearings materials adopted by LYC are given.

7.1 Material of Bearing Rings and Rolling Elements

7.1.1 Fully Hardening Steel

Most bearing rings and rolling elements of LYC' s bearings are all made of through-hardening high-carbon chromium bearing steel. Most common used steel brands are GCr15, GCr15SiMn or GCr18Mo. High-carbon chromium bearing steel is one of the most common steels with longest history and most comprehensive research. Steel GCr18Mo is an example of good impact resistance steel developed recently.
The hardness of high-carbon chromium bearing steel could reach 58~65HRC after martensitic or bainitic heat treatment, other performance index could also meet the bearing application requirements.

7.1.2 Case- Hardening Steel

Bearings carrying heavy impact load in application such as the railway bearing, rolling mill bearing and bearings with larger interference can be made by all brands of carburized steel.
The hardness of carburized steel could be around 60HRC after case-carburizing and heat treatment, while its central structure has good toughness (30~35HRC), which, is fit for the applications with heavy impact load.
The main brands of carburized steel used by LYC are 20CrNi2MoA, 20Cr2Ni4A, 10CrNi3MoA, 15CrNi4MoA etc.

7.1.3 Induction Hardening Steel

The partial surface of components (e.g. raceway) could be hardened by the method of induction hardening, and other surfaces are not influenced, so material of the same component could have different performance. Induction hardening steels 42CrMo, 50Mn and 5CrMnMo are commonly used by LYC.

7.1.4 High-Temperature Bearing Steel

Bearings made by high-carbon chromium bearing steel and case-hardening steel should operate under the temperature below 120℃. If working temperature is higher than 120℃, then special heat treatment for stability should be made. The material after stabilizing treatment could reach the highest temperature 350℃, but, the load capacity, abrasion resistance of bearing will reduce under this situation and only be suitable to work under high temperature for a short period.
Bearings with working temperature over 350℃ or working under temperature over 250℃ for a long period need to be made of high- temperature bearing steel.
High-temperature bearing steels Cr4Mo4V, W18Cr4V are often used by LYC.
LYC also supply bearings made of stainless steels, anticorrosion steels, vacuum degassing steels, electro-slag refined steels etc. Bearings made of such high quality and material purity steels should satisfy customers' individuation, multi-performance and long service life requirements, but their prices will be different from bearings made of normal materials.
The bearings made of different materials, except high-carbon chromium bearing steel, need to add supplementary suffix codes for materials, and all kinds of material code can be found in bearing code part of this catalogue.

7.2 Materials for Cage

The main function of cage is :

- Segregate the rolling elements and prevent contact friction between them.
- For separable bearings, cages retain the rolling elements on the raceway, which are good for mounting and dismounting of

bearing.

- Guiding the movement of rolling elements, such as the cage of needle bearings and thrust ball bearings.
- In grease lubrication, cage could have the effect of storing the grease to improve the bearing lubrication surface of the bearing.

The cage supports mixed strength during operation, such as friction between elements (or rings), the commutation strength of cage beam, and the remaining strength during high speed.
Because of the difference in the bearing type and size, structures of cages are also different, the differences include structures of cage, material, manufacturing methods, production cost and so on.
Depending on technological procedure of cages, these should be classified as pressed steel cage, injection mold cages, machined solid cage etc.

7.2.1 Pressed Steel Cage

Most pressed steel cages are made of a cold (hot) strip of low carbon, such as 10# steel. Cages made of these materials have high strength and can reduce friction abrasion through surface treatment, and internal stress caused by pressing procedure.
Pressed steel cages are mostly used for medium and small bearings.
Pressed steel cages could also be made of brass strips.

7.2.2 Machined Solid Cage

According to the materials of cages, machined solid cages mainly include steel cages and brass cages. Aluminum ZL102, powder metallurgy or phenolic compress tube are also used in some applications.
The blank of steel cages and brass cages can be casted or forged.

- **Steel Cages**

The mechanical strength of machined steel cages is superior to that of pressed steel cages. Some steel cages should be surface treated to improve the capacity of antifriction and abrasion resistance.
Machined solid steel cages are usually used for larger size bearings, or in the application unsuitable for brass cages, e.g. the application that brass is naturally fractured due to chemical reaction.
The highest operating temperature for machined solid steel cages is 300℃, and usually isn't influenced by mineral oil or synthetic lubricant and organic solvent for cleaning.
The main materials for machined steel cages are steel 20#, 30# etc.

- **Brass Cages**

Machined solid brass cages are usually used for medium and small size bearings. Brass cages aren't usually affected by bearing lubrication, and could be cleaned by normal organic solvent.
Brass cages are not suitable for working application with the temperature over 250℃.
The materials for brass cages are mainly brass Cuzn40Pb2, bronze CuAL10Fe3Mn2 etc.

7.2.3 Injection Mold Cages

Most injection mold cages are made of staple glass fiber reinforced nylon 66. These materials have good intensity, flexibility and gliding, and can keep working for some time under the situation of oil starvation.
When adopting injection mold cages made of reinforced nylon 66, the influences of allowed working temperature (Table 7.1) and lubricants corrosion should be noticed. If bearings work under allowable temperature, the performance of nylon cages isn't influenced, and if exceeding this temperature, the material will be aging.
Because nylon will lose flexibility at low temperature, nylon cages are not fit for bearings continuously working under the temperature -40℃.
Under the vacuum conditions, nylon will become crisp due to dehydration, so nylon cages should not be adopted.

Table7. 1

Lubricant		Allowable Working Temperature (℃)
Mineral oil	Lubricant without extreme pressure additive, such as engine oil, hydraulic oil Lubricant with extreme pressure additive, such as industrial and automobile gear oil Lubricant with extreme pressure additive, such as back axle and differential gear oil, hypoid gear oil	120 110 100
Synthetic oil	Polyglycol ether Oxalic acid , diester, silicon oil Organic phosphate	120 110 80
Grease	Lithium base, polyurea base, bentonite, complex calcium lubricating grease	120

7.3 Material for Seals

The seals used by LYC are often made by nitrile rubber (NBR). NBR has a good carrying capacity toward the following medium:

- Most of mineral oil and mineral oil grease
- General Fuel, such as gasoline, diesel oil and other liquid fuel
- Animal oil, vegetable oil and fat
- Hot water

NBR seals may be allowed to operate in a short time under oil starvation conditions. The working temperature of NBR is-40℃~+100℃, and can reach 120℃ for short time, if exceeding this temperature, NBR will harden and lose its performance.

8 .General Data

8.1 Boundary Dimensions

The boundary dimensions and dimension series of LYC standard bearings conform to Chinese national standards, as follows:

- GB/T273.1 <Rolling bearings-Boundary dimensions general plan-part 1: Tapered roller bearings>
- GB/T273.2 <Rolling bearing-Thrust bearings-Boundary dimensions, general plan>
- GB/T273.3 <Rolling bearing-Radial bearings-Boundary dimensions, general plan>
- GB/T274 <Rolling bearing-Chamfer dimension-Maximum Values>
- Other related standards

Inch sized taper roller bearings conform to American national standard ANSI.
Each type of standard bearing is indicated by dimension series code made by diameter series and width series. Dimension series is indicated by double figures, the first one is width series (or height series), and the second one is diameter series.
Diameter series means bearings with the same standard inner diameter have different outer diameters at radial direction. Diameter series of radial bearings are divided into 7, 8, 9, 0, 1, 2, 3, 4 series, which is in the order of increasing of outer diameter. Similarly, diameter series of thrust bearings is 0, 1, 2, 3, 4, 5 series.
Width series means bearings with the same standard inner diameter have different widths at axial direction. Width series of radial bearings are divided into 8, 0, 1, 2, 3, 4, 5, 6 series, which is in the order of increasing of outer diameter. Similarly, diameter series of thrust bearings is 7, 9, 1, 2 series.
Dimension series is shown in Fig 8.1.

Example: 6202E
where
"02"- dimension series
"0"- height series
"2"- diameter series
In recent years, with the increasing requirement for the individualization of bearing performance, there appear many non-standard bearings with the variation of structures or outer dimensions. So when reorganizing the catalogue, part of non-standard bearings are added to meet the needs of some special customers.

8.2 Chamfer Dimensions

In order to ensure the close fit of rolling bearing with matched parts, the chamfer dimensions of LYC standard bearings conform to the stipulations of national standard GB/T 274 < Rolling Bearing Maximum Value of Chamfer>.

8.3 Tolerances

The tolerance of LYC standard bearings conforms to Chinese national standards:

- GB/T307.1 <Roller Bearing Radial Bearings Tolerance>
- GB/T273.2 <Roller Bearing Thrust Bearings Tolerance >

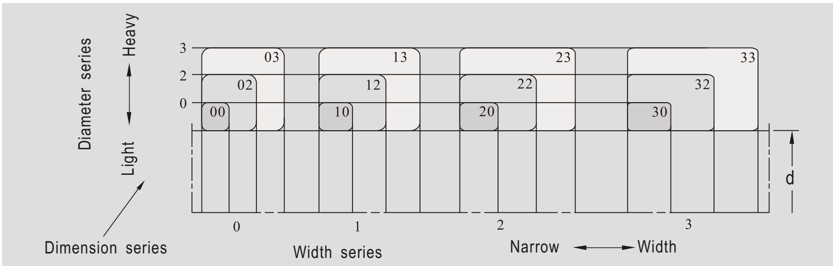


Fig 8.1

The tolerance of special bearings such as rolling mill bearings, machine tool spindle bearings and inch size bearings, execute their related stipulations separately.
The dimension and rotating accuracy of rolling bearing have been internationalized (Table 8.1). According to the stipulations in national standard, the dimension and rotating accuracy of metric bearings are divided into five tolerance classes, class 0, class 6, class 5, class 4, class 2, and the precision classes are increasing in sequence.

Table 8.1

Code	Tolerance Class				
LYC	0	6	5	4	2
ISO	0	6	5	4	2
SKF	0	P6	P5	P4	
JIS	0	6	5	4	
DIN	0	P6	P5	P4	
ANSI	ABEC1		ABEC5	ABEC7	ABEC9
	RBEC2		RBEC5		

8.3.1 Tolerance Symbols

- **d** Bearing bore diameter, nominal
- Δ_{ds} Deviation of a single bore diameter
- Δ_{dmp} Single plane mean bore diameter deviation (for a tapered bore, refers only to the theoretical small end of bore)
- V_{dp} Bore diameter variation in a single radial plane
- V_{dmp} Mean bore diameter variation (only applies to a cylindrical bore)
- **D** Bearing outer diameter, nominal
- D_1 Outer ring flange outer diameter, nominal
- ΔD_s Deviation of a single outer diameter
- ΔD_{1s} Deviation of outer flange of a single outer ring
- ΔD_{mp} Single plane mean outer diameter deviation
- VD_p Outer diameter variation in a single radial plane
- Vd_{mp} Mean outer diameter variation
- **B** Inner ring width, nominal shaft washer
- Δ_{Bs} Deviation of a single width of the inner ring
- V_{Bs} Inner ring width variation
- **C** Outer ring width, nominal
- C_1 Outer flange width, nominal
- Δ_{cs} Deviation of a single width of the outer ring
- V_{cs} Outer ring width variation
- K_{ia} Radial runout of assembled bearing inner ring
- K_{ea} Radial runout of assembled bearing outer ring
- S_d Verticality of end face of inner ring towards bore
- S_D Verticality of outer surface of outer ring towards end face
- S_{D1} Verticality of outer surface of outer ring towards flange backface
- S_{ia} Axial runout of assembled bearing inner ring
- S_{ea} Axial runout of assembled bearing outer ring
- S_{ea1} Axial runout of assembled bearing flange backface

Added Tolerance Symbols of Taper Roller Bearing

- T Bearing width, nominal
- T_1 Bearing nominal width composed by sub-unit and standard outer ring
- T_2 Bearing nominal width composed by outer ring and standard sub-unit
- Δ_{Ts} Deviation of the actual bearing width
- Δ_{T1s} Actual deviation of T1
- Δ_{T2s} Actual deviation of T2

8.3.2 Tolerance Values

- The tolerance values for radial bearings (except taper roller bearings) are given in Table 8.2~8.11
- The tolerance values for taper roller bearings are given in Table 8.12~8.19
- The tolerance values for radial bearings with flange are given in Table 8.20
- The tolerance values of taper bore are given in Table 8.21~8.22
- The tolerance values of thrust bearing are given in Table 8.23~8.30
- Maximum values of chamfer are given in Table 8.31~8.35

8.4 Bearing Clearance

8.4.1 Basic Concept

Bearing clearance is including radial internal clearance and axial internal clearance.
Radial clearance: when bearings do not carry any outer loads in different directions, the arithmetic mean value of radial distance that the one bearing ring relative to the other bearing ring moves from one radial eccentricity limit to the opposite limit position.
Axial clearance: when bearings do not carry any outer loads, the mean value of radial distance that the one bearing ring relative to the other bearing ring moves from one axial limit position to the other opposite limit position.
Radial and axial clearances are shown in Fig 8.7.

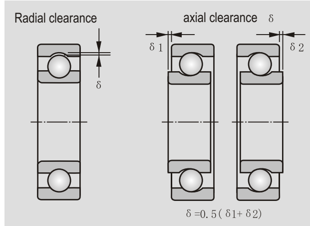


Fig 8.7

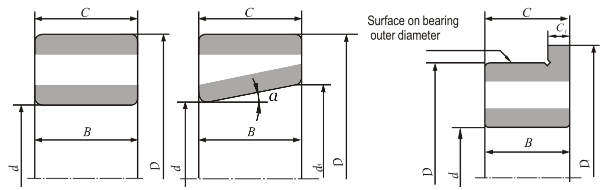


Fig 8.2 Boundary dimension symbols

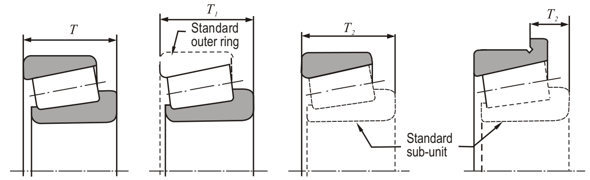


Fig 8.3 Additional symbols for tapered roller bearings

Table 8.2 Radial Bearings (except taper roller bearings)

Tolerance class 0 Inner ring

μm

d mm		Δd_{mp}		V_{dp} 2) Diameter Series 9	V_{dp} 2) Diameter Series 0,1	V_{dp} 2) Diameter Series 2,3,4	V_{dmp}	K_{ia}	ΔB_s All	ΔB_s Normal	ΔB_s Modified 3)	V_{Bs}
over	incl	high	low	max	max	max	max	max	high	low	low	max
0.6 1)	2.5	0	-8	10	8	6	6	10	0	-40	-	12
2.5	10	0	-8	10	8	6	6	10	0	-120	-250	15
10	18	0	-8	10	8	6	6	10	0	-120	-250	20
18	30	0	-10	13	10	8	8	13	0	-120	-250	20
30	50	0	-12	15	12	9	9	15	0	-120	-250	20
50	80	0	-15	19	19	11	11	20	0	-150	-380	25
80	120	0	-20	25	25	15	15	25	0	-200	-380	25
120	180	0	-25	31	31	19	19	30	0	-250	-500	30
180	250	0	-30	38	38	23	23	40	0	-300	-500	30
250	315	0	-35	44	44	26	26	50	0	-350	-500	35
315	400	0	-40	50	50	30	30	60	0	-400	-630	40
400	500	0	-45	56	56	34	34	65	0	-450	-	50
500	630	0	-50	63	63	38	38	70	0	-500		60
630	800	0	-75	-	-	-	-	80	0	-750		70
800	1000	0	-100	-	-	-	-	90	0	-1000		80
1000	1250	0	-125	-	-	-	-	100	0	-1250		100
1250	1600	0	-160	-	-	-	-	120	0	-1600		120
1600	2000	0	-200	-	-	-	-	140	0	-2000		140

Note : 1) Including 0.6 .
2) No stipulated values for diameter series 7 and 8.
3) This refers to the inner rings of single bearings made for paired or stack mounting.

Table 8.3 Radial Bearings (except taper roller bearings)

Tolerance class 0 Outer ring

μm

D mm		ΔD_{mp}		V_{Dp}[2)4)] Open Bearings, Diameter Series 9	Open Bearings, Diameter Series 0,1	Open Bearings, Diameter Series 2,3,4	Capped[3)] Bearings, Diameter Series 2,3,4	V_{Dmp}[4)]	K_{ea}	ΔC_s[5)] / ΔC_{1s}[5)]		V_{Cs}[5)] / V_{C1s}[5)]
over	incl	high	low	max	max	max	max	max	max	high	low	max
2.5[1)]	6	0	-8	10	8	6	10	6	15			
6	18	0	-8	10	8	6	10	6	15			
18	30	0	-9	12	9	7	12	7	15			
30	50	0	-11	14	11	8	16	8	20			
50	80	0	-13	16	13	10	20	10	25			
80	120	0	-15	19	19	11	26	11	35			
120	150	0	-18	23	23	14	30	14	40	Identical to ΔB_s and V_{Bs} of inner ring of same bearing		
150	180	0	-25	31	31	19	38	19	45			
180	250	0	-30	38	38	23	-	23	50			
250	315	0	-35	44	44	26	-	26	60			
315	400	0	-40	50	50	30	-	30	70			
400	500	0	-45	56	56	34	-	34	80			
500	630	0	-50	63	63	38	-	38	100			
630	800	0	-75	94	94	55	-	55	120			
800	1000	0	-100	125	125	75	-	75	140			
1000	1250	0	-125	-	-	-	-	-	160			
1250	1600	0	-160	-	-	-	-	-	190			
1600	2000	0	-200	-	-	-	-	-	220			
2000	2500	0	-250	-	-	-	-	-	250			

Note : The tolerance provision for outer ring flange outer diameter, see table 8.20

1) Including 2.5.
2) No values have been established for diameter series 7 and 8.
3) No values have been established for diameter series 9 ,0 and1.
4) Applies before mounting and after removal of internal or external snap ring.
5) This only apply to deep groove ball bearings.

Table 8.4 Radial Bearings (except taper roller bearings)

Tolerance class 6 Inner ring

μm

d mm		Δd_{mp}		V_{dp}[2)] Diameter Series 9	Diameter Series 0,1	Diameter Series 2,3,4	V_{dmp}	K_{ia}	ΔB_s All	ΔB_s Normal	ΔB_s Modified[3)]	V_{Bs}
over	incl	high	low	max	max	max	max	max	high	low	low	max
0.6[1)]	2.5	0	-7	9	7	5	5	5	0	-40	-	12
2.5	10	0	-7	9	7	5	5	6	0	-120	-250	15
10	18	0	-7	9	7	5	5	7	0	-120	-250	20
18	30	0	-8	10	18	6	6	8	0	-120	-250	20
30	50	0	-10	13	10	8	8	10	0	-120	-250	20
50	80	0	-12	15	15	9	9	10	0	-150	-380	25
80	120	0	-15	19	19	11	11	13	0	-200	-380	25
120	180	0	-18	23	23	14	14	18	0	-250	-500	30
180	250	0	-22	28	28	17	17	20	0	-300	-500	30
250	315	0	-25	31	31	19	19	25	0	-350	-500	35
315	400	0	-30	38	38	23	23	30	0	-400	-630	40
400	500	0	-35	44	44	26	26	35	0	-450	-	45
500	630	0	-40	50	50	30	30	40	0	-500	-	50

Note : 1) Including 0.6.
2) No values have been established for diameter series 7 and 8.
3) This refers to the inner rings of single bearings made for paired or stack mounting.

Table 8.5 Radial Bearings (except taper roller bearings)

Tolerance class 6 Outer ring

μm

D mm		ΔD_{mp}		V_{Dp}[2)4)] Open Bearings, Diameter Series 9	Open Bearings, Diameter Series 0,1	Open Bearings, Diameter Series 2,3,4	Capped[3)] Bearings, Diameter Series 2,3,4	V_{Dmp}[4)]	K_{ea}	ΔC_s[5)] / ΔC_{1s}[5)]		V_{Cs}[5)] / V_{C1s}[5)]
over	incl	high	low	max	max	max	max	max	max	high	low	max
2.5[1)]	6	0	-7	9	7	5	9	5	8			
6	18	0	-7	9	7	5	9	5	8			
18	30	0	-8	10	8	6	10	6	9			
30	50	0	-9	11	9	7	13	7	10			
50	80	0	-11	14	11	8	16	8	13			
80	120	0	-13	16	16	10	20	10	18	Identical to ΔB_s and V_{Bs} of inner ring of same bearing		
120	150	0	-15	19	19	11	25	11	20			
150	180	0	-18	23	23	14	30	14	23			
180	250	0	-20	25	25	15	-	15	25			
250	315	0	-25	31	31	19	-	19	30			
315	400	0	-28	35	35	21	-	21	35			
400	500	0	-33	41	41	25	-	25	40			
500	630	0	-38	48	48	29	-	29	50			
630	800	0	-45	56	56	34	-	34	60			
800	1000	0	-60	75	75	45	-	45	75			

Note : The tolerance provision for outer ring flange outer diameter, see table 8.20

1) Including 2.5.
2) No values have been established for diameter series 7 and 8.
3) No values have been established for diameter series 9 .
4) Applies before mounting and after removal of internal or external snap ring.
5) This only applies to deep groove ball bearings.

Table 8.6 Radial Bearings (except taper roller bearings)

Tolerance class 5 Inner ring

μm

d mm		Δd_{mp}		V_{dp}[2)] Diameter Series 9	Diameter Series 0,1,2,3,4	V_{Dmp}	K_{ia}	S_d	S_{ia}[3)]	ΔB_s All	ΔB_s Normal	ΔB_s Modified[3)]	V_{Bs}
over	incl	high	low	max	max	max	max	max	max	high	low	low	max
0.6[1)]	2.5	0	-5	5	4	3	4	7	7	0	-40	-250	5
2.5	10	0	-5	5	4	3	4	7	7	0	-40	-250	5
10	18	0	-5	5	4	3	4	7	7	0	-80	-250	5
18	30	0	-6	6	5	3	4	8	8	0	-120	-250	5
30	50	0	-8	8	6	4	5	8	8	0	-120	-250	5
50	80	0	-9	9	7	5	5	8	8	0	-150	-250	6
80	120	0	-10	10	8	5	6	9	9	0	-200	-380	7
120	180	0	-13	13	10	7	8	10	10	0	-250	-380	8
180	250	0	-15	15	12	8	10	11	11	0	-300	-500	10
250	315	0	-18	18	14	9	13	13	15	0	-350	-500	13
315	400	0	-23	23	18	12	15	15	20	0	-400	-630	15

Note : 1) Including 0.6.
2) No values have been established for diameter series 7 and 8.
3) This only applies to deep groove ball bearings.
4) This refers to the inner rings of single bearings made for paired or stack mounting.

Table 8.7 Radial Bearings (except taper roller bearings)

Tolerance class 5 Outer ring

μm

D mm		ΔD_{mp}		V_{Dp}[2,3] Diameter Series		V_{dmp}	K_{ea}	S_D[4] / S_D[5]	S_{ea}[4,5]	S_{ea1}[4,5]	ΔC_s[5] / ΔC_{1s}[5]	V_{Cs}[5] / V_{C1s}[5]
				9	0,1,2,3,4							
over	incl	high	low	max	max	max	max	max	max	max	high	max
2.5[1]	6	0	-5	5	4	3	5	8	8	11		5
6	18	0	-5	5	4	3	5	8	8	11		5
18	30	0	-6	6	5	3	6	8	8	11		5
30	50	0	-7	7	5	4	7	8	8	11		5
50	80	0	-9	9	7	5	8	8	10	14		6
80	120	0	-10	10	8	5	10	9	11	16	Identical to △Bs and VBs of inner ring of same bearing	8
120	150	0	-11	11	8	6	11	10	13	18		8
150	180	0	-13	13	10	7	13	10	14	20		8
180	250	0	-15	15	12	8	15	11	15	21		10
250	315	0	-18	18	14	9	18	13	18	25		11
315	400	0	-20	20	15	10	20	13	20	28		13
400	500	0	-23	23	17	11	23	15	23	33		15
500	630	0	-28	28	21	14	25	18	25	35		18
630	800	0	-35	35	26	18	30	20	30	42		20

Note : The tolerance provision for outer ring flange outer diameter, see table 8.20

1) Including 2.5.

2) No values have been established for diameter series 7 and 8.

3) No values have been established for capped bearings.

4) It does not apply to bearings with flange.

5) This only applies to deep groove ball bearings.

Table 8.8 Radial Bearings (except taper roller bearings)

Tolerance class 4 Inner ring

μm

d mm		Δd_{mp}		Δd_s[2]		V_{dp}[2] Diameter Series		V_{dmp}	K_{ia}	S_d	S_{ia}[3]	ΔB_s			V_{Bs}
						9	0,1,2,3,4					All	Normal	Modified[3]	
over	incl	high	low	high	low	max	max	max	max	max	max	high	low	low	max
0.6[1]	2.5	0	-4	0	-4	4	3	2	2.5	3	3	0	-40	-250	2.5
2.5	10	0	-4	0	-4	4	3	2	2.5	3	3	0	-40	-250	2.5
10	18	0	-4	0	-4	4	3	2	2.5	3	3	0	-80	-250	2.5
18	30	0	-5	0	-5	5	4	2.5	4	4	3	0	-120	-250	2.5
30	50	0	-6	0	-6	6	5	3	4	4	4	0	-120	-250	3
50	80	0	-7	0	-7	7	5	3.5	4	5	5	0	-150	-250	4
80	120	0	-8	0	-8	8	6	4	5	5	5	0	-200	-380	4
120	180	0	-10	0	-10	10	8	5	6	6	7	0	-250	-380	5
180	250	0	-12	0	-12	12	9	6	7	7	8	0	-300	-500	6

Note:
1) Including 0.6 .

2) This only applies to diameter series 0,1,2,3 and 4.

3) No values have been established for diameter series 7 and 8.

4) This only applies to deep groove ball bearings.

5) This refers to the inner rings of single bearings made for paired or stack mounting.

Table 8.9 Radial Bearings (except taper roller bearings)

Tolerance class 4 Outer ring

μm

D mm		ΔD_{mp}		ΔD_a[2,3,4]		V_{Dp}[3,4] Diameter Series		V_{Dmp}	K_{ea}	S_D[5] / S_D[6]	S_{ea}[5,6]	S_{ea1}[6]	ΔC_s / ΔC_{1s}		V_{cs} / V_{c1s}
						9	0,1,2,3,4								
over	incl	high	low	high	low	max	max	max	max	max	max	max	high	low	max
2.5[1]	6	0	-4	0	-4	4	3	2	3	4	5	7			2.5
6	18	0	-4	0	-4	4	3	2	3	4	5	7			2.5
18	30	0	-5	0	-5	5	4	2.5	4	4	5	7			2.5
30	50	0	-6	0	-6	6	5	3	5	4	5	7			2.5
50	80	0	-7	0	-7	7	5	3.5	5	4	5	7			3
80	120	0	-8	0	-8	8	6	4	6	5	6	8	Identical to △Bs and VBs of inner ring of same bearing		4
120	150	0	-9	0	-9	9	7	5	7	5	7	10			5
150	180	0	-10	0	-10	10	8	5	8	5	8	11			5
180	250	0	-11	0	-11	11	8	6	10	7	10	14			7
250	315	0	-13	0	-13	13	10	7	11	8	10	14			7
315	400	0	-15	0	-15	15	11	8	13	10	13	18			8

Note : The tolerance provision for outer ring flange outer diameter, see table 8.20

1) Including 2.5.

2) This only applies to diameter series0,1,2,3 and 4.

3) No values have been established for diameter series 7 and 8.

4) No values have been established for capped bearings.

5) It does not apply to bearings with flange.

6) It only applies to deep groove ball bearings.

Table 8.10 Radial Bearings (except taper roller bearings)

Tolerance class 2 Inner ring

μm

d mm		Δd_{mp}		Δd_s		V_{dp}[2]	V_{dmp}	K_{ia}	S_d	S_{ia}[3]	ΔB_s			V_{Bs}
											All	Normal	Modified	
over	incl	high	low	high	low	max	max	max	max	max	high	low	low	max
0.6[1]	2.5	0	-2.5	0	-2.5	2.5	1.5	1.5	1.5	1.5	0	-40	-250	1.5
2.5	10	0	-2.5	0	-2.5	2.5	1.5	1.5	1.5	1.5	0	-40	-250	1.5
10	18	0	-2.5	0	-2.5	2.5	1.5	1.5	1.5	1.5	0	-80	-250	1.5
18	30	0	-2.5	0	-2.5	2.5	1.5	2.5	1.5	2.5	0	-120	-250	1.5
30	50	0	-2.5	0	-2.5	2.5	1.5	2.5	1.5	2.5	0	-120	-250	1.5
50	80	0	-4	0	-4	4	2	2.5	1.5	2.5	0	-150	-250	1.5
80	120	0	-5	0	-5	5	2.5	2.5	2.5	2.5	0	-200	-380	2.5
120	150	0	-7	0	-7	7	3.5	2.5	2.5	2.5	0	-250	-380	2.5
150	180	0	-7	0	-7	7	3.5	5	4	5	0	-250	-380	4
180	250	0	-8	0	-8	8	4	5	5	5	0	-300	-500	5

Note : 1) Including 0.6.

2) It does not apply to diameter series 7,8 and 9.

3) This only applies to deep groove ball bearings.

4) This refers to the inner rings width deviation of single bearings made for paired or stack mounting.

Table 8.11 Radial Bearings (except tapered roller bearings)

Tolerance class 2 Outer ring

μm

D mm		ΔD_{mp}		ΔD_s [2]		V_{dp} [2]	V_{Dmp}	K_{ea}	S_D [3] S_{D1} [4]	S_{ea} [3)4)]	S_{ea1} [4]	ΔC_s [4] ΔC_{1s} [4]		V_{Cs} [4] V_{C1s} [4]
over	incl	high	low	high	low	max	max	max	max	max	max	high	low	max
2.5 [1]	6	0	-2.5	0	-2.5	2.5	1.5	1.5	1.5	1.5	3	Identical to ΔB_s and V_{Bs} of inner ring of same bearing		1.5
6	18	0	-2.5	0	-2.5	2.5	1.5	1.5	1.5	1.5	3			1.5
18	30	0	-4	0	-4	4	2	2.5	1.5	2.5	4			1.5
30	50	0	-4	0	-4	4	2	2.5	1.5	2.5	4			1.5
50	80	0	-4	0	-4	4	2	4	1.5	4	6			1.5
80	120	0	-5	0	-5	5	2.5	5	2.5	5	7			2.5
120	150	0	-5	0	-5	5	2.5	5	2.5	5	7			2.5
150	180	0	-7	0	-7	7	3.5	5	2.5	5	7			2.5
180	250	0	-8	0	-8	8	4	7	4	7	10			4
250	315	0	-8	0	-8	8	4	7	5	7	10			5
315	400	0	-10	0	-10	10	5	8	7	8	11			7

Note: The tolerances for the outside diameter of an outer ring flange are given in Table 8.20

1) Including 2.5.
2) Only applies to open bearings and close bearings with diameter series 0,1,2,3, and 4.
3) Not applies to outer ring flange bearings.
4) Only applies to deep groove ball bearings.

Table 8.12 Taper Roller Bearing

Tolerances class 0 Inner ring – Diameter tolerance and radial runout

μm

d mm		Δd_{mp}		V_{dp}	V_{dmp}	K_{ia}
over	incl	high	low	max	max	max
10	18	0	-12	12	9	15
18	30	0	-12	12	9	18
30	50	0	-12	12	9	20
50	80	0	-15	15	11	25
80	120	0	-20	20	15	30
120	180	0	-25	25	19	35
180	250	0	-30	30	23	50
250	315	0	-35	35	26	60
315	400	0	-40	40	30	70

Table 8.13 Taper Roller Bearing

Tolerances Class 0 Outer ring – Diameter tolerance and radial runout

μm

D mm		ΔD_{mp}		V_{Dp}	V_{Dmp}	K_{ea}
over	incl	high	low	max	max	max
18	30	0	-12	12	9	18
30	50	0	-14	14	11	20
50	80	0	-16	16	12	25
80	120	0	-18	18	14	35
120	150	0	-20	20	15	40
150	180	0	-25	25	19	45
180	250	0	-30	30	23	50
250	315	0	-35	35	26	60
315	400	0	-40	40	30	70
400	500	0	-45	45	34	80
500	630	0	-50	50	38	100

Note: The tolerances for the outside diameter D_1 of an outer ring flange are given in Table8.20

Table 8.14 Taper Roller Bearing

Tolerance Class 0 Width – Inner and outer ring, single row bearing and their sub-units

μm

d mm		ΔB_s		ΔC_s		ΔT_s		ΔT_{1s}		ΔT_{2s}	
over	incl	high	low	high	low	high	low	high	low	high	low
10	18	0	-120	0	-120	+200	0	+100	0	+100	0
18	30	0	-120	0	-120	+200	0	+100	0	+100	0
30	50	0	-120	0	-120	+200	0	+100	0	+100	0
50	80	0	-150	0	-150	+200	0	+100	0	+100	0
80	120	0	-200	0	-200	+200	-200	+100	-100	+100	-100
120	180	0	-250	0	-250	+350	-250	+250	-150	+200	-100
180	250	0	-300	0	-300	+350	-250	+150	-150	+200	-100
250	315	0	-350	0	-350	+350	-250	+150	-150	+200	-100
315	400	0	-400	0	-400	+400	-400	+200	-200	+200	-200

Table 8.15 Taper Roller Bearing

Tolerance Class 6X Width – Inner and outer ring, single row bearing and their sub-units

μm

d mm		ΔB_s		ΔC_s		ΔT_s		ΔT_{1s}		ΔT_{2s}	
over	incl	high	low	high	low	high	low	high	low	high	low
10	18	0	-50	0	-100	+100	0	+50	0	+50	0
18	30	0	-50	0	-100	+100	0	+50	0	+50	0
30	50	0	-50	0	-100	+100	0	+50	0	+50	0
50	80	0	-50	0	-100	+100	0	+50	0	+50	0
80	120	0	-50	0	-100	+100	0	+50	0	+50	0
120	180	0	-50	0	-100	+150	0	+50	0	+100	0
180	250	0	-50	0	-100	+150	0	+50	0	+100	0
250	315	0	-50	0	-100	+200	0	+100	0	+100	0
315	400	0	-50	0	-100	+200	0	+100	0	+100	0

Table 8.16 Taper Roller Bearing

Tolerances class 5 Inner ring and single row bearing width

μm

d mm		Δd_{mp}		V_{dp}	V_{dmp}	K_{ia}	S_d	ΔB_s		ΔT_s	
over	incl	high	low	max	max	max	max	high	low	high	low
10	18	0	-7	5	5	5	7	0	-200	+200	-200
18	30	0	-8	6	5	5	8	0	-200	+200	-200
30	50	0	-10	8	5	6	8	0	-240	+200	-200
50	80	0	-12	9	6	7	8	0	-300	+200	-200
80	120	0	-15	11	8	8	9	0	-400	+200	-200
120	180	0	-18	14	9	11	10	0	-500	+350	-250
180	250	0	-22	17	11	13	11	0	-600	+350	-250

Table 8.17 Taper Roller Bearing

Tolerance Class 5 Outer ring

μm

D mm		ΔD_{mp}		V_{Dp}	V_{Dmp}	K_{ea}	S_D[1], S_{D1}	ΔC_s	
over	incl	high	low	max	max	max	max	high	low
18	30	0	-8	6	5	6	8	Identical to ΔB_s of inner ring of same bearing	
30	50	0	-9	7	5	7	8		
50	80	0	-11	8	6	8	8		
80	120	0	-13	10	7	10	9		
120	150	0	-15	11	8	11	10		
150	180	0	-18	14	9	13	10		
180	250	0	-20	15	10	15	11		
250	315	0	-25	19	13	18	13		
315	400	0	-28	22	14	20	13		

Note: The tolerances for the outside diameter D1 of an outer ring flange are given in Table8.20
1) Not apply to outer ring flange bearings.

Table 8.18 Taper Roller Bearing

Tolerances Class 4 Inner ring and single row bearing width

μm

d mm		Δd_{mp}		Δd_s		V_{dp}	V_{dmp}	K_{ia}	S_d	S_{id}	ΔB_s		ΔT_s	
over	incl	high	low	high	low	max	max	max	max	max	high	low	high	low
10	18	0	-5	0	-5	4	4	3	3	3	0	-200	+200	-200
18	30	0	-6	0	-6	5	4	3	4	4	0	-200	+200	-200
30	50	0	-8	0	-8	6	5	4	4	4	0	-240	+200	-200
50	80	0	-9	0	-9	7	5	4	5	4	0	-300	+200	-200
80	120	0	-10	0	-10	8	5	5	5	5	0	-400	+200	-200
120	180	0	-13	0	-13	10	7	6	6	7	0	-500	+350	-250
180	250	0	-15	0	-15	11	8	8	7	8	0	-600	+350	-250

Table 8.19 Taper Roller Bearing

Tolerance Class 4 Outer ring

μm

D mm		ΔD_{mp}		ΔD_s		V_{Dp}	V_{Dmp}	K_{ea}	S_D[1], S_{D1}	S_{ea}[1]	S_{ea1}	ΔC_s	
over	incl	high	low	high	low	max	max	max	max	max	max	high	low
18	30	0	-6	0	-6	5	4	4	4	5	7	Identical to ΔB_s of inner ring of same bearing	
30	50	0	-7	0	-7	5	5	5	4	5	7		
50	80	0	-9	0	-9	7	5	5	4	5	7		
80	120	0	-10	0	-10	8	5	5	5	6	8		
120	150	0	-11	0	-11	8	6	6	5	7	10		
150	180	0	-13	0	-13	10	7	7	5	8	11		
180	250	0	-15	0	-15	11	8	10	7	10	14		
250	315	0	-18	0	-18	14	9	11	8	10	14		
315	400	0	-20	0	-20	15	10	13	10	13	18		

Note: The tolerances for the outside diameter D1 of an outer ring flange are given in Table8.20
1) Not apply to outer ring flange bearings.

Table 8.20 Radial Bearings with Flanged Outer Ring

Tolerance for flanged outer diameter

μm

D_1 mm		ΔD_{1s}			
		Mounting Flange		Non-Mounting Flange	
over	incl	high	low	high	low
-	10	0	-36	+220	-36
10	18	0	-43	+270	-43
18	30	0	-52	+330	-52
30	50	0	-62	+390	-62
50	80	0	-74	+460	-74
80	120	0	-87	+540	-87
120	180	0	-100	+630	-100
180	250	0	-115	+720	-115
250	315	0	-130	+810	-130
315	400	0	-140	+890	-140
400	500	0	-155	+970	-155
500	630	0	-175	+1100	-175
630	800	0	-200	+1250	-200
800	1000	0	-230	+1400	-230
1000	1250	0	-260	+1650	-260
1250	1600	0	-310	+1950	-310
1600	2000	0	-370	+2300	-370
2000	2500	0	-440	+2800	-440

Tapered bore, taper 1:12 and 1:30 (Fig 8.4 and Fig 8.5)

Taper 1:12

Nominal half tapered angle

a=2° 23′ 9. 1=2. 385 94° =0.041643 Radian

Basic diameter of nominal bigger tapered bore

$$d_1 = d + \frac{1}{12} B$$

Taper 1:30

Nominal half tapered angle

a=0° 57′ 17.4″ =0. 954 84°=0.01667 Radian

Basic diameter of nominal bigger tapered bore

$$d_1 = d + \frac{1}{30} B$$

Tapered bore tolerance includes

1) Mean diameter tolerance, shown by the limit of the actual mean diameter deviation <$\triangle d_{mp}$ for nominal smaller tapered bore.
2) Taper tolerance, shown by the limit of the actual mean diameter deviation difference($\triangle d_{1mp}$ -$\triangle d_{mp}$) Of the both ends of tapered bore.
3) Diameter variation tolerance, shown by the maximum of the inner diameter variation V_{dp} within any radial plane of the tapered bore.

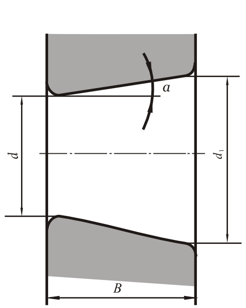


Fig 8.4 Nominal tapered bore

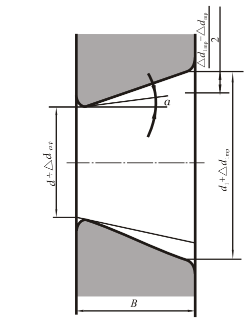


Fig 8.5 Tapered bore with actual mean diameters and their deviations

Table 8.21 Radial Bearings Tolerance Class 0 Tapered Bore(1:12)

μm

d mm		Δd_{mp}		$\Delta d_{1mp} - \Delta d_{mp}$		V_{dp} [1)2)]
over	incl	high	low	high	low	max
	10	+22	0	+15	0	9
10	18	+27	0	+18	0	11
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	1000	+140	0	+90	0	-
1000	1250	+165	0	+105	0	-
1250	1600	+195	0	+125	0	-

Note: 1) Apply to any single radial plane of inner bore.
2) Not apply to diameter series 7 and 8.

Table 8.22 Radial Bearings Tolerance Class 0 Tapered Bore(1:30)

μm

d mm		Δd_{mp}		$\Delta d_{1mp} - \Delta d_{mp}$		V_{dp} [1)2)]
over	incl	high	low	high	low	max
50	80	+15	0	+30	0	19
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

Note: 1) Apply to any radial plane of inner bore.
2) Not apply to diameter series 7 and 8.

Table 8.23 Thrust Bearings Tolerance Class 0 Shaft Washer and Bearing Height

μm

d, d_2/mm		Δd_{mp}, Δd_{2mp}		V_{dp}, V_{d2p}	S_i	ΔT_s		ΔT_{1s}	
over	incl	high	low	max	max	high	low	high	low
-	18	0	-8	6	0	+20	-250	+150	-400
18	30	0	-10	8	10	+20	-250	+150	-400
30	50	0	-12	9	10	+20	-250	+150	-400
50	80	0	-15	11	10	+20	-300	+150	-500
80	120	0	-20	15	15	+25	-300	+200	-500
120	180	0	-25	19	15	+25	-400	+200	-600
180	250	0	-30	23	20	+30	-400	+250	-600
250	315	0	-35	26	25	+40	-400	-	-
315	400	0	-40	30	30	+40	-500	-	-
400	500	0	-45	34	30	+50	-500	-	-
500	630	0	-50	38	35	+60	-600	-	-
630	800	0	-75	55	40	+70	-750	-	-
800	1000	0	-100	75	45	+80	-1000	-	-
1000	1250	0	-125	95	50	+100	-1400	-	-
1250	1600	0	-160	120	60	+120	-1600	-	-
1600	2000	0	-200	150	75	+140	-1900	-	-
2000	2500	0	-250	190	90	+160	-2300	-	-

Note: For double direction bearings, tolerance only applies to bearings $d_2 \leq 190$mm.

Table 8.24 Thrust Bearings Tolerance Class 0 Housing Washer

μm

D/mm		ΔD_{mp}		V_{Dp}	S_e
over	incl	high	low	max	max
10	18	0	-11	8	
18	30	0	-13	10	
30	50	0	-16	12	
50	80	0	-19	14	
80	120	0	-22	17	
120	180	0	-25	19	
180	250	0	-30	23	
250	315	0	-35	26	
315	400	0	-40	30	Equivalent to the value si of shaft washer of same bearing
400	500	0	-45	34	
500	630	0	-50	38	
630	800	0	-75	55	
800	1000	0	-100	75	
1000	1250	0	-125	95	
1250	1600	0	-160	120	
1600	2000	0	-200	150	
2000	2500	0	-250	190	
2500	2850	0	-300	225	

Note: For double direction bearings, tolerance only applies to bearings D≤360mm.

Table 8.25 Thrust Bearings Tolerance Class 6 Shaft Washer and Bearing Height

μm

d, d_2/mm		Δ_{dmp}, Δ_{d2mp}		V_{dp}, V_{d2p}	S_i	Δ_{Ts}		Δ_{T1s}	
over	incl	high	low	max	max	high	low	high	low
-	18	0	-8	6	5	+20	-250	+150	-400
18	30	0	-10	8	5	+20	-250	+150	-400
30	50	0	-12	9	6	+20	-250	+150	-400
50	80	0	-15	11	7	+20	-300	+150	-500
80	120	0	-20	15	8	+25	-300	+200	-500
120	180	0	-25	19	9	+25	-400	+200	-600
180	250	0	-30	23	10	+30	-400	+250	-600
250	315	0	-35	26	13	+40	-400	-	-
315	400	0	-40	30	15	+40	-500	-	-
400	500	0	-45	34	18	+50	-500	-	-
500	630	0	-50	38	21	+60	-600	-	-
630	800	0	-75	55	25	+70	-750	-	-
800	1000	0	-100	75	30	+80	-1000	-	-
1000	1250	0	-125	95	35	+100	-1400	-	-
1250	1600	0	-160	120	40	+120	-1600	-	-
1600	2000	0	-200	150	45	+140	-1900	-	-
2000	2500	0	-250	190	50	+160	-2300	-	-

Note: For double direction bearings, tolerance only applies to bearings d_2≤190mm.

Table 8.26 Thrust Bearings Tolerance Class 6 Housing Washer

μm

D/mm		Δ_{Dmp}		V_{Dp}	S_e
over	incl	high	low	max	max
10	18	0	-11	8	Equivalent to the value si of shaft washer of same bearing
18	30	0	-13	10	
30	50	0	-16	12	
50	80	0	-19	14	
80	120	0	-22	17	
120	180	0	-25	19	
180	250	0	-30	23	
250	315	0	-35	26	
315	400	0	-40	30	
400	500	0	-45	34	
500	630	0	-50	38	
630	800	0	-75	55	
800	1000	0	-100	75	
1000	1250	0	-125	95	
1250	1600	0	-160	120	
1600	2000	0	-200	150	
2000	2500	0	-250	190	
2500	2850	0	-300	225	

Note: For double direction bearings, tolerance only applies to bearings D≤360mm.

Table 8.27 Thrust Bearings Tolerance Class 5 Shaft Washer and Bearing Height

μm

d, d_2/mm		Δ_{dmp}, Δ_{d2mp}		V_{dp}, V_{d2p}	S_i	Δ_{Ts}		Δ_{T1s}	
over	incl	high	low	max	max	high	low	high	low
	18	0	-8	6	3	+20	-250	+150	-400
18	30	0	-10	8	3	+20	-250	+150	-400
30	50	0	-12	9	3	+20	-250	+150	-400
50	80	0	-15	11	3	+20	-300	+150	-500
80	120	0	-20	15	4	+25	-300	+200	-500
120	180	0	-25	19	5	+25	-400	+200	-600
180	250	0	-30	23	5	+30	-400	+250	-600
250	315	0	-35	26	7	+40	-400	-	-
315	400	0	-40	30	7	+40	-500	-	-
400	500	0	-45	34	9	+50	-500	-	-
500	630	0	-50	38	11	+60	-600	-	-
630	800	0	-75	55	13	+70	-750	-	-
800	1000	0	-100	75	15	+80	-1000	-	-
1000	1250	0	-125	95	18	+100	-1400	-	-
1250	1600	0	-160	120	25	+120	-1600	-	-
1600	2000	0	-200	150	30	+140	-1900	-	-
2000	2500	0	-250	190	40	+160	-2300	-	-

Note: For double direction bearings, tolerance only applies to bearings d_2≤190mm.

Table 8.28 Thrust Bearings Tolerance Class 5 Housing Washer

μm

D/mm		Δ_{Dmp}		V_{Dp}	S_e
over	incl	high	low	max	max
10	18	0	-11	8	Equivalent to the value si of shaft washer of same bearing
18	30	0	-13	10	
30	50	0	-16	12	
50	80	0	-19	14	
80	120	0	-22	17	
120	180	0	-25	19	
180	250	0	-30	23	
250	315	0	-35	26	
315	400	0	-40	30	
400	500	0	-45	34	
500	630	0	-50	38	
630	800	0	-75	55	
800	1000	0	-100	75	
1000	1250	0	-125	95	
1250	1600	0	-160	120	
1600	2000	0	-200	150	
2000	2500	0	-250	190	
2500	2850	0	-300	225	

Note: For double direction bearings, tolerance only applies to bearings D≤360mm.

Table 8.29 Thrust Bearings Tolerance Class 4 Shaft Washer and Bearing Height

μm

d, d_2/mm		Δ_{dmp}, Δ_{d2mp}		V_{dp}, V_{d2p}	S_i	Δ_{Ts}		Δ_{T1s}	
over	incl	high	low	max	max	high	low	high	low
-	18	0	-7	5	2	+20	-250	+150	-400
18	30	0	-8	6	2	+20	-250	+150	-400
30	50	0	-10	8	2	+20	-250	+150	-400
50	80	0	-12	9	3	+20	-300	+150	-500
80	120	0	-15	11	3	+25	-300	+200	-500
120	180	0	-18	14	4	+25	-400	+200	-600
180	250	0	-22	17	4	+30	-400	+250	-600
250	315	0	-25	19	5	+40	-400	-	-
315	400	0	-30	23	5	+40	-500	-	-
400	500	0	-35	26	6	+50	-500	-	-
500	630	0	-40	30	7	+60	-600	-	-
630	800	0	-50	40	8	+70	-750	-	-

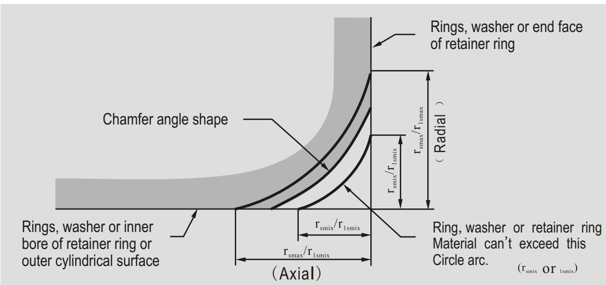
Note: For double direction bearings, tolerance only applies to bearings $d_2 \leq 190$mm.

Table 8.30 Thrust Bearings Tolerance Class 4 Housing Washer

μm

D/mm		Δ_{Dmp}		V_{Dp}	S_e
over	incl	high	low	max	max
10	18	0	-7	5	Equivalent to the value si of shaft washer of same bearing
18	30	0	-8	6	
30	50	0	-9	7	
50	80	0	-11	8	
80	120	0	-13	10	
120	180	0	-15	11	
180	250	0	-20	15	
250	315	0	-25	19	
315	400	0	-28	21	
400	500	0	-33	25	
500	630	0	-38	29	
630	800	0	-45	34	
800	1000	0	-60	45	

Note: For double direction bearings, tolerance only applies to bearings D≤360mm.



Note: The exact shape of the chamfer will not be specified, but its profile should not overstep the circle arc, which is tangent to the end face and inner bore or the surface of outer cylinder of the bearing rings within the radial plane. Refer to this Figure.

Fig 8.6

Table 8.31 The Maximum of Chamfer Dimension of Radial Bearing

mm

r_{smin} [1]	d		r_{smax} [2]	
	over	incl	radial	axial
0.05	–	–	0.1	0.2
0.08	–	–	0.16	0.3
0.1	–	–	0.2	0.4
0.15	–	–	0.3	0.6
0.2	–	–	0.5	0.8
0.3	–	40	0.6	1
	40	–	0.8	1
0.6	–	40	1	2
	40	–	1.3	2
1	–	50	1.5	3
	50	–	1.9	3
1.1	–	120	2	3.5
	120	–	2.5	4
1.5	–	120	2.3	4
	120	–	3	5
2	–	80	3	4.5
	80	220	3.5	5
	220	–	3.8	6
2.1	–	280	4	6.5
	280	–	4.5	7
2.5 [3]	–	100	3.8	6
	100	280	4.5	6
	280	–	5	7
3	–	280	5	8
	280	–	5.5	8
4	–	–	6.5	9
	–	–	8	10
	–	–	10	13
	–	–	12.5	17
	–	–	15	19
	–	–	18	24
	–	–	21	30
	–	–	25	38

1) The permissible maximum single chamfer dimension "r_{asmax}" of shaft and outer bore should not be larger than the permissible minimum single chamfer dimension "r_{smin}" or "r_{1smin}" of the corresponding bearing ring or washer.

2) For the bearing whose width is less than 2mm, the radial value of r_{smax} is also suitable for axial.

Table 8.32 The Maximum Chamfer Dimensions of Cylindrical Roller Bearing Loose Rib, Thrust Collar and One Side Outer Ring with Snap Ring Groove.

mm

r_{1smin} [1]	d or D		r_{1smax} [2]	
	over	incl	radial	axial
0.2	-	-	0.5	0.5
0.3	-	40	0.6	0.8
	40	-	0.8	0.8
0.5	-	40	1	1.5
	40	-	1.3	1.5
0.6	-	40	1	1.5
	40	-	1.3	1.5
1	-	50	1.5	2.2
	50	-	1.9	2.2
1.1	-	120	2	2.7
	120	-	2.5	2.7
1.5	-	120	2.3	3.5
	120	-	3	3.5
2	-	80	3	4
	80	220	3.5	4
	220	-	3.8	4
2.1	-	280	4	4.5
	280	-	4.5	4.5
2.5 [2]	-	100	3.8	5
	100	280	4.5	5
	280	-	5	5
3	-	280	5	5.5
	280	-	5.5	5.5
4	-	-	6.5	6.5
5	-	-	8	8
6	-	-	10	10

1) The allowable maximum single chamfer dimension between shaft and housing r_{amax} should not be over the allowable minimum single chamfer dimension between the corresponding ring and washer r_{smin} or r_{1smin}.

Table 8.33 Maximum Chamfer Dimension of Inner and Outer Narrow End Faces of Cylindrical Roller Bearing and Outer Narrow End Faces of Angular Contact Ball Bearing

mm

r_{1smin} [1]	d or D		r_{1smax}	
	over	incl	radial	axial
0.1	-	-	0.2	0.4
0.15	-	-	0.3	0.6
0.2	-	-	0.5	0.8
0.3	-	40	0.6	1
	40	-	0.8	1
0.6	-	40	1	2
	40	-	1.3	2
1	-	50	1.5	3
	50	-	1.9	3
1.1	-	120	2	3.5
	120	-	2.5	4
1.5	-	120	2.3	4
	120	-	3	5
2	-	80	3	4.5
	80	220	3.5	5
	220	-	3.8	6

1) The allowable maximum single chamfer dimension between shaft and housing r_{amax} should not be over the allowable minimum single chamfer dimension between the corresponding ring and washer r_{smin} or r_{1smin}.

Table 8.34 Maximum Chamfer Dimension of Taper Roller Bearings

mm

r_{smin} [1]	d or D		r_{smax}	
	over	incl	radial	axial
0.3	-	40	0.7	1.4
	40	-	0.9	1.6
0.6	-	40	1.1	1.7
	40	-	1.3	2
1	-	50	1.6	2.5
	50	-	1.9	3
1.5	-	120	2.3	3
	120	250	2.8	3.5
	250	-	3.5	4
2	-	120	2.8	4
	120	250	3.5	4.5
	250	-	4	5
2.5	-	120	3.5	5
	120	250	4	5.5
	250	-	4.5	6
3	-	120	4	5.5
	120	250	4.5	6.5
	250	400	5	7
	400	-	5.5	7.5
4	-	120	5	7
	120	250	5.5	7.5
	250	400	6	8
	400	-	6.5	8.5
5	-	180	6.5	8
	180	-	7.5	9
6	-	180	7.5	10
	180	-	9	11

1) The allowable maximum single chamfer dimension between shaft and housing r_{amax} should not be over the allowable minimum single chamfer dimension between the corresponding ring and washer r_{smin} or r_{1smin}.

Table 8.35 Maximum Chamfer Dimension of Thrust Bearings

mm

r_{smin} 1) or r_{1smin} 1)	r_{smax} or r_{1smax} Radial and Axial
0.3	0.8
0.6	1.5
1	2.2
1.1	2.7
1.5	3.5
2	4
2.1	4.5
3	5.5
4	6.5
5	8
6	10
7.5	12.5
9.5	15
12	18
15	21
19	25

Note： The specified chamfer dimensions in this table are fit for:
a） Bottom surface of housing washer and chamfer of outer cylindrical surface.
b） Shaft washer bottom surface and bore surface chamfer of single-way bearing.
c） Central washer end face and bore surface chamfer of double-way bearing.
1） The allowable maximum single chamfer dimension between shaft and housing r_{asmax} should not be over the allowable minimum single chamfer dimension between the corresponding ring and washer r_{smin} or r_{lsmin}.

In the actual application, bearing clearance is divided into original clearance, mounting clearance, working clearance, and decrease in turn.
Original clearance: clearance after the assembling of bearing;
Mounting clearance: clearance after the mounting of bearing;
Working clearance: clearance under actual working condition.

8.4.2 Function of Clearance

Bearing clearances have a relatively great influence on the bearing life, revolution precision, vibration, noise, temperature, friction resistance etc. The main function of clearance includes:

- Guarantee the flexibility of bearing revolution
- Adjust the space of bearing load
  Guarantee the bearing gets the correct contact angle (angular contact ball bearing)
- Reduce the friction between the parts
- Diminish or eliminate the influence for bearing running performance due to the dimension deviation resulted from the heat expansion, interference fit of parts
- Helpful for the form of lubricating oil film
- Convenience for the inspection of bearing precision

8.4.3 Selection of Clearance

In order to guarantee the good state of bearing running, it is necessary to choose suitable bearing clearance. To select bearing clearance should pay attention to several questions as below:

- The internal dimension alternation of bearing under interference fit
- The dimension variation resulted from the temperature alternation when the bearing is running
- The internal dimension deviation due to the different material expansion factors of axis or bearing blocks

In the actual operation, the general rules of selecting clearance are:

- The working clearance of ball bearing should be zero, or have slight preload
- Cylindrical roller bearing and spherical roller bearing must have certain working clearance
- Taper roller bearing should usually have certain clearance, but if there is requirement for bearing rigidity, should be imposed on certain preload

Theoretically, when bearing working clearance is slightly negative (with a certain preload), the fatigue life of bearing is the longest, refer to Fig. 8.8. But the ideal state is difficult to keep due to many non-predicative factors, it could have the possibility to realize after iterative practice and adjust. It shows in this fig, when the negative clearance of bearing becomes large further, the

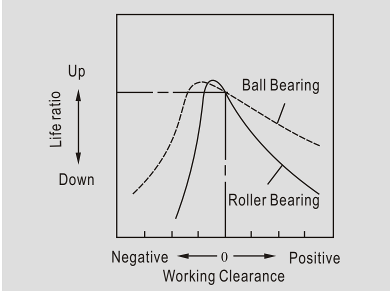


Fig 8.8

bearing fatigue life will obviously decline. This is a reliable method to select a larger working clearance value (over zero).

In GB/T4604<Rolling Bearing Radial Clearance>, the radial clearance of rolling bearing separately stipulated several different groups of clearance values according to the bearing structures to meet the selections of different customers. For example, the radial clearance of deep groove ball bearing is divided into C2, C0, C3, C4, C5 five clearance groups, in which C0 is the basic group, C2 is the smaller clearance group, C3, C4, C5 are the larger clearance groups.

The basic clearance group should be the priority selection for the bearings in normal working conditions. The basic clearance group should be the priority selection for the bearings in normal working conditions refer to:

- Inner ring rotating, inner ring and axis is assembled with interference fit
- The load of bearing P≤0.1Cr
- The speed of bearing is approximately less than 50% of its limiting speed
- Sufficient lubrication

For some bearings under the certain working condition, it should select different groups of bearing clearance according to their specific working condition. In order to lower the noise of motor bearings, the selected bearing clearance could be relatively smaller. In the situation of high rotating precision it should also select smaller clearance. However, the larger group of clearance should be selected for the high speed bearing or rolling mill bearings to reduce the rotating friction and lower the temperature of bearing. When the working temperature of bearing is higher, then a larger clearance should be selected.

Usually, this would mainly control the radial clearance of bearing, for three-point, four-point contact bearing and double-row, four-row taper roller bearing etc., it should control the axial clearance of bearing during the process of production.

The original clearance of bearing was mostly "errorred" due to the influence of the factor of heat during the assembling and working process etc., so the working clearance of bearing is usually smaller than original and assembling clearance.

Estimated according to the experience:

After assembling the bearing, the raceway of inner ring will expand due to the interference fit, the original clearance will reduce accordingly, the reduction is approximately 70%~80% of the interference fit value. In the same way, if the outer ring is interference fit, the raceway will reduce, the original clearance is also reduce.

During the rotating of bearing, the temperature difference will emerge between the inner ring and outer ring, the temperature of inner ring (inner ring rotating) is usually higher than that of outer ring (outer ring is static), the expansion of inner ring due to the heat will result in the reduction of clearance. The reduction could be estimated according to the following formula:

$$\Delta G_t \approx \alpha \cdot \Delta t \cdot F$$

where

- ΔG_t – The reduction of radial clearance resulted from the heat difference between the two rings, mm
- α – The linear expansion factor of bearing steel 12.5×10^{-6}, 1/℃
- Δt – The temperature difference between inner and outer rings, ℃
- F – The diameter of outer raceway, mm

The working clearance should be the difference value that the original clearance of bearing minus the above mentioned two reductions of the radial clearance.

8.4.4 Clearance Value

- The radial clearance of radial bearing refers to the table 8.36 ~ table 8.43.
- The axial clearance of the four-point contact ball bearing refers to the table 8.44.
- The radial clearance of double-row and four-row taper roller bearing refers to the table 8.4.

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Table 8.36 Deep Groove Ball Bearings

μm

Nominal Inner Diameter d mm		Group 2		Group 0		Group 3		Group 4		Group 5	
over	incl	min	max	min	max	min	max	min	max	min	max
2.5	6	0	7	2	13	8	23	-	-	-	-
6	10	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
800	900	20	160	140	320	300	500	480	700	670	940
900	1000	20	170	150	350	330	550	530	770	740	1040
1000	1120	20	180	160	380	360	600	580	850	820	1150
1120	1250	20	190	170	410	390	650	630	920	890	1260

Table 8.37 Self-Aligning Ball Bearings with Cylindrical Bore

μm

Nominal Inner Diameter d mm		Group 2		Group 0		Group 3		Group 4		Group 5	
over	incl	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
24	30	5	16	11	24	19	35	29	46	40	58
30	40	6	18	13	29	23	40	34	53	46	66
40	50	6	19	14	31	25	44	37	57	50	71
50	65	7	21	16	36	30	50	45	69	62	88
65	80	8	24	18	40	35	60	54	83	76	108
80	100	9	27	22	48	42	70	64	96	89	124
100	120	10	31	25	56	50	83	75	114	105	145
120	140	10	38	30	68	60	100	90	135	125	175
140	160	15	44	35	80	70	120	110	161	150	210

Table 8.38 Self-Aligning Ball Bearings with Tapered Bore

μm

Nominal Inner Diameter d mm		Group 2		Group 0		Group 3		Group 4		Group 5	
over	incl	min	max	min	max	min	max	min	max	min	max
18	24	7	17	13	26	20	33	28	42	37	55
24	30	9	20	15	28	23	39	33	50	44	62
30	40	12	24	19	35	29	46	40	59	52	72
40	50	14	27	22	39	33	52	45	65	58	79
50	65	18	32	27	47	41	61	56	80	73	99
65	80	23	39	35	57	50	75	69	98	91	123
80	100	29	47	42	68	62	90	84	116	109	144
100	120	35	56	50	81	75	108	100	139	130	170
120	140	40	68	60	98	90	130	120	165	155	205
140	160	45	74	65	110	100	150	140	191	180	240

Table 8.39 Cylindrical Roller Bearings with Cylindrical Bore

μm

Nominal Inner Diameter d mm		Group 2		Group 0		Group 3		Group 4		Group 5	
over	incl	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
24	30	0	25	20	45	35	60	50	75	70	95
30	40	5	30	25	50	45	70	60	85	80	105
40	50	5	35	30	60	50	80	70	100	95	125
50	65	10	40	40	70	60	90	80	110	110	140
65	80	10	45	40	75	65	100	90	125	130	165
80	100	15	50	50	85	75	110	105	140	155	190
100	120	15	55	50	90	85	125	125	165	180	220
120	140	15	60	60	105	100	145	145	190	200	245
140	160	20	70	70	120	115	165	165	215	225	275
160	180	25	75	75	125	120	170	170	220	250	300
180	200	35	90	90	145	140	195	195	250	275	330
200	225	45	105	105	165	160	220	220	280	305	365
225	250	45	110	110	175	170	235	230	300	330	395
250	280	55	125	125	195	190	260	260	330	370	440
280	315	55	130	130	205	200	275	275	350	410	485
315	355	65	145	145	225	225	305	305	385	455	535
355	400	100	190	190	280	280	370	370	460	510	600
400	450	110	210	210	310	310	410	410	510	565	665
455	500	110	220	220	330	330	440	440	550	625	735

Note: Radial internal clearance in needle roller bearings

Needle roller bearings with inner ring, outer ring and cage take the radial internal clearance shown in Table 8.39, except the outer-ring-punched needle roller bearings and the heavy series ones.

The radial internal clearance in needle roller bearings, which are delivered with inner rings as separate parts and belong to heavy series needle roller bearings with inner ring and outer ring (refer to GB4603), is decided by the diameter of inner ring raceway and needle roller parts. The tolerance of the diameter is defined in GB4603 and GB5801.

Table 8.40 Self-Aligning Roller Bearings with Cylindrical Bore

μm

Nominal Inner Diameter d mm		Group 2		Group 0		Group 3		Group 4		Group 5	
over	incl	min	max	min	max	min	max	min	max	min	max
14	18	10	20	20	35	35	45	45	60	60	75
18	24	10	20	20	35	35	45	45	60	60	75
24	30	15	25	25	40	40	55	55	75	75	95
30	40	15	30	30	45	45	60	60	80	80	100
40	50	20	35	35	55	55	75	75	100	100	125
50	65	20	40	40	65	65	90	90	120	120	150
65	80	30	50	50	80	80	110	110	145	145	180
80	100	35	60	60	100	100	135	135	180	180	225
100	120	40	75	75	120	120	160	160	210	210	260
120	140	50	95	95	145	145	190	190	240	240	300
140	160	60	110	110	170	170	220	220	280	280	350
160	180	65	120	120	180	180	240	240	310	310	390
180	200	70	130	130	200	200	260	260	340	340	430
200	225	80	140	140	220	220	290	290	380	380	470
225	250	90	150	150	240	240	320	320	420	420	520
250	280	100	170	170	260	260	350	350	460	460	570
280	315	110	190	190	280	280	370	370	500	500	630
315	355	120	200	200	310	310	410	410	550	550	690
355	400	130	220	220	340	340	450	450	600	600	750
400	450	140	240	240	370	370	500	500	660	660	820
450	500	140	260	260	410	410	550	550	720	720	900
500	560	150	280	280	440	440	600	600	780	780	1000
560	630	170	310	310	480	480	650	650	850	850	1100
630	710	190	350	350	530	530	700	700	920	920	1900
710	800	210	390	390	580	580	770	770	1010	1010	1300
800	900	230	430	430	650	650	860	860	1120	1120	1440
900	1000	260	480	480	710	710	930	930	1220	1220	1570

Table 8.41 Self-Aligning Roller Bearings with Tapered Bore

μm

Nominal Inner Diameter d mm		Group 2		Group 0		Group 3		Group 4		Group 5	
over	incl	min	max	min	max	min	max	min	max	min	max
18	24	15	25	25	35	35	45	45	60	60	75
24	30	20	30	30	40	40	55	55	75	75	95
30	40	25	35	35	50	50	65	65	85	85	105
40	50	30	45	45	60	60	80	80	100	100	130
50	65	40	55	55	75	75	95	95	120	120	160
65	80	50	70	70	95	95	120	120	150	150	200
80	100	55	80	80	110	110	140	140	180	180	230
100	120	65	100	100	135	135	170	170	220	220	280
120	140	80	120	120	160	160	200	200	260	260	330
140	160	90	130	130	180	180	230	230	300	300	380
160	180	100	140	140	200	200	260	260	340	340	430
180	200	110	160	160	220	220	290	290	370	370	470
200	225	120	180	180	250	250	320	320	410	410	520
225	250	140	200	200	270	270	350	350	450	450	570
250	280	150	220	220	300	300	390	390	490	490	620
280	315	170	240	240	330	330	430	430	540	540	680
315	355	190	270	270	360	360	470	470	590	590	740
355	400	210	300	300	400	400	520	520	650	650	820
400	450	230	330	330	440	440	570	570	720	720	910
450	500	260	370	370	490	490	630	630	790	790	1000
500	560	290	410	410	540	540	580	580	870	870	1100
560	630	320	460	460	600	600	760	760	980	980	1230
630	710	350	510	510	670	670	850	850	1090	1090	1360
710	800	390	570	570	750	750	960	960	1220	1220	1500
800	900	440	640	640	840	840	1070	1070	1370	1370	1690
900	1000	490	710	710	930	930	1190	1190	1520	1520	1860

Table 8.42 Recommended Radial Internal Clearance in Double Row Cylindrical Roller Bearings with Tapered Bore

μm

Nominal Inner Diameter d mm		Group 1		Group 2	
over	incl	min	max	min	max
	24	10	20	20	30
24	30	15	25	25	35
30	40	15	25	25	40
40	50	17	30	30	45
50	65	20	35	35	5
65	80	25	40	40	60
80	100	35	55	45	70
100	120	40	60	50	80
120	140	45	70	60	90
140	160	50	75	65	100
160	180	55	85	75	110
180	200	60	90	80	120
200	225	60	95	90	135
225	250	65	100	100	150
250	280	75	110	110	165
280	315	80	120	120	180
315	355	90	135	135	200
355	400	100	150	150	225
400	450	110	170	170	255
455	500	120	190	190	285

Table 8.43 Recommended Radial Internal Clearance in Double Row Cylindrical Roller Bearings with Cylindrical Bore

μm

Nominal Inner Diameter d mm		Group 1		Group 2		Group 3	
over	incl	min	max	min	max	min	max
	24	5	15	10	20	20	30
24	30	5	15	10	25	25	35
30	40	5	15	12	25	25	40
40	50	5	18	15	30	30	45
50	65	5	20	15	35	35	50
65	80	10	25	20	40	40	60
80	100	10	30	25	45	45	70
100	120	10	30	25	50	50	80
120	140	10	35	30	60	60	90
140	160	10	35	35	65	65	100
160	180	10	40	35	75	75	110
180	200	15	45	40	80	80	120
200	225	15	50	45	90	90	135
225	250	15	50	50	100	100	150
250	280	20	55	55	110	110	165
280	315	20	60	60	120	120	180
315	355	20	65	65	135	135	200
355	400	25	75	75	150	150	225
400	450	25	85	85	170	170	255
450	500	25	95	95	190	190	285

Table 8.44 Axial Internal Clearance in Four-Point Contact Ball Bearings

μm

Nominal Inner Diameter d mm		Group 2		Group 0		Group 3		Group 4	
over	incl	min	max	min	max	min	max	min	max
10	18	15	55	45	85	75	115	105	145
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	216
80	100	56	116	96	156	136	196	176	236
100	140	66	136	116	176	156	216	196	256
140	180	76	156	136	196	176	236	216	276
180	220	96	176	156	216	196	256	236	296
220	260	115	195	175	235	215	295	275	335
260	300	135	215	195	275	255	335	295	355

Table 8.45 Radial Internal Clearance in Double Row and Four-row Taper Roller Bearings

μm

Nominal Inner Diameter d mm		Group 1		Group 2		Group 0		Group 3		Group 4		Group 5	
over	incl	min	max	min	max	min	max	min	max	min	max	min	max
	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	90	110
50	65	0	15	15	30	30	50	50	70	70	90	90	120
65	80	0	20	20	40	40	60	60	80	80	110	110	150
80	100	0	20	20	45	45	70	70	100	100	130	130	170
100	120	0	25	25	50	50	80	80	110	110	150	150	200
120	140	0	30	30	60	60	90	90	120	120	170	170	230
140	160	0	30	30	65	65	100	100	140	140	190	190	260
160	180	0	35	35	70	70	110	110	150	150	210	210	280
180	200	0	40	40	80	80	120	120	170	170	230	230	310
200	225	0	40	40	90	90	140	140	190	190	260	260	340
225	250	0	50	50	100	100	150	150	210	210	290	290	380
250	280	0	50	50	110	110	170	170	230	230	320	320	420
280	315	0	60	60	120	120	180	180	250	250	350	350	460
315	355	0	70	70	140	140	210	210	280	280	390	390	510
355	400	0	70	70	150	150	230	230	310	310	440	440	580
400	450	0	80	80	170	170	260	260	350	350	490	490	650
450	500	0	90	90	190	190	290	290	390	390	540	540	720
500	560	0	100	100	210	210	320	320	430	430	590	590	790
560	630	0	110	110	230	230	350	350	480	480	660	660	880
630	710	0	130	130	260	260	400	400	540	540	740	740	910
710	800	0	140	140	290	290	450	450	610	610	830	830	1100
800	900	0	160	160	330	330	500	500	670	670	920	920	1240
900	1000	0	180	180	360	360	540	540	720	720	980	980	1300
1000	1120	0	200	200	400	400	600	600	820	-	-	-	-
1120	1250	0	220	220	450	450	670	670	900	-	-	-	-
1250	1400	0	250	250	500	500	750	750	980	-	-	-	-

Note: Radial clearance is converted into approximate value of axial clearance (Ga=Gr*1.5/e or Ga=Cr·cot a;
Ga=axial internal clearance; Gr=radial internal clearance; factor e is given in bearing dimension tables;
a=angle of outer raceway).

9.Bearing Application

9.1 Fits

There must be even supports on the whole circle surface of the inner and outer diameters as the basis to make the bearing give full play of its load capacity.

The assembly of the shaft with a certain basic dimension and the bore with the same basic dimension is called fit. The fit of rolling bearing is the fits of the inner ring with a shaft, outer ring with housing, that is the radial location of bearings.

Bearing fits are usually taken two ways: interference fits and clearance fits. Interference fit is applied more between rotating parts, such as the fits of inner bore with the shaft. Clearance fits are generally applied between static parts, such as the fits of outer ring with housing.

Insufficient fit interference can lead to sliding between the bearing with shaft or housing bore, once sliding appears, it will result in abrasion and make the surface precision of shaft or housing destroyed. If particulates caused by abrasion slide into the bearing, it will influence the bearings application performance. Serious sliding will also cause high temperature and make bearing failure premature.

However, the exceeding interference fit will result in the pulling stress on the inner raceway surface and affect the fatigue life of bearing.

9.1.1 Selection of Fits

9.1.1.1 Principle of Selecting Fits

- There must be good support on the surface of inner, outer diameter and end faces. Good support should play an effect of shaft supporting.
- Bearing rings under “rotating load” could not slide along the circumference direction.

However, bearing rings under fixed load are permitted to have slight circumference sliding to slowly change its load area, which, make the raceway carry equal loads on the circumference direction.

- If a non-separable bearing is adopted at the wandering end, then the axial move may be allowed. So the small clearance fits may be considered.
  When selecting interference fits, it should not be too large, interference should be reduced under the precondition of no-sliding. Excessive interference will reduce clearance and make the inner raceway surface have a pulling stress, which, influences the normal application and life of bearings.
- The bearings are precision parts with thin-section.After fitting,the geometry precesion of shaft or housing would be reflected on bearings.This must require the parts installed have suitable precision so that can match with the bearings .
- It should be considered the convenience of mounting and dismounting when choosing fits. Excessive interference fit is uneasy to mount and dismount and it is easy to damage the bearing when mounting and dismounting.

It is difficult to meet all the above mentioned requirements due to their contradiction when selecting bearing fits. In actual selection it is enough to seize the main factor according to specific application.

9.1.1.2 Selection of Fits

To select proper fits, we should consider the bearing structures, loads, temperatures, precision, material of shaft and housing, processing precision, thickness, stress, mounting and dismounting methods should be considered.

• The Characteristic and Magnitude of Bearing Loads and Fits

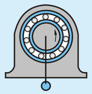
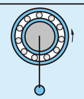
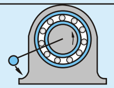
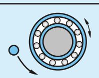
The characteristic of bearings mainly refers to the acting direction of loads and its variation and with vibratory shock or not. Rotation or static of the load acting direction towards bearing inner ring or outer ring is the basic requirement to assure the fits of bearing with shaft and housing.

If one load acting direction towards a certain ring is rotation, the load towards the ring is called "rotating load". For example, when there is a load with fixed direction acted on the bearing, whose inner ring is rotating and outer ring is static, so the load towards inner ring is "rotating load", and "static load" toward outer ring.

If one load acting direction towards a certain ring is static, the load towards the ring is called "static load". For example, when there is a load with fixed direction acted on the bearing, whose inner ring is static and outer ring is rotating, so the load towards inner ring is "static load", and "rotating load" toward outer ring.

The relation of several load characteristics and fit methods is shown in Table 9.1.

Table 9.1

Condition of rotation and load Condition of Movement	Sketch	Load	Application	Fits way by suggested
Inner ring rotating Outer ring static		Inner ring rotating load Outer ring static load Condition of constant load	Shaft driven by belt	Inner ring interference fits Outer ring clearance fits
Inner ring static Outer ring rotating		Inner ring static load Outer ring rotating load Direction of constant load	Roller of transport tape vehicle hub bearing	Inner ring clearance fits Outer ring interference fits
Inner ring rotating Outer ring static		Inner ring static load Outer ring rotating load Load along with inner ring running	Vibration machine Riddler	Outer ring interference fits Inner ring clearance fits
Inner ring static Outer ring rotation		Inner ring rotating load Outer ring static load Load along with outer ring running	Slewing crusher Whirligig drive	Inner ring interference fits Outer ring clearance fits

In general:

- Bearing ring carrying "rotating load" should adopt interference fits
- Bearing ring carrying "static load" should adopt small clearance fits and small interference fits
- Bearing ring carrying impact and vibration load should adopt interference fits

To those which should adopt interference fits but have to adopt clearance fits for some limitations of working condition. The lubrication of the fitting surface should be done.

Load acted on rolling bearing will make the fit surface partially deformed, which, will lead to effective interference reduce or loose and generate an abrasion by pressure. In general, the load is heavier, the fit is tighter. The magnitude of load may use the ratio of load (equivalent dynamic load P to the basic rating C) as reference, and their relations are shown in Table 9.2

Table 9.2

Magnitude of load	P/C
Light load	<0.07
Normal load	>0.07～0.15
Heavy load	>0.15

The reduction of interference caused by load can be estimated as follows:

$$Fr \leqslant 0.3Co \qquad \Delta d_F = 0.08\sqrt{\frac{d}{B}}\,Fr$$

$$Fr > 0.3Co \qquad \Delta d_F = 0.2\frac{Fr}{B}$$

where:

Δd_F – the reduction of interference caused by radial load, μm
d – Inner diameter, mm
B – Width, mm
Fr – Radial load, N
Co – Basic static load rating, N

The fit ways are selected based on the characteristic and magnitude of load:

- Fits of radial bearing with shaft and the code of shaft tolerance zone, see Table 9.3
- Fits of radial bearing with shell and the code of bore tolerance zone, see Table 9.4
- Fits of thrust bearing with shaft and the code of shaft tolerance zone, see Table 9.5
- Fits of thrust bearing with housing and the code of bore tolerance zone, see Table 9.6
- Fits of radial bearing with shaft and shell (except taper roller bearing), see Table 9.7～9.10
- Fits of taper roller bearing with shaft and housing, see Table 9.11～9.12

• Working Temperatures and Fits

When bearing is running without the influence of outer heat source, its working temperature is usually higher than the adjacent parts by reason of the abrasion, which will affect the tightness degree of fits. The fits of inner ring with shaft probably become loose by reason of thermal expansion, and the interference is increased or reduced between outer ring and housing by reason of the difference of temperature and the difference of material linear expansion coefficient even under the high temperature working conditions. In general, if the difference of temperature between bearing itself and its surrounding environment is ΔT(℃), and then, the temperature of inner ring is higher than the shaft about (0.1～0.15) ΔT, the reduction Δd_T of inner ring caused by the temperature difference of inner ring with shaft can be estimated as following:

$$\Delta d_T = (0.1\sim0.15)\,\Delta T \cdot \alpha \cdot d$$

where:

α – Linear expansion coefficient. Linear expansion coefficient of bearing steel is 12.5×10^{-6}/℃
d – Inner diameter, mm

While selecting the proper fits, if the housing elevates to a higher temperature than the bearing, the fit of outer ring and housing bore should be tight; if not, the fit should be loose. If the shaft gets a higher temperature than the bearing, the fit of inner ring and shaft should be loose; if not, the fit should be tight.

• Roughness and Interference of the Fitting Surface

If the fitting surface of shaft is rough, the housing bore will be trowelled when the boring is fixed, as a result, the actual effective interference fit will be smaller than theoretically calculated or actually measured. The actual effective interference fit can be estimated as follows:

$$\text{Grinding shafts} \qquad \Delta d' = \frac{d}{d+2}\Delta d$$

$$\text{Lathy shafts} \qquad \Delta d' = \frac{d}{d+3}\Delta d$$

where:

Δd′ – Effective interference fit, mm
Δd – Theoretically calculated interference fit, mm
d – Inside diameter of bearing, mm

- **Inner Stress of Bearing Rings Caused by Fits**

When the fit of bearings is tight, the internal stress will emerge on the outer ring raceway because of shrinking, the tensile stress will emerge on the inner ring because of expansion. From the point of a crack expansion, the internal stress can slow down the speed of crack expansion, and the tensile stress can speed up it. Therefore, when adopting interference fit, the interference should be under control, especially for the interference fit of inner ring and shaft which should be less than 1/1000 of the inside diameter.

- **Supports and Fits**

Bearings having thin-section components must be designed to have enough supporting surface and rigided. When bearings are fixed on the easy-deformation thin-section housing bores, light metal housing bores or hollow shafts, the fits should be tighter than on the cylindrical housing bores, cast-iron cylinders and solid shafts. For the bearings fixed on the free side of the supporting structure, the fitting surface should adopt tight fit to ensure axial move. For cylindrical roller bearings without flanges, the fit of inner (outer) ring and shaft (housing) can be interference fit when the moving distance is short.
Because the split bearing housings have a comparatively bad accuracy which may cause elliptic outer rings or deformation, we should try not to use this structure. If we have to, we should choose small interference fit or clearance fit to keep bearings from extruded deformation.

- **Assembling and Disassembling Fits**

For clearance fits, the methods and instruments to assemble and disassemble bearings are easy to apply. For interference fits, we must think about methods and instruments to assemble and disassemble bearings. If the bearings need to be assembled and disassembled frequently, loose fits or clearance fits should be chosen. If the bearings have long lives and don't need to be assembled and disassembled frequently, tight fits should be chosen.

- **Fits of Bearings with Tapered Bores**

Bearings with tapered bores usually require tight fits. The fits are determined not by journal tolerance, but by axial distance of bearings being pushed into tapered contact surface. When bearings are pushed into tapered journal, the journal force on the inner rings to expand constantly, the expansion of inner rings reduces the radial clearance of bearings. Therefore, interference fits can be controlled by clearance reduction while assembling. For solid axis of 1:12 taper, normal bearings' axial distance on the radial direction is about 15 times the reduction of radial clearance, and the reduction of radial clearance is about 0.8 times of the interference fit.
The advantages of adaptor sleeve and withdraw sleeve are easy of assembly and disassembly, and low requests for journal tolerance and surface roughness. Adaptor sleeve is flexible and can fit shafts deformation, but the journal tolerance must be controlled. This kind of fit is only suitable for occasions requesting low running accuracy.

- **Requests for Accuracy and Chamfer of Fitting Surface**

Bearings belong to thin-section components. When interference fit is needed, the geometry form discrepancy of the journal and housing bore will directly affect the geometry size and running accuracy of the components. For example, the shaft shoulder and the housing bore supporters are the setting faces of the bearings' axial positions, and if their end faces run out, the bearing's assembly will appear deviated. The roundness and cylindricity errors of journal surface will affect the raceway of inner ring, and result in vibration and local force. Therefore, requests must be taken for the geometry form accuracy of the journal surface and the housing bore, especially for the precision bearings(see Table 9.1). Or else, even the precision bearings can not perform to their original accuracy.

Table 9.3 Fits of Radial Bearings with Shaft Code of Shaft Tolerance Zone

Bearings with Cylindrical Bore						
Conditions of Rotation		Conditions of Loads	Deep Groove Ball Bearings, Self-Aligning Ball Bearings, Angular Contact Ball Bearings	Cylindrical Roller Bearings, Taper Roller Bearings	Self-Aligning Roller Bearings	Tolerance Zones
Condition	Examples		Nominal Bore Diameter mm			
Inner ring is rotating or oscillating	Machineries, motors, machine tool spindles, turbines, gear boxes, pumps, engines, Axial boxes of railway vehicles, crushers	Light loads	≤18 >18～100 >100～200 –	– ≤40 >40～140 >140～200	– ≤40 >40～100 >100～200	h5 j6[1] k6[1] m6[1]
		Normal loads	≤18 >18～100 >100～140 >140～200 >200～280 – –	– ≤40 >40～100 >100～140 >140～200 >200～400 –	– ≤40 >40～65 >65～100 >100～140 >140～280 >280～500	j5 js5 k5[2] m5[2] m6 n6 p6 r6
		Heavy loads		>50～140 >140～200 >200 –	>50～100 >100～140 >140～200 >200	n6[3] p6 r6 r7
Inner ring is stationary	All wheels on the stationary shaft, tensioner, riddler, inertial vibrator	All	All			f6[1] g6 h6 j7
Axial loads only		All				j6、js6
Bearings with Tapered Bore						
All	Axile boxes of railway vehicles	All diameters mounted on the with drawal sleeve				h8(IT6)[5][4]
	General mechanical transmission	All diameters mounted on the with drawal sleeve				h9(IT7)[5][4]

Note:1) For bearings of higher accuracy, please use j5, k5…instead of j6, k6 etc.
2) Single row tapered roller bearings and single row angular contact ball bearings can Use K6, m6 instead of k5, m5, because the effect of internal clearance is not significant.
3) Bearing clearance should select greater than group 0 under heavy loads.
4) For bearings of higher accuracy and higher speed rotation, please select h7(IT5)instead of h8(IT6).
5) IT6 and IT7 stand for the cylindricity tolerance.

Table 9.4 Fits of Radial Bearings with Housing Code of Bore Tolerance

Conditions of Rotation		Conditions of Loads	Other Conditions	Tolerance Zone[1]	
Condition	Examples			Ball Bearings	Roller Bearings
Outer ring is stationary	Machineries, axile boxes of railway vehicles, motors, pumps,etc	Light, normal	Select the split housing when easily moving in the axial direction	H7、G7[2]	
		Punch	Select one-piece or split housing when could move in the axial direction	J7、Js7	
Outer ring is oscillating		Light, normal			
		Normal, heavy	Select one-piece housings when no moving in the axial direction	K7	
		Punch		M7	
Outer ring is rotating	Tensioners, pulleys	Light		J7	K7
		Normal		K7、M7	M7、N7
		Heavy		—	N7、P7

Note: 1) Tolerance zones are chosen from left to right with the growth of size. For bearings of higher accuracy, tolerance can be raised by one level.
2) Not suitable for split housing.

Table 9.5 Fits of Thrust Bearings with Shaft Code of Shaft Tolerance Zone

Conditions of Rotation	Conditions of Loads	Thrust Ball and Roller Bearings	Thrust Self-aligning Roller Bearings	Tolerance Zone
		Nominal Bore Diameter mm		
Axial loads only		All the sizes		j6、js6
Shaft washer is stationary	Combined loads of radial and axial	— —	≤250 >250	j6 js6
Shaft washer is Rotating or oscillating		— — —	≤200 >200～400 >400	k6[1] m6 n6

Note: 1) For bearings of small interference, please use j6, k6, m6 instead of k6, m6, n6.
2) Also including tapered roller thrust bearings and angular contact thrust ball Bearings.

Table 9.6 Fits of Thrust Bearings and Outer Housing Tolerance Zones for The Housing Bore

Condition of Rotation	Condition of Loads	Bearing Types	Tolerances	Remarks
Axial loads only		Thrust ball bearings	H8	
		Cylindrical and taper roller thrust bearings	H7	
		Self-aligning roller thrust bearings		The clearance between outer bore and housing is 0.001D (D is nominal outside diameter)
Housing washer is stationary	Combined loads of radial and axial	Angular contact thrust ball bearings Self-aligning roller thrust bearings Taper roller thrust bearings	H7	Common condition
Housing washer is rotating or oscillating			K7	Under heavy radial loads
			M7	

Table 9.7 The Fits between Radial Bearing and Shaft (except taper roller bearing), Class P0

Normal Dimensions mm		Inner Diameters Δ dmp		Tolerance Zones for Shafts: g6		g5		h6		h5		j5		j6	
over	include	high	low	Limiting Deviation of Journal Diameter											
3	6	0	-8	-4	-12	-4	-9	0	-8	0	-5	+3	-2	+6	-2
6	10	0	-8	-5	-14	-5	-11	0	-9	0	-6	+4	-2	+7	-2
10	180	0	-8	-6	-17	-6	-14	0	-11	0	-8	+5	-3	+8	-3
18	30	0	-10	-7	-20	-7	-16	0	-13	0	-9	+5	-4	+9	-4
30	50	0	-12	-9	-25	-9	-20	0	-16	0	-11	+6	-5	+11	-5
50	80	0	-15	-10	-29	-10	-23	0	-19	0	-13	+6	-7	+12	-7
80	120	0	-20	-12	-34	-12	-27	0	-22	0	-15	+6	-9	+13	-9
120	140														
140	160	0	-25	-14	-39	-14	-32	0	-25	0	-18	+7	-11	+14	-11
160	180														
180	200														
200	225	0	-30	-15	-44	-15	-35	0	-29	0	-20	+7	-13	+16	-13
225	250														
250	280	0	-35	-17	-49	-17	-40	0	-32	0	-23	+7	-16	-	-
280	315														
315	355	0	-40	-18	-54	-18	-43	0	-36	0	-25	+7	-18	-	-
355	400														
400	450	0	-45	-20	-60	-20	-47	0	-40	0	-27	+7	-20	-	-
450	500														

Normal Dimensions mm		Clearance(C) or Interference(I): g6 max (c)	g6 max (i)	g5 max (c)	g5 max (i)	h6 max (c)	h6 max (i)	h5 max (c)	h5 max (i)	j5 max (c)	j5 max (i)	j6 max (c)	j6 max (i)
over	include												
3	6	12	4	9	4	8	8	5	8	2	11	2	14
6	10	14	3	11	3	9	8	6	8	2	12	2	15
10	18	17	2	14	2	11	8	8	8	3	13	3	16
18	30	20	3	16	3	13	10	9	10	4	15	4	19
30	50	25	3	20	3	16	12	11	12	5	18	5	23
50	80	29	5	23	5	19	15	13	15	7	21	7	27
80	120	34	8	27	8	22	20	15	20	9	26	9	33
120	140												
140	160	39	11	32	11	25	25	18	25	11	32	11	39
160	180												
180	200												
200	225	44	15	35	15	29	30	20	30	13	37	13	46
225	250												
250	280	49	18	40	18	32	35	23	35	16	42	-	-
280	315												
315	355	54	22	43	22	36	40	25	40	18	47	-	-
355	400												
400	450	60	25	47	25	40	45	27	45	20	52	-	-
450	500												

Normal Dimensions mm		Tolerance Zones for Shafts: js6		k5		k6		m5		m6		n6		p6		r6		r7	
over	include	Limiting Deviation of Journal Diameter																	
3	6	+4	-4	+6	+1	+9	+1	+9	+4	+12	+4	+16	+8	+20	+12	-	-	-	-
6	10	+4.5	-4.5	+7	+1	+10	+1	+12	+6	+15	+6	+19	+10	+24	+15	-	-	-	-
10	180	+5.5	-5.5	+9	+1	+12	+1	+15	+7	+18	+7	+23	+12	+29	+18	-	-	-	-
18	30	+6.5	-6.5	+11	+2	+15	+2	+17	+8	+21	+8	+28	+15	+35	+22	-	-	-	-
30	50	+8	-8	+13	+2	+18	+2	+20	+9	+25	+9	+33	+17	+42	+26	-	-	-	-
50	80	+9.5	-9.5	+15	+2	+21	+2	+24	+11	+30	+11	+39	+20	+51	+32	-	-	-	-
80	120	+11	-11	+18	+3	+25	+3	+28	+13	+35	+13	+45	+23	+59	+37	-	-	-	-
120	140															+88	+63		
140	160	+12.5	-12.5	+21	+3	+28	+3	+33	+15	+40	+15	+52	+27	+68	+43	+90	+65	-	-
160	180															+93	+68		
180	200															+106	+77	+123	+77
200	225	+14.5	-14.5	+24	+4	+33	+4	+37	+17	+46	+17	+60	+31	+79	+50	+109	+80	+126	+80
225	250															+113	+84	+130	+84
250	280	+16	-16	+27	+4	+36	+4	+43	+20	+52	+20	+66	+34	+88	+56	+126	+94	+146	+94
280	315															+130	+98	+150	+98
315	355	+18	-18	+29	+4	+40	+4	+46	+21	+57	+21	+73	+37	+98	+62	+144	+108	+165	+108
355	400															+150	+114	+171	+114
400	450	+20	-20	+32	+5	+45	+5	+50	+23	+63	+23	+80	+40	+108	+68	+166	+126	+189	+126
450	500															+172	+132	+195	+132

Normal Dimensions mm		Clearance: js6 max (c)	js6 max (i)	k5 min	k5 max	k6 min	k6 max	m5 min	m5 max	m6 min	m6 max	n6 min	n6 max	p6 min	p6 max	r6 min	r6 max	r7 min	r7 max
over	include																		
3	6	4	12	1	14	1	17	4	17	4	20	8	24	12	28	-	-	-	-
6	10	4.5	12.5	1	15	1	18	6	20	6	23	10	27	15	32	-	-	-	-
10	18	5.5	13.5	1	17	1	20	7	23	7	26	12	31	18	37	-	-	-	-
18	30	6.5	16.5	2	21	2	25	8	27	8	31	15	38	22	45	-	-	-	-
30	50	8	20	2	25	2	30	9	32	9	37	17	45	26	54	-	-	-	-
50	80	9.5	24.5	2	30	2	36	11	39	11	45	20	54	32	68	-	-	-	-
80	120	11	31	3	38	3	45	13	48	13	55	23	65	37	79	-	-	-	-
120	140															63	113		
140	160	12.5	37.5	3	46	3	53	15	58	15	65	27	77	43	93	65	115	-	-
160	180															68	118		
180	200															77	136	77	153
200	225	14.5	44.5	4	54	4	63	17	67	17	76	31	90	50	109	80	139	80	156
225	250															84	143	84	160
250	280	16	51	4	62	4	71	20	78	20	87	34	101	56	123	94	161	94	181
280	315															98	165	98	185
315	355	18	58	4	69	4	80	21	86	21	97	37	113	62	138	108	184	108	205
355	400															114	190	114	211
400	450	20	65	5	77	5	90	23	95	23	108	40	125	68	153	126	211	126	234
450	500															132	217	132	240

Table 9.8 The Fits between Radial Bearing and Housing (except taper roller bearing), Class P0

Normal Dimensions mm		Inner Diameters Δ Dmp		Tolerance Zones for Shafts													
				G7		H8		H7		H6		J7		J6		Js7	
				Limiting Deviation of Journal Diameter													
over	include	high	low														
10	18	0	-8	+24	+6	+27	0	+18	0	+11	0	+10	-8	+6	-5	+9	-9
18	30	0	-9	+28	+7	+33	0	+21	0	+13	0	+12	-9	+8	-5	+10	-10
30	50	0	-11	+34	+9	+39	0	+25	0	+16	0	+14	-11	+10	-6	+12	-12
50	80	0	-13	+40	+10	+46	0	+30	0	+19	0	+18	-12	+13	-6	+15	-15
80	120	0	-15	+47	+12	+54	0	+35	0	+22	0	+22	-13	+16	-6	+17	-17
120	150	0	-18	+54	+14	+63	0	+40	0	+25	0	+26	-14	+18	-7	+20	-20
150	180	0	-25	+54	+14	+63	0	+40	0	+25	0	+26	-14	+18	-7	+20	-20
180	250	0	-30	+61	+15	+72	0	+46	0	+29	0	+30	-16	+22	-7	+23	-23
250	315	0	-35	+69	+17	+81	0	+52	0	+32	0	+36	-16	+25	-7	+26	-26
315	400	0	-40	+75	+18	+89	0	+57	0	+36	0	+39	-18	+29	-7	+28	-28
400	500	0	-45	+83	+20	+97	0	+63	0	+40	0	+43	-20	+33	-7	+31	-31

Normal Dimensions mm		Tolerance Zones for Shafts																	
		JS6		K6		K7		M6		M7		N6		N7		P6		P7	
over	include	Limiting Deviation of Journal Diameter																	
10	18	+5.5	-5.5	+2	-9	+6	-12	-4	-15	0	-18	-9	-20	-5	-23	-15	-26	-11	-29
18	30	+6.5	-6.5	+2	-11	+6	-15	-4	-17	0	-21	-11	-24	-7	-28	-18	-31	-14	-35
30	50	+8	-8	+3	-13	+7	-18	-4	-20	0	-25	-12	-28	-8	-33	-21	-37	-17	-42
50	80	+9.5	-9.5	+4	-15	+9	-21	-5	-24	0	-30	-14	-33	-9	-39	-26	-45	-21	-51
80	120	+11	-11	+4	-18	+10	-25	-6	-28	0	-35	-16	-38	-10	-45	-30	-52	-24	-59
120	150	+12.5	-12.5	+4	-21	+12	-28	-8	-33	0	-40	-20	-45	-12	-52	-36	-61	-28	-68
150	180	+12.5	-12.5	+4	-21	+12	-28	-8	-33	0	-40	-20	-45	-12	-52	-36	-61	-28	-68
180	250	+14.5	-14.5	+5	-24	+13	-33	-8	-37	0	-46	-22	-51	-14	-60	-41	-70	-33	-79
250	315	+16	-16	+5	-27	+16	-36	-9	-41	0	-52	-25	-57	-14	-66	-47	-79	-36	-88
315	400	+18	-18	+7	-29	+17	-40	-10	-46	0	-57	-26	-62	-16	-73	-51	-87	-41	-98
400	500	+20	-20	+8	-32	+18	-45	-10	-50	0	-63	-27	-67	-17	-80	-55	-95	-45	-108

Normal Dimensions mm		Clearance		Clearance or Interference											
over	include	min	max	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)
10	18	32	6	35	0	26	0	19	0	18	8	14	5	17	9
18	30	37	7	42	0	30	0	22	0	21	9	17	5	19	10
30	50	45	9	50	0	36	0	27	0	25	11	21	6	23	12
50	80	53	10	59	0	43	0	32	0	31	12	26	6	28	15
80	120	62	12	69	0	50	0	37	0	37	13	31	6	32	17
120	150	72	14	81	0	58	0	43	0	44	14	36	7	38	20
150	180	79	14	88	0	65	0	50	0	51	14	43	7	45	20
180	250	91	15	102	0	76	0	59	0	60	16	52	7	53	23
250	315	104	17	116	0	87	0	67	0	71	16	60	7	61	26
315	400	115	18	129	0	97	0	76	0	79	18	69	7	68	28
400	500	128	20	142	0	108	0	85	0	88	20	78	7	76	31

Normal Dimensions mm		Clearance or Interference														Interference			
over	include	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	min	max	min	max
10	18	13.5	5.5	10	9	14	12	4	15	8	18	-1	20	3	23	7	26	3	29
18	30	15.5	6.5	11	11	15	15	5	17	9	21	2	24	2	28	9	31	5	35
30	50	19	8	14	13	18	18	7	20	11	25	-1	28	3	33	10	37	6	42
50	80	22.5	9.5	17	15	22	21	8	24	13	30	-1	33	4	39	13	45	8	51
80	120	26	11	19	18	25	25	9	28	15	35	-1	38	5	45	15	52	9	59
120	150	30.5	12.5	22	21	30	28	10	33	18	40	-2	45	6	52	18	61	10	68
150	180	37.5	12.5	29	21	37	28	17	33	25	40	5	45	13	52	11	61	3	68
180	250	44.5	14.5	35	24	43	33	22	37	30	46	8	51	16	60	11	70	3	79
250	315	51	16	40	27	51	36	26	41	35	52	10	57	21	66	12	79	1	88
315	400	58	18	47	29	57	40	30	46	40	57	14	62	24	73	11	87	1	98
400	500	65	20	53	32	63	45	35	50	45	63	18	67	28	80	10	95	0	108

Note: “--” stands for interference

Table 9.9 The Fits between Radial Bearing and Shaft (except taper roller bearing), Class P6

Normal Dimensions mm		Inner Diameters Δ dmp		Tolerance Zones for Shafts — Limiting Deviation of Journal Diameter											
				g6		g5		h6		h5		j5		j6	
over	include	high	low												
3	6	0	-7	-4	-12	-4	-9	0	-8	0	-5	+3	-2	+6	-2
6	10	0	-7	-5	-14	-5	-11	0	-9	0	-6	+4	-2	+7	-2
10	180	0	-7	-6	-17	-6	-14	0	-11	0	-8	+5	-3	+8	-3
18	30	0	-8	-7	-20	-7	-16	0	-13	0	-9	+5	-4	+9	-4
30	50	0	-10	-9	-25	-9	-20	0	-16	0	-11	+6	-5	+11	-5
50	80	0	-12	-10	-29	-10	-23	0	-19	0	-13	+6	-7	+12	-7
80	120	0	-15	-12	-34	-12	-27	0	-22	0	-15	+6	-9	+13	-9
120	140														
140	160	0	-18	-14	-39	-14	-32	0	-25	0	-18	+7	-11	+14	-11
160	180														
180	200														
200	225	0	-22	-15	-44	-15	-35	0	-29	0	-20	+7	-13	+16	-13
225	250														
250	280	0	-25	-17	-49	-17	-40	0	-32	0	-23	+7	-16	-	-
280	315														
315	355	0	-30	-18	-54	-18	-43	0	-36	0	-25	+7	-18	-	-
355	400														
400	450	0	-35	-20	-60	-20	-47	0	-40	0	-27	+7	-20	-	-
450	500														

Normal Dimensions mm		Clearance or Interference											
over	include	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)
3	6	12	3	9	3	8	7	5	7	2	10	2	13
6	10	14	2	11	2	9	7	6	7	2	11	2	14
10	18	17	1	14	1	11	7	8	7	3	12	3	15
18	30	20	1	16	1	13	8	9	8	4	13	4	17
30	50	25	1	20	1	16	10	11	10	5	16	5	21
50	80	29	2	23	2	19	12	13	12	7	18	7	24
80	120	34	3	27	3	22	15	15	15	9	21	9	28
120	140												
140	160	39	4	32	4	25	18	18	18	11	25	11	32
160	180												
180	200												
200	225	44	7	35	7	29	22	20	22	13	29	13	38
225	250												
250	280	49	8	40	8	32	25	23	25	16	32	-	-
280	315												
315	355	54	12	43	12	36	30	25	30	18	37	-	-
355	400												
400	450	60	15	47	15	40	35	27	35	20	42	-	-
450	500												

over	include	Tolerance Zones for Shafts — Limiting Deviation of Journal Diameter																	
		js6		k5		k6		m5		m6		n6		p6		r6		r7	
3	6	+4	-4	+6	+1	+9	+1	+9	+4	+12	+4	+16	+8	+20	+12	-	-	-	-
6	10	+4.5	-4.5	+7	+1	+10	+1	+12	+6	+15	+6	+19	+10	+24	+15	-	-	-	-
10	180	+5.5	-5.5	+9	+1	+12	+1	+15	+7	+18	+7	+23	+12	+29	+18	-	-	-	-
18	30	+6.5	-6.5	+11	+2	+15	+2	+17	+8	+21	+8	+28	+15	+35	+22	-	-	-	-
30	50	+8	-8	+13	+2	+18	+2	+20	+9	+25	+9	+33	+17	+42	+26	-	-	-	-
50	80	+9.5	-9.5	+15	+2	+21	+2	+24	+11	+30	+11	+39	+20	+51	+32	-	-	-	-
80	120	+11	-11	+18	+3	+25	+3	+28	+13	+35	+13	+45	+23	+59	+37	-	-	-	-
120	140															+88	+63		
140	160	+12.5	-12.5	+21	+3	+28	+3	+33	+15	+40	+15	+52	+27	+68	+43	+90	+65	-	-
160	180															+93	+68		
180	200															+106	+77	+123	+77
200	225	+14.5	-14.5	+24	+4	+33	+4	+37	+17	+46	+17	+60	+31	+79	+50	+109	+80	+126	+80
225	250															+113	+84	+130	+84
250	280	+16	-16	+27	+4	+36	+4	+43	+20	+52	+20	+66	+34	+88	+56	+126	+94	+146	+94
280	315															+130	+98	+150	+98
315	355	+18	-18	+29	+4	+40	+4	+46	+21	+57	+21	+73	+37	+98	+62	+144	+108	+165	+108
355	400															+150	+114	+171	+114
400	450	+20	-20	+32	+5	+45	+5	+50	+23	+63	+23	+80	+40	+108	+68	+166	+126	+189	+126
450	500															+172	+132	+195	+132

over	include	Clearance																	
		max (c)	max (i)	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
3	6	4	11	1	13	1	16	4	16	4	19	8	23	12	27	-	-	-	-
6	10	4.5	11.5	1	14	1	17	6	19	6	22	10	26	15	31	-	-	-	-
10	18	5.5	12.5	1	16	1	19	7	22	7	25	12	30	18	36	-	-	-	-
18	30	6.5	14.5	2	19	2	23	8	25	8	29	15	36	22	43	-	-	-	-
30	50	8	18	2	23	2	28	9	30	9	35	17	43	26	52	-	-	-	-
50	80	9.5	21.5	2	27	2	33	11	36	11	42	20	51	32	63	-	-	-	-
80	120	11	26	3	33	3	40	13	43	13	50	23	61	37	74	-	-	-	-
120	140															63	106		
140	160	12.5	30.5	3	39	3	46	15	51	15	58	27	70	+43	86	65	108	-	-
160	180															68	111		
180	200															77	128	77	145
200	225	14.5	36.5	4	46	4	55	17	59	17	68	31	82	+50	101	80	131	80	148
225	250															84	135	84	152
250	280	16	41	4	52	4	61	20	68	20	77	34	91	+56	113	94	151	94	171
280	315															98	155	98	175
315	355	18	48	4	59	4	70	21	76	21	87	37	103	+62	128	108	174	108	195
355	400															114	180	114	201
400	450	20	55	4	67	4	80	23	85	23	98	40	115	+68	143	126	201	126	224
450	500															132	207	132	230

Table 9.10 The Fits between Radial Bearing and Housing (except taper roller bearing), Class P6

Normal Dimensions mm		Inner Diameters ΔD_{mp}		Tolerance Zones for Shafts													
				G7		H8		H7		H6		J7		J6		Js7	
				Limiting Deviation of Journal Diameter													
over	include	high	low														
10	18	0	-7	+24	+6	+27	0	+18	0	+11	0	+10	-8	+6	-5	+9	-9
18	30	0	-8	+28	+7	+33	0	+21	0	+13	0	+12	-9	+8	-5	+10	-10
30	50	0	-9	+34	+9	+39	0	+25	0	+16	0	+14	-11	+10	-6	+12	-12
50	80	0	-11	+40	+10	+46	0	+30	0	+19	0	+18	-12	+13	-6	+15	-15
80	120	0	-13	+47	+12	+54	0	+35	0	+22	0	+22	-13	+16	-6	+17	-17
120	150	0	-15	+54	+14	+63	0	+40	0	+25	0	+26	-14	+18	-7	+20	-20
150	180	0	-18	+54	+14	+63	0	+40	0	+25	0	+26	-14	+18	-7	+20	-20
180	250	0	-20	+61	+15	+72	0	+46	0	+29	0	+30	-16	+22	-7	+23	-23
250	315	0	-25	+69	+17	+81	0	+52	0	+32	0	+36	-16	+25	-7	+26	-26
315	400	0	-28	+75	+18	+89	0	+57	0	+36	0	+39	-18	+29	-7	+28	-28
400	500	0	-33	+83	+20	+97	0	+63	0	+40	0	+43	-20	+33	-7	+31	-31

over	include	Tolerance Zones for Shafts																	
		JS6		K6		K7		M6		M7		N6		N7		P6		P7	
		Limiting Deviation of Journal Diameter																	
10	18	+5.5	-5.5	+2	-9	+6	-12	-4	-15	0	-18	-9	-20	-5	-23	-15	-26	-11	-29
18	30	+6.5	-6.5	+2	-11	+6	-15	-4	-17	0	-21	-11	-24	-7	-28	-18	-31	-14	-35
30	50	+8	-8	+3	-13	+7	-18	-4	-20	0	-25	-12	-28	-8	-33	-21	-37	-17	-42
50	80	+9.5	-9.5	+4	-15	+9	-21	-5	-24	0	-30	-14	-33	-9	-39	-26	-45	-21	-51
80	120	+11	-11	+4	-18	+10	-25	-6	-28	0	-35	-16	-38	-10	-45	-30	-52	-24	-59
120	150	+12.5	-12.5	+4	-21	+12	-28	-8	-33	0	-40	-20	-45	-12	-52	-36	-61	-28	-68
150	180	+12.5	-12.5	+4	-21	+12	-28	-8	-33	0	-40	-20	-45	-12	-52	-36	-61	-28	-68
180	250	+14.5	-14.5	+5	-24	+13	-33	-8	-37	0	-46	-22	-51	-14	-60	-41	-70	-33	-79
250	315	+16	-16	+5	-27	+16	-36	-9	-41	0	-52	-25	-57	-14	-66	-47	-79	-36	-88
315	400	+18	-18	+7	-29	+17	-40	-10	-46	0	-57	-26	-62	-16	-73	-51	-87	-41	-98
400	500	+20	-20	+8	-32	+18	-45	-10	-50	0	-63	-27	-67	-17	-82	-55	-95	-45	-108

Normal Dimensions mm		Clearance		Clearance or Interference													
over	include	min	max	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)
10	18	31	6	34	0	25	0	18	0	17	8	13	5	16	9
18	30	36	7	41	0	29	0	21	0	20	9	16	5	18	10
30	50	43	9	48	0	34	0	25	0	23	11	19	6	21	12
50	80	51	10	57	0	41	0	30	0	29	12	24	6	26	15
80	120	60	12	67	0	48	0	35	0	35	13	29	6	30	17
120	150	69	14	78	0	55	0	40	0	41	14	33	7	35	20
150	180	72	14	81	0	58	0	43	0	44	14	36	7	38	20
180	250	81	15	92	0	66	0	49	0	50	16	42	7	43	23
250	315	94	17	106	0	77	0	57	0	61	16	50	7	51	26
315	400	103	18	117	0	85	0	64	0	67	18	57	7	56	28
400	500	116	20	130	0	96	0	73	0	76	20	66	7	64	31

over	include	Clearance or Interference														Interference			
		max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	min	max	min	max
10	18	12.5	5.5	9	9	13	12	3	15	7	18	-2	20	2	23	8	26	4	29
18	30	14.5	6.5	10	11	14	15	4	17	8	21	-3	24	1	28	10	31	6	35
30	50	17	8	12	13	16	18	5	20	9	25	-3	28	1	33	12	37	8	42
50	80	20.5	9.5	15	15	20	21	6	24	11	30	-3	33	2	39	15	45	10	51
80	120	24	11	17	18	23	25	7	28	13	35	-3	38	3	45	17	52	11	59
120	150	27.5	12.5	19	21	27	28	7	33	15	40	-5	45	3	52	21	61	13	68
150	180	30.5	12.5	22	21	30	28	10	33	18	40	-2	45	6	52	18	61	10	68
180	250	34.5	14.5	25	24	33	33	12	37	20	46	-2	51	6	60	21	70	13	79
250	315	41	16	30	27	41	36	16	41	25	52	0	57	11	66	22	79	11	88
315	400	46	18	35	29	45	40	18	46	28	57	2	62	12	73	23	87	13	98
400	500	53	20	41	32	51	45	23	50	33	63	6	67	16	80	22	95	12	108

Table 9.11 The Fits between Taper Roller Bearing and Shaft, Class P0, P6x

Normal Dimensions mm		Inner Diameters Δ dmp		Tolerance Zones for Shafts — Limiting Deviation of Journal Diameter											
				f6		g6		g5		h6		h5		j5	
over	include	high	low												
10	18	0	-12	-16	-27	-6	-17	-6	-14	0	-11	0	-8	+5	-3
18	30	0	-12	-20	-33	-7	-20	-7	-16	0	-13	0	-9	+5	-4
30	50	0	-12	-25	-41	-9	-25	-9	-20	0	-16	0	-11	+6	-5
50	80	0	-15	-30	-49	-10	-29	-10	-23	0	-19	0	-13	+6	-7
80	120	0	-20	-36	-58	-12	-34	-12	-27	0	-22	0	-15	+6	-9
120	140														
140	160	0	-25	-43	-68	-14	-39	-14	-32	0	-25	0	-18	+7	-11
160	180														
180	200														
200	225	0	-30	-50	-79	-15	-44	-15	-35	0	-29	0	-20	+7	-13
225	250														
250	280	0	-35	-56	-88	-17	-49	-17	-40	0	-32	0	-23	+7	-16
280	315														
315	355	0	-40	-62	-98	-18	-54	-18	-43	0	-36	0	-25	+7	-18
355	400														
400	450	0	-45	-68	-108	-20	-60	-20	-47	0	-40	0	-27	+7	-20
450	500														

Normal Dimensions mm		Clearance or Interference											
over	include	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)
10	18	27	4	17	6	14	6	11	12	8	12	3	18
18	30	33	8	20	5	16	5	13	12	9	12	4	18
30	50	41	13	25	3	20	3	16	12	11	12	5	18
50	80	49	15	29	5	23	5	19	15	13	15	7	21
80	120	58	16	34	8	27	8	22	20	15	20	9	26
120	140												
140	160	68	18	39	11	32	11	25	25	18	25	11	32
160	180												
180	200												
200	225	79	20	44	15	35	15	29	30	20	30	13	37
225	250												
250	280	88	21	49	18	40	18	32	35	23	35	16	42
280	315												
315	355	98	22	54	22	43	22	36	40	25	40	18	47
355	400												
400	450	108	23	60	25	47	25	40	45	27	45	20	52
450	500												

Normal Dimensions mm		Tolerance Zones for Shafts — Limiting Deviation of Journal Diameter																	
over	include	j6		js5		k5		k6		m5		m6		n6		p6		r6	
10	18	+8	-3	+5.5	-5.5	+9	+1	+12	+1	+15	+7	+18	+7	+23	+12	+29	+18	-	-
18	30	+9	-4	+6.5	-6.5	+11	+2	+15	+2	+17	+8	+21	+8	+28	+15	+35	+22	-	-
30	50	+11	-5	+8	-8	+13	+2	+18	+2	+20	+9	+25	+9	+33	+17	+42	+26	-	-
50	80	+12	-7	+9.5	-9.5	+15	+2	+21	+2	+24	+11	+30	+11	+39	+20	+51	+32	-	-
80	120	+13	-9	+11	-11	+18	+3	+25	+3	+28	+13	+35	+13	+45	+23	+59	+37	-	-
120	140																	+68	+63
140	160	+14	-11	+12.5	-12.5	+21	+3	+28	+3	+33	+15	+40	+15	+52	+27	+68	+43	+90	+65
160	180																	+93	+68
180	200																	+106	+77
200	225	+16	-13	+14.5	-14.5	+24	+4	+33	+4	+37	+17	+46	+17	+60	+31	+79	+50	+109	+80
225	250																	+113	+84
250	280	-	-	+16	-16	+27	+4	+36	+4	+43	+20	+52	+20	+66	+34	+88	+56	+126	+94
280	315																	+130	+98
315	355	-	-	+18	-18	+29	+4	+40	+4	+46	+21	+57	+21	+73	+37	+98	+62	+144	+108
355	400																	+150	+114
400	450	-	-	+20	-20	+3	+5	+45	+5	+50	+23	+63	+23	+80	+40	+108	+68	+166	+126
450	500																	+172	+132

Normal Dimensions mm		Clearance																	
over	include	max (c)	max (i)	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
10	18	3	20	5.5	17.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	30	4	21	6.5	18.5	2	23	2	27	-	-	-	-	-	-	-	-	-	-
30	50	5	23	8	20	2	25	2	30	9	32	9	37	-	-	-	-	-	-
50	80	7	27	9.5	24.5	2	30	2	36	11	39	11	45	20	54	-	-	-	-
80	120	9	33	11	31	3	38	3	45	13	48	13	55	23	65	37	79	-	-
120	140																	63	113
140	160	11	39	12.5	37.5	3	46	3	53	15	58	15	65	27	77	43	93	65	115
160	180																	68	118
180	200																	77	136
200	225	13	46	14.5	44.5	4	54	4	63	17	67	17	67	31	90	50	109	80	139
225	250																	84	143
250	280	-	-	16	51	4	62	4	71	20	78	20	87	34	101	56	123	94	161
280	315																	98	165
315	355	-	-	18	58	4	69	4	80	21	86	21	97	37	113	62	138	108	184
355	400																	114	190
400	450	-	-	20	65	5	77	5	90	23	95	23	108	40	125	68	153	126	211
450	500																	132	217

Table 9.12 The Fits Between Taper Roller Bearing and Housing, Class P0, P6x

Normal Dimensions mm		Inner Diameters Δ dmp		Tolerance Zones for Shafts — Limiting Deviation of Journal Diameter													
				G7		H8		H7		H6		J7		J6		Js7	
over	include	high	low														
30	50	0	-14	+34	+9	+39	0	+25	0	+16	0	+14	-11	+10	-6	+12	-12
50	80	0	-16	+40	+10	+46	0	+30	0	+19	0	+18	-12	+13	-6	+15	-15
80	120	0	-18	+47	+12	+54	0	+35	0	+22	0	+22	-13	+16	-6	+17	-17
120	150	0	-20	+54	+14	+63	0	+40	0	+25	0	+26	-14	+18	-7	+20	-20
150	180	0	-25	+54	+14	+63	0	+40	0	+25	0	+26	-14	+18	-7	+20	-20
180	250	0	-30	+61	+15	+72	0	+46	0	+29	0	+30	-16	+22	-7	+23	-23
250	315	0	-35	+69	+17	+81	0	+52	0	+32	0	+36	-16	+25	-7	+26	-26
315	400	0	-40	+75	+18	+89	0	+57	0	+36	0	+39	-18	+29	-7	+28	-28
400	500	0	-45	+83	+20	+97	0	+63	0	+40	0	+43	-20	+33	-7	+31	-31

Normal Dimensions mm		Clearance		Clearance or Interference											
over	include	min	max	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)
30	50	48	9	50	0	39	0	30	0	28	11	24	6	26	12
50	80	56	10	59	0	46	0	35	0	34	12	29	6	31	15
80	120	65	12	69	0	53	0	40	0	40	13	34	6	35	17
120	150	74	14	81	0	60	0	45	0	46	14	38	7	40	20
150	180	79	14	88	0	65	0	50	0	51	14	43	7	45	20
180	250	91	15	102	0	76	0	59	0	60	16	52	7	53	23
250	315	104	17	116	0	87	0	67	0	71	16	60	7	61	26
315	400	115	18	129	0	97	0	76	0	79	18	69	7	68	28
400	500	128	20	142	0	108	0	85	0	88	20	78	7	76	31

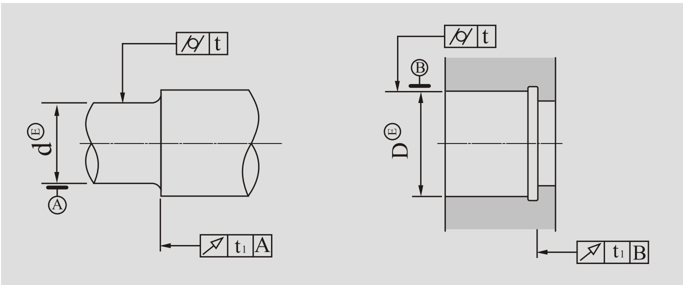


Fig 9.1

The form tolerances of shaft and housing bores are shown in Table 9.13, and the roughness of fitting surface are shown in Table 9.14.

Tolerance Zones for Shafts — Limiting Deviation of Journal Diameter																	
Js6		K6		K7		M6		M7		N6		N7		P6		P7	
+8.5	-8.5	+3	-13	+7	-18	-4	-20	0	-25	-12	-28	-8	-33	-21	-37	-17	-42
+9.5	-9.5	+4	-15	+9	-21	-57	-24	0	-30	-14	-33	-9	-39	-26	-45	-21	-51
+11	-11	+4	-18	+10	-25	-6	-28	0	-35	-16	-38	-10	-45	-30	-52	-24	-59
+12.5	-12.5	+4	-21	+12	-28	-8	-33	0	-40	-20	-45	-12	-52	-36	-61	-28	-68
+12.5	-12.5	+4	-21	+12	-28	-8	-33	0	-40	-20	-45	-12	-52	-36	-61	-28	-68
+14.5	-14.5	+5	-24	+13	-33	-8	-37	0	-46	-22	-51	-14	-60	-41	-70	-33	-79
+16	-16	+5	-27	+16	-36	-9	-41	0	-52	-25	-57	-14	-66	-47	-79	-36	-88
+18	-18	+7	-29	+17	-40	-10	-46	0	-57	-26	-62	-16	-73	-51	-87	-41	-98
+20	-20	+8	-32	+18	-45	-10	-50	0	-63	-27	-67	-17	-80	-55	-95	-45	-108

Clearance or Interference														Interference			
max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	max (c)	max (i)	min	max	min	max
22	8	17	13	21	18	10	20	14	25	2	28	6	33	7	37	3	42
25.5	9.5	20	15	25	21	11	24	16	30	2	33	7	39	10	45	5	51
29	11	22	18	28	25	12	28	18	35	2	38	8	45	12	52	6	59
32.5	12.5	24	21	32	28	12	33	20	40	0	45	8	52	16	61	8	68
37.5	12.5	29	21	37	28	17	33	25	40	5	45	13	52	11	61	3	68
44.5	14.5	35	24	43	33	22	37	30	46	8	51	16	60	11	70	3	79
51	16	40	27	51	36	26	41	35	52	10	57	21	66	12	79	1	88
58	18	47	29	57	40	30	46	40	57	14	62	24	73	11	87	1	98
65	20	53	32	63	45	35	50	45	63	18	67	28	80	10	95	0	108

Table 9.13

Normal Dimensions mm		Cylindricity t				Face Runout t_1			
		Journal		Housing Bore		Shoulder		Shoulder of Housing Bore	
		Tolerance Class							
		P0	P6（P6x）	P0	P6（P6x）	P0	P6（P6x）	P0	P6（P6x）
Over	Include	Tolerance Value, um							
	6	2.5	1.5	4	2.5	5	3	8	5
6	10	2.5	1.5	4	2.5	6	4	10	6
10	18	3	2	5	3	8	5	12	8
18	30	4	2.5	6	4	10	6	15	10
30	50	4	2.5	7	4	12	8	20	12
50	80	5	3	8	5	15	10	25	15
80	120	6	4	10	6	15	10	25	15
120	180	8	5	12	8	20	12	30	20
180	250	10	7	14	10	20	12	30	20
250	315	12	8	16	12	25	15	40	25
315	400	13	9	18	13	25	15	40	25
400	500	15	10	20	15	25	15	40	25

Table 9.14

Diameter of Shaft or Housing mm		Tolerance Class of Fitting Surface Diameter of Shaft of Housing								
		IT7			IT6			IT5		
		Surface Roughness								
Over	Incl	Rz	Ra Grinding	Ra Turning	Rz	Ra Grinding	Ra Turning	Rz	Ra Grinding	Ra Turning
	80	10	1.6	3.2	6.3	0.8	1.6	4	0.4	0.8
80	500	16	1.6	3.2	10	1.6	3.2	6.3	0.8	1.6
End face		25	3.2	6.3	25	3.2	3.2	10	1.6	3.2

9.2 Bearing Configuration

The bearings supporting structure plays an important role in assuring the bearing's running accuracy, therefore, while designing the supporting structure, the bearings configuration should be considered.
As mentioned previously, rotating shafts in normal machines usually adopt double supporting structure, each one is made up by one or two sets of supporting structure. The fixed shafts in the supporting structure are limited in the radial direction by two supporting structures, which, is carried out through matching. In the axial direction there will be three methods to limit. This, which, are supporting with both ends fixed, supporting with a fixed end and a wandering end, and supporting with both ends wandering.

9.2.1 Supporting with Both Ends Fixed

Supporting with both ends fixed means the supporting structure with each one of the two supporting respectively must limit any axial movement. This is shown in Fig 9.2. These types of structures allow for maintenance adjustment when necessary. When angular contact bearings (E.g. angular contact ball bearing, taper roller bearings) are selected and are preloaded this allows for improved running accuracy of the bearing, this also improves the potential so as to avoid roller slippage. These types of mounts are normally used where high accuracy, light load and high speed are required.

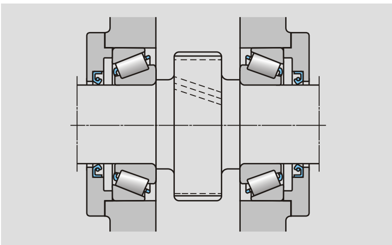


Fig 9.2

9.2.2 Supporting with a Fixed End and a Wandering One

Supporting with a fixed end and a wandering one means one of the supporting ends on the shaft allows the bearing fixed relative to the shaft and the housing (called the fixed end), which, is in order to limit the shaft's axial distance. Moreover, on the other ends, the bearing can wander relative to the shaft or the housing (called the walking end), which, is in order to make up the length change of the shaft because of heating deformation, manufacture or installation error. The supporting structure is shown in Fig 9.3, in which the left end is fixed end and the right end is the wandering end. In this kind of supporting structure, the axial position accuracy of the shaft lies on the axial clearance of the bearing on the fixed end.
Supporting with a fixed end and a wandering one has a high running accuracy and a high flexibility for all types of working situations, this is especially suitable for the low requirement of axial position space between the two supporting on the shaft and the housing. This type of structure is widely used in various machine tools' principal axis, worm shafts in high working temperature and long shafts of large span.

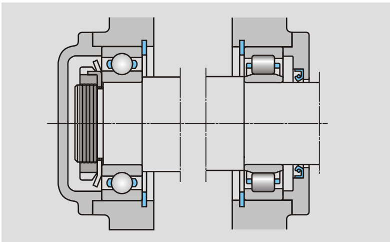


Fig 9.3

9.2.3 Supporting with Both Ends Wandering

Supporting with both ends wandering means the two supporting ends have no limit for axial distance of the shaft. Therefore, this kind of supporting is usually used in the conditions of the axial position of shaft having been limited by other components, such as herringbone wheel shaft supporting. Supporting structure is shown in Fig 9.4.
The supporting with both ends does not need to limit the shaft's axial position accurately, therefore, there is no need to adjust the bearing's axial clearance while assembling. The bearing will not lock even working in a high-temperature situation.

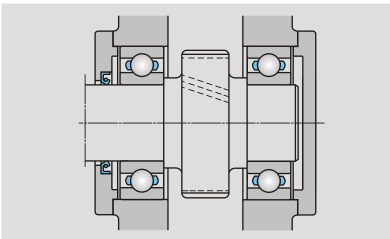


Fig 9.4

9.3 Axial Fixation

Only interference fit is not enough for bearing's axial fixation, especially when under axial loads. Therefore, to prevent the bearings from unnecessary axial movement on the shaft or the housing, the inner and outer ring must be axial fixed. Axial fixation includes axial location and axial fastening.

9.3.1 Axial Location

When the bearing is mounted, one side of the inner or outer end face abuts a shoulder on the shaft or in the housing bore at one side. Usually, the base end face of inner ring is located by the shaft shoulder; the base end face of outer ring is located by the shoulder of housing bore. In order to make sure the bearing end face clung to the shaft shoulder, we must make sure the chamfer r_{asmax} of the shaft shoulder (supporter) is less than the chamfer of fixation r_{smin}, which is shown in Fig 9.5. The choice of the max radius of rounded angle of shaft shoulder (supporter) is shown in Fig 9.15. The min height of shaft shoulder(supporter) is shown in Fig 9.16.
The shaft shoulder should be designed with a certain height to transfer axial load. The more the axial load, the higher the height is. However, concerning the problem of disassembling, the height of shaft shoulder is usually no more than the size of flange (or raceway). If they are very close, then a disassembling slot should be designed on the shaft shoulder.

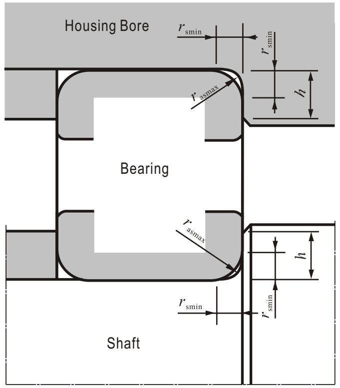


Fig 9.5

Table 9.15

Max Fillet Radius of Shoulder

mm

r_{smin}	r_{asmax}	r_{smin}	r_{asmax}
0.05	0.05	2	2
0.08	0.08	2.1	2
0.1	0.1	3	2.5
0.15	0.15	4	3
0.2	0.2	5	4
0.3	0.3	6	5
0.6	0.6	7.5	6
1	1	9.5	8
1.1	1.1	12	10
1.5	1.5	15	12

Table 9.16

Min Height of Shoulder

mm

r_{smin}	h min		r_{smin}	h min	
	Normal Condition	Special Condition [a]		Normal Condition	Special Condition [a]
0.05	0.2	-	2	5	4.5
0.08	0.3	-	2.1	6	5.5
0.1	0.4	-	3	7	6.5
0.15	0.6	-	4	9	8
0.2	0.8	-	5	11	10
0.3	1.2	1	6	14	12
0.6	2.5	2	7.5	18	-
1	3	2.5	9.5	22	-
1.1	3.5	3.3	12	27	-
1.5	4.5	4	15	32	-

Note: Special conditions mean thrust load is infinite small, or shoulder is designed to be less than.

The types of axial location of bearings, inner ring fixation is shown in Table 9.17 and outer ring fixation is shown in Table 9.18.

Table 9.17

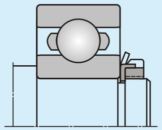
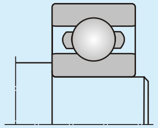
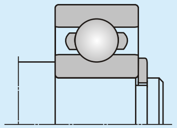
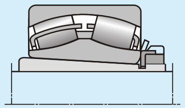
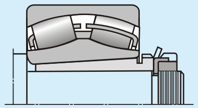
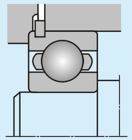
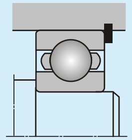
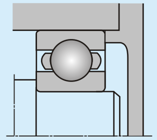
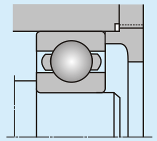
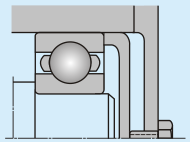
Types of Fixation	Sketches	Examples of Application
Lock nut		Inner ring is axially fixed by shoulder and lock nut, and the lock washer is used to prevent from loosening. It is suitable for high speed and heavy load.
Shoulder		Inner ring achieves axial fixation by shoulder and interference fit, and outside of the outer ring is fastened by end cover. Its characteristic is simple in structure and small size outline which is suitable for supporting arrangement at both sides.
Elastic washer		Axial fixation is achieved by shoulder and elastic washer. Light axial load of double direction can be carried. It is space saving and also easy to mount and dismount.
Adaptor sleeve		Inner ring is radically pressed by adaptor and lock nut and fixed on the shaft to achieve axial fixation. It is suitable for lower speed, steady radial load and small axial load.
Withdrawal sleeve		Similar to the adaptor sleeve, the withdraw sleeve itself has a shaft nut. It is easy to mount and dismount. It is suitable for heavier radial load and light axial load.

Table 9. 18

Types of Fixation	Sketches	Examples of Application
Snap ring		It is often used in deep groove ball bearings with snap ring groove on the outer ring. It is simple in structure and has small axial dimension, but larger axial load cannot be endured.
Elastic washer		It is simple in structure, easy to mount or dismount, and the axial dimension is small. Put the adjusting ring between axial end surface and bead flange which can also adjust the bearing's axial location, and compensate for the errors in processing and assembling. It is suitable for the condition with high speed and lighter axial load.
End cover		It is used to fix where radial bearing and angular contact bearing at the axle head. End covers can be made in many types. When end cover is through hole, it can also have various kinds of seal glands. It is suitable for the condition with high speed and heavier axial load.
Screw thread		It is suitable for the condition with high speed and heavier axial load. It can also adjust inner clearance of the radial thrust bearing. Screw ring should have methods to prevent loosen.
Adjusting bolt and cover fixation		It is similar to the end cover and easy to adjust the bearing clearance at the outside of the boxes. Screw adjustment should have the corresponding measures to prevent loosen.

9.3.2 Axial Tightening

The bearing's axial tightening is to ensure that the bearing be always on the position confirmed by axial fixation. Axial tightening includes inner ring fixed on the shaft and outer ring fixed in the shaft block. Although the inner and outer rings are required to be fixed accurately, the simultaneous axial fixation is not a necessary. This should depend on the supporting requirement:

- The structure of supporting with both ends fixed needs to be fixed only in one direction against the load, because it carries the axial load only in one direction.
- The structure of supporting with a fixed end and a wandering one needs to be fixed in both directions because the fixed end will carry the bidirectional loads. The wandering end should depend on the bearing types. If a non-separable bearing is selected then only one of the rings needs to be fixed and the walking ring is not fixed. If the separable bearing is selected, then two rings should be fixed in both directions typically in the cylindrical roller bearing.

9.3.3 Axial Fixation Device

There are many types of device for axial fixation. When selecting them, many factors such as magnitude of axial load, rotating speed, bearing's type, installation position, disassembling condition and so on should be considered.
Generally, the larger the load and rotating speed are, the more reliable the bearing is fixed. Meanwhile, inner rings usually use lock nut, tab washer, etc. Outer rings usually adopt the fixtures such as end cover, screwed ring, etc. When the load is smaller and the rotating speed is lower

then inner rings usually use a circlip for the shaft, or adapter sleeve, withdrawal sleeve, etc. Outer rings usually use elastic washer or snap ring. Just like the bearing, many axial fixing devices now use standardized components, such as lock nut, tab washer, circlip, adapter sleeve, withdrawal sleeve, etc. Therefore, customers can select them directly.

9.4 Bearing 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 “preload”.

9.4.1 Purpose of Preload

The purpose of preload is:

- To enhance the stiffness of the bearing
- To maintain the shaft in exact position both radially and axially and to increase running accuracy
- To decrease noise and vibration
- To provide the minimum load to prevent bearing from auto rotating and slipping
- To ensure the correct contact position between the rolling elements and inner & outer raceway
- To compensate for the dimension consuming of components in operating

9.4.2 Preload Mode

Depending on the direction of the preload, the preload can be divided into radial or axial preload.

- Deep groove ball bearing can be axially preloaded
- Angular contact ball bearing and taper roller bearing can be axially preloaded
- Cylindrical roller bearings can be radially preloaded because of the design structure
- Thrust ball bearing and thrust cylindrical roller bearing only can be axially preloaded

The method of imposing axial preload on the bearing is to impose axial load between two bearings face to face which make the corresponding axial displacement appear between inner and outer ring. It can be divided into location preload and constant-pressure preload.

9.4.2.1 Position Preload

Position preload is achieved by adjusting the length of sleeve or the thickness of washer to impose axial load on the bearing.
Angular contact ball bearings arranged in pairs are usually ground a certain amount of pre-deflection δ ao off the inner or outer ring faces, when bearings are mounted, two bearings are in the preloaded state after mating faces are clamped by clamping device, see Fig 9.6.

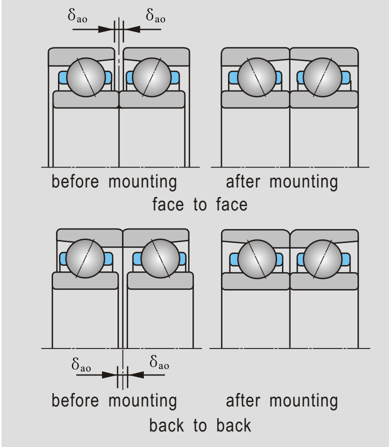


Fig 9.6

If the two bearings are kept a distance and their faces are not mated, the bearings can be preloaded by spacer sleeve and the necessary amount of preload can be obtained by adjusting the width of spacer sleeve, Fig 9.7.

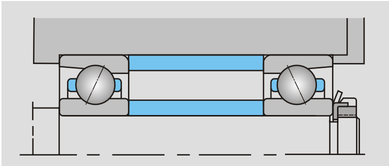


Fig 9.7

When two angular contact ball bearings arranged face-to-face or back-to-back are in-pair mounted, their axial loads and deflection curves are shown in Fig 9.8. The intersection of the two curves shows that preloading deflection of two bearings are δ ao under preloading loads Fao. When external axial loads Fa are applied on the shaft, the shaft will move displacement δ a along the direction of Fa. At the same time deflection of bearing I δ a, while that deflection of bearing II decreases δ a. Deflection amount shows the following respectively.

$$\delta_{aI}=\delta_{ao}+\delta_a$$
$$\delta_{aII}=\delta_{ao}-\delta_a$$

corresponding axial loads are:

$$F_{aI}=F_{ao}+\Delta F_{aI}$$
$$F_{aII}=F_{ao}+\Delta F_{aII}$$

from the equilibrium of forces:

$$F_a=F_{aI}-F_{aII}$$

It can be seen that axial displacement of supporting system is only δ a under the axial load Fa. Therefore, mounted angular contact ball bearings arranged in pairs can increase the stiffness of supporting system greatly by preload.

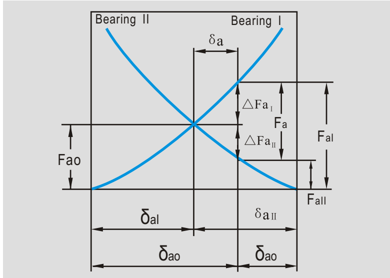


Fig 9.8

When two single row tapered roller bearings are mounted in pairs, their axial loads and deflection curves are shown in Fig 9.9. It can be seen that the stiffness of mounted tapered roller bearings in pairs may be increased by two times.

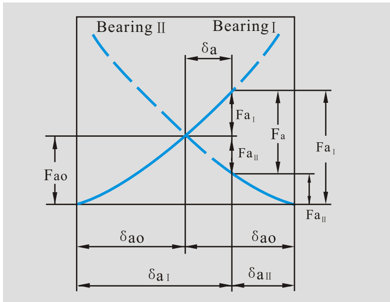


Fig 9.9

9.4.2.2 Constant-Pressure Preload

A constant-pressure preload is achieved using a coil or leaf spring to impose a constant preload. A certain preload can be obtained by adjusting the compression value of the spring, Fig 9.10 is an example of application.

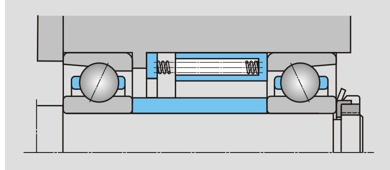


Fig 9.10

Fig 9.11 shows the axial load and deflection curve of an angular contact ball bearing arranged in pairs under constant-pressure preload.

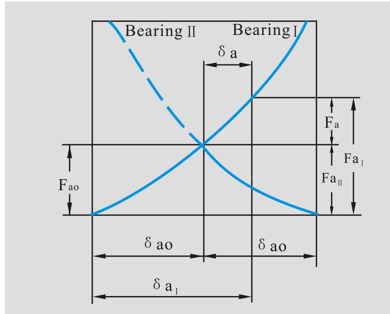


Fig 9.11

Under external axial load, deflection of the bearing I will increase δa, and deflection and preload of bearing II will keep constant. Compared with constant-pressure preload, under the same pre-deflection, position preload increases axial stiffness of supporting system. Length differences caused by temperature difference between the shaft and the bearing housing, and radial expansion caused by temperature difference between the inner and outer rings can effect the pre-deflection amount. Under constant-pressure preload they have no effect on the pre-deflection amount at all. Selecting the preload method should be dependant on actual applications. Generally, position preload should be selected in high stiffness constant-pressure, high speed applications.
You can consult the load under the different work conditions from LYC technical department.

10. Lubrication

10.1 Purpose of Lubrication

To make bearing operate effectively and reliably, enough lubrication is necessary. The purposes of lubrication are:

- To prevent or reduce friction and wear by the direct contact among rolling elements, raceways and cages.
- To form an oil film on the friction surface and enlarge the contacted loading area of components.
  Therefore, it can reduce contact stress and prolonging rolling contact life.
- To prevent against rust and corrosion.
- To dissipate heat and carry off the worn particles generated in operation or contamination ingress.
- To improve tightness so as to prevent the contamination entering
- To reduce noise and vibration.

10.2 Lubricant Selection

The lubrication can be divided into grease lubrication and oil lubrication. Solid lubrication can also be chosen under some special conditions.
When selecting lubricants, it could be comprehensively considered according to factors such as the structure of machinery, the working conditions of bearings and the structure, lubricating method and maintaining of adjacent components of bearings etc.
The factors which should be considered for the selection of oil lubrication or grease lubrication are listed in Table 10.1.
It is essential to maintain sufficient lubrication in any bearing application, so as to avoid seizure. In most applications this is performed by the insertion of either oil or grease between the rolling elements and the raceways. Filling the bearing with lubrication is calculated as a percentage of the available space, this space should not be filled beyond the calculated percentage of the available space, any overfilling can result in overheating, with the net result being premature bearing failure.
The selection of the lubrication method and the lubrication itself is dependent on many factors; these factors are described more details in Table 10.1.

Table10.1

Lubrication Characteristics	Oil Lubrication	Grease Lubrication
Liquid power lubricity	excellent	ok
Borderline lubricity	bad～excellent	bad～excellent
Cooling	very good	bad
Frictional behavior	ok～good	ok
Capability of supplying to bearing	good	ok
Absorbability	bad	good
Leakproofness	bad	very good
Anticorrosive property(to air)	ok～excellent	Good～excellent
Working temperature	generally, it can be used at 90℃(the bulk temperature of oil) or 200℃(the temperature of bearing); it can be used at 250℃ by adopting special lubricant oil.	generally, it can be used below the temperature 120℃. however, it can work at 220℃ by using special or shorten the cycle of changing grease
Permissible rotating speeds	$4.5\sim5\times10^5$	$3\text{-}5\times10^5$
Permissible load	high	medium
Volatility	very high	low
Flammability	very high～very low	low
Shock resistance	normal	good
Adaptability	very low ～ medium	medium
Service life	short	long
Cost of lubrication	low-high	quite high
Adjusting the amount of supplied oil or grease	easy	hard
Leakage of lubrication	more	less
Effect on environment	dirty	no affection
The replacement of lubrication	easy	hard
Maintenance	hard	easy
Capability of removing pollution	good	bad
The complexity of designing bracing structures	quite low	quite low
Affection on service life	deterioration or pollution	deterioration

10.3 Grease Lubrication

Considering the structure of the lubrication system, grease lubrication is used in many applications because of its simple sealing structure.
Lubricant grease is a half-solid agent which is made of a base oil, thickening agents and additives. Base oil is about 70-95%, the thickening agent is about 5-30%, and the additive is minimum.
The most widely used lubricating greases are calcium base grease, lithium based grease, calcium-sodium based grease and molybdenum disulfide grease, etc.
The main properties of grease lubrication are shown as the following:

- **Base Grease Viscosity**

Lubricating properties of lubricants are based on the viscosity of base oil which is important to form lubricant film. Usually, the viscosity of base oil used by rolling bearing is in the range of 15-500mm^2/s (40º). If the viscosity is over 500mm2 (40º), then the base oil will be very difficult to be dissolved out from the lubricant grease, which, could make the lubrication inadequate. However, if the viscosity is less than 15mm^2/s (40º), it will be difficult to form a film.

- **Consistency**

The ability of resisting deformation under outer force is named consistency. It can be measured with a needle penetrator. The designation of lubricant grease is indicated by the grade of needle penetration. The smaller the needle penetration, the thicker the consistency of lubricant grease is, and worse the liquidity. Needle penetration (or the designation) is divided into nine grades; grade 1, grade 2 and grade 3 are used by bearing. Grade 2 is used most frequently.
Generally, greases with light consistency can be used at low temperatures. Greases with high consistency can be used at high temperatures.
Its consistency changes little while the grease is used in the range of its normal working temperature. If the working temperature is higher than that allowed, lubricant grease will turn soft and easily leak. Generally, greases which soften at elevated temperatures may leak from the bearing or housing, those which stiffen at a low temperature may restrict the rotation of the bearing.

- **Thickening Agent**

The main function of thickening agent is to keep lubricant grease in a half-solid state. Therefore, some characteristics such as the working temperature, mechanical stability, heat resistance, and water resistance of lubricant grease are decided by thickening agents. The performance of lubricant grease changes with different thickening agents.

- **Additive**

Currently base oil is hard to satisfy comprehensive lubrication requirements of friction couples. Therefore, in order to increase the performance of oils, some additives which will improve the quality of oil and must be added into the base oil in order to make greases suitable for various special working conditions. However, lubricant greases added with additives may bring up a negative influence on the bearing parts, such as corrosion.

Types of main additives:

1) additives protecting the surface of metal,e.g. extreme pressure additive, etc.
2) additives improve the capability of lubrication e.g. adhesive, etc.
3) Additives protect the lubricant grease itself, e.g. antioxidant, etc.

- **Miscibility**

The miscibility of greases with different designations must be considered when changing the designation of greases. Combined lubricant grease with different designations are likely to make the consistency change considerably, which, would cause lubrication failure and leakage. Generally, greases with the same thickening agent and similar base oil can be mixed with each other.

10.3.2 Selection of Grease Lubrication

When selecting lubricant grease, the working temperature, load and rotating speed should be taken into consideration.
The lubricity of grease is largely dependant on base oil, which, is chosen according to the usage and using condition of grease lubrication. Low-viscosity base oil is suitable for bearings which work at low temperatures, light loads, and high speeds. Machine oil and engine oil are suitable as base oil for mid-speed bearings. Cylinder oil is suitable to be used as a base oil for bearings which are operating in high temperature, heavy load and slow-speed conditions. Synthetic base oil can be used in other special conditions.
The structure and precision of the bearing can influence by the selection of lubricant grease. The available space inside the bearing or clearance is

smaller, then the finishing precision on the working surface is higher and the base oil to be chosen would be of less viscosity. This allows for the unnecessary waste of energy. The viscosity value of base oil must be improved when the working surface is rough. Meanwhile, an oil film cannot be formed easily because of the comparably heavy pressure which would be caused by partial contacting.
In watery working conditions, calcium base grease is the first choice because it will not dissolve in water. Sodium base grease will dissolve easily, it should not be used in a dry and hydroponic conditions.

When selecting lubricant grease, attention must be paid to the following several points points:

- Under normal speed, load, and temperature, a minimum movement viscosity of grease used by most kinds of bearings is not less than 15mm^2/s.
- The dropping point of the grease should be higher than its working temperature 20-30℃ to avoid leakage.
- Due to bad liquidity, heavy friction resistance, little thermal conductivity of lubricant grease, circle lubrication is inadvisable. If it must be used in the applications where concentrated lubrication is needed, lubricant grease with comparatively large needle penetration should be the first choice.
- In specified range of temperature, grease lubricant is not sensitive to temperature. Grease lubricant has a high adaptability to great changes of load chrematistics and moving speeds, so it can be used in those machineries whose working ambient temperature and speeds change greatly.
- Lubricant grease will not leak easily and need not be changed often. The needed sealing devices are comparatively simple, therefore, the lubricant grease itself has a certain sealing function, So it is suitable to be used in dusty situations where it is difficult to refill greases.
- When lubricating in high temperature, grease with good resistance to oxidation, less evaporation, with a high dropping point should be the first choice.
- For one-off lubricated sealed bearings, the life of lubricant grease should be longer than the fatigue life of bearing. If shorter, then the practical life of bearings is dependant on the life of greases. Generally, the life of lubricant grease is corresponds with the time of medium repair and heavy repair of equipment.

The most widely used lubricating greases are calcium based grease, lithium based grease, aluminum based grease and molybdenum disulfide grease etc.
Sealed bearings listed in this catalogue have been filled with grease before leaving LYC's factory and can be applied directly in service. Generally, the bearings are filled with 2# lithium base grease. If you have other special requirements, please consult LYC technical department.

10.3.3 The Filling Amount of Lubricant Grease

The filling amount of lubricant grease changes with the bearing structure, space, speed, and the type of lubricant grease. The filling amount of lubricant grease is composed of two parts, one is filled inside the bearing, and the other is filled in bearing block.
The filling amount of lubricant grease is confirmed by the ratio of the allowed limiting speed and the practical working speeds when selecting lubricant grease. See Table 10.2

Table 10.2

Rotating Speed Ratio	Filling Amount
A≤1. 25	grease lubrication is 1/3 of bearing free space
1. 25<A≤5	grease lubrication is 1/3 -2/3 of bearing free space
A>5	grease lubrication is above 1/3 of bearing free space

Table 10.2 only shows the filling amount inside the bearing, but, bearings are often fixed in the bearing block, in order to prevent lubricant grease from leaking out. When the bearing is operating, enough lubricant grease inside the bearings has to be kept to satisfy the need of lubrication. The free space in the bearing block is filled with a certain amount of lubricant grease (except sealed bearing). According to our experience, 1/3-1/2 of the free space in the bearing block should be filled.
The amount should be reduced when the bearing is operating at high speeds. alternatively, the amount is increased.

10.3.4 The Subrogation Cycle of Lubricant Grease

The subrogation cycle of lubricant grease is not only based on the property and character of itself, but, also the lubricant working condition, temperature, speed, and load.
When the temperature is getting higher, the base oil of lubricant grease would be vaporized,

oxidative deteriorated, the grease net structure destroyed and indurate, which, would reduce the capability of lubricant grease. When base oil loses are 50-60%, especially under high temperature, the capability of lubrication descends more quickly. The higher the temperature is, the shorter the life of grease is. Accordingly, replace the old lubricant grease before the capability of the lubricating lost. For the widely used lubricant grease, we judge the grease whether it loses its efficacy or not by examining the function parameter of the grease. See Fig 10.3

Table 10.3

Item	Index
Change of consistency	>15%
Change of dropping oil	>20%
Acid number	>3mg KOH/g
Lubricant grease leaking	>50%
Oil separation percent	>40%
Mechanism impurity	iron>0.1% copper>0.3%

- **Re-Lubrication Quantity**

When the subrogation cycle of lubricant grease is corresponding to the checking period of machines, new grease with the same amount filled in the new bearings should be filled in the cleaned and washed old bearings. While cleaning, please do not destroy bearings, and do not allow any impurity into the bearings. Meanwhile, the bearing block should also be washed too.
Sometimes when the machine is not up to maintenance period, but the lubricant grease requires to be replaced. In this condition,the new lubricant grease have to be filled regularly before the time of machine mantenance. The quality of relubrication should be restricted according to the relubrication period. Normally, the shorter on this peiod, the less on quanity refilled. This can be calculated by the following empirical formula

$$m=xDB$$

where

m– the new filled lubricant grease amount each time
D– bearing outer diameter, mm
B– bearing inner diameter, mm
X– modulus of the grease newly filled, see Fig 10.4

Table 10.4

X	0. 001	0. 002	0. 003	0. 004	0. 005
Lubricating periods	every day	every week	every month	every year	every 2-3 year

There are exceptions as to when the calculated available space may be exceeded, typically when there are large amounts of available free space, or when the bearing operates at low speed. If the bearing is to be operated in an extraneous environmental condition and to prevent the ingress of contaminants. When regreasing it is essential to purge the used grease and ensure that fresh grease reaches all working surface of the bearing, marginally more grease may be applied to make up for premature grease loss and/or evaporation.

10.4 Oil Lubrication

Oil lubrication is recommended in the following situations

- when bearing works at high speeds and high temperatures
- when the frictional or applied heat has to be removed from the bearing
- when lubricant grease can't satisfy the needs
- when abutting machines adopt oil lubrication

10.4.1 Oil Lubrication Modes

- **Drip Feed Lubrication**

Drip feed lubrication is a method of dripping oil into bearings by a serving oiling orifice. The strong points of drip feed lubrication are that the device structure is simple, it can be used conveniently, more oil can be saved by this way. The amount of oil supplied can be measured and adjusted. A drop should be provided at intervals of 3-8 seconds. Too much oil may cause the temperature to rise. Drip oil lubrication is suitable for slow speed and light load.

- **Oil Bath Lubrication**

Oil bath lubrication is a method that allows of bearing into lubricant oil to be picked up by rotating elements, after circulating through the bearing, it drains back to the oil bath. See Fig 10.1. Oil bath lubrication is one of the most widely and conveniently used lubrication methods.

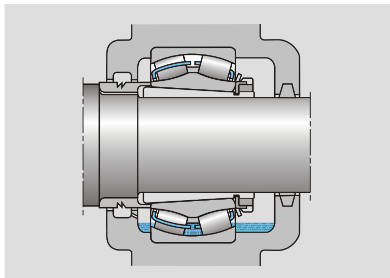


Fig 10.1

Oil bath lubrication can lubricate well, but the quantity of oil supplied is not accommodated easily; and there is no filtration equipment, which would bring impurities into the bearing easily and cause damages to the inside of the bearings. Oil bath lubrication is only suitable for low or medium speeds.

- **Splash Lubrication**

Splash lubrication is a lubricating system where the oil is induced into the bearing by a splashing motion created by the movement of the bearings rotating elements. See Fig 10.2.
The quantity of oil supplied by this splash motion is not easily controlled. Once again it is essential to maintain any pre-subscribed oil level, as over filling can also be detrimental, the results of over filling can lead to elevated temperatures, these elevated temperatures under heating and cooling can create a vacuum resulting in the possibility of the ingress of contaminants.

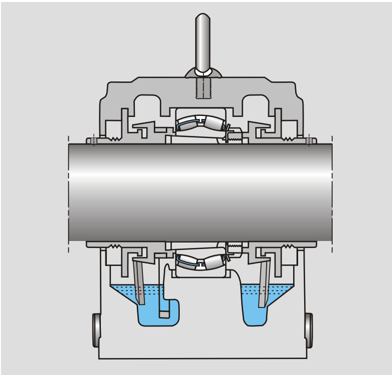


Fig 10.2

- **Circulating Oil Lubrication**

Lubricant oil can be sucked out by an oil pump from an oil box, then it is transported to the parts in the bearing requiring lubrication, then it is returned to oil box from an oil jaw. The sucked oil can be used again after filtration. See Fig 10.3.
The circulation oil method is a superior system to all other lubrication methods as temperatures can be controlled by additional cooling injection; filtration can be applied to filter out contaminants. When applicable oil monitoring can be applied to that oil replacement is made automatically.
Regulated flow is easily adjusted for optimum performance. These regulated flows can be matched to high speeds and high loads. These types of system are not suited for all applications and have the disadvantage of generally being expensive, however they do provide optimum performance.

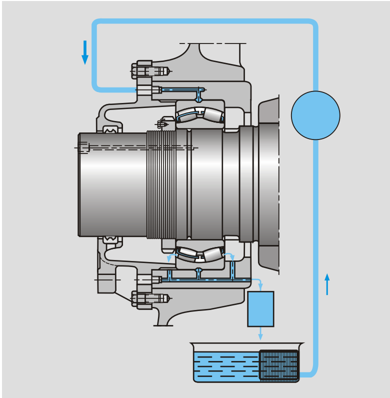


Fig 10.3

- **Oil Mist Lubrication**

Oil mist lubrication employs oil droplets which are transported to the bearing by an air current (see Fig 10.4), oil mist is produced in an atomizer. Dry compressed air and oil mixture are transported to every part of of bearing where it needs lubrication. Oil mist lubrication allows little whisking wastage and temperature rise. Therefore, the air current in the housing will also serve to cool the bearing and produce a slightly higher temperature in the housing to assist in preventing impurities from entering. However, the cost of oil mist lubrication is high, there are some special requirement on the oil viscosity, generally, the viscosity of the oil is no more than 340mm2/s, otherwise, the effect cannot be made. Additionally, if the lubricating device dose not seal well and tightly, some oil mist may leak out and pollute the environment. If necessary, oil and gas separators can be used to collect oil mist. This method is often used for high speed applications.

- **Oil Jet Lubrication**

Oil jet lubrication is a method that is adapted to jet oil into the bearings. See Fig 10.5
When the bearing is operating at a high speed, rolling elements and cages are also rotating at high speed. By this way, turbulence air is formed around the bearing, which can make the lubricant oil reach the parts that needs to be lubricated. However, after the oil is sprayed out, the lubricating oil will flow back into the oil bath from the side because of centrifugal force. In order to provide adequate oil for fast rotating bearings, lubricant oil must be jetted out from the other side.

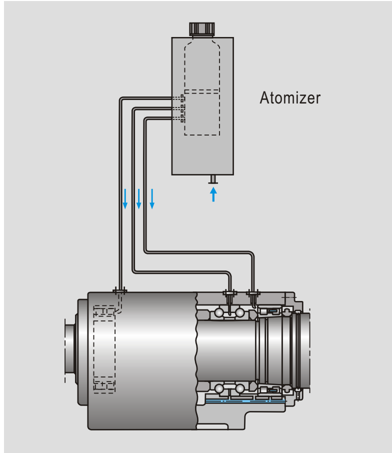


Fig 10.4

When designing this lubricating system, the position of the high pressure standard nozzle should be placed between the inner ring and cage. By centrifugal effect, lubricant oil must be thrown out of the outer raceway. In order to keep the lubrication efficient, the jetting speed should not be less than 15m/s.
No matter which way it is to be used, the cleaness of the lubricant oil or greases should be considered first, thus ensuring and lengthening bearing life.

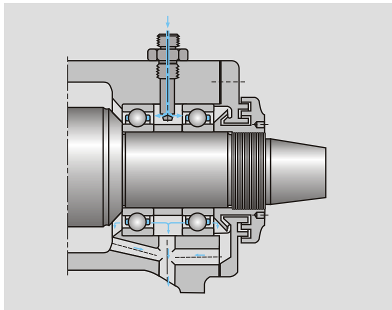


Fig 10.5

- **10.4.2 Lubricant Selection**

Lubricant selection is almost the same as the grease lubrication selection. It is mainly based on the viscosity of oil which can provide enough lubrication to the bearing at working temperatures. Lubrication viscosity would fall with the increase of temperature. Therefore the lowest oil viscosity would be ensured at working temperatures. In normal working conditions, the lowest movement viscosity should not be over 15mm2/s in order to form a lubrication oil layer with enough thickness on the contact surface between raceway and rolling element.
Mineral oil without any additive could be used in normal conditions. The lubrication with additive or compound oil is suitable for special working conditions. However, lubrication with additive would have a negative effect on the bearing, typically corrosion.
Generally speaking, when the bearing is rotating at high speed, the lubricant with a low viscosity could be used. For the bearing under heavy load, lubrication with a high viscosity should be chosen. The widely used lubricants are machine oil, high-speed machine oil, stream-turbine oil, compressor oil, transformer oil, and cylinder oil, etc.

- **10.4.3 Replacing Intervals**

In order to ensure that the bearings lubrication in maintained good working condition, lubrications should be replaced regularly, even when oil lubrication systems are adopted.
The replacement intervals for lubricants are dependent on working conditions, environmental conditions, oil mass, oil pollution and the type lubricant. Only careful monitoring of the lubricants condition can determine as to when to change the lubricant, after time a trend can be developed in order to establish a maintenance interval, premature oil changes can be wasteful in down time and expensive in purchasing, whilst there could be additional lubricating life remaining within the existing lubricant.
When adopting Circulating Oil Lubrication, Oil Bath Lubrication, Splash Feed Lubrication, Oil Spray Lubrication, or small lubrication systems with oil deposits below 250 litres, then replacing oil at predetermined intervals should be referred to in Fig 10.5 Circulating Oil Lubrication.
For lubrication systems with capacities larger than 250 litres, then the oil replacement interval should be ensured by periodically checking chemical characteristics, in addition to content of mechanical impurities, refer to Table 10.6 below.
When lubricating by Gas Oil Lubrication, the lubricant itself disposable or can be recycled to avoid environmental pollution.

Table 10.5

Lubricating System	Oil Bath Lubrication	Circulating Lubrication		
Working temperature	~70	~50	50~70	>70
Change period	one year	2~3year	one year	3 months

Table 10.6

Item	Precision Machine	Normal Machine
Change of viscosity	±10%	±15%
Acid increasing	<15%	<25%
Flash point change	<10%	<15%
Solidifying point(ascended)	<10%	<15%
Moisture content(within oil)	<1%	<2%
Mechanism impurity	<0. 1%	<0. 2%
Anti-emulsification(ascended)	<15%	<20%

For lubrication systems with capacities larger than 250 litres, then the oil replacement interval should be ensured by periodically checking chemical characteristics, in addition to content of mechanical impurities, refer to Table 10.6 below. When lubricating by Gas Oil Lubrication, the lubricant itself disposable or can be recycled to avoid environmental pollution.

10.5 Solid Lubrication

When neither oil or grease lubrication are able to satisfied some special working conditions then solid lubrication can be adopted. An example of this is in the use of bearings for ceramic roasting ovens or where in a application that temperature would exceed 270 centidegree. Other typical applications could be used in bearings for satellite facilities.
Solid Lubricants have the advantage of avoiding pollution as opposed to using oil or grease. Solid Lubricants require less on going maintenance. However, solid lubricants powder characteristics do have a higher coefficient of friction factor, there is no cooling benefit and working life is generally shorter.
Commonly used solid lubricants for rolling bearings are Lead, Silver, Black Lead, Supramoly, Lead Oxide, Polyfluortetraethylene, and nylon etc.

11. Seals

Seals for bearing arrangements are used to prevent dust, contaminant or moisture from entering the bearing and to retain the lubricant in the bearing. The efficiency of the sealing arrangement has a decisive effect on the lubricant cleanliness, the performance and the operational life of a bearing.
There are two types of seals: the distinction is made between seals which are integral with the bearing and those that are positioned outside the bearing. The former is sealed well before leaving the factory.
There are many types of seals positioned outside the bearing, according to the configuration relationships between sealing arrangements and bearings, they can be divided into non-rubbing seals and rubbing seals. In the selection of seals, the following should be considered:

- Working environment of bearings
- Rotating speed of the bearings
- Structure characteristics of the bearing with its matching parts
- Type of lubricant
- Working temperature of the bearing
- Space and position
- Cost

11.1 Noncontact Seals

The effectiveness of noncontact seals mainly depends on a certain clearance between sealing arrangements and bearings without direct contact. Because of clearance, except some lubricant friction in clearance, other types of frictions will not appear. Therefore, the wear as well as the frictional heat will not appear, the seals life will be relatively longer. If the clearance is selected inappropriately, it will be easily affected by the external contamination or moisture and cause the lubricant to be lost. Noncontact seals are suitable for high speeds and high requirement on working temperature.
According to the different positions of clearance configuration, noncontact seals can be arranged axially, radially, or axially and radially in combination. Considering some factors such as operating errors, shaft deformation, the dimensions of clearance are shown in Table 11.1 and typical examples are shown in Table 11.2.

Table 11.1

Journal	Radial Clearance	Axial Clearance
<50	0. 1~0. 3	1~2
≥50	0. 5~1. 0	3~5

11.2 Contact Seals

Contact seals means existing a certain joint pressure between sealing agreements and bearings by direct contacting. The pressure is generated from the following ways:

- The self-resilience of the seal
- A force exerted by the fit clearance between the sealing arrangement and its counter-face
- A force exerted by a spring in the sealing arrangement

Though contact seals are in need of pressure, under the precondition to meet the using requirements, the pressure should be as low as possible, for the friction moment and working temperature will increase with the growing pressure. The friction moment and working temperature are not only related to the pressure, but, closely related to others such as contact way, dimensional accuracy of the contact site, surface roughness, sliding speed etc.
In addition, all rubbing seals will lead to wearing; its degree is related to environmental pollution, pressure, rotating temperature and speed, lubrication etc. But if the wearing area is lubricated properly, the wear must be reduced.
Because of the frictional heat existing in the contact seals when operating, it's suitable for medium and lower speeds or oil lubrication.
The common structures of rubbing seals are shown in Table 11.3.
In practice, the types of seal can be a combination design according to different working conditions and specific requirements on sealing arrangement. Typical structures are shown in Fig 11.1.

Table 11.2

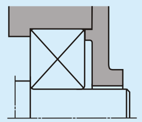
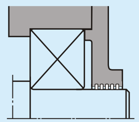
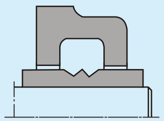
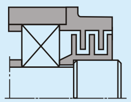
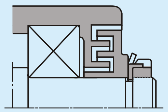
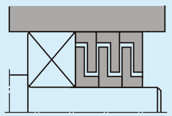
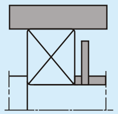
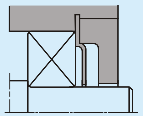
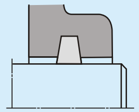
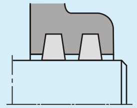
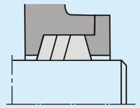
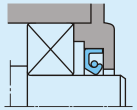
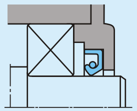
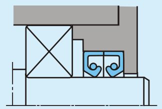
Types of Seal		Sketches	Examples
Gaptypes	Narrow gap		The smaller and longer the length of gap between the shaft and end cover, the more effective will be the sealing effect.
	Helical groove		There are over three grooves on the end cover. The groove width is 3-4mm, the depth is 4-5mm (the grooves take the shape of helical groove). They are used to fill grease to improve the effect of sealing.
	W-type		Used for oil lubrication. There is W-groove on the shaft or in the housing. The oil from the flinger is collected in a channel in the housing seal bore and returned to the housing through suitable ducts.
Labyrinths	Radial		Radial labyrinth passages are composed of the gap between housing and end cover, end cover is separable. Radial labyrinth passages distribute axially, the size in axial direction is compact, the effect of sealing is better. Suitable for dirty environment, e.g. metal-cutting machine.
	Axial		Axial labyrinth passages are composed of the gap between housing and end cover. Labyrinth passages distribute radially, end cover is one-piece, easy to mount and dismount, wider use than radial labyrinth.
	Combined		Labyrinth passages are composed of two- “「” shaped washers, saving space, low cost, suitable for mass production, washer should be mounted combined.The more combination is, the better the effect of sealing is.
Washers	Rotating washer		Washer is rotating with shaft while working. The higher the rotation of the shaft is, the better the effect of sealing is. The rotating washer can prevent oil from emerging and can also prevent contaminants from entering.
	Stationary washer		Washer and outer ring of bearing are fixed while working. Used to prevent dirts and contaminants form entering.

Table 11.3

Types of Seal		Sketches	Examples
Felt	Single-felt		Used for clean lubrication environment. Peripheral speed can not exceed 4-5m/s and working temperature is 90℃. The peripheral speed can reach up to 7-8m/s after the shaft surface is ground. Felt seals can be divided into single-felt, double-felt and multi-felt. To prevent the shaft from wearing early, the sleeve should contact directly with the felt washer. The effect of sealing is not very good, so rarely used.
	Double-felt		
	Multi-felt		
Leather cup			Leather cup seal is made of oilproof rubber and suitable for sealing arrangement with grease or oil lubrication. Peripheral speed can not exceed 7m/s and working temperature is not over 100 ℃.The sealing lip should be pressured on the surface by a spring. To improve the effect of sealing, two cups can be mounted face to face.
			
			

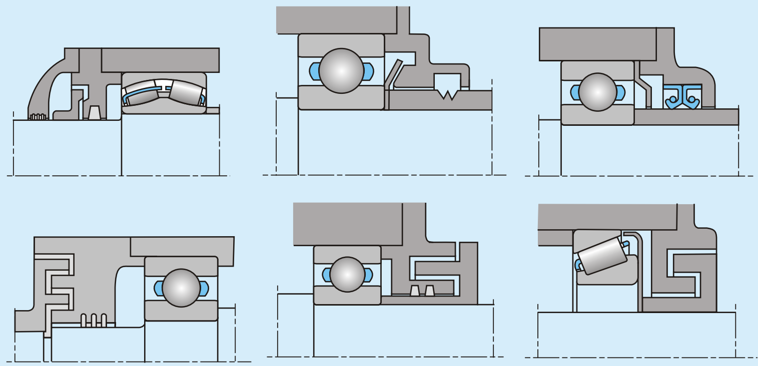


Fig 11.1

12. Package, Transportation and Storage

12.1 Antirust

Bearings are precision manufactured components, during transportation and storage they are susceptible to rusting, consequently LYC take measures to prevent this happening by applying liberal amounts of Anti-rust rust coatings (Anti-corrosive).

12.1.1 Rust-Proof Period

LYC use the China national standard GB/T8597 <Rolling Bearings Antirust Packaging> this standard states that the rust-proof period can be divided into half-year, one-year and two-year periods. Bearings that would be used and installed in a short period are required to have a half-year rust-proof period; standard bearings require a one year rust-proof period; and bearings with a higher use requirement require a two-year rust-proof period.
If bearings are not used during the rust-proof period then they should to be cleaned by removing the original rust preventative then re-coated with anti-rust.

12.1.2 Rust-Proof Material

The most commonly used rust-proof materials are oil (grease) film, emulsifier oil or other water based anti-rust inhibitors, the use of vapor phase inhibitor, and vapor phase anti-rust oil are also acceptable.
Oil film anti-rust oil can be used to anti-rust the bearing in addition to lubrication for the bearing. Bearings using this type oil can be installed directly without cleaning.
Grease film rust-preventive oils include liquid anti-rust grease, solvent-diluting anti-rust oil, and hot petroleum anti-rust grease etc. Solvent diluting anti-rust oil can be sprayed and used easily.
Vapor phase anti-rust oil is a mixture of a vapor phase inhibitor combined into the lubricating oil. This provides lubrication and the anti-corrosion properties. The vapor phase inhibitor is used to prevent moisture within the atmosphere becoming in contact with the metal surface by slow evaporation. It is unnecessary for the vapor phase inhibitor to be in contact directly with the metal. This method of anti-rusting has a very low viscosity and has the ability to penetrate even the smallest cavity, basically being able to ensure 100% coverage for all parts of the bearing.
If customers have special requirements so as to avoid any contravention of their local and national standards in respect to environmental concerns with regards to anti-corrosion materials, then they should contact the LYC Technical Department for guidance.

12.2 Packaging

The bearing packaging itself is referred to as inner packaging, outer packaging and promotional packaging. It is important at all times to maintain the integrity of this packaging; the packaging ensures that the bearing will be ready to be put in service when the bearing is required.

12.2.1 Inner Packaging

In order to ensure the effectiveness of the anti-rust coating, the inner packaging is used to prevent the anti-rust from leaking/evaporating during transportation or storage periods. This inner packaging is also used to prevent the anti-rust from being in contact with other external contamination influences.
The following materials are typically used by LYC for inner packaging:

- Polyethylene plastic film, plastic tubes or boxes
- Nylon belt or plastic braid
- Pergamyn paper and Kraft paper
- Polyethylene composite paper
- Cardboard box
- High strength waterproof plastic belt

The type of packaging used to pack bearings depends on the dimensions of bearings. For example,

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- Bearings with an outer diameter less than 52mm are normally packed within a plastic tube, or several pieces are rolled together with Polyethylene composite paper.
- Bearings with an outer diameter 52mm~80mm are firstly packed with Polyethylene plastic film piece by piece, several sets are then placed into a specially made carton; or rolled separately with Polyethylene plastic film, the bearings are then rolled in combination sets with Polyethylene plastic film.
- Bearings with an outer diameter 52mm~80mm are packed with Polyethylene plastic film separately; these are then placed into specially made cartons. Bearings with an outer diameter over 200mm are normally wrapped with Polyethylene plastic film or Polyethylene composite paper, and then wrapped with a Nylon belt or plastic braid, finally a high strength water-proof plastic belt is wrapped around the bearing to act as a protective cover.

12.2.2 Outer Packaging

The function of the outer packaging once again is to protect these precision components, whilst in transport and storage. Bearings with a diameter of less than 200mm are usually packed in wooden cases; all markings are of China national standards. LYC do promote their own brand labeling on the outer surface of the carton. Customer's can request their own markings to their own international standards, including, if required barcode labeling.
LYC manufacture their own packaging. Box sizing and the number or bearings within each box are all calculated, if there is spare space then this is filled with, corrugated paper or foam board etc. It is very important to fill the remaining space in the outer package fully so as to prevent the possibility of fretting, which, could occur during transportation. All wooden cases are bound with metal strips in order to assure the integrety of the carton; the carton is then sealed with scotch tape and Kraft paper tape, this is then bound with a nylon belt.

12.3 Transportation

The quality of the transportation should be equal to the quality of the bearings themselves, as shipments that have been handled inappropriately have the potential for damaging the bearings within the packaging.
LYC design the outer packaging to take into account many factors, such as carrying capacity, durability against shock absorption, handling, and pressure resistance etc., anyone or a combination of these factors can cause damage to the bearings during transportation, these factors are taken seriously by LYC. The loading and unloading of bearings should be reduced to a minimum where possible to reduce the potential for damage. Pallets and containers should be used to transfer any larger-size or heavy bearings. Mechanical handling and auxiliaries should be chosen in order to maximize smooth transition from point A to point B. For small to medium bearings with larger quantities, mechanical handling should also be adopted as desscribed previously. Throwing or tipping over bearings is strictly forbidden. Bearings should always have a smooth transition at any time they are being moved.
Bearings should always be placed in a horizontal orientation. It is forbidden to place any pressure on any bearing so as to avoid deformation. Boxes should be placed together closely; this can help reduce shock and vibration during transportation. If bearings are transported by truck, then the bearing boxes should be affixed firmly with strapping and covered with a water and dust-proof awning. If bearings are transported by rail, then the boxes should be placed steadily and firmly on the trains. If bearings are transported by vessel, then water and moisture-proof facilities should be adopted.

12.4 Storage

As Bearings are precise mechanical components as compared with general mechanical products, there must be much stricter requirements for their storage environment; otherwise, it would become very easy for bearings to lose their precision or to become rusty.

12.4.1 Requirements of Warehousing

- It is important for warehousing to be structurally sound and preferably to be environmentally controlled. Bearings should not be placed in direct sunlight.
- The relative humidity in the warehouse should be below 80%. If the humidity were higher then it could be very easy for the bearings to become rusty. The temperature of the warehouse should be controlled at 25℃±10℃, evening temperatures should vary little, large temperature difference can cause condensation, if the RH has been high through the day and there are cooler temperatures through the evening then condensation could form on the bearings, with the net result of them developing rust.
- All warehousing should have a firm concrete base and be free from dust.
- Bearings should not be stored in the same warehouse where there maybe acids, alkalis, salts, or other industrial chemicals which may be corrosive, gasses should also be avoided as in some cases these also may be corrosive to Bearings.

12.4.2 Requirements for Warehousing

- The outer packaging of the bearings should be checked to ensure it is in good order before entering the warehouse. If the seal on the packaging should be found to be damaged, then the carton should be opened immediately and the bearings inspected prior to been stored.
- The main packaging should be opened in any event so as to inspect the bearing quantity, quality, certificates, specifications, and the manufacturer's date of production etc.

12.4.3 Requirements for System Storage

- Bearings having an OD of less than 200 mm should be placed on storage racks in the horizontal position, other bearings can be placed on top of each other providing there is sufficient support between each bearing so as to avoid potential distortion.
- Bearings with an OD exceeding 200 mm should be placed at ground level, with well placed intermediate supports to lift the bearing off the ground for a minimum of 200 mm in height. As a general rule these size bearings should not be stacked above 1.5 metres in height.
- When placing bearings upon each other use caution so as to avoid damage and distortion between each bearing. Bearings should be used on the first in first out system.

12.4.4 General Requirements for Bearing Storage

- The bearings rust proof coating generally has an expiration life of one year. Consideration of minimum stock levels should be given so as to minimum turn in inventory time, once again the first in first out should apply. Dependent on environmental conditions and time exceeding one year then there is the possibility for bearings to lose their tolerance stability.
- Bearing should be placed in store rooms that are environmentally controlled in respect of temperature and humidity, in addition to filtration so as to remove airborne particulates.
- The Bearings inner packaging should not be removed until the bearing is ready to be placed into service, periodically (3 months average) some of the bearings packaging should be removed so that the bearing can be inspected for rust, if rust should be found then this should be removed, the bearing should then be recoated with rust preventative and re- sealed.
- A lot of these types of bearings in storage service should be kept so as to maintain accurate records for bearings in storage.

13. Mounting and Dismounting

13.1 Mounting

Roller Bearings are precision mechanical components with tight dimensional tolerances. Care must be taken when mounting bearings so as to ensure the integrity of the bearing is maintained. Improper mounting can result in poor performance and premature failure.

13.1.1 Preparations Before Mounting

Preparations should be carried out in the following manor prior to mounting as follows:

- Bearings should be mounted in an area that is dry and dust free, avoid areas with chemical contaminants.
- The mounting tools should clean and well maintained so as to avoid any kind of particulates entering the bearing.
- Before mounting, check the components size, shape, position, accuracy and that any chamfers match with bearing, See Fig 13.1. Unqualified components should not be used. Pay attention to all tolerances within the ID, OD of the bearing so as to ensure that tolerances are with the prescribed limits of the mounting apertures, if these are not within the limits then bearing should not be mounted.
- Clean all the suitable and pre-qualified components, and remove sharp burrs.
- Bearings adopting oil lubrication, should have their hydraulic system checked first, this hydraulic equipments filtrating system must work efficiently, and the filtrating accuracy should not be less than 3 micron.
- Bearings should not be unpacked and cleaned, until all preparations for mounting are complete. Bearings lubricated with antirust oil should be cleaned with kerosene (ensure that there is no potential for fire whilst carrying out this operation). If grease with a high viscosity was used to seal the bearing (currently use rarely), then it needs to be dissolved first with a light-weight mineral oil such as NO.10 mechanical oil or transformer oil, its temperature should not exceeding 100℃. After this operation clean with kerosene or appropriate petroleum degreaser. Bearings that are lubricated with the oil provide a double function, namely that of anti-corrosion and lubrication, these can be mounted and used directly without cleaning. Bearings should be mounted as soon as cleaning is completed so as to avoid additional contamination. Bearings that can not be mounted immediately after cleaning should be placed in a clean area so as to avoid becoming contaminated with moisture or other contaminants. When handling bearings with your hands you should apply some anti-rust to surface of your hands so as to avoid additional contamination.

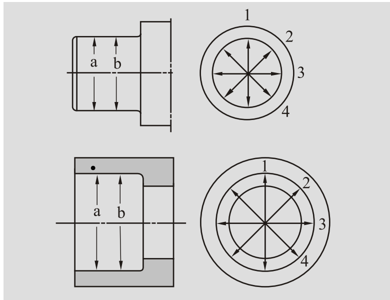

Fig 13.1

13.1.2 Methods of Mounting

There are three main methods for bearing mounting: Pressure Method, Temperature Difference Method and Hydraulic Pressure Method.

- **Pressure Method**

The pressure mounting (or dismounting) is a method that applies pressure directly without changing the matched components' dimension under a constant temperature condition, see Fig 13.2. This method is commonly used for small and medium size bearings with interference fit that is not so large. Bearings having a large interference fit, large size bearings or components with a weaker rigidity should not adopt this method, so as to avoid deformation.

When adopting this method the end face of the bearing should receive pressure evenly, the alignment between the bearing shaft neck and the housing bore should be kept homocentric so as to prevent deflection. The pressure should not be allowed to transfer through rolling element and cage as this will damage the surface of the components and have a detrimental effect on the normal operation of the bearing. Knocking the bearing with a hammer directly is prohibited.

Pressure is obtained by applying the force to the end face circle evenly by pressing machine. Lubricant can be used to protect the surface, but, excessive use of lubricant will influence the quality of interference fit and can cause slipping. Cautious use of lubricant should be applied with small interference fits.

- **Temperature Difference**

This method is suitable for the bearing with larger interference or the bearing been mounted and dismounted frequently. This is to make the interference vanish temporarily by heating or freezing, and regain after the temperature is normal so that the bearing can be mounted and dismounted easily.

When adopting this method to mount or dismount, no mater which heating or freezing method be selected, the most important thing is to control the temperature. Too high temperature will cause the change of material, hardness or dimension. While much low temperature may cause the bearing to fracture. Generally, the heating temperature should be 60~70℃ lower than the tempering temperature. For the ordinary bearing steel, the highest heating temperature should be below 100℃and the lowest freezing temperature should be above -50℃.

The temperature difference method can be divided into oil bath, air heating, flame heating, electromagnetic induction, etc.

Among them, air heating needs a heat box, electromagnetic induction needs a related device. Air heating can be controlled by the temperature easily. Electromagnetic induction is more suitable for batch mounting of the bearings with same specification. When using flame heating, the

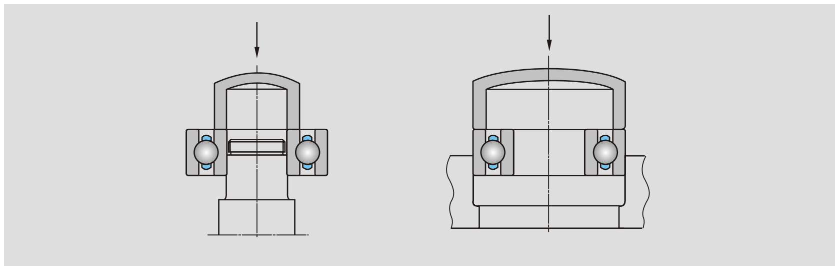

Fig 13.2 Mounting Bearing Under Pressure

distance between flame and component surface should not be too close to prevent the surface from been damaged, equal heating should be done along the circle.
In practice the most commonly heating method is oil heating, this, operation is simple without special tools. The heating oil mostly uses non-corrosive mineral oils such as transformer oil with its splash point of 250℃, see Fig 13.3. When oil bath is being exerted, transformer oils are put into the oil groove and a support with bearings on is located at the bottom of the groove with the distance of 60mm. The purpose of this is to heat equally and prevent bearings from polluting. A temperature gauge should be put in the groove to control heating temperature. The oil heating method is not only fit for the mounting of medium and small sized bearings, but, also fit for separable and non-separable bearings.

- **Hydraulic Pressure Method**

Hydraulic pressure is quite an advanced method. Its principle is that the hydraulic oil enters the interference fit place through the preprocessed oil hole and oil groove to form a film ring, then mount or dismount by using tensile force to roll out the mating surface(see Fig 13.4). However, this method requires higher dimension accuracy, otherwise the oil will leak easily and the high pressure will not appear. The mounting method is shown in Fig 13.4.

13.2 Dismounting

There are two purposes of dismounting: one is for replacement, the other is for inspection or maintenance so as to use the bearing again.
For the latter purpose, it should be careful not to damage the bearing. When dismounting the interference fitting ring, the dismounting force is only allowed to act on the ring which is prohibited to pull out by rolling elements. Special tools should be adopted when dismounting.
The dismounting methods are similar to mounting, which are also including pressure (see Fig 13.6), temperature difference, and the hydraulic pressure method (see Fig 13.4) etc. However, the tools are different, for the temperature difference method, electromagnetic induction heating or hot oil pouring bearing parts (for the separable bearing) heating can be adopted, and the parts should be dismounted after heating.

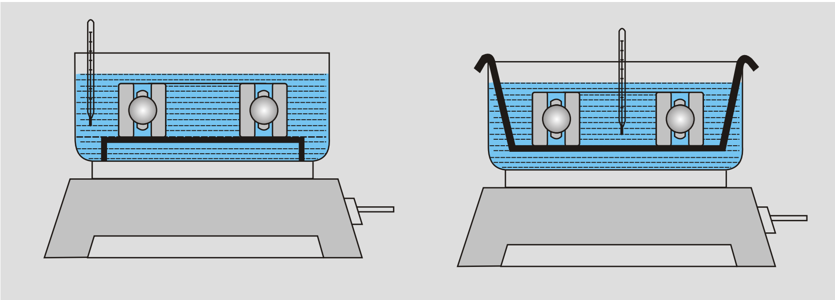

Fig 13.3

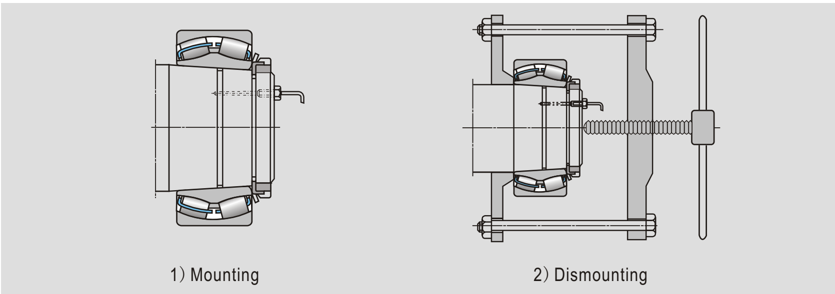

Fig 13.4

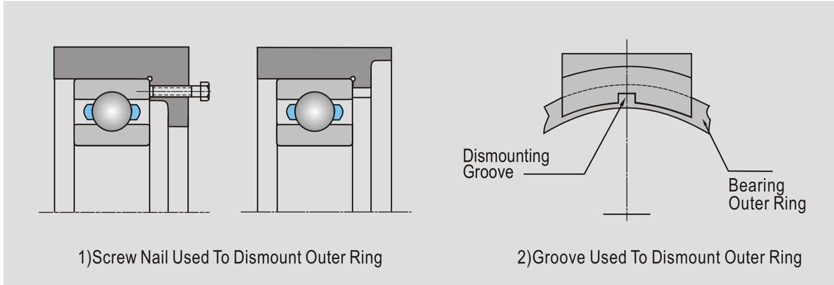

Fig 13.5

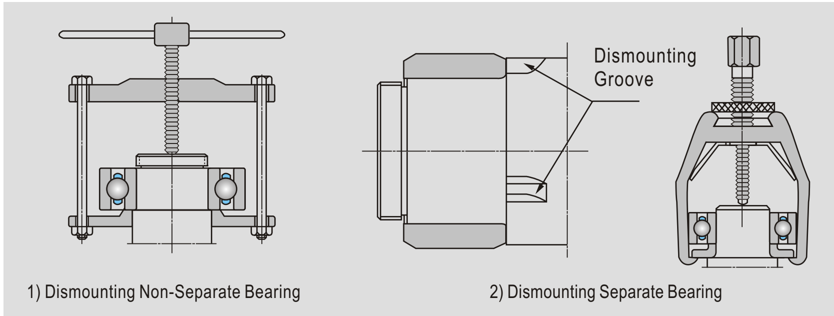

Fig 13.6