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BALL & ROLLER BEARINGS

UBC Precision Bearing Manufacturing Co., Ltd.
An IKO Company

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UBC
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Reliability & Innovation

BALL & ROLLER BEARINGS

General Catalogue

SGS SGS

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UBC Foreword

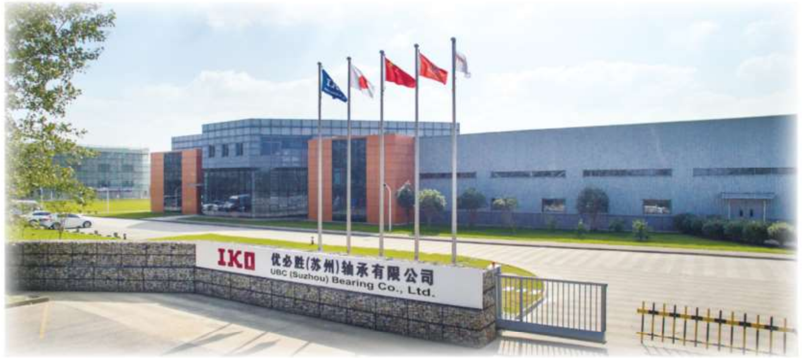
This catalogue contains technical information on UBC bearings that are typically used in industrial applications.

This catalogue is divided into two parts:

The first part (A1 to A98) is general technical information for bearings, which contains basic knowledge and general information about bearings, how to select a bearing, mounting and dismounting of a bearing, possible bearing failures and countermeasures.

The second part (B1 to N20) is divided into sections by bearing type. In each type, we sort the bearings by bearing inner diameter. You can find your desired bearing structure sketch, basic dimensions, load ratings, limiting speed, and reference weight.

We hope this catalogue will support you in selecting the optimum bearing for your application. In case assistance is needed, please contact UBC or UBC's authorized distributors for more details.



UBC Precision Bearing Manufacturing Company is a manufacturer of premium products for OEM, distributors and MRO. Technology, know-how and vast experience enable UBC engineers to provide adequate specific solutions for each application.

By efficiently manufacturing its products, UBC provides top quality bearings at competitive prices, becoming a perfect alternative for end users to reduce their costs without compromising quality or performance.

In 2017, UBC became a 100% subsidiary of IKO Nippon Thompson Group of Japan. Making the most of IKO's know-how and its resources, UBC has significantly boosted its performance, brand awareness and recognition worldwide.

Years of accumulated experience in the bearing industry has given UBC the advantage, the know-how and necessary expertise for the development and production of technological value-added bearings, particularly for the power transmission industry like gearbox and speed reducer, air compressors and pumps, heavy industry applications in construction machinery, cranes, oil & gas, steel, mining, power generation, sugar mills, etc…

To ensure that customers receive exceptional engineering support, both and after sales, our team of technical engineers provides technical support both online and on site upon request.

Our factory is located in Suzhou, China with ISO 9001 and IATF 16949 certified by SGS together with Japanese quality control.

For more information about UBC, please visit our website at www.ubc-bearing.com

Contents

1. Rolling bearing types and their features

Rolling bearings can be categorized as ball bearings and roller bearings by the rolling element or as radial and thrust bearings.

The overall rules of bearing selection are that roller bearings are applicable for higher load and ball bearings for higher speed. The differences between a radial bearing and a thrust bearing is that radial bearings can take load from both the radial and axial direction in most cases but thrust bearings can only take axial load. Based on the above bearing categories, rolling bearings can also be divided into radial ball bearings, radial roller bearings, thrust ball bearings and thrust roller bearings. Detailed rolling bearing variations and their key features can be found below in Tables 1-1 and 1-2.

Table 1-1 Bearing ranges and their features

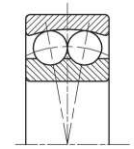
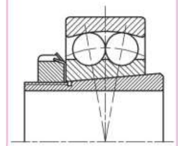
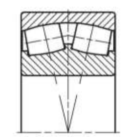
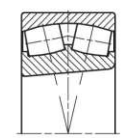
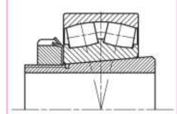
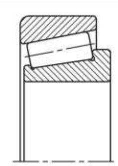
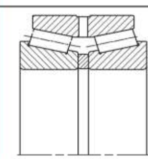
←	Single direction	√√√	Best
←→	Dual direction	√√	Good
×	Poor	√	Normal
××	Unapplicable		

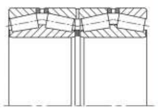
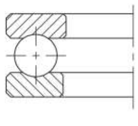
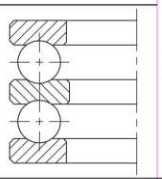
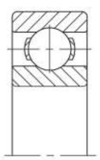
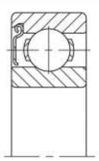
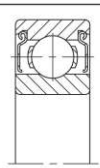
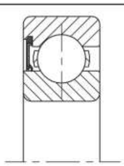
Bearing Ranges					Axial load	Radial load	High speed	High rotating precision	Low noise	High stiffness	Self-alignment	Axial displacement	Locating end	Non-locating end
Radial bearings	Ball bearings	DGBB	Single row		√ ←→	√	√√√	√√√	√√√	√	××	××	√√	√
			Double row		√ ←→	√	√	√	√	√	××	××	√	√
			Insert Bearing		√ ←→	√	√	√	√√	√	√√	××	√√	√
		ACBB	Single row		√ ←	√	√√√	√√√	√√	√	××	××	√√	××
			Double row		√ ←→	√√	√√	√√	√	√√	××	××	√√	√
		Self-aligning ball bearing			×	√	√	√√	√√	√	√√√	××	√	√
		4 points contact ball bearing			√ ←→	×	√√	√	√	√	××	××	√√	×
	Roller bearings	Cylindrical roller bearings	Single row	non-rib outer ring	××	√√	√√	√√	√√	√√	××	√√√	××	√√√
				One rib outer ring	√ ←	√√	√√	√√	√√	√√	××	√	√	√
				non-rib inner ring	××	√√	√√	√√	√√	√√	××	√√√	××	√√√
				One rib inner ring	√ ←	√√	√√	√√	√√	√√	××	√	√	√
				Flat rib	√ ←→	√√	√√	√√	√√	√√	××	××	√	×
			Double row	non-rib outer ring	××	√√√	√√	√√√	√√	√√√	××	√√√	××	√√√
				non-rib inner ring	××	√√√	√√	√√√	√√	√√√	××	√√√	××	√√√

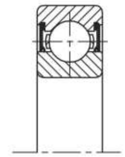
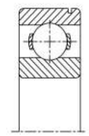
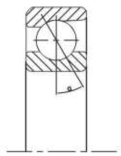
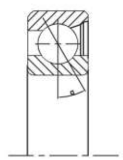
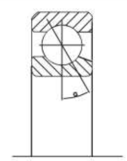
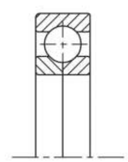
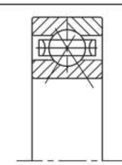
Rolling Bearing Types and Features UBC

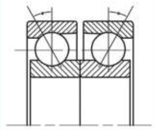
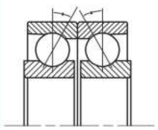
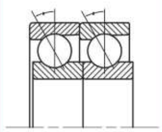
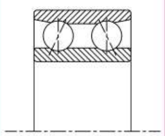
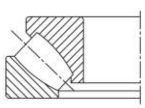
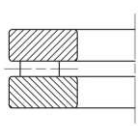
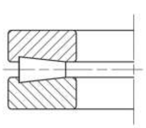
Radial bearings	Roller bearings	Taper roller bearing	Single row		√√ ←	√√	√	√√	√	√√	××	××	√√	××
			Double row	2 inner rings	√√√ ↔	√√√	√	√	√	√√√	××	××	√√√	××
				2 outer rings	√√√ ↔	√√√	√	√	√	√√√	××	××	√√√	××
			4 row	2 inner rings	√√√ ↔	√√√	√	√	√	√√√	××	××	√√√	××
		Spherical roller bearing			××	√√	√	√	√	√√	√√√	××	√√	√
	Needle roller bearing		Needles and cage assemblies		××	√	×	×	√	√√	××	√√√	××	√√√
			With inner ring		××	√	×	×	√	√√	××	√√√	××	√√√
			Without inner ring		××	√	×	×	√	√√	××	√√√	××	√√√
			Pressed outer ring		××	√	×	×	√	√√	××	√√√	××	√√√
Thrust bearings	Ball bearings	Thrust ball bearings	Single row	Flat	√ ←	××	√	√√	√√	√	××	××	√	××
				Spherical	√ ←	××	√	√√	√√	√	××	××	√	××
			Double row	Flat	√ ↔	××	√	√√	√√	√	××	××	√	××
				Spherical	√ ↔	××	√	√√	√√	√	××	××	√	××
	Roller bearings	cylindrical roller	Single row	Flat type	√√ ←	××	×	√√	√	√√	××	××	√	××
		taper roller			√√ ←	××	×	√	√	√√	××	××	√	××
		spherical roller			√√√ ←	××	×	√	√	√√	√√√	××	√√	××
	Needle bearings	Thrust needle and cage assemblies			√ ↔	××	√	√	√	√√	××	××	√	××
Bearings for linear motion					××	√	××	×	√	√	××	√√√	√	√√√
Special application bearings		Crane sheave bearings			√ ↔	√√√	√	√	√	√√	××	√	××	√√√
		Slewing ring bearings			√√	√	×	√	√	√√	××	××	√	××

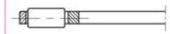
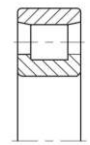
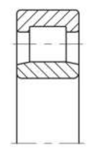
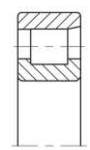
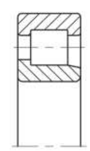
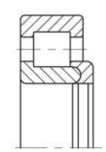
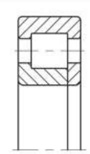
Table 1-2 Bearing categories, structure, and characteristics

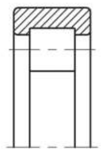
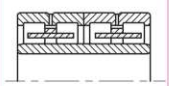
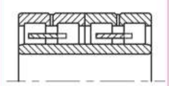
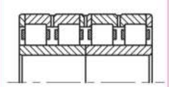
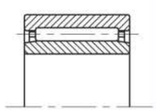
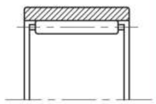
Bearing Types		Sketch	Characteristics
Self-aligning ball bearings	Self-aligning ball bearings		Its inner ring bore can be tapered or cylindrical bore. Accommodating radial load and limited axial load; Maximum shaft axial displacement must be less than its clearance; Self-aligning property, the permissible angular misalignment between inner and outer ring is no larger than 3 degrees;
	Self-aligning ball bearings with adapter sleeves		As above Adapter sleeves can be applied to shafts without any shoulder for convenience of mounting and dismounting, and easy adjustment for radial clearance.
Spherical roller bearings	Spherical roller bearings		Accommodating high radial and limited axial loads; Good self-aligning property, the permissible angular misalignment between inner ring and outer ring is no less than 2.5 degrees; Radial clearance can be adjusted by moving tapered bore inner ring in axial direction. Bearings with adapter sleeves are suitable for shafts without any shoulder, and applications that need frequent mounting and dismounting. Lubrication holes in the outer ring, designation suffix W33.
	Spherical roller bearings with tapered bore (1:12)		
	Spherical roller bearings with adapter sleeves		
Tapered roller bearings	Single row tapered roller bearings		Accommodating combined (radial and axial) loads, bearings with large contact angle accommodating mainly axial loads combined with radial loads; Additional axial load will be generated by radial load, so two single bearings must be paired for combined loads. 313 Series bearing has large contact angle (27°~30°) for larger axial load and other taper roller bearings with a contact angle of 10°~18°.
	Double row tapered roller bearings		Consisting of an outer ring, two inner rings and a spacer; Accommodating radial loads and bi-directional axial loads; Bearing clearance can be adjusted by width of spacer; confining shaft or housing's axial displacement within bearing clearance range.

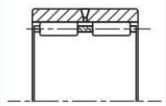
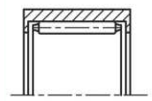
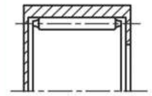
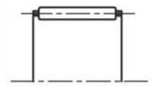
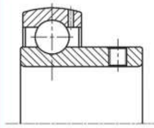
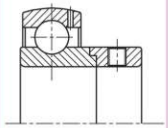
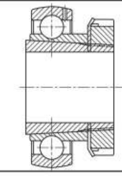
	Bearing Types	Sketch	Characteristics
	Four row tapered roller bearings		A spacer ring between inner ring and outer ring for clearance adjustment; Similar properties with double row taper roller bearing; High load capacity but lower limiting speed; For use in heavy machineries, eg. steel rolling mill.
Thrust ball bearings	Single direction thrust ball bearings		Only accommodating axial load and supporting single direction axial displacement; Low limiting speed;
Thrust ball bearings	Dual direction thrust ball bearings		Bidirectional thrust bearing applied for bidirectional axial loads and supporting bi-directional axial displacement ; Low limiting speed.
Deep groove ball bearings	Single row deep groove ball bearing		Accommodating radial load and limited axial load, supporting shaft axial displacement within bearing clearance range; Permissible misalignment angle between inner and outer ring: 8'~15'
Deep groove ball bearings	Single row deep groove ball bearings with single shield		Shield type deep groove ball bearing Narrow gap between shield and inner ring rib, similar limiting speed with open type deep groove ball bearing, but with better sealing performance. Already packed with grease for two-side-shield-type deep groove ball bearing, no need to re-grease the bearing during usage.
Deep groove ball bearings	Single row deep groove ball bearing with shields on both sides		
Deep groove ball bearings	Single row deep groove ball bearings with single side seal		Sealed type deep groove ball bearing Contact sealing type with suffix "RS" "2RS" Non-contact sealing type with suffix "RZ" "2RZ" Contact sealing type with better sealing performance, but larger friction and lower limiting speed.

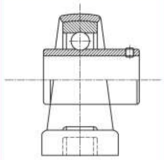
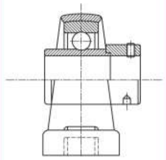
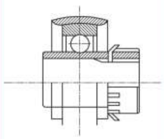
	Bearing Types	Sketch	Characteristics
Deep groove ball bearings	Single row deep groove ball bearings with seals on both sides		Non-contact sealing type deep groove ball bearing's limiting speed is similar to that of open type. Already packed with grease for two-side-sealed-type deep groove ball bearing, no need to re-grease the bearing during usage.
Deep groove ball bearings	Deep groove ball bearings with snap ring		Shield or Sealed type deep groove ball bearings Easy to axially locate bearing in housing using a snap ring
Angular contact ball bearings	Single row angular contact ball bearings (non-separable)		Carrying combined (radial and single-direction axial) loads or only axial load; Axial load carrying capacity increases as the contact angle α increases; High limiting speed; Paired angular contact ball bearings mounted onto the shaft, can supporting bi-directional axial displacement. Usually paired in usage. Inner ring and/or outer ring can be mounted separately in separable angular contact ball bearings, suitable for applications with limited mounting conditions.
Angular contact ball bearings	Single row angular contact ball bearings (Separable)		
Angular contact ball bearings	Single row angular contact ball bearings with counterbored inner ring		
Angular contact ball bearings	Four-point contact ball bearings with split inner rings		Inner ring and/or outer ring can be separated from each other with 35° contact angle; There are 4 contact points between balls and rings if bearing is without loads or with pure radial load. There are 2 contact points between balls and rings if bearing has pure axial load. Can carry bi-directional axial loads, moment loads, functioning somewhere between a single-row and a double-row angular contact ball bearing. This type of bearing can only work properly when bearing has 2 points of contact.
Angular contact ball bearings	Four-point contact ball bearings with split outer rings		

Bearing Types		Sketch	Characteristics
Angular contact ball bearings	Paired mounting bearings with face-to -face arrangement		Carrying combined radial and axial loads but mainly radial load. Tandem arrangement can only carry single direction axial load, while the other two-row arrangement can carry axial load from any direction. Generally, manufacturers supply this type of bearing as a pair. To improve bearing's stiffness and rotation precision, end user should set preload after mounting the bearing. Light preload, medium preload, heavy preload are available.
	Paired mounting bearings with back-to-back arrangement		
	Paired mounting bearings with tandem arrangement		
	Double row angular contact ball bearings		Carrying combined radial and axial loads but mainly radial load, and also moment load. It supports bi-directional axial displacement of shaft (housing).
Thrust spherical roller bearings	Thrust spherical roller bearings		Carrying combined radial and axial loads but mainly radial load. Max. radial load should be less than 55% of axial load. Carrying single direction axial load, supporting single direction axial displacement of shaft (housing).
	Thrust cylindrical roller bearings		Carrying higher single direction axial load. Supporting single direction axial displacement. With low limiting speed.
	Thrust taper roller bearings		Suitable for low speed applications.

Bearing types		Sketch	Characteristics
Thrust needle & cage assembly	Needle roller and cage assembly		Suitable for low speed applications.
Cylindrical roller bearings	Outer ring without rib		Inner ring and outer ring are separable. Easy mounting and dismounting. Normally carrying radial load only, while single row cylindrical roller bearings with rib on both inner ring and outer ring, can carry limited small axial load or larger intermittent axial load. Bearings with single rib can only carry axial load from one direction. Bearings without an inner or outer ring are used for applications with limited radial space, in which the journal shaft and housing bore will act as the raceway of the bearing, meaning these surfaces must be finished to similar quality as a bearing's inner and outer ring
	Inner ring without rib		
	Outer ring with a rib		
	Inner ring with a rib		
	Inner ring with a rib and L-shaped separable rib		
	Inner ring with a rib and a separable rib		

Bearing Types		Sketch	Characteristics
Cylindrical roller bearings	Without inner ring		As above
	Four-row cylindrical roller bearings		Inner ring and outer ring are separable; Only accommodating radial load; Mainly applicable for Heavy machinery, e.g. steel rolling mill; Special designations differ from normal code rules. ● Two double-row outer rings and one inner ring ● Two double-row outer rings and two double-row inner rings ● Two double-row outer rings and two double-row inner rings, and outer ring with a separable rib
			
			
Needle bearings	Single row needle roller bearing		Carrying radial road with small outer diameter; Special design for limited radial mounting space; High limiting speed; Bore diameter (d) of single row needle bearings d<32mm; If d≤7mm, its outer ring has two ribs; If d>7mm, its outer ring has two separable flange rings; The bore diameter of double row needle bearings d≥32mm
	Double row needle roller bearing		
	Without inner ring		Applicable for limited radial mounting space; Shaft journal surface functions as inner ring raceway and its hardness is between 58~64HRC;For single row bearings, if FW≤10mm, its outer ring has two ribs; if FW> 10mm, its outer ring has two integral flanges; For double row bearings, its FW≥40mm; Only accommodating radial load; High limiting speed.

Bearing Types		Sketch	Characteristics
Needle roller bearings	Double row without inner ring		As above
	Drawn cup needle bearings with open ends		Low cost with high load carrying capacity; Applicable for limited mounting space and uses shaft journal surface as raceway; Directly pressed into bearing housing; Avoid axial position adjustment; Lubricated with grease before mounting; BK design is for when the shaft does not extend and can accommodate small axial guidance forces.
	Drawn cup needle bearings with close end		
	Needle roller and cage assembly		Very small radial dimension with high load carrying capacity; For extremely limited radial space; Both surfaces of shaft journal and housing functions as bearing raceway and their surface hardness should be around 58~64HRC; Depth of surface hardened layer should be 0.6~1mm; Surface roughness Ra should be 0.20 - 0.32 μm
Insert bearings	Insert bearings with set screws locking		The spherical outer ring can match with a spherical housing to allow for self-alignment Consists of a double shielded ball bearing and one cast iron housing; Internal structure is similar to ball bearing; Inner ring is often mounted on the shaft by set screws screws or eccentric locking collar or adapter sleeves and rotate with shaft.
	Insert bearings with eccentric locking collar		
	Insert bearings with adapter sleeve		

Bearing Types		Sketch	Characteristics
Bearing Units	Pillow block units with set screws		Two designations with UC and UB; For changing rotating direction of the machine shaft; Has two designations: UEL and UE; For non-changed rotating direction of the machine shaft; Various housing structures are available for different applications.
	Pillow block units with eccentric locking collar		
	Pillow block units with adapter sleeve		

2. General information of rolling bearing

2.1 Bearing designations

The bearing designations of roller bearing define its structure, main dimensions, material, clearance and its configuration. Typical bearing designations consist of combinations of prefix, basic designation and suffix.

The boundary dimensions of rolling bearings comply with ISO standards for rolling bearings. Please contact UBC if any request for special dimensions.

Detailed coding rules of UBC bearings please refer to Table 2-1, Table 2-2 for prefixes, Table 2-3 for basic designations and for suffixes please refer to (Table 2-4 for internal structure, Table 2-5 for seals, shields and transformation rings, Table 2-6 for cage and its material, Table 2-7 for bearing material, Table 2-8 for tolerance and fitness, Table 2-9 for bearing clearance, Table 2-10 for bearing arrangement, Table 2-11 for other coding rules).

Table 2-1

Bearing Designations											
Prefix	Basic Designation										
Bearing components	Types	Dimension series	Size codes	Internal structure	Seals,Shields ring changes	Cage and its material	Bearing material	Tolerance	Clearance	Arrangement	Others

Table 2-2

	Bearing Components
Code	Definition
S	Stainless steel material
F	Ball bearing with flange on outer ring
GS	Housing for thrust cylinder roller bearing
L	Separable bearing inner ring or outer ring
LR	Separable inner ring (or outer ring) with cage & rollers assembly
KOW-	Thrust bearing without shaft washer
KIW-	Thrust bearing without housing washer
R	Rollers & cage assembly without separable inner ring (or outer ring)
	For needle roller bearings, only valid for NA series
	Thermoplastic housing for unit bearing
WS	Shaft washer of thrust cylindrical roller bearings
K	Rollers & cage assembly

Table 2-3

Type Code		Dimension Series Code		Size Code	
Code	Definition	Code	Definition	Code	Definition Size(mm)
0	Double row angular contact ball bearings	Refer Table 2-1 and Table 2-2		1	1
1	Self-aligning ball bearings			2	2
2	Spherical roller bearings			3	3
	Spherical roller thrust bearings			⋮	⋮
3	Tapered roller bearings			⋮	⋮

Type Code		Dimension Series Code		Size Code	
Code	Definition	Code	Definition	Code	Definition Size(mm)
4	Double row deep groove ball bearings	As above		9	9
5	Thrust ball bearings			00	10
6	Deep groove ball bearings			01	12
7	Angular contact ball bearings			02	15
8	Cylindrical roller thrust bearings			03	17
N	Cylindrical roller bearings			04	20
U	Insert bearings			/22	22
QJ	Four point angular contact ball bearings			05	25
				/28	28
				06	30
				/32	32
				07	35
				08	40
				09	45
				⋮	⋮
				88	440
				92	460
				96	480
				/500	500
				/530	530
				/560	560

Table 2-4

Internal Structure	
Code	Definition
A	1. Double row angular contact ball bearing or deep groove ball bearing without filling slots
	2. Deep grove ball bearing of linear raceway
	3. Needle roller bearing with 2 locking rings on outer ring (d>9mm, FW<12mm)
	4. Enhanced internal structure
B	1. Angular contact ball bearing with a contact angle 40°
	2. Taper roller bearing with increased contact angle
C	1. Angular contact ball bearing with a contact angle 15°
	2. Spherical roller bearing with enhanced design, non-rib inner ring with centered guide ring, press steel cage and symmetrical roller
D	1. Split type bearings
	2. Double row angular contact ball bearing with contact angle of 45°, with two inner rings.
E	Enhanced design

Internal Structure	
Code	Definition
AC	Angular contact ball bearing with a contact angle 25°
CA	One-piece machined brass cage, with a floating guide ring centered on the inner ring
CC	Two-pieces window-type pressed steel cage guided by inner ring
MA	Two-pieces machined brass cage guided by outer ring
MB	Two-pieces machined brass cage guided by inner ring
E	Two-pieces pressed steel cage, through hardened, with one floating guide ring centered on inner ring (d≤65mm, structure similar to CC design) or centered on cage (d≥65mm).

Table 2-5

Seals, Shields and Transformation Rings	
Code	Definition
K	Tapered bore, taper 1:12
K30	Tapered bore, taper 1:30
R	Integral flange on outer ring
N	Snap ring groove in the outer ring
NR	Snap ring groove in the outer ring with appropriate snap ring
RS	Contact seal of acrylonitrile-butadiene rubber on one side
2RS	Contact seal of acrylonitrile-butadiene rubber on both sides
RL	Light contact seal of acrylonitrile-butadiene rubber on one side
2RL	Light contact seal of acrylonitrile-butadiene rubber on both sides
RZ	Sheet steel reinforced low friction seal of acrylonitrile-butadiene rubber on one side, non-contact seal
2RZ	RZ low friction seal of acrylonitrile-butadiene rubber on both sides, non-contact seal
	High temperature fluorine rubber seal
Z	Shield of pressed sheet steel on one side
2Z	Shield of pressed sheet steel on both sides
RSZ	RS seal on one side, Z shield on the other side
ZN	Shield on one side, and with snap ring groove on the other side of the outer ring
ZNR	Shield on one side, and with snap ring groove and snap ring on the other side of the outer ring
ZNB	Shield on one side, and with snap ring groove on the same side of the outer ring
2ZN	Shield of pressed sheet steel on both sides with snap groove on outer ring
PP	Soft rubber seal on both sides
2K	Double tapered bores, taper 1:12
D	1. Double row angular contact ball bearing with double inner ring
	2. Double row taper roller bearing without cone spacer, non-ground side surface
DC	Double row angular contact ball bearing with double outer ring
D1	Double row taper roller bearing without cone spacer, ground side surface
DH	Single-direction thrust bearing with double housing washer
DS	Single-direction thrust bearing with double shaft washer

Seals, Shields and transformation rings	
Code	Definition
P	Spherical roller bearings with 2 split outer rings
PR	P design, with spacer between 2 split outer rings
S	1. Bearing with spherical outer ring (insert bearing)
	2. Needle bearing with adjustable clearance
WB	Extended inner ring at both sides; WB1: extended inner ring at one side
WC	Extended outer ring
N1	Outer ring with one locating notch
N2	Outer ring with two locating notches
N4	N+N2 with one snap groove at other side
N6	N+N2 with one snap groove at same side
X	Needle bearing with cylindrical outer ring

Table 2-6

Cage and Its Material	
Code	Definition
	Cage Material
F	Steel, cast iron or powder metallic cage
Q	Machined one piece bronze cage
M	Machined one piece brass cage
L	Machined light alloy cage
T	Phenolic resin cage
TH	Fiberglass reinforced phenolic resin cage
TN	Plastic cage
J	Pressed steel cage
Y	Pressed brass cage
	Cage structure and surface process (Jointed with above code)
H	Self-locking pocket cage
W	Welded cage
R	Riveted cage for large size bearings
E	Phosphate coated cage
D	Carbonitrided cage
D1	Carburized cage
D2	Nitrided cage
C	Coated cage (C1: Silver coated)
A	Outer ring guide
B	Inner ring guide
	No cages
V	Full complement roller bearing

Table 2-7

Bearing Material	
Code	Definition
/HC1	Inner ring and outer ring carburized
/HC2	Outer ring carburized
/HC3	Inner ring carburized
/HC4	Inner ring, outer ring and rollers carburized
/HC5	Rollers carburized
/HC6	Outer ring and rollers carburized
/HC7	Inner ring and rollers carburized
/HQ1	Ceramic balls

Table 2-8

Tolerance Table	
Code	Definition
/P0	Dimensional tolerance precision is according to ISO tolerance class 0,equal to ABEC1
/P6	Dimensional tolerance precision is according to ISO tolerance class 6,equal to ABEC3
/P6X	Dimensional tolerance precision is according to ISO tolerance class 6x
/P5	Dimensional tolerance precision is according to ISO tolerance class 5,equal to ABEC5
/P4	Dimensional tolerance precision is according to ISO tolerance class 4,equal to ABEC7
/P2	Dimensional tolerance precision is according to ISO tolerance class 2,equal to ABEC9
/SP	Dimensional precision is according to P5, and rotation precision is according to P4
/UP	Dimensional precision is according to P4, and rotation precision higher than P4

Table 2-9

Bearing Clearance	
Code	Definition
/C1	Bearing internal clearance smaller than C2
/C2	Bearing internal clearance smaller than Normal
C0（CN）	Normal internal clearance
/C3	Bearing internal clearance greater than Normal
/C4	Bearing internal clearance greater than C3
/C5	Bearing internal clearance greater than C4
/C9	Bearing internal clearance different from current standards
/CM	Deep groove ball bearing internal clearance for motor

Table 2-10

Bearing Arrangement	
Code	Definition
/DB	Paired bearing in a back-to-back arrangement
/DF	Paired bearing in a face-to-face arrangement
/DT	Paired bearing in a tandem arrangement
/TBT	3 bearings with two in a tandem and one in back-to-back arrangement
/TFT	3 bearings with two in a tandem and one in face-to-face arrangement
/TT	3 bearings in a tandem arrangement

Preload for Bearing Arrangement	
G	Special preload, followed by information on specific preload value requested
GA	Light preload
GB	Medium preload
GC	High preload

Table 2-11

Other Codes	
Code	Definition
/Z	Max. vibration noise (by acceleration) with additional number to represent different maximum value
	Z1: Bearing's max. vibration noise level (by acceleration) is in Z1 group
	Z2: Bearing's max. vibration noise level (by acceleration) is in Z2 group
	Z3: Bearing's max. vibration noise level (by acceleration) is in Z3 group
	Z4: Bearing's max. vibration noise level (by acceleration) is in Z4 group
/V	Groups of maximum vibration velocity with additional number to represent different maximum value
	V1: Bearing's max. vibration noise level (by velocity) is in V1 group
	V2: Bearing's max. vibration noise level (by velocity) is in V2 group
	V3: Bearing's max. vibration noise level (by velocity) is in V3 group
	V4: Bearing's max. vibration noise level (by velocity) is in V4 group
EMQ	Very low running noise (for miniature ball bearings)
EMQ5	Very low running noise (for deep groove ball bearings)
/S0	Tempered rings with maximum running temperature of 150° C
/S1	Tempered rings with maximum running temperature of 200° C
/S2	Tempered rings with maximum running temperature of 250° C
/S3	Tempered rings with maximum running temperature of 300° C
/S4	Tempered rings with maximum running temperature of 350° C
/W20	3 lubrication holes in outer ring
/W33	Annular groove with 3 lubrication holes in outer ring
/LHT	Grease fill for low and high temperatures
	LHT1: -40 to +150℃
	LHT2: -40 to +200℃
	LHT3: -40 to +250℃
	LHT4: -40 to +300℃
/Y	Combination of Y and other letter or number to identify the special designs which cannot be represented by available suffixes
	YA: Altered structure
	YA1: The outer ring surface is different from standard design
	YA2: The bearing bore is different from standard design
	YA3: The ring side surface is different from standard design

Code	Definition
/Y	YA4: The raceway is different from standard design
	YA5: The roller is different from standard design
	YB: Modified technical conditions
	YB1: Coated rings
	YB2: Modified dimension and tolerance
	YB3: Modified surface roughness
	YB4: Modified heat treatment process i.e. Hardness

Bearing width series

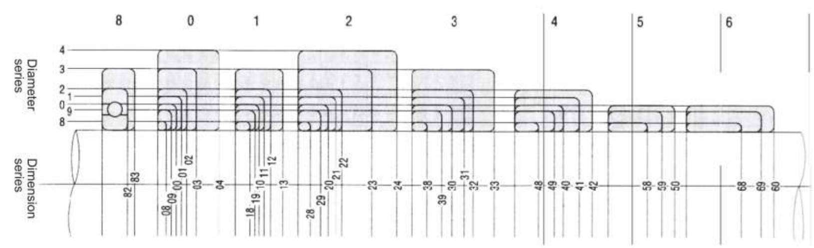


Figure 2-1 Dimension series of radial bearings (excluding TRB)

Bearing height series

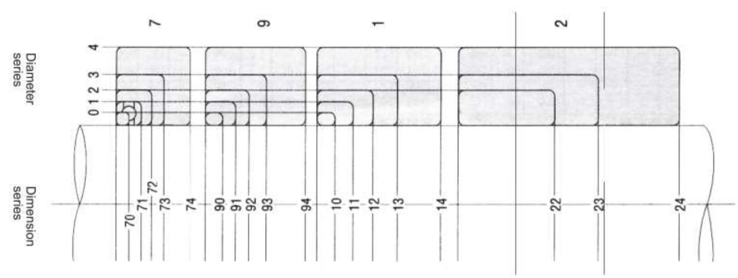


Figure 2-2 Dimension series of thrust bearings

2.2 Rolling Bearings Tolerances

2.2.1 Radial Bearings Tolerances

2.2.1.1 Symbol

d —— Nominal bore diameter
d_s —— Single bore diameter
d_1 —— Nominal diameter at theoretical large end of a tapered bore
d_{mp} —— Deviation of single mean bore diameter
Δd_{mp} —— Deviation of the mean bore diameter from the nominal = d_{mp}-d
Δd_s —— Deviation of a single bore diameter from the nominal
Δd_{1mp} —— Deviation of the mean bore diameter at the theoretical large end of tapered bore from the nominal = d_{1mp}-d_1
V_{dmp} —— Mean bore diameter variation; Difference between the largest and smallest mean bore diameters of one ring or washer = d_{mpmax}-d_{mpmin}
V_{dsp} —— Bore diameter variation in single radial plane; Difference between the largest and smallest single bore dia-meters in one plane

D —— Nominal outside diameter
D_1 —— Nominal flange outer ring diameter
D_{mp} —— Average bore diameter of single plane
ΔD_s —— Deviation of a single outside diameter from the nominal = D_S-D
ΔD_{mp} —— Deviation of the mean outside diameter from the nominal = D_{mp}-D
V_{Dsp} —— Outside diameter variation; Difference between the largest and smallest single outside diameters in one plane
V_{Dmp} —— Mean outside diameter variation;
ΔD_{1s} —— Outer ring flange single outer diameter deviation
B,(C) —— Nominal width of inner ring and outer ring, respectively
B_s,(C_s) —— Single width of inner ring and outer ring, respectively
ΔB_s,(ΔC_s) —— Deviation of single inner ring width or single outer ring width from the nominal
V_{Bs}(V_{Cs}) —— Ring width variation; Difference between the largest and smallest single widths of inner ring and of outer ring, respectively
T —— Nominal width of taper roller bearing
ΔT_s —— Deviation of measured single width of taper roller bearing from the nominal
ΔT_{1s} —— Deviation of measured single width of cone from the nominal
ΔT_{2s} —— Deviation of measured single width of cup from the nominal
K_{ia} —— Radial runout of inner ring of assembled bearing
K_{ea} —— Radial runout of outer ring of assembled bearing
S_d —— Side face runout with reference to bore
S_D —— Outside inclination variation; Variation in inclination of outside cylindrical surface to outer ring side face
S_{ia} —— Axial runout of inner ring of assembled bearing
S_{ea} —— Axial runout of outer ring of assembled bearing

2.2.1.2 Bearing tolerances for radial bearings, except taper roller bearing

(1) Class P0 tolerances

Table 2-12 Inner rings

μm

d/mm		Δd_{mp}		V_{dp} Diameter Series			V_{dmp}	K_{ia}	ΔB_S			V_{Bs}
				9	0、1	2、3、4			all	Normal	Modified①	
>	≤	h	l	max			max	max	h	l		max
0.6	2.5	0	-8	10	8	6	6	10	0	-40	-250	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	-250	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	-380	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

① Applicable to inner ring or outer ring of single bearing in case of paired arrangement. Also applicable to inner ring of tapered bearings with d≥50mm.

Table 2-13 Outer rings

μm

D/mm		ΔD_{mp}		V_{Dsp} Open Bearing Diameter Series 9	V_{Dsp} Open Bearing Diameter Series 0、1	V_{Dsp} Open Bearing Diameter Series 2、3、4	V_{Dsp} Closed Bearing① Diameter Series 2、3、4	V①	K_{ea}	ΔC_s		V_{Cs}
>	≤	h	l	max				max	max	h	l	max
2.5	6	0	-8	10	8	6	10	6	15	Values are identical to those for inner ring of same bearing (ΔB_s & V_{bs})		
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			
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			

① Only applicable when the inner or outer snap rings are not mounted

Table 2-14 Inner rings

μm

d/mm		Δd_{mp}		V_{dsp} Diameter Series 9	V_{dsp} Diameter Series 0、1	V_{dsp} Diameter Series 2、3、4	V_{dmp}	K_{ia}	ΔB_s all	ΔB_s Normal	ΔB_s Modified①	V_{Bs}
>	≤	h	l	max			max	max	h	l		max
0.6	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	8	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

① Applicable to inner ring or outer ring of single bearing in case of paired arrangement.

Table 2-15 outer rings

μm

D/mm		ΔD_{mp}		V_{Dsp} Open Bearing Diameter Series 9	V_{Dsp} Open Bearing Diameter Series 0、1	V_{Dsp} Open Bearing Diameter Series 2、3、4	V_{Dsp} Closed Bearing Diameter Series 0、1、2、3、4	V_{Dmp}	K_{ea}	ΔC_s		V_{Cs}
>	≤	h	l	max				max	max	h	l	max
2.5	6	0	-7	9	7	5	9	5	8	Values are identical to those for inner ring of same bearing (ΔB_s & V_{bs})		
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			
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			

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3) class P5 tolerances

Table 2-16 Inner rings

µm

d/mm		Δd_{mp}		V_{dsp} Diameter Series 9	V_{dsp} Diameter Series 0、1 2、3、4	V_{dmp}	K_{ia}	S_d	S_{ia} ①	ΔB_s all	ΔB_s Normal	ΔB_s Modified ②	V_{Bs}
>	≤	h	l	max		max	max	max	max	h	l		max
0.6	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	13	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

① Only applicable for deep groove and angular contact ball bearing

② Applicable to inner ring or outer ring of single bearing in case of paired arrangement.

Table 2-17 Outer rings

µm

D/mm		ΔD_{mp}		V_{Dsp} ① Diameter Series 9	V_{Dsp} ① Diameter Series 0、1 2、3、4	V_{Dmp}	K_{ea}	S_D	S_{ea} ②	ΔC_s		V_{Bs}
>	≤	h	l	max		max	max	max	max	h	l	max
2.5	6	0	-5	5	4	3	5	8	8	Values are identical to those for inner ring of same bearing (ΔB_s)		5
6	18	0	-5	5	4	3	5	8	8			5
18	30	0	-6	6	5	3	6	8	8			5
30	50	0	-7	7	5	4	7	8	8			5
50	80	0	-9	9	7	5	8	8	10			6
80	120	0	-10	10	8	5	10	9	11			8
120	150	0	-11	11	8	6	11	10	13			8
150	180	0	-13	13	10	7	13	10	14			8
180	250	0	-15	15	11	8	15	11	16			10
250	315	0	-18	18	14	9	18	13	18			11
315	400	0	-20	20	15	10	20	13	20			13
400	500	0	-23	23	17	12	23	15	23			15
500	630	0	-28	28	21	14	25	18	25			18
630	800	0	-35	35	26	18	30	20	30			20

① Only applicable for deep groove and angular contact ball bearing

4) class P4 tolerances

Table 2-18 Inner ring

µm

d/mm		Δd_{mp}		Δd_s ①		V_{dsp} Diameter Series 9	V_{dsp} Diameter Series 0、1 2、3、4	V_{dmp}	K_{ia}	S_d	S_{ia} ②	ΔB_s all	ΔB_s Normal	ΔB_s Modified ③	V_{Bs}
>	≤	h	l	h	l	max		max	max	max	max	h	l		max
0.6	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	3	4	4	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	8	7	8	0	-300	-500	6

① Only applicable for diameter series 0, 1, 2, 3 and 4

② Only applicable for deep groove and angular contact ball bearing

③ Applicable to inner ring or outer ring of single bearing in case of paired arrangement.

Table 2-19 Outer rings

µm

D/mm		ΔD_{mp}		ΔD_s ①		V_{Dsp} ② Diameter Series 9	V_{Dsp} ② Diameter Series 0、1 2、3、4	V_{Dmp}	K_{ea}	S_D	S_{ea} ③	ΔC_s		V_{Cs}
>	≤	h	l	h	l	max		max	max	max	max	h	l	max
2.5	6	0	-4	0	-4	4	3	2	3	4	5	Values are identical to those for inner ring of same bearing (ΔB_s)		2.5
6	18	0	-4	0	-4	4	3	2	3	4	5			2.5
18	30	0	-5	0	-5	5	4	2.5	4	4	5			2.5
30	50	0	-6	0	-6	6	5	3	5	4	5			2.5
50	80	0	-7	0	-7	7	5	3.5	5	4	5			3
80	120	0	-8	0	-8	8	6	4	6	5	6			4
120	150	0	-9	0	-9	9	7	5	7	5	7			5
150	180	0	-10	0	-10	10	8	5	8	5	8			5
180	250	0	-11	0	-11	11	8	6	10	7	10			7
250	315	0	-13	0	-13	13	10	7	11	8	10			7
315	400	0	-15	0	-15	15	11	8	13	10	13			8

① Only applicable for diameter series 0, 1, 2, 3 and 4

② Only applicable for deep groove and angular contact ball bearing

5) class P2 tolerances

Table 2-20 Inner rings

μm

d/mm		Δd_{mp}		Δd_s		V_{dsp}	V_{dmp}	K_{ia}	S_d	S_{ia}①	ΔB_s		V_{Bs}
>	≤	h	l	h	l	max	max	max	max	max	h	l	max
0.6①	2.5	0	-2.5	0	-2.5	2.5	1.5	1.5	1.5	1.5	0	-40	1.5
2.5	10	0	-2.5	0	-2.5	2.5	1.5	1.5	1.5	1.5	0	-40	1.5
10	18	0	-2.5	0	-2.5	2.5	1.5	1.5	1.5	1.5	0	-80	1.5
18	30	0	-2.5	0	-2.5	2.5	1.5	2.5	1.5	2.5	0	-120	1.5
30	50	0	-2.5	0	-2.5	2.5	1.5	2.5	1.5	2.5	0	-120	1.5
50	80	0	-4	0	-4	4	2	2.5	1.5	2.5	0	-150	1.5
80	120	0	-5	0	-5	5	2.5	2.5	2.5	2.5	0	-200	2.5
120	150	0	-7	0	-7	7	3.5	2.5	2.5	2.5	0	-250	2.5
150	180	0	-7	0	-7	7	3.5	5	4	5	0	-250	4
180	250	0	-8	0	-8	8	4	5	5	5	0	-300	5

① Only applicable for deep groove and angular contact ball bearing

Table 2-21 Outer rings

μm

D/mm		ΔD_{mp}		ΔD_s		V_{Dsp}①	V_{Dmp}	K_{ea}	S_D	S_{ea}②	ΔC_s		V_{cs}
>	≤	h	l	h	l	max	max	max	max	max	h	l	max
2.5	6	0	-2.5	0	-2.5	2.5	1.5	1.5	1.5	1.5	Values are identical to those for inner ring of same bearing (ΔB_s)		1.5
6	18	0	-2.5	0	-2.5	2.5	1.5	1.5	1.5	1.5			1.5
18	30	0	-4	0	-4	4	2	2.5	1.5	2.5			1.5
30	50	0	-4	0	-4	4	2	2.5	1.5	2.5			1.5
50	80	0	-4	0	-4	4	2	4	1.5	4			1.5
80	120	0	-5	0	-5	5	2.5	5	2.5	5			2.5
120	150	0	-5	0	-5	5	2.5	5	2.5	5			2.5
150	180	0	-7	0	-7	7	3.5	5	2.5	5			2.5
180	250	0	-8	0	-8	8	4	7	4	7			4
250	315	0	-8	0	-8	8	4	7	5	7			5
315	400	0	-10	0	-10	10	5	8	7	8			7

① Only applicable for deep groove and angular contact ball bearing

2.2.1.3 Tolerances for taper roller bearing

(1) class P0 tolerances

Table 2-22 Inner ring

μm

d/mm		Δd_{mp}		V_{dsp}	V_{dmp}	K_{ia}
>	≤	h	l	max	max	max
0	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
400	500	0	-45	45	34	80
500	630	0	-60	60	40	90
630	800	0	-75	75	45	100
800	1000	0	-100	100	55	115
1000	1250	0	-125	125	65	130
1250	1600	0	-160	160	80	150
1600	2000	0	-200	200	100	170

Table 2-23 Outer ring

μm

D/mm	ΔD_{mp}		V_{Dsp}	V_{Dmp}	K_{ea}
	h	l	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	60	38	100
630-800	0	-75	80	55	120
800-1000	0	-100	100	75	140
1000-1250	0	-125	130	90	160
1250-1600	0	-160	170	100	180
1600-2000	0	-200	210	110	200
2000-2500	0	-250	265	120	220

Table 2-24 Width

μm

d/mm		ΔB_s		ΔC_s		ΔT_s		ΔT_{1s}		ΔT_{2s}	
>	≤	h	l	h	l	h	l	h	l	h	l
0	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	+150	-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
400	500	0	-450	0	-450	+450	-450	+225	-225	+225	-225
500	630	0	-500	0	-500	+500	-500	-	-	-	-
630	800	0	-750	0	-750	+600	-600	-	-	-	-
800	1000	0	-1000	0	-1000	+750	-750	-	-	-	-
1000	1250	0	-1250	0	-1250	+900	-900	-	-	-	-
1250	1600	0	-1600	0	-1600	+1050	-1050	-	-	-	-
1600	2000	0	-2000	0	-2000	+1200	-1200	-	-	-	-

(2) Class P6x tolerances. The tolerances of diameter and radial runout of inner ring and outer ring refer to class P0 values in table 2-22 and 2-23, and the width tolerances refer to table 2-25

Table 2-25 Width of inner or outer ring and bearing assembly

μm

d/mm		ΔB_s		ΔC_s		ΔT_s		ΔT_{1s}		ΔT_{2s}	
>	⩽	h	l	h	l	h	l	h	l	h	l
0	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
400	500	0	-50	0	-100	+200	0	+100	0	+100	0

(3) Class P5 tolerances

Table 2-26 Inner ring

μm

d/mm		Δd_{mp}		V_{dsp}	V_{dmp}	K_{ia}	S_d
>	⩽	h	l	max	max	max	max
0	18	0	-7	5	5	5	7
18	30	0	-8	6	5	5	8
30	50	0	-10	8	5	6	8
50	80	0	-12	9	6	7	8
80	120	0	-15	11	8	8	9
120	180	0	-18	14	9	11	10
180	250	0	-22	17	11	13	11
250	315	0	-25	19	13	13	13
315	400	0	-30	23	15	15	15
400	500	0	-35	28	17	20	17
500	630	0	-40	35	20	25	20
630	800	0	-50	45	25	30	25
800	1000	0	-60	60	30	37	30
1000	1250	0	-75	75	37	45	40
1250	1600	0	-90	90	45	55	50

Table 2-27 Outer ring

μm

D/mm		ΔD_{mp}		V_{dsp}	V_{Dmp}	K_{ea}	S_d
>	⩽	h	l	max	max	max	max
18	30	0	-8	6	5	6	8
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
400	500	0	-33	26	17	24	17
500	630	0	-38	30	20	30	20
630	800	0	-45	38	25	36	25
800	1000	0	-60	50	30	43	30
1000	1250	0	-80	65	38	52	38
1250	1600	0	-100	90	50	62	50
1600	2000	0	-125	120	65	73	65

Table 2-28 Width

μm

d/mm		ΔB_s		ΔC_s		ΔT_s		ΔT_{1s}		ΔT_{2s}	
>	⩽	h	l	h	l	h	l	h	l	h	l
0	10	0	-200	0	-200	+200	-200	+100	-100	+100	-100
10	18	0	-200	0	-200	+200	-200	+100	-100	+100	-100
18	30	0	-200	0	-200	+200	-200	+100	-100	+100	-100
30	50	0	-240	0	-240	+200	-200	+100	-100	+100	-100
50	80	0	-300	0	-300	+200	-200	+100	-100	+100	-100
80	120	0	-400	0	-400	+200	-200	+100	-100	+100	-100
120	180	0	-500	0	-500	+350	-250	+150	-150	+200	-100
180	250	0	-600	0	-600	+350	-250	+150	-150	+200	-100
250	315	0	-700	0	-700	+350	-250	+150	-150	+200	-100
315	400	0	-800	0	-800	+400	-400	+200	-200	+200	-200
400	500	0	-900	0	-900	+450	-450	+225	-225	+225	-225
500	630	0	-1100	0	-1100	+500	-500	-	-	-	-
630	800	0	-1600	0	-1600	+600	-600	-	-	-	-
800	1000	0	-2000	0	-2000	+750	-750	-	-	-	-
1000	1250	0	-2000	0	-2000	+750	-750	-	-	-	-
1250	1600	0	-2000	0	-2000	+900	-900	-	-	-	-

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4）Class P4 tolerances

Table 2-29 Inner ring

μm

d/mm		V_{dmp}		Δd_s		V_{dsp}	Δd_{mp}	K_{ia}	S_d	S_{ia}
>	≤	h	l	h	l	max	max	max	max	max
0	18	0	-5	0	-5	4	4	3	3	3
18	30	0	-6	0	-6	5	4	3	4	4
30	50	0	-8	0	-8	6	5	4	4	4
50	80	0	-9	0	-9	7	5	4	5	4
80	120	0	-10	0	-10	8	5	5	5	5
120	180	0	-13	0	-13	10	7	6	6	7
180	250	0	-15	0	-15	11	8	8	7	8
250	315	0	-18	0	-18	12	9	9	8	9

Table 2-30 Outer ring

μm

D/mm		ΔD_{mp}		ΔD_s		V_{Dsp}	V_{Dmp}	K_{ea}	S_D	S_{ea}
>	≤	h	l	h	l	max	max	max	max	max
0	30	0	-6	0	-6	5	4	4	4	5
30	50	0	-7	0	-7	5	5	5	4	5
50	80	0	-9	0	-9	7	5	5	4	5
80	120	0	-10	0	-10	8	5	6	5	6
120	150	0	-11	0	-11	8	6	7	5	7
150	180	0	-13	0	-13	10	7	8	5	8
180	250	0	-15	0	-15	11	8	10	7	10
250	315	0	-18	0	-18	14	9	11	8	10
315	400	0	-20	0	-20	15	10	13	10	13

Table 2-31 Width

μm

d/mm		ΔB_s		ΔC_s		ΔT_s		ΔT_{1s}		ΔT_{2s}	
>	≤	h	l	h	l	h	l	h	l	h	l
-	10	0	-200	0	-200	+200	-200	+100	-100	+100	-100
10	18	0	-200	0	-200	+200	-200	+100	-100	+100	-100
18	30	0	-200	0	-200	+200	-200	+100	-100	+100	-100
30	50	0	-240	0	-240	+200	-200	+100	-100	+100	-100
50	80	0	-300	0	-300	+200	-200	+100	-100	+100	-100
80	120	0	-400	0	-400	+200	-200	+100	-100	+100	-100
120	180	0	-500	0	-500	+350	-250	+150	-150	+200	-100
180	250	0	-600	0	-600	+350	-250	+150	-150	+200	-100
250	315	0	-700	0	-700	+350	-250	+150	-150	+200	-100

5）Class P2 tolerances

Table 2-32 Inner rings

μm

d/mm		Δ_{dmp} Δ_{ds}		V_{dsp}	V_{dmp}	K_{ia}	S_d	S_{ia}
>	≤	h	l	max	max	max	max	max
-	10	0	-4	2.5	1.5	2	1.5	2
10	18	0	-4	2.5	1.5	2	1.5	2
18	30	0	-4	2.5	1.5	2.5	1.5	2.5
30	50	0	-5	3	2	2.5	2	2.5
50	80	0	-5	4	2	3	2	3
80	120	0	-6	5	2.5	3	2.5	3
120	180	0	-7	7	3.5	4	3.5	4
180	250	0	-8	7	4	5	5	5
250	315	0	-8	8	5	6	5.5	6

Table 2-33 Outer rings

μm

D/mm		Δ_{Dmp} Δ_{Ds}		V_{dsp}	V_{dmp}	K_{ea}	S_D[a] S_{D1}	S_{ea}[a]	S_{ea1}
>	≤	h	l	max	max	max	max	max	max
-	18	0	-5	4	2.5	2.5	1.5	2.5	4
18	30	0	-5	4	2.5	2.5	1.5	2.5	4
30	50	0	-5	4	2.5	2.5	2	2.5	4
50	80	0	-6	4	2.5	4	2.5	4	6
80	120	0	-6	5	3	5	3	5	7
120	150	0	-7	5	3.5	5	3.5	5	7
150	180	0	-7	7	4	5	4	5	7
180	250	0	-8	8	5	7	5	7	10
250	315	0	-9	8	5	7	6	7	10
315	400	0	-10	10	6	8	7	8	11

[a] not applicable for bearings with flanged outer ring

Table 2-34 Width

μm

d/mm		ΔB_s		ΔC_s		ΔT_s		ΔT_{1s}		ΔT_{2s}	
>	≤	h	l	h	l	h	l	h	l	h	l
-	10	0	-200	0	-200	+200	-200	+100	-100	+100	-100
10	18	0	-200	0	-200	+200	-200	+100	-100	+100	-100
18	30	0	-200	0	-200	+200	-200	+100	-100	+100	-100
30	50	0	-240	0	-240	+200	-200	+100	-100	+100	-100
50	80	0	-300	0	-300	+200	-200	+100	-100	+100	-100
80	120	0	-400	0	-400	+200	-200	+100	-100	+100	-100
120	180	0	-500	0	-500	+200	-250	+100	-100	+100	-150
180	250	0	-600	0	-600	+200	-300	+100	-150	+100	-150
250	315	0	-700	0	-700	+200	-300	+100	-150	+100	-150

2.2.1.4 Outer ring flange of radial bearing

(1) Tolerance of flange's outer diameter of radial ball bearing and taper roller bearing

Table 2-35 Flanged outer ring tolerances

μm

d/mm		Δ_{D1S}			
		Orientation Flange		Not Orientation FCClange	
>	≤	h	l	h	l
-	6	0	-36	+220	-36
6	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

2.2.1.5 Class P0 tolerances of tapered bore

Table 2-36 tapered bore (1:12)

μm

d/mm		Δ_{dmp}		$\Delta_{d1mp}-\Delta_{dmp}$		V_{dsp} [a,b]
>	≤	h	l	h	l	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	-

[a] Applicable to any bore single radial plane; [b] Not applicable to diameter series 7 and 8

Table 2-37 tapered bore (1:30)

μm

d/mm		Δ_{dmp}		$\Delta_{d1mp}-\Delta_{dmp}$		V_{dsp} [a,b]
>	≤	h	l	h	l	max
-	50	+15	0	+30	0	19
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

[a] Applicable to any bore single radial plane;

[b] Not applicable to diameter series 7 and 8

2.2.2 Thrust ball bearing tolerances

2.2.2.1 Symbol

d —— Nominal bore diameter

d_s —— Single bore diameter

Δd_{mp} —— Deviation of single direction bearing the mean of bore diameter

Δd_{2mp} —— Deviation of the mean bi-directional bearing bore diameter from the nominal

D —— Nominal outside diameter of bearing housing

ΔD_{mp} —— Deviation of the mean bearing housing outside diameter from the nominal

S_e —— variation of the housing washer raceway from housing base thickness

Note —— Only applicable for thrust ball bearing (90°) and thrust cylindrical roller bearing

S_i —— variation of the shaft washer raceway from housing base thickness

Note —— Only applicable for thrust ball bearing(90°) and thrust cylindrical roller bearing

T —— the height of single direction bearing

T_1 —— the height of bi-directional bearing

ΔT_s —— Deviation of measured height of single direction bearing

ΔT_{1s} —— Deviation of measured height of bi-directional bearing

V_{dp} —— diameter variation of single direction shaft ring in one radial plane

V_{d2p} —— diameter variation of bi-directional shaft ring in one radial plane

V_{Dp} —— outer diameter variation of bearing housing in one radial plane

2.2.2.2 Single and double directional thrust bearing tolerances

(1) class P0 tolerances

Table 2-38 Shaft washer and bearing height

μm

d, d_2/mm	Δd_{mp} Δd_{2mp}		V_{dp} V_{d2p}	S_i	ΔT_s		ΔT_{1s}	
> − ≤	h	l	max	max	h	l	h	l
--18	0	-8	6	10	+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 bi-directional bearings, above tolerances are only applicable for bearings with d2≤190mm

Table 2-39 Housing washer

μm

D/mm		ΔD_{mp}		V_{dp}	S_e
>	≤	h	l	max	max
10	18	0	-11	8	Values are identical to those for shaft ring of same bearing(S_i)
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 bi-directional bearings, above tolerances are only applicable for bearings with D≤360mm

(2) class P6 tolerance

Table 2-40 Shaft washer and bearing height

μm

d, d_2/mm	Δd_{mp} Δd_{2mp}		V_{dp} V_{d2p}	S_i	ΔT_s		ΔT_{1s}	
> − ≤	h	l	max	max	h	l	h	l
--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 bi-directional bearings, above tolerances are only applicable for bearings with d2≤190mm

Table 2-41 Housing washer

μm

D/mm		ΔD_{mp}		V_{dp}	S_e
>	≤	h	l	max	max
10	18	0	-11	8	Values are identical to those for shaft ring of same bearing(S_i)
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 bi-directional bearings, above tolerances are only applicable for bearings with D≤360mm

3) Class P5 tolerances

Table 2-42 Shaft washer and bearing height

μm

d, d_2/mm	Δd_{mp} Δd_{2mp}		V_{dp} V_{d2p}	S_i	ΔT_s		ΔT_{1s}	
> – ≤	h	l	max	max	h	l	h	l
--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	4	+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 bi-directional bearings, above tolerances are only applicable for bearings with d2<=190mm

Table 2-43 Housing washer

μm

D/mm		ΔD_{mp}		V_{dp}	S_e
>	≤	h	l	max	max
10	18	0	-11	8	Values are identical to those for shaft ring of same bearing(S_i)
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 bi-directional bearings, above tolerances are only applicable for bearings with D<=360mm

4) Class P4 tolerances

Table 2-44 Shaft washer and bearing height

μm

d, d_2/mm	Δd_{mp} Δd_{2mp}		V_{dp} V_{d2p}	S_i	ΔT_s		ΔT_{1s}	
> – ≤	h	l	max	max	h	l	h	l
--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 bi-directional bearings, above tolerances are only applicable for bearings with d2<=190mm

Table 2-45 Housing washer

μm

D/mm		ΔD_{mp}		V_{dp}	S_e
>	≤	h	l	max	max
10	18	0	-7	5	Values are identical to those for shaft ring of same bearing(S_i)
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 bi-directional bearingss, above tolerances are only applicable for bearings with D<=360mm

2.3 Bearing Internal Clearance

Bearing internal clearance is defined as the total distance through which one bearing inner ring can be moved relative to the other in the radial direction (radial clearance) or in the axial direction (axial clearance).The bearing clearance can be divided into several groups,1,2,0 (basic group),3,4,5,etc group. The clearance in group1 is minimum, and in group 5 is maximum. The group number and the value of each bearing clearance are different. Below is the clearance group and the value.

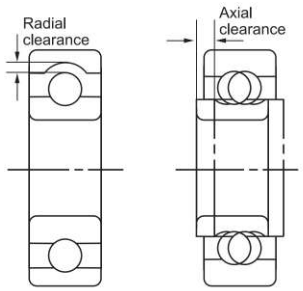


Fig 2 Bearing Clearance

2.3.1 Radial internal clearance of deep groove ball bearings in Table2-46

Table 2-46 Radial internal clearance of deep groove ball bearings

μm

Nominal Bore Diameter (d/mm)		C2		CN		C3		C4		C5	
>	⩽	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
16	24	0	10	5	20	13	28	26	35	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	8	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	500	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

2.3.2 Radial internal clearance of self-aligning ball bearings in Table 2-47 to Tab2-48

Table2-47 Radial internal clearance of self-aligning ball bearings (cylindrical bore)

μm

Nominal Bore Diameter (d/mm)		C2		CN		C3		C4		C5	
>	⩽	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	35	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	86	124
100	120	10	31	25	56	50	83	75	114	105	145
120	140	10	38	30	68	60	100	80	135	125	175
140	160	15	44	35	80	70	120	110	161	130	210

Table2-48 Radial internal clearance of self-aligning ball bearings (tapered bore)

μm

Nominal Bore Diameter (d/mm)		C2		CN		C3		C4		C5	
>	⩽	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

2.3.3 Radial internal clearance of spherical roller bearings in Table2-49 to Table2-50

Table2-49 Radial internal clearance of spherical roller bearings (cylindrical bore)

μm

Nominal Bore Diameter (d/mm)		C2		CN		C3		C4		C5	
>	≤	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	15	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	60	110	110	1450	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	280
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	556	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	560	410	410	550	550	720	720	900
500	560	150	280	580	440	440	600	600	780	780	1000
560	630	170	310	310	480	480	65	650	850	850	1100
630	710	190	350	350	530	530	700	700	920	920	1190
710	800	210	390	390	580	580	770	770	1010	10140	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

Table2-50 Radial internal clearance of spherical roller bearings (tapered bore)

μm

Nominal Bore Diameter (d/mm)		C2		CN		C3		C4		C5	
>	≤	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	660	680	870	870	1100
560	630	320	460	460	600	600	760	760	980	980	1230
630	710	350	510	540	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

2.3.4 Radial internal clearance of cylindrical roller bearings in table 2-51 to 2-52

Table 2-51 Radial internal clearance of cylindrical roller bearings (cylindrical bore)

μm

Nominal Bore Diameter (d/mm)		C2		CN		C3		C4		C5	
>	⩽	min	max	min	max	min	max	min	max	min	max
-	10	0	25	20	45	35	60	50	75	65	90
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	235	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
450	500	110	220	220	330	330	440	440	550	625	735

Table 2-52 Radial internal clearance of double-row cylindrical roller bearing (cylindrical bore)

μm

Nominal Bore Diameter (d/mm)		C2		CN		C3		C4	
>	⩽	min	max	min	max	min	max	min	max
-	10	15	40	30	55	40	65	50	75
10	24	15	40	30	55	40	65	50	75
24	30	20	45	35	60	45	70	55	80
30	40	20	45	40	65	55	80	70	95
40	50	25	55	45	75	60	90	75	105
50	65	30	60	50	80	70	100	90	120
65	80	35	70	60	95	85	120	110	145
80	100	40	75	70	105	95	130	120	155
100	120	50	90	90	130	115	155	140	180
120	140	55	100	100	145	130	175	160	205
140	160	60	110	110	160	145	195	180	230
160	180	75	125	125	175	160	210	195	245
180	200	85	140	140	195	180	235	220	275
200	225	95	155	155	215	200	260	245	305
225	250	105	170	170	235	220	285	270	335
250	280	115	185	185	255	240	310	295	365
280	315	130	205	205	280	265	340	325	400
315	355	145	225	225	305	290	370	355	435
355	400	165	255	255	345	330	420	405	495
400	450	185	285	285	385	370	470	455	555
450	500	205	315	315	425	410	520	505	615

2.3.5 Needle roller bearing clearance

For a needle roller bearing with inner ring, outer ring and cage, except for the pressed outer ring and heavy bearing series, you can refer to the radial clearances of cylindrical roller bearings.For the heavy-duty series needle roller bearings with inner and outer rings and cage, or needle roller bearings with inner rings delivered as aseparate components, refer to the radial clearance of cylindrical roller bearings, based on the inner raceway diameter or cage and roller assembly's inscribed circle diameter.you can refer to the radial clearance of cylindrical roller bearings

2.3.6 Axial internal clearance of angular contact ball bearings in table 2-53

Table2-53 Axial internal clearance of double-row angular contact ball bearing

μm

Nominal Bore Diameter (d/mm)		C2		CN		C3	
>	⩽	min	max	min	max	min	max
-	10	1	11	5	21	12	28
10	18	1	12	6	23	13	31
18	24	2	14	7	25	16	34
24	30	2	15	8	27	18	37
30	40	2	16	9	29	21	40
40	50	2	18	11	33	23	44
50	65	3	22	13	36	26	48
65	80	3	24	15	40	30	54
80	100	3	26	18	46	35	63
100	110	4	30	22	53	42	73

2.3.7 Radial internal clearance of tapered roller bearings in table 2-54

Table2-54 Radial internal clearance of double row and four row tapered roller bearings

μm

Nominal Bore Diameter (d/mm)		C1		C2		CN		C3		C4		C5	
>	⩽	min	max	min	max	min	max	min	max	min	max	min	max
-	30	0	10	10	20	20	30	30	50	50	60	60	80
30	40	0	12	12	25	25	40	40	60	60	75	75	95
40	50	0	15	15	30	30	45	45	65	65	80	80	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
60	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	266	266	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	580
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				

2.3.8 Radial internal clearance of insert bearing in table 2-55 and 2-56

Table 2-55 Radial internal clearance of insert bearings (cylindrical bore)

μm

Nominal Bore Diameter (d/mm)		2,3 Series					
		C2		CN		C3	
>	⩽	min	max	min	max	min	max
10	18	3	18	10	25	18	33
18	24	5	20	12	28	20	35
24	30	5	20	12	28	23	41
30	40	6	20	13	33	28	46
40	50	6	23	14	36	30	51
50	65	8	28	18	43	38	61
65	80	10	30	20	51	46	71
80	100	12	35	24	58	53	84
100	120	15	41	28	66	61	97
120	140	18	48	33	81	71	114

Table 2-56 Radial internal clearance of insert bearings (tapered bore)

μm

Nominal Bore Diameter (d/mm)		2,3 Series					
		C2		CN		C3	
>	⩽	min	max	min	max	min	max
10	18	10	25	18	33	25	45
18	24	12	28	20	35	28	48
24	30	12	28	23	41	30	53
30	40	13	33	28	46	40	64
40	50	14	35	30	51	45	73
50	65	18	43	38	61	55	90
65	80	20	51	46	71	65	105
80	100	24	58	53	84	75	120
100	120	28	66	61	97	90	140
120	140	33	81	71	114	105	160

2.4 Bearing vibration

Bearing vibration is defined as all periodic motion during bearing rotation between components except motion that is determined by bearing operation and required for its function

2.4.1 The vibration limit of deep groove ball bearing in table 2-57,2-58,2-59,and2-60

Table 2-57 The vibration (by velocity) limit

μm/s

Nominal Bore Diameter (d/mm)	V			V1			V2			V3			V4		
	LF	IF	HF	LF	IF	HF	LF	IF	HF	LF	IF	HF	LF	IF	HF
3	80	44	44	60	35	32	48	26	22	31	16	15	28	10	10
4	80	44	44	60	35	32	48	26	22	31	16	15	28	10	10
5	110	72	60	74	48	40	58	36	30	35	21	18	32	11	11
6	110	72	60	74	48	40	58	36	30	35	21	180	32	11	11
7	130	96	80	92	66	54	72	48	40	44	28	24	38	12	12
8	130	96	80	92	66	54	72	48	40	44	28	24	38	12	12
9	130	96	80	92	66	54	72	48	40	44	28	24	38	12	12
10	160	120	100	120	80	70	90	60	50	55	35	30	45	14	15
12	160	120	100	120	80	70	90	60	50	55	35	30	45	14	15
15	210	150	120	150	100	85	110	78	60	65	46	35	52	18	18
17	210	150	120	150	100	85	110	78	60	65	46	35	52	25	25
20	260	190	150	160	125	100	130	100	75	80	60	45	60	25	25
22	260	190	150	180	125	100	130	100	75	80	60	45	60	30	32
25	260	190	150	180	125	100	130	100	75	80	60	45	60	30	32
28	260	190	150	180	125	100	130	100	75	90	60	45	60	35	40
30	300	240	190	200	150	130	150	120	100	90	75	60	70	35	40
32	300	240	190	200	150	130	150	120	100	90	75	60	70	35	40
35	300	240	190	200	150	130	150	120	100	90	75	60	70	42	45
40	350	300	260	240	180	160	180	150	130	110	90	80	82	50	50
45	350	300	260	240	180	160	180	150	130	110	90	80	82	60	60
50	420	320	320	280	200	200	210	160	160	125	100	100	95	70	70
55	420	360	360	280	220	200	210	180	180	125	110	110	95	70	70
60	480	360	440	320	220	240	240	180	200	145	110	130	100	80	80

Table 2-58 The vibration (by velocity) limit

μm/s

Nominal Bore Diameter (d/mm)	V			V1			V2			V3			V4		
	LF	IF	HF	LF	IF	HF	LF	IF	HF	LF	IF	HF	LF	IF	HF
65	300	260	420	180	160	240	130	100	150	105	80	105	50	50	75
70	360	310	460	200	180	280	150	120	200	110	90	135	58	58	88
75	360	310	460	200	180	280	150	120	200	110	90	135	58	58	88
80	420	360	540	240	210	320	180	120	240	130	110	160	65	65	100
85	420	360	540	240	210	320	180	150	240	130	110	160	65	65	110
90	480	420	600	290	250	370	210	180	270	145	125	180	75	75	115
95	480	420	600	290	250	370	210	180	270	145	125	180	75	75	115
100	560	490	670	340	300	420	250	215	310	170	145	200	88	88	135
105	560	490	670	340	300	420	250	215	310	170	145	200	88	88	135
110	640	570	750	400	350	480	290	260	350	190	175	225	100	100	160
120	640	570	750	400	350	480	290	260	350	190	175	225	100	100	160

Table 2-59 The vibration acceleration (dB) limit

Nominal Bore Diameter (d/mm)	Diameter (0)			Diameter (2)				Diameter (3)			
	Z	Z1	Z2	Z	Z1	Z2	Z3	Z	Z1	Z2	Z3
65	49	48	46	50	49	47	47	51	50	48	43
70	50	49	47	51	50	48	43	52	51	49	44
75	51	50	48	52	51	49	44	53	52	50	45
80	52	51	49	53	52	50	45	54	53	51	46
85	53	52	50	54	53	51	46	56	55	52	47
90	54	53	52	56	55	53	48	58	57	54	49
95	56	55	54	58	57	55	50	60	59	56	51
100	58	57	56	60	59	57	52	62	61	58	53
105	60	59	58	62	61	59	54	64	63	60	55
110	62	61	60	64	63	61	56	66	65	62	57
120	64	63	62	66	65	63	58	68	67	64	59

Table 2-60 The vibration acceleration (dB) limit

Inner diameter d/mm	Diameter (0)							Diameter (2)							Diameter (3)						
	Z	Z1	Z2	Z3	Z4	ZP3	ZP4	Z	Z1	Z2	Z3	Z4	ZP3	ZP4	Z	Z1	Z2	Z3	Z4	ZP3	ZP4
3	35	34	32	28	24	44	40	36	35	32	30	26	46	42	37	36	33	31	27	47	43
4	35	34	32	28	24	44	40	36	35	32	30	26	46	42	37	36	33	31	27	47	43
5	37	36	34	30	26	46	42	38	37	34	32	28	48	44	39	37	35	33	29	49	45
6	37	36	34	30	26	46	42	38	37	34	32	28	48	44	39	37	35	33	29	49	45
7	39	38	35	31	27	47	43	40	38	36	34	29	50	45	41	39	37	35	30	51	46
8	39	38	35	31	27	47	43	40	38	36	34	29	50	45	41	39	37	35	30	51	46
9	41	40	36	32	28	48	44	42	40	37	35	30	51	46	43	41	39	37	32	53	48
10	43	42	38	33	28	49	44	44	42	39	35	30	51	46	46	44	40	37	32	53	48
12	44	43	39	34	29	50	45	45	43	39	35	30	51	46	47	45	40	37	32	53	48
15	45	44	40	35	30	51	46	46	44	41	36	31	52	47	48	46	42	38	33	54	49
17	46	44	40	35	30	51	46	47	45	41	36	31	52	47	49	47	42	38	33	54	49
20	47	45	41	36	31	52	47	48	46	42	38	33	54	49	50	48	43	39	34	55	50
22	47	45	41	36	31	52	47	48	46	42	38	33	54	49	50	48	43	39	34	55	50
25	48	46	42	38	34	54	50	49	47	43	40	36	56	52	51	49	44	41	37	57	53
28	49	47	43	39	35	55	51	50	48	44	41	37	57	53	52	50	45	42	38	58	54
30	49	47	43	39	35	55	51	50	48	44	41	37	57	53	52	50	45	42	38	58	54
32	50	48	44	40	36	56	52	51	49	45	42	38	58	54	53	51	46	43	39	59	55
35	51	49	45	41	37	57	53	52	50	46	43	39	59	55	54	52	47	44	40	60	56
40	53	51	46	42	38	58	54	54	52	47	44	40	60	56	56	54	49	45	41	61	57
45	55	53	48	45	42	61	58	56	54	49	46	43	62	59	58	56	51	47	44	63	60
50	57	54	50	47	44	63	60	58	55	51	48	45	64	61	60	57	53	49	46	65	62
55	59	56	52	49	46	65	62	60	57	53	50	47	66	63	62	59	54	51	48	67	64
60	61	58	54	51	48	67	64	62	59	54	51	48	67	64	64	61	56	53	50	69	66

2.4.2 The vibration limit of tapered roller bearings in table 2-61 to 2-62

Table 2-61 The vibration (by velocity) limit

μm/s

Inner diameter d/mm	V			V1			V2			V3		
	LF	IF	HF	LF	IF	HF	LF	IF	HF	LF	IF	HF
15	310	500	500	220	360	360	150	220	220	100	100	100
17	330	550	550	240	400	400	170	240	240	110	110	110
20	330	550	550	240	400	400	170	240	240	110	110	110
25	360	590	600	280	440	450	210	280	280	120	140	130
30	360	590	600	280	440	450	210	280	280	120	140	130
35	400	640	670	320	480	500	250	320	300	150	180	160
40	440	690	740	360	530	560	280	350	320	170	210	190
45	440	690	740	360	530	560	280	350	320	170	210	190
50	480	750	810	400	600	620	320	400	360	220	260	240
55	480	750	840	400	600	680	320	400	360	220	260	240
60	530	850	1000	450	680	760	370	460	420	300	330	300

Table 2-62 The vibration (acceleration) limit

dB

Inner diameter d/mm	30200, 32200 Series			30300, 32300 Series		
	Z	Z1	Z2	Z	Z1	Z2
15	-	-	-	56	54	50
17	56	54	50	58	56	52
20	57	55	51	61	58	53
25	58	56	52	64	61	56
30	59	56	52	67	64	59
35	61	58	53	68	65	60
40	63	60	55	69	66	61
45	65	62	57	69	66	61
50	67	64	59	71	68	63
55	69	66	61	74	71	66
60	71	68	63	77	74	69

2.4.3 The vibration limit of cylindrical roller bearings in Table 2-63 to 2-64

Table 2-63 The vibration (by velocity) limit

μm/s

Inner diameter d/mm	V			V1			V2			V3		
	LF	IF	HF	LF	IF	HF	LF	IF	HF	LF	IF	HF
15	340	420	420	260	310	310	200	190	190	140	100	100
17	370	460	460	290	350	350	230	220	220	160	110	110
20	370	460	460	290	350	350	230	220	220	160	110	110
25	420	530	530	330	400	400	260	260	260	180	130	130
30	420	530	530	330	400	400	260	260	260	180	130	130
35	490	610	610	380	470	470	300	300	300	210	150	150
40	490	610	610	380	470	470	300	300	300	210	150	150
45	570	690	690	430	540	540	340	340	340	240	170	170
50	570	690	690	430	540	540	340	340	340	240	170	170
55	650	780	780	500	610	610	380	380	380	280	190	190
60	650	780	780	500	610	610	380	380	380	280	190	190

Table 2-64 The vibration (by velocity) limit of single bearing

μm/s

Inner diameter d/mm	V			V1			V2			V3		
	LF	IF	HF	LF	IF	HF	LF	IF	HF	LF	IF	HF
65	420	500	500	310	360	380	240	230	230	170	120	120
70	470	560	560	350	430	430	290	270	270	200	140	140
75	470	560	560	350	430	430	290	270	270	200	140	140
80	530	630	630	410	500	500	330	300	300	230	160	160
85	530	630	630	410	500	500	330	300	300	230	160	160
90	610	710	710	460	570	570	370	350	350	260	180	180
95	610	710	710	460	570	570	370	350	350	260	180	180
100	690	800	800	540	650	650	430	400	400	300	210	210
105	690	800	800	540	650	650	430	400	400	300	210	210
110	780	920	920	630	740	740	500	470	470	350	240	240
120	780	920	920	630	740	740	500	470	470	350	240	240

3. Rolling bearing selection

3.1 The diagram of rolling bearing selection

Rolling bearings have been one of the most important mechanical parts due to the variety of applications it can be used in, and the increasing needs of industry development. There are a variety of types of rolling bearings supplied to match different needs of various applications. Selecting the right bearing has a significant impact on its running capacity and its service life, meanwhile it's also not easy to select the right bearing for one specific application from so many different bearings. Figure 3-1 illustrates the bearing selection process. Please contact UBC for support in the case of special applications.

Figure 3-1 Diagram of rolling bearing selection

Understanding machine and bearing application conditions	Function and structure of machine; bearing positions; load and its direction; rotating speed; vibration and fluctuations; temperature of bearing and environment conditions
↓ Select bearing category and types	Dimension limits; bearing load; rotation speed; bearing accuracy; stiffness; allowed misalignment between inner ring and outer ring; friction torque; mounting and dismounting requirement; bearing price and stock volume
↓ Select bearing size	Expected bearing life; Rated basic dynamic/static load; safety coefficient; permissible speed and axial load; mounting space
↓ Select bearing precision	Shaft tolerance; speed; torque range
↓ Select bearing internal clearance	Material and type of shaft/housing; fit; temperature difference between inner and outer ring; allowed misalignment between inner ring and outer ring; load and preload; speed
↓ Select bearing cage and its material	Speed; noise frequencies; vibration and variable load; shock load; lubricant relubrication schedule
↓ Selection of lubrication and seals	Operating temperature; speed; lubricant and relubrication schedule; seal type; maintenance and inspection
↓ Select special bearing	Operating environment (high/low temperature, vacuum, chemical environment); high reliability requirement
↓ Determine installation method	Mounting tolerance; procedure of mounting and dismounting
↓ End of selection	

3.2 Selection of bearing type, tolerance and clearance

3.2.1 Selection of bearing type

When selecting a bearing for a specific application, both the characteristic properties and application condition of the bearing must be taken into consideration, including load, speed, self-alignment, allowable mounting space, accuracy, stiffness noise and vibration and axial displacement, meanwhile without neglect of its cost and availability. Following are the key factors of bearing selection.

3.2.1.1 Bearing load

The main factor of bearing selection is the load and its magnitude, direction and type usually determines the size of bearing.

(1) Magnitude and type of load. Generally, ball bearings are applicable for light to medium loads, as well as static loads,while roller bearings are used for heavy and high vibration load.

(2) Direction of load.

1) Radial load

All radial bearings can accommodate radial load. NU and N design cylindrical bearings and needle bearings can only support pure radial loads.

2) Axial Load

Thrust ball bearing and four-point contact ball bearings are suitable for light or moderate loads that are purely axial. Thrust cylindrical roller bearings and thrust needle bearings are normally used for heavy, purely axial load. Single direction thrust bearings can only accommodate axial loads acting in one direction; for axial loads acting in both directions, bi-directional thrust ball bearings are needed. For heavy alternating axial loads, two paired thrust cylindrical roller bearings or self-aligning thrust roller bearings are needed.

3) Combined load

For combined loads, single and double row angular contact ball bearings and single row taper roller bearings are most commonly used. Self-aligning ball bearings and NJ and NUP design cylindrical roller bearings as well as NJ and NU design cylindrical can be used for combined loads where the axial load is relatively small. For axial loads of alternating direction these bearings must be combined with a second bearing.

Thrust angular ball bearings and four-point contact ball bearings as well as self-aligning thrust roller bearings can be used for combined loads where the radial load is relatively small.

4) Moment load

When a load acts eccentrically on a bearing, a titling moment will occur. Double row bearings, e.g. deep groove or angular contact ball bearings, can accommodate titling moment, but paired single row angular contact ball bearings or taper roller bearings arranged face-to-face, or back-to-back, are more suitable.

3.2.1.2 Speed

Bearing limiting speed is the maximum rotating speed under certain load and lubrication conditions.
The limiting speed is dependent on a bearing's type, dimensions, accuracy, internal clearance, cage material and structure, lubricants and relubrication schedule, the magnitude and direction of the load, and heat dissipation, etc.

The limiting speed of different bearings can be found in its parameter table, and it's measured under lubrication by oil or grease, equivalent dynamic load P≤0.1C; normal lubrication and cooling; pure radial load for radial bearings and pure axial load for thrust bearings; rigid bearing housing and shaft tolerance of Grade 0. When the actual operation condition changes, the limiting speed can also be calculated, e.g., when a bearing accommodates heavy loads (P > 0.1C) or combined loads, its actual limiting speed (rpm) would be calculated as,

$$n_{max} \leqslant f_1 f_2 n_{lim}$$

f_1: load coefficient refer to Figure 3-2, when a bearing is running at equivalent dynamic load P > 0.1C, bearing contact stress increases and will generate more heat and worsen the effect of lubrication, thus reducing the limiting speed of the bearing.

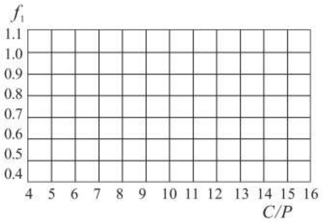


Figure 3-2 Load coefficient

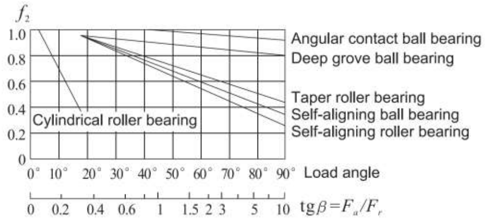


Figure 3-3 Load distribution coefficient

f_2: load distribution coefficient in Figure 3-3,when a bearing is running under a combined load , the number of rollers taking load increases and will cause more friction with raceway and worsen its lubrication effect, thus reducing the limiting speed of the bearing.

N_{lim}: measured limiting speed from one batch of bearing sample.

To run the bearing at speeds higher values given in the bearing tables, some of the speed-limiting factors need to be improved, such as the running accuracy, cage material and design, lubrication and heat dissipation, and larger bearing internal clearance.
Following are some guidelines for bearing selection based on rotating speed,

(1) Ball bearings have higher limiting speed than roller bearings and ball bearings are the most suitable selection for high speed applications.

(2) The smaller the bearing contact angle, the larger the centrifugal force subjected to the bearing. So the limiting speed of thrust bearings are less than radial bearings and the limiting speed of single row radial bearings is higher than double row self-aligning bearings. For light and moderate axial load, angular contact ball bearings are the most suitable selection.

(3) For high speed applications, it's recommended to select the smaller outer diameter bearings if the bore diameters are same. Two bearings in tandem arrangement or wide width bearings could be used if the applied load is larger than can be supported by a single bearing

(4) The limiting speed of bearings with machined cage is higher than bearings with pressed sheet steel cage.

3.2.1.3 Self-alignment

For the misalignment of the centerline of housing and shaft caused by manufacture and/or mounting error, or deformation of shaft and housing, bearings with good self-alignment property would be the preferred selection, such as self-aligning ball bearings and self—aligning roller bearings. U designation bearings are the most suitable for when there is misalignment in bearing installation process. Needle bearings and roller bearings are not recommended for applications where there may be shaft misalignment

3.2.1.4 Stiffness

Generally the stiffness of a rolling bearing is characterized by the magnitude of the elastic deformation under load, which is very small and can be neglected. In some cases, however, e.g. spindle bearing arrangements for machine tools or pinion bearing arrangements, stiffness is very important.

Because of the contact conditions between the rolling elements and raceways, roller bearings, e.g cylindrical or taper roller bearings have a higher degree of stiffness than ball bearings. Bearing stiffness can be further enhanced by applying a preload.

3.2.1.5 Axial displacement

UN design or N design cylindrical roller bearings and needle bearings are suitable for applications which need the bearing moving forward or backward in the axial direction and one of the rings must have an interference fit If non-separable bearings are used such as deep groove ball bearings or self-aligning roller bearings, one of the rings must have a loose enough fit as to have enough freedom of axial displacement. Many rolling bearings can accommodate very minor axial displacement by its internal clearance.

3.2.1.6 Available space

When radial space is limited, bearings with a small cross section should be selected, such as needle roller bearings, deep groove ball bearings, angular contact ball bearings, cylindrical roller bearings and other low cross-sectional height bearings.

When axial space is limited, small width series bearings can be used, such as ball bearings or roller bearings with width serial 0 or 1.

3.2.1.7 Mounting and dismounting

Separable bearings are preferable if frequent mounting and dismounting are required or in difficult mounting or dismounting applications, e.g. cylindrical roller bearings and taper roller bearings. Tapered bore bearings with an adapter sleeve can be easily mounted on a long shaft.

3.2.1.8 Others

Whether the bearings are chosen with snap ring, seal, shield or quiet running are dependent on actual application conditions and their prices and availability.

3.2.2 Selection of bearing tolerance

Bearing tolerance selected must be matched with the accuracy of the machine. Machine's accuracy, vibration and noise can not be fully improved by increasing bearing tolerance only, they also depend on the precision and quality of manufacturing and mounting of the fitted components.

Each type of bearing is usually supplied with tolerance grade 0 which is applicable to general applications. For most of machine applications, bearing with tolerance grade 0 can meet the application requirement. For higher rotating precision, bearings with higher grade tolerance or special tolerance can be selected, e.g. bearings for machine spindles, high precision machines and instruments. For high speed machines, bearings with high grade tolerance are also preferable.

3.2.3 Selection of bearing clearance

Bearing internal clearance has a significant impact on its load capacity, service life and temperature increase and noise level. Radial clearance can be defined as either initial clearance, mounting clearance or operational clearance. Bearing initial clearance is greater than its operational clearance. The basic rated dynamic load in the bearing table is based on zero operational clearance.

Correct selection of bearing clearance must consider the fit and temperature difference of bearing rings and its carrying load as to achieve its best operation condition. Generally, bearings with normal clearance are preferable for normal operating temperature and fit. Where operating and mounting conditions differ from the normal, e.g. interference fit are used for both rings, unusual temperature differences, external heat resource, etc, bearings with greater or smaller internal clearance are required.
For high rotating accuracy or limited axial displacement, smaller internal clearance is preferable.

For low speed or oscillating movement applications, bearings without internal clearance or preload are often selected.

The operational clearance of angular contact ball bearings, taper roller bearings and tapered bore bearings can be adjusted during mounting or handling process.

Under normal application conditions, bearings with Grade 0 clearance can be used if the fit tolerance of bearing rings fall within the values given in Table 3-1.

Table 3-1 Fits for Normal internal clearance

Bearing Type	Shaft	Housing
Ball bearing	jk…k5	J6
Roller bearing and needle roller bearing	k5…m5	K6

4. Rolling bearing load and life, and limiting speed

4.1 Rolling bearing basic load rating

4.1.1 Temperature modification for bearing basic dynamic load rating

When a bearing is used in high temperature conditions , the structure of material will be changed, and the rigidity will decrease, and then the bearing basic dynamic load rating will decrease compared with use in normal conditions.

Once the structure of material has been changed due to overheating, the structure can't be recovered even if the temperature returns to normal temperature.

Therefore, when a bearing is used in high temperature situation, the basic dynamic load rating must be adjusted according to the temperature factor given in Table 4-1.

For bearings that are used in above 120 Celsius conditions, dimensional changes will be large with normal heat treatment process, so the stabilization.

treatment to maintain dimensions must be taken. The code of dimension stabilization treatment and the range of usage temperature listed in Table 4-2. But after the dimension stabilization treatment, the rigidity of bearing will be reduced, sometimes the basic rating dynamic load will decrease.

Table 4-1 Temperature coefficient

Bearing temperature ℃	125	150	175	200	250
Temperature coefficient	1	1	0.95	0.90	0.75

Table 4-2 Dimension stabilization treatment

The code of dimension stabilization treatment	The range of usage temperature
S0	Above 100℃ to 150℃
S1	150℃ to 200℃
S2	200℃ to 250℃

4.1.2 Basic static load rating

Partly-permanent distortion will occur between rollers and the interface of raceway when the bearing experiences too large of a static load, or is subjected to vibration at very slow speed.

The basic static load rating is calculated based on the contact stresses between the rollers and raceway in the center of the raceway, where the roller is subjected to the greatest stress.

- Ball bearing 4200MPa (except self aligning bearing)
- Roller bearing 4000MPa

$$f_s = \frac{C_0}{P_0} \quad \text{……………………(formula 4-1)}$$

Where : f_s: Safety factor
C_0: Basic static load rating
P_0: Equivalent static load

The allowable value of bearing equivalent static load depends on the bearing's basic load rating. The limits of the bearing's use fluctuate depending upon the amount of plastic deformation and if the requirements of performance and operating conditions vary.

Therefore, to analyze the degree of safety of bearing basic load rating, the safety factor was established based on experience. Formula 4-1 is the calculation method for the safety factor and recommended safety factors for various conditions are given in Table 4-3

Table 4-3 Safety factor f_s

Usage Conditions		f_s (minimum) Ball Bearing	f_s (minimum) Roller Bearing
General rotation	General usage condition	1	1.5
	Shock load	1.5	3
Infrequent rotation (sometimes oscillate)	General usage condition	0.5	1
	Shock load or Variable load	1	2

Note: For Thrust self-aligning roller bearing, the $f_s \geqslant 4$

4.2 Rolling bearing equivalent load

4.2.1 Equivalent dynamic load

Many bearings encounter combined load which is a combination of radial load and axial load. Moreover, there are various conditions of loading, for example, if the load is fluctuating

Therefore it is not possible to directly compare actual bearing load with basic dynamic load rating.The nominal load can be used to estimate the value and direction of the actual load. In the case of nominal load, the bearing has the life same as the condition of actual loading and speed.

The nominal load can be regarded as equivalent dynamic load, and can be expressed as P.

4.2.2 Equivalent static load

The equivalent static load is nominal load. When the bearing is stationary or rotates at very low speed, and under the nominal load, it will cause a contact stress on the rolling elements, which is maximum at the center of the raceway.This contact stress is the same as the actual load to which the bearing is subjected.

The radial load which goes through the center of bearing and the axial load which goes through the center line of bearing are applied respectively for the equivalent of radial bearing and thrust bearing.

(Notes) The equation used for equivalent load is listed in table of dimension classified by bearing type.

4.2.3 Calculation of bearing load

The load to which the bearing is subjected includes the weight of bearing support , the inertia of gear or belt and the load induced during machine rotation.

The actual exact load on a bearing is affected by many factors and as such, it is difficult to determine the load actually applied to a bearing with a simple calculation

Therefore, we usually calculate the loading on a bearing multiplying the theoretical value by a operating factor.

(1) Load

Though the radial load or axial load on bearing can be calculated by simple mechanical formulas, but the actual load to which the bearing is subjected is larger than the nominal value due to shock, vibration or a combination of the two. Therefore, we calculate the load on a bearing by multiplying the theoretical value by a factor related to vibration or shock.

It is obtained from the equation 4-2, and the load factor listed in table 4-4.

$$F = f_w \cdot F_c \quad \text{……………(formula 4-1)}$$

Where : F: Actual load, N
F_c: Theory load,N
f_w: Load factor

(2) The load in belt or chain drives

The theoretical load on the belt axle can be obtained by calculation of effective belt drive force.

But the actual load can be obtained by multiplying by a theoretical load factor above and belt factor, which is related to belt strain.

Table 4-4 Load factor f_w

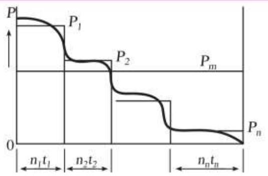
Usage Condition	Purpose	f_w
Almost no vibration or shock	Motor, Machine tool, Instrument	1.0-1.2
General rotation (Slight shock)	Railway vehicle, Auto, Paper machine, Fan, Compressor, Agriculture machine	1.2-2.0
Severe vibration or shock	Rolling mill, Rock crushers, construction machinery, shaker screens	2.0-3.0

4.2.4 Equivalent dynamic load in load change

When the bearing is under a load which varies by magnitude or direction, it is necessary to calculate the average of the dynamic load which give the same life as the actual operating conditions.
The method for calculation of average equivalent dynamic load Pm illustrated in (1)-(4).

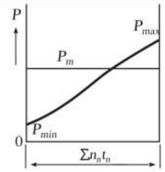
(3) Sine transformation

(1) Ladder transformation



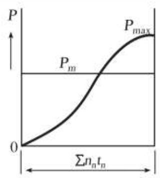
$$P_m = \sqrt[P]{\frac{P_1^P n_1 t_1 + P_1^P n_2 t_2 + \cdots\cdots + P_n^P n_n t_n}{n_1 t_1 + n_2 t_2 + \cdots\cdots n_n t_n}} \quad \cdots\cdots (5.2)$$

(2) Monotonously changing



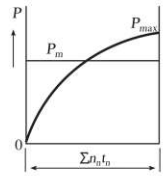
$$P_m = \frac{P_{min} + 2P_{max}}{3} \quad \cdots\cdots (5.3)$$

(3) Sine transformation



$$P_m = 0.68\, P_{max} \quad \cdots\cdots (5.4)$$

(4) Sine transformation (1/4 cycle of Sine wave)



$$P_m = 0.75\, P_{max} \quad \cdots\cdots (5.5)$$

In (1)~(4)

- P_m: The average of equivalent dynamic load, N
- P_1: The equivalent dynamic load on loading time t_1 at speed n_1, N
- P_2: The equivalent dynamic load on loading time t_2 at speed n_2, N
- : :
- P_n: The equivalent dynamic load on loading time tn at speed nn, N
- P_{min}: The minimum of equivalent dynamic load, N
- P_{max}: The maximum of equivalent dynamic load, N
- $\sum n_i t_i$: The total rotation on $t_1+t_2+\ldots t_n$
- P: Index
  - Ball bearing………..P=3
  - Roller bearing……...P=10/3

The average of speed can be calculated by

$$n_m = \frac{n_1 t_1 + n_2 t_2 + \cdots\cdots + n_n t_n}{t_1 + t_2 + \cdots\cdots\cdots\cdots + t_n}$$

4.3 Rolling bearing life

The life of a rolling bearing is defined as the number of revolutions at ideal condition, which the bearing is capable of enduring before the first sign of metal fatigue occurs on one of its inner rings, outer ring or rolling elements (or the number of operating hours at a given speed).

Identical bearings operating under identical conditions, such as dimension, structure, material, the method of manufacture, will have different individual operating lives . The life of a bearing can only be predicted statistically, because the fatigue of material is not perfectly predictable. Life calculations refer only to a bearing population in same running condition, and a given degree of reliability, i.e. 90 %.

Furthermore failures in the field are not generally caused by fatigue, but are more often caused by wear, corrosion, fracture, Brinelling or overheating.

4.3.1 The calculation of bearing life

Basic dynamic load rating

The basic dynamic load rating is the ability to resist fatigue due to rolling. It is assumed that the load is constant in magnitude and direction and is radial for radial bearings and axial, acting on the center of the bearing (for thrust bearings), the basic rating life is 1, 000, 000 revolutions. The basic dynamic load rating of radial bearing and thrust bearing is defined as the radial basic dynamic load rating and the axial basic dynamic load rating respectively, and can be defined as Cr and Ca, and its value is listed in the table of bearing dimensions.

Basic rating life

The formula (4-3) explains the relationship between the bearing basic rating life, basic dynamic load rating and equivalent dynamic load. If the speed is constant, it is often preferable to calculate the life expressed in operating hours, using the equation (4-4).

(Revolution) $L_{10} = \left(\frac{C}{P}\right)^P$ ———— (formula 4-3)   (Time) $L_{10h} = \frac{10^6}{60n}\left(\frac{C}{P}\right)^P$ ———— (formula 4-4)

where:
- L_{10}: basic rating life, millions of revolutions
- L_{10h}: basic rating, operating hours
- C: basic dynamic load rating, N
- P: equivalent dynamic bearing load, N
- n: rotational speed, r/min
- p: exponent of the life equation
  3 for ball bearings   10/3 for roller bearings

4.3.2 Rating life modification

L10 is the basic rating life at 90% reliability, but sometimes a reliability of higher than 90% is needed based on a different usage.

Furthermore, the bearing life can be extended by using special materials, and also be influenced by usage condition, such as lubrication.

Considering these factors mentioned above, the basic life rating is used to determine modified rated life

$L_{na} = a_1 a_2 a_3 L_{10}$ ———— (formula 4-5)

where:
- L_{na}: modified rated life, millions of revolutions. Lna is life at 100-n%reliability considering bearing characteristics and usage condition. N% is the failure rate.
- L_{10}: basic rating life (at 90% reliability), millions of revolutions
- a_1: reliability coefficient
- a_2: bearing characteristic coefficient
- a_3: usage condition coefficient

{Note} More attention should be paid to the tolerance of shaft and housing, when selecting a bearing for a reliability of higher than 90%.

(1) Reliability Factor a_1

When calculating the bearing life based on the Reliability>=90% (Failure Probability<=10%), choose the Reliability Factor a_1 in Table 4-5.

Table 4-5 Reliability factor a_1

Reliability %	L_{na}	a_1
90	L_{10a}	1
95	L_{5a}	0.62
96	L_{4a}	0.53
97	L_{3a}	0.44
98	L_{2a}	0.33
99	L_{1a}	0.21

(2) Characteristic Factor a_2

According to the material, designation and manufacturing process, the characteristic related to the life of bearing may be changed. We use a_2 for correction.

According to testing, high quality vacuum carbon deoxidized steel, as a standard bearing material, can obviously extend the bearing life. All the basic dynamic load ratings in the table of bearing dimension are based on this material, and therefore $a_2=1$.

Otherwise, for material which are designed for extending the bearing life, $a_2 >1$.

(3) Application Environment Factor a_3

The application environment (especially the lubrication) has a direct influence on the bearing life. We use a_3 for correction.

When lubricated correctly, $a_3=1$. And we use $a_3>1$ in situations with excellent lubrication.

But for the below conditions, $a_3 <1$.

- kinematic viscosity is decreasing when running.
  - For ball bearing, viscosity is less than 13mm²/s;
  - For roller bearing, viscosity is less than 20mm²/s.
- There is contamination in the lubricant.
- When inner ring is quite skewed compared with the outer ring, and the rigidity is decreases when in high temperature environment, we must correct the basic dynamic load rating with temperature factor. (according to the Table 4-1).
- The speed is quite low, as the pitch diameter of the roller element multiplied by the speed is less than 10000.

[Note] Even with special material ($a_2>1$), $a_2 x a_3>1$ is not valid without proper lubrication. Consequently, in this situation ($a_3<1$), $a_2 \leqslant 1$.

Because we can not separate a_2 with a_3, it is sometimes recommended to use a combined correction factor a23.

4.4 Limit Speed of Rolling Bearing

The speed of a bearing is restricted by the heat caused by friction. After exceeding limit speed, a bearing will fail due to overheating.

The limit speed of a bearing is defined as that at which a bearing can run continuously rather than overheat by the heat caused by friction.

Consequently, the limit speed of a bearing is determined by the type,dimension,precision of the bearing, the type, quality, quantity of the lubrication, the material, type of the cage, the loads and so on.

The limit speeds of all kinds of bearings for grease and oil lubrication are shown separately on bearing dimension table, the value represents the limit value when bearing in normal condition (C/P ≥13, Fa/ Fr ≤0.25)

Besides, lubricants, according to their types and series, may excel at some functions, but is not suitable for high-speed applications

4.4.1 Correction for Limit Speed

When C/P<13 (the equivalent dynamic load is larger than 8% of the basic load rating C), or the axial load is larger than 25% of the radial load in combined load, we use formula 4-6 for correction.

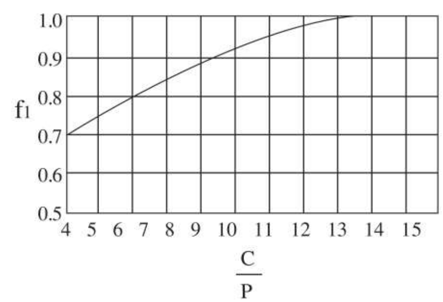
$$n_a = f1 \cdot f2 \cdot n \cdots\cdots (4\text{-}6)$$

where:

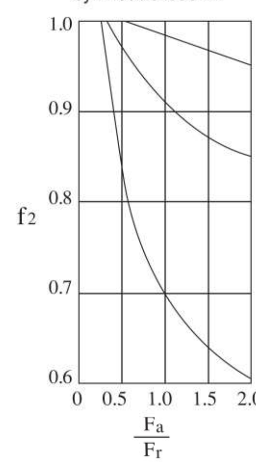
n_a: limit speed after correction, R/min
f1: correction factor related to load
f2: correction factor related to combined load
n: limit speed in normal condition, R/min

C: basic load rating, N {kgf}
P: equivalent dynamic load
Fr: radial load, N {kgf}
Fa: axial load, N {kgf}

Plot 4-1 correction factor related load f1



Plot 4-2 correction factor related synthesize load f2



4.4.2 Limit speed of Sealed Ball Bearings

The limit speed of ball bearings with contact seals (type RS) is restricted by the surface speed of the seals interface. This limit of the surface speed is determined by the rubber material of the seals.

4.4.3 **Recommendations** for High Speed Applications

When a bearing must run at high speed, especially when it's approaching or over the maximum listed speed, recommendations are listed below.

(1) use of precision bearings;

(2) Reviewing the internal clearance (the internal clearance decreases as a result of increase in temperature)

(3) Reviewing the material and type of cage (for high speed application,we prefer machined copper alloy and phenolic resin cage, besides, molding synthetic resin cage is applicable)

(4) Reviewing the lubrication (we recommend lubrication methods that are suitable for high-speed rotation, such as, cycle lubrication, injection lubrication, oil mist and oil air lubrication)

4.4.4 Friction Factor of Bearing (Reference)

Compared with a sliding bearing, the friction torque of the rolling bearing can be calculated according to the inner diameter as following:

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

where: M: friction torque, Nm, M{kgf, mm} P: load, N{kgf}
μ: friction factor, table 4-6 d: nominal bore diameter, mm

The type of the bearing, the load, the speed and the type of lubrication, all have a big influence on the friction factor. Generally, when under constant speed, the friction factor listed in Table 7.1.

Generally speaking, for sliding bearing, μ=0.01~0.02. Sometimes u=0.1~0.2.

Table 4-6 Friction coefficient of each type bearing

The type of bearing	Friction coefficient μ
Deep groove ball bearing	0.0010-0.0015
Angular contact ball bearing	0.0012-0.0020
Self-aligning ball bearing Cylindrical roller bearing	0.0008-0.0012
Full-complement	0.0025-0.0035
Needle roller bearing with cage	0.0020-0.0030
Taper roller bearing	0.0017-0.0025
Self-aligning roller bearing	0.0020-0.0025
Thrust ball bearing	0.0010-0.0015
Thrust self-aligning roller bearing	0.0020-0.0025

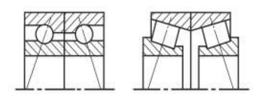
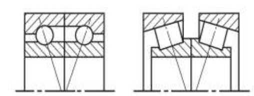
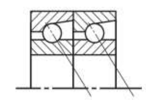
5. Basic types of rolling bearing support structures

5.1 Rolling bearing arrangements and common methods of bearing support

5.1.1 Bearing arrangements

The arrangements of mechanical drive shafts, the shafts of machine tool, generally require two supports. Every support is composed of one or several bearings. The radial bearing, such as deep groove ball bearing, can be used in two supports if the bearings support the radial load only, sometimes taper roller bearings can be used for the convenience of mounting and dismounting. When supporting combined load, generally taper roller bearing, angular contact ball bearing can be used, these two types bearings can't be used singly or several bearings used in series in one direction, but two bearings must be used together.The types of arrangements are listed in Table 5-1.

Table 5-1 The basic arrangements of bearings

The Type of Bearing	Diagram	Characteristic
Back-to-back arrangement (DB)		The center of load acting outside the center line of bearing, the span between supports is long, the length of cantilever is short, and the stiffness is large. It does not readily seize as a result of thermal expansion or change in clearance
Face-to-face arrangement (D		The center of load acting inside the center line of bearing, the span between supports is short, simple structure, easy for mounting and dismounting. It readily seizes with thermal expansion and therefore is generally used for closely spaced supports, be sure to carefully adjust clearance
Tandem (DT)		The center of loading acts on the same side as the center line of the bearing, This arrangement usually applied in the situation in which axial load is large, and requires multiple bearings to support the load. It must be applied symmetrically, such as face-to-face or back-to-back.

5.1.2 The basic structure of bearing support

Generally, locating in the radial direction needs two supports, and there are three types of axial locating: two locating supports, one locating and one floating supports and two floating supports.

(1) Two locating supports.The position between bearing and shaft and bore of the housing (See plot 1 in table 5-3). Under the axial load, one bearing surface is in contact with a stop and there is a gap △ between another bearing surface and another bearing end plate, and the gap can be used to compensate for thermal expansion. If the gap is too large, the vibration of the shaft will be too severe, but on the other hand, if the gap is too small, it can't adequately compensate for thermal expansion. For a steel shaft, the value of △ can be calculated by using below equation.

$$\Delta = 12\times16^{-6}L\Delta t + 0.15,\ \text{mm}$$

Where, L： the length of shaft, mm
Δt： the change of shaft temperature, ˚C

Generally,the value of Δ is 0.5~1mm,and it can be adjusted with clearance during mounting.This support is suitable where only radial load or small axial load is encountered.

If the shaft accommodates a combined load, it's typical to use the two locating supports,which are composed of the arrangement of face to face or back to back pair of angular contact ball bearing or taper roller bearing (See plot 4, 5, 6 in table 5-3). The clearance or preload can be modified by adjusting the axial ovement of bearing clearance relative to bearing stoppers. The structure is very suitable for machines that need high running accuracy.

(2) One locating and one floating support. For this structure, the position between bearing and shaft or housing bore is fixed at one shaft end, so the shaft can be axially located (See plot 8 in table5-3) At another shaft end, there is relative movement between bearing and shaft or housing bore, so that the thermal expansion and any error from manufacturing and mounting can be compensated for. In this support, the precision of axial location depends on the axial clearance of the located bearing. Therefore, the precision of locating support composed of a pair of angular contact ball bearing or taper roller bearing or radial bearing is higher compared with using a pair of deep groove ball bearing.

This structure is applicable to standard conditions and so this structure is widely used for the shafts of various machine tools, such as shafts that operate at high temperature or long shafts

(3) Two floating supports. For this structure, the axial position of the shaft does not need to be precisely located by two bearings, such as in the herringbone driving gear, this structure is generally used in the pinion shaft. The meshing portion of the gear can self-locate by floating as needed, and it helps to have enough gap at the two sides of bearing.

Almost all bearings which do not require adjustment can be used as a floating support, except deep groove ball bearing.

The familiar type and characteristics of support structure listed in table 5-2, and the typical structure of bearing support listed in table 5-3.

Table5-2 Familiar type and characteristics of support structure

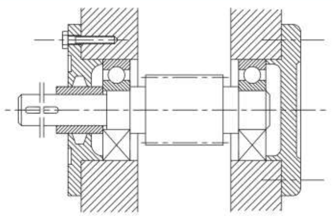
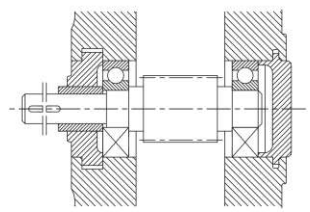
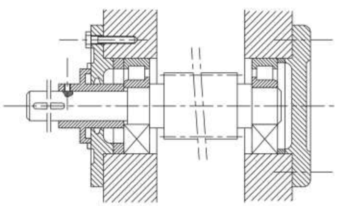
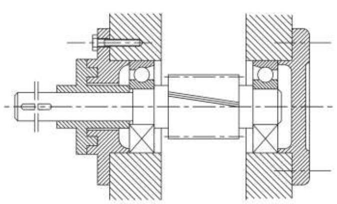
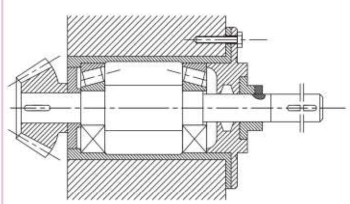
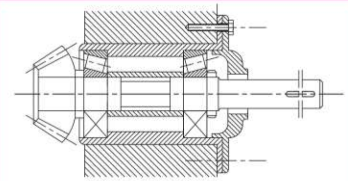
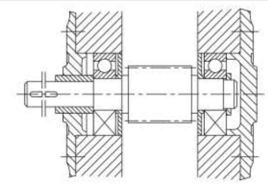
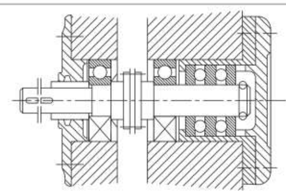
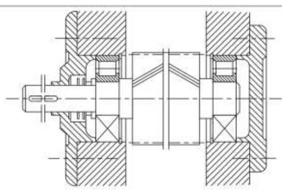
Support Type	Diagram	Bearing Arrangement	Axial Load	Accommodate Shaft Expansion	Others Characteristics
Two locating supports		A pair of deep groove ball bearings	Can accommodate axial loads in single direction (one side which has no clearance)	The clearance between outer ring cover and end plates	High speed, simple structure and convenient to mounting and dismounting
		A pair of outer spherical deep groove ball bearings	Can accommodate axial loads in both directions	Bearing clearance	
		A pair of angular contact ball bearing with face-to-face arrangement			
		A pair of angular contact ball bearing with back-to-back arrangement			
		A pair of cylindrical roller bearing, which outer ring has single flange	Can accommodate small axial loads in both directions	The clearance between outer ring cover and end plates	Simple structure and convenience to mounting and dismounting
		A pair of taper roller bearing with face-to-face arrangement	Can accommodate axial loads in both directions		
		A pair of taper roller bearing with back-to-back arrangement			
		Two sets combined of deep groove ball bearing and thrust ball bearing			Used for vertical shaft with low speed
		Angular contact ball bearing series with back-to-back arrangement		Bearing clearance increase because of shaft thermal expansion, and the preload depends on the compressed spring.	Used for shaft with high speed
		The combination of deep groove ball bearing, thrust ball bearing and double row cylindrical roller bearing with taper bore		Bearing clearance	Stiffness of the support can be enhanced by radial preload

Note: In diagram, " ¦ " is the symbol for limit housing ring move

Support Type	Diagram	Bearing Arrangement		Axial Load	Accommodate Shaft Expansion	Others Characteristics
		Locating	Non-locating			
Locating and floating support		Deep groove ball bearing (at right side)	Deep groove ball bearing (at left side)	Can endure axial loads in both direction	Dynamic fit between outer ring of radial ball bearing at right side and housing bore	High speed, simple structure and convenience of mounting and dismounting
		Deep groove ball bearing (at left side)	Cylindrical roller bearing (at left side)		Roller can move axially relative to outer ring raceway	Simple structure and convenience of mounting and dismounting
		Angular contact ball bearing paired mounted back-to-back (at right side)	Cylindrical roller bearing (at left side)			Improvement of stiffness of support by axial preload
		Angular contact ball bearing paired mounted face-to-face (at right side)	Cylindrical roller bearing (at left side)			
		Three points contact ball bearing and cylindrical roller bearing which outer ring has no flange (at right side)	Cylindrical roller bearing (at left side)		Roller at left side can move axially relative to outer ring raceway	High speed, compact structure and can endure large radial loads
		Three points contact ball bearing and cylindrical roller bearing which outer ring has no flange (at right side)	Taper bore double rows cylindrical roller bearing (at right side)			Can endure axial and radial loads, high stiffness of support
		Taper roller bearing paired mounted back-to-back (at right side)	Cylindrical roller bearing with outer ring has external flange (at left side)			Can endure axial and radial loads, simple structure, and convenient to adjust
		Taper roller bearing paired mounted face-to-face (at right side)	Cylindrical roller bearing with outer ring has external flange (at left side)			
		Angular contact ball bearing paired mounted back-to-back (at right side)	Angular contact ball bearing paired mounted (series)	Can endure axial loads in both direction	Dynamic fit between outer ring of bearing at left side and housing bore	High speed
		Thrust angular contact ball bearing in both directions and taper bore double rows cylindrical roller bearing (at right side)	Cylindrical roller bearing with inner ring having no flange		Roller of left bearing axial move relatively to inner ring raceway	High running precision, can endure axial and radial loads, high stiffness
		A pair of spherical roller bearing		Can accommodate small axial loads in both directions	Dynamic fit between outer ring of right side bearing and housing	Rollers of the bearings of the two sides move relative to outer ring raceways
Two non-locating supports		A pair of cylindrical roller bearings		Can not accommodate axial loads	Applicable for a shaft which is under large radial load and can self-align	Applied in situation that have requirements of shaft moving in axial direction
		A pair of needle roller bearings without inner rings			Needle at two sides supports move relatively to shaft	

Rolling Bearing Arrangements and Normal Support Types UBC

Table5-3 The typical structure of bearing support

Number	Structure Type	Characteristic and Application
1		Deep groove ball bearing, bearing axially fixed by housing cover. There isn't large clearance (0.5~1mm) between outer ring of right side bearing and housing cover to move;This type needs a felt seal and lubrication oil, it is suitable for light load, the sliding speed of felt seal is maximum of v<=4-5 m/s, and requires clean environment.
2		The design is basically same as Number 1 design, the difference is embedded housing cover; Necessary bearing axial clearance is ensured by adjusting shim between outer ring of right side bearing and housing shim; grooved seal.
3		Cylindrical roller bearing, its inner ring has no flange, and there is clearance between outer ring (right side in diagram) of bearing and adjustment shim; combined seal. It is suitable for large, purely radial loads, difficult operating environments and bearing span is less than 600mm.
4		Angular contact ball bearing, labyrinth seal; it depends on adjustment shim between housing cover and box, a suitable axial clearance is needed when mounting; and can support radial load and bidirectional axial load, It is suitable for light load, high speed,and bearing span is less than 300mm.
5		It is suitable to support a small taper gear, there are the below advantages compared to design # 6 1, Bearing which supports small radial load supports axial load. 2, Axial clearance of bearing adjusted by adjusting the shim between housing cover and ring. 3, Simple structure, for example, there isn't the need for a nut to fix axially.
6		There are the below advantages compared to design #5 1, The allowable shaft expansion is large. 2, The stiffness of structure is good.
7		The design is basically same as above design, the difference is the shaft bi-directional axially fixed on right-side of bearing; and can support radial load and limited bidirectional axial load. Adding an oil baffle can be used to prevent grease loss. It is applicable to supports with a large span.
8		Bidirectional thrust ball bearing and deep groove ball bearing mounted at right side, and removable deep groove ball bearing mounted at left side. It can support very large bidirectional axial load, and also support radial load simultaneously. Large displacement is permitted. Suitable axial clearance can be achieved through the adjustment of the shim between housing cover and housing bore.
9		Cylindrical Roller Bearing with no-rib outer ring. In the double-helical gear drive, a shaft (often a high-speed shaft) is required to use the scheme that the shaft can travel bidirectionally, so that the teeth on both sides can be automatically adjusted to uniform force. Reversed oil seal is adopted.

5.2 Axial fitting

Axial fitting includes both axially locating and axially retained types.

5.2.1 Axial locating

Generally, the inner and outer rings are located by the shoulder of shaft or housing bore. To guarantee the contact between the bearing end plates and shoulder, and to prevent friction between fillet and transition angle (see diagram 5-1), the maximal of fillet radius of shaft and housing bore should comply with the rules listed
in table 5-4.

The height of shoulder is not only to guarantee full contact between shoulder and bearing end plates, but also convenient for the usage of mounting and dismounting tools. Generally the minimum shoulder height should be in accordance with the requirements listed in Table 5-5.

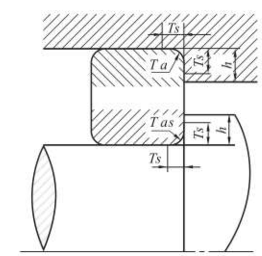


Diagram 5-1 The relationship between bearing fillet radius ra and height h of housing shoulder

Table 5-4 the maximum value of fillet radius of shaft and housing bore

mm

The Minimum of Bearing Single Direction Fillet	r_{as}	The Minimum of Bearing Single Direction Fillet	r_{as}
0.05	0.05	2.0	2.0
0.08	0.08	2.1	2.1
0.10	0.10	3.0	2.5
0.15	0.15	4.0	3.1
0.20	0.20	5.0	4.0
0.30	0.30	6.0	5.0
0.60	0.60	7.5	6.0
1.00	1.00	9.5	8.0
1.10	1.10	12.0	10.0
1.50	1.50	15.0	12.0

Table 5-5 The minimum of housing shoulder height

mm

Minimum of Bearing Single Direction Fillet	The Minimum of h		Minimum of Bearing Single Direction Fillet	The Minimum of h	
	Normal Condition	Special Condition①		Normal Condition	Special Condition①
0.05	0.2	-	2.0	5	4.5
0.08	0.3	-	2.0	6	5.5
0.10	0.4	-	3.0	7	6.5
0.15	0.6	-	4.0	9	8.0
0.20	0.8	-	5.0	11	10.0
0.30	1.2	1.0	6.0	14	12.0
0.60	2.5	2.0	7.5	18	-
1.00	3.0	2.5	9.5	22	-
1.10	3.3	3.5	12.0	27	-
1.50	4.5	4.0	15.0	32	-

① Special condition means thrust load is very small, or small housing shoulder is required.

5.2.2 Axially retained

The axial retention of a bearing includes retained inner ring at shaft and outer ring in housing bore. Although axially retained bearings are required for both inner and outer ring, but do not need to be fixed simultaneously. For the structure of two locating supports, it only needs to be fixed in one direction because every bearing only supports a single-direction axial load. For the structure of one locating and one floating support, because the bearing in the locating support is under bi-directional axial loading, so it needs to be secured in both directions, and the fixing structures for the floating bearing depend on the type of bearing and the mode of floating.

There are many types of methods for axial retention. The selection depends on the axial load, speed, the type of bearing, mounting position and dismounting environment. The higher the load and speed, the more reliability is required for axial retention. In this situation, lock nuts and snap collar are often used for inner ring, and end plates for outer ring. If the load is smaller and the speed is lower, spring collar and snap ring are often applied for inner and outer ring. The general methods for inner and outer ring listed in table5-6 and table 5-7.

Table 5-6 Normal methods of fixing of bearing inner ring

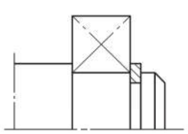
Diagram	Retention Type	Application and Characteristic
	Fixed by Spring collar	Simple structure, convenient for mounting and dismounting, takes up minimal space, often applied for fixing radial bearings.

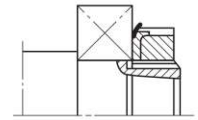
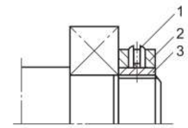
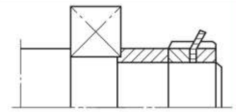
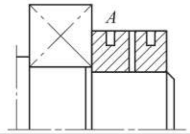
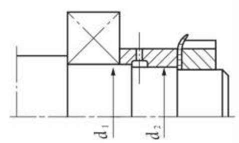
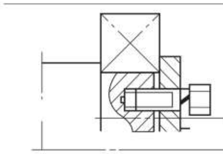
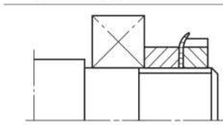
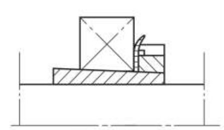
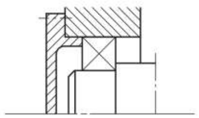
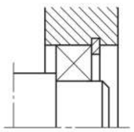
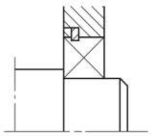
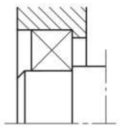
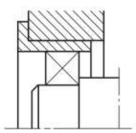
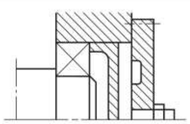
Diagram	Retention Type	Application and Characteristic
	Inner ring fixed by nut and snap ring	Simple structure, convenient for mounting and dismounting, and high fixed reliability.
	Inner ring fixed by nut-2,and loosening is prevented by set screw-1, shim-3 is made of soft metal to enhance the effectiveness of prevention of loosening and mitigate against damage of the threads	Often applied in ends support or middle support of machine tool shaft.
	Inner ring fixed by two nuts and a sleeve.	Two nuts have a highly reliable prevention of loosening and the sleeve can prevent misalignment of the nuts
	Inner ring fixed by nut with two grooves, bolt used to prevent loosening.	It can guarantee the nut cover is vertical to the center line of shaft, applicable for a vertical shaft of machine tool.
	Inner ring fixed by ladder sleeve, interference fit for sleeve and shaft diameter d1 and d2.	This type of fit is applicable for a high-speed shaft of a high-precision machine tool and it can compensate for any misalignment between the end-face of the nut and the axis. First mount the sleeve on shaft by heating, after it has cooled, expand the sleeveby injecting pressurized oil between sleeve and shaft. then adjust the position of sleeve by nuts.
	Bearing fixed by bolts and plate, and looseness is prevented by a spring shim.	This type can't adjust the bearing clearance, often applied in the condition of shaft diameter > 70mm, high speed, and without turning thread on shaft.
	Inner bore with taper matched to the taper bearing, and fixed by shim and nuts.	The bearing radial clearance can be adjusted, and suitable for a bearing with tapered bore.
	inner ring fixed by set sleeve, nuts, and snap ring.	Axial position and radial clearance of bearing can be adjusted. It's convenient for mounting and dismounting, often applied for fixing inner ring of self-aligning bearing. This type is applicable to supports with several pivots and when it is difficult to create a housing shoulder.

Table 5-7 Normal methods of fixing of bearing outer ring

Diagram	Retention Type	Characteristic
	Outer ring fixed by cover	Simple structure, strong retention, convenient for mounting and dismounting
	Outer ring fixed by Spring collar	Simple structure, convenient for mounting and dismounting, requires a small space, often applied on radial bearings.
	Outer ring fixed by snap ring	Simple structure, Applicable when axial space is limited
	Outer located by housing shoulder, and the support fixed by bolt or plate.	Simple structure and high reliability.
	Outer located by shoulder on sleeve, and the support fixed by bolt or end plates.	Simple structure, housing bore can be a open bore, the axial position can be adjusted by shims, and has a simple assembly procedure
	Outer ring fixed by bolt and top cover	Convenient to adjust clearance, and often applied for fixing angular contact ball bearing and taper roller bearing.

5.3 Rolling bearings preload

5.3.1 The characteristics, theory and types of bearing preload

Bearing preload is defined as a given quantity of initial force and elastic deformation which is maintained between rolling elements and raceway when mounting to reduce the actual bearing deformation under running load.
Suitable preload can increase the support stiffness, running accuracy, life, dampening, and can reduce running noise. Research shows that preload can have both a positive and negative effect on accuracy, life, dampening and noise. In moderation, preload has an obvious effect on running accuracy, stiffness, life, dampening and reducing noise, but on the contrary, when the preload reaches a given degree, the improvement will not be noticeable if the preload is further enhanced, and the more the preload, the higher the temperature, and the faster bearing life declines. Therefore, the bearing preload should be appropriate.

For bearings in a precision machine tool, their temperature increase has a limit, table 5-8 lists permissible temperature of each precision machine tool bearing under high speed, unloaded and continuous running. The ambient temperature is 20 Celsius, and lubricated well. If the ambient temperature is not 20 centigrade, an adjusted value can be calculated by the below equation because of the change of lubricant viscosity.

$$T=T_{20}+K_T(t-20)$$

Where, K_T is lubrication correction factor, and K_T depends on the selected lubricant. K_T= 0.6~0.5 if L-HM-L-HV.HS 662 and 32 liquefied oil are applied, and if applies 3~6 shaft lubricant, Then K_T= 0.85~0.8, and K_T= 0.9 if grease applied.

Table 5-8 The permissible temperature of each precision

The precision level of machine tool	
Normal Level	small-type Machine tool 45 - 50 large-scale Machine tool 50 - 55
Precision Level	35 - 40
High Precision Level	28 - 30

The bearing preload depends on the relative movement between inner ring and outer ring, and for a thrust bearing, the preload depends on the relative movement between bearing ring and seating. The preload can eliminate the clearance and achieve suitable interference. Preload can be divided into radial preload and axial preload based on the direction of preload, and and preload also can be divided into located preload and static preload. In actual operation, located preload is applied for ball bearings where as static preload is applied to cylindrical roller bearings.

5.3.2 Radial preload

Radial preload utilizes an interference fit between bearing and shaft seating, so that the radial clearance can be eliminated and the pre-deformation can be achieved through the bearing inner ring expanding or outer ring compressing.
For bearings with a tapered bore, different expansion can be achieved depending on the different locating of bearing inner ring on the cylindrical shaft seating. The preload structure illustrated in the design of support structure in this chapter.

5.3.3 Axial preload

(1) Located preload means the bearing is statically positioned in the axial direction, see figure 5-2. The preload can be achieved by the difference in width of spacer sleeve between two bearings or through the width of inner and outer ferrule on thin seating.
(2) Constant pressure preload means the bearing is under a static axial force, see figure 5-3. The preload can be achieved through the spring compression.

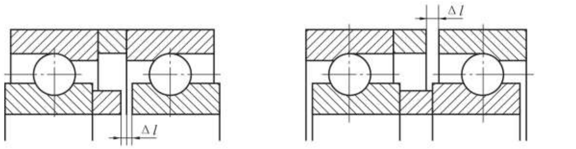


Diagram 5-2 Located preload

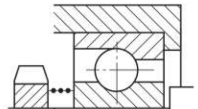


Diagram 5-3 Constant pressure preload

(3) The selection of located and constant pressure preload. For the same preload deflection, it is not possible to increase the axial stiffness of the support by constant pressure preload and the temperature has no impact on the distortion. For the located preload, the axial and radial expansion have an impact on a preload. Axial expansion induces preload by the temperature difference between bearing and housing, the same is true for radial expansion resulting from the temperature difference between bearing inner ring and outer ring, therefore the selection of preload must depend on the technical requirement in detail. Generally, the located preload is applied for high stiffness while the constant pressure preload is used for high speed.

5.3.4 Determining preload

Preload is mainly adjusted and controlled during mounting, this part of the bearing mounting procedure requires great care

The suitable preload depends on the value of bearing load and the requirement of usage, and can be confirmed by calculation in combination with practical testing and the bearing's actual rotation. Generally it can be divided into one of the below cases.

(1) Light preload is applied under high speed and light load, or to reduce the vibration and noise of support system, in order to improve running accuracy.

(2) Moderate and heavy preload are applied under moderate speed with medium load or low speed with heavy load, to improve the support stiffness.

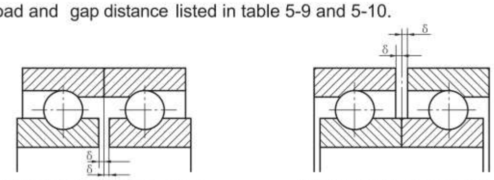
(3) Where the same type of angular contact bearings are mounted in a pair (figure 5-4), the additional axial preload Fa less than 2.83*Fao (Fao is preload). Otherwise, the situation of one bearing enduring entire axial preload should be avoided.

(4) Where the same type of taper roller bearing are mounted in a pair, the additional axial preload Fa is less than 2*Fao (Fao is bearing preload) Otherwise, the situation of one bearing enduring entire axial preload should be avoided.

(5) Regarding the preload of angular contact ball bearings that are mounted in face-to-face or back-to-back, UBC stipulates axial deformations under three preloads (light preload, moderate preload, heavy preload) for design convenience.

When paired bearings are mounted, there will be a gap between the inner and outer rings which is adjusted by pressing the bearings together. When paired bearings are mounted to the shaft and housing, preload of the bearings is achieved by applying pressure using certain methods, see Figure 5-4

This bearing preload and gap distance listed in table 5-9 and 5-10.



(a) Back-to back arrangement (b) Face-to-face arrangement

Diagram 5-4 Preload mounting of paired angular contact ball bearing

(6) Minimum axial preload. For angular contact ball bearing, taper roller bearing, thrust ball bearing, thrust roller bearing, have centrifugal forces acting on them when in rotation and there is the possibility of sliding between roller and raceway. To ensure the bearing functions properly, a certain axial preload must be used, the minimum axial preload Famin listed in table 5-11.

Table 5-9 The preload of angular contact ball bearing paired mounted

Preload / Bearing series	7000C			7200C			7000AC			7200AC			7200B			7300B		
d/mm	Light	Medium	Heavy	Light	Medium	Heavy	Light	Medium	Heavy	Light	Medium	Heavy	Light	Medium	Heavy	Light	Medium	Heavy
10	25	50	100	50	100	200	40	80	160	75	150	300	-	-	-	-	-	-
12	25	50	100	60	120	240	40	80	160	90	180	360	-	-	-	-	-	-
15	30	60	120	70	140	280	45	90	180	105	210	420	-	-	-	-	-	-
17	35	70	140	90	180	360	55	110	220	140	280	560	-	-	-	-	-	-
20	50	100	200	115	230	460	80	160	320	175	350	700	175	350	700	-	-	-
25	60	120	240	130	260	520	90	180	360	200	400	800	195	390	780	320	640	1280
30	80	160	320	180	360	720	110	220	440	270	540	1080	250	500	1000	400	800	1600
35	150	300	600	250	500	1000	210	420	840	380	760	1520	335	670	1340	470	940	1880
40	155	310	620	280	560	1120	220	440	880	435	870	1740	400	800	1600	580	1160	2320
45	190	380	760	310	620	1240	280	560	1120	480	960	1920	445	890	1780	735	1470	2440
50	200	400	800	330	660	1320	290	580	1160	500	1000	2000	480	960	1950	840	1680	3360
55	270	540	1080	410	820	1640	405	810	1620	620	1240	2480	570	1140	2280	970	1940	3880
60	280	560	1120	400	980	1960	430	860	1720	750	1500	3000	690	1380	1760	1010	2020	4040
65	280	560	1120	515	1030	2060	440	880	1760	780	1560	3120	780	1560	3210	1270	2540	5080
70	350	700	1400	560	1120	2240	530	1060	2120	850	1700	3400	865	1730	3460	1410	2820	5640
75	360	720	1440	640	1280	2560	540	1080	2160	970	1940	3880	900	1800	3600	1620	3240	6480
80	450	900	1800	690	1380	2760	655	1330	2660	1045	2090	4180	990	1980	3960	1660	3320	6640
85	460	920	1840	800	1600	3200	685	1370	2740	1220	2440	4880	1150	2300	4600	1820	3640	7280
90	550	1100	2200	945	1890	3780	850	1700	3400	1440	2880	5760	1310	2620	5240	1950	3900	7800
95	570	1140	2280	1085	2170	4340	875	1750	3500	1650	3300	6600	1485	2970	5940	2120	4240	8480
100	580	1160	2320	1200	2400	4800	895	1790	3580	1830	3660	7320	1600	3200	6400	2340	4680	9360
105	650	1300	2600	1340	2620	5240	1000	2000	4000	1995	3990	7980	1765	3530	7060	2485	4970	9940
110	780	1560	3120	1420	2840	5680	1190	2380	4760	2160	4320	8640	1895	3790	7580	2660	5320	10640
120	790	1580	3160	1530	3060	6120	1215	2430	4860	2330	4660	9320	-	-	-	-	-	-
130	940	1880	3760	1590	3180	6360	1460	2920	5840	2415	4830	9660	-	-	-	-	-	-

Note: The table doesn't list the preload of these bearings with inner diameter d>100mm.
7000C series: The light, medium, heavy preload equal 0.009, 0.018, 0.036 times dynamic load rating respectively.
7200C series: The light, medium, heavy preload equal 0.010, 0.020, 0.040 times dynamic load rating respectively.
7000AC series: The light, medium, heavy preload equal 0.015, 0.030, 0.060 times dynamic load rating respectively.
7200AC,7200B,7300B series: The light, medium, heavy preload equal 0.016, 0.032, 0.064 times dynamic load rating respectively.

Table 5-10 Bearing preload and gap distance

μm

$\Delta\delta_1+\Delta\delta_2$ (Face-to-Face or Back-to-Back), $\Delta\delta_1-\Delta\delta_2$ (Tandem)																			
Preload / Bearing Series / d/mm		7000C				7200C				7000AC 7200B				7200AC 7300B					
		Light Medium		Heavy		Light Medium		Heavy		Light Medium		Heavy		Light		Medium		Heavy	
>	≤ to	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max
-	18	-0.5	+0.5	-1	+1	-0.5	+0.5	-1	+1	-0.5	+0.5	-0.5	+0.5	-0.5	+0.5	-0.5	+0.5	-0.5	+0.5
18	30	-1	+1	-1	+1	-1	+1	-1	+1	-0.5	+0.5	-1	+1	-0.5	+0.5	-0.5	+0.5	-1	+1
30	50	-1	+1	-1	+1	-1	+1	-1.5	+1.5	-0.5	+0.5	-1	+1	-0.5	+0.5	-1	+1	-1	+1
50	80	-1	+1	-1.5	+1.5	-1.5	+1.5	-2	+2	-1	+1	-1.5	+1.5	-1	+1	-1	+1	-1.5	+1.5
30	120	-2	+2	-2	+2	-2	+2	-2.5	+2.5	-1	+1	-1.5	+1.5	-1	+1	-2	+2	-2	+2
120	150	-2	+2	-2	+2	-2.5	+2.5	-3	+3	-1	+1	-2	+2	-1	+1	-2	+2	-3	+3

Note: for these paired bearing with inner diameter d>150mm, the tolerance gap distance between two bearings is $\triangle\delta 1\pm\triangle\delta 2$, it is permitted that the gap distance is 1 μm larger than the value listed in the d = 120~150mm row.

Table5-11 Preload of angular contact ball bearing paired mounted

Bearing Types	Under Load *Famin*		Description
	Pure Axial Load	Combined Load	
Angular contact ball bearing	$\geq 0.35Fa$	$\geq 1.7F_r\mathrm{I}+\tan\alpha_{\mathrm{I}}-\frac{F_a}{2}$ $\geq 1.7F_r\mathrm{II}\tan\alpha_{\mathrm{II}}-\frac{F_a}{2}$	$F_r\mathrm{I}$ — Radial load supported by bearing I KN $F_r\mathrm{II}$ — Radial load supported by bearing II KN
Taper roller bearing	$\geq 0.5Fa$	$\geq 1.9F_r\mathrm{I}\tan\alpha_{\mathrm{I}}-\frac{F_a}{2}$ $\geq 1.9F_r\mathrm{II}\tan\alpha_{\mathrm{II}}-\frac{F_a}{2}$ Select larger one	α_{II} 、α_{I} – Contact angle of bearing Ⅰ，Ⅱ
Thrust ball bearing	$=A\left(\frac{n}{1000}\right)^2$		F_a — Axial load, KN
Cylindrical, taper roller thrust bearing	$\frac{Coa}{1000}\leq$Famin$>A\left(\frac{n}{1000}\right)^2$		F_r — Radial load, KN Coa — Bearing basic static load rating, KN (Listed in table of bearing dimension, 2 chapter)
Self-aligning roller thrust bearing		$\frac{Coa}{1000}\leq$Famin$>1.8F_r+A\left(\frac{n}{1000}\right)^2$	A — Minimum constant of load (Listed in table of bearing dimension, 2 chapter)
Thrust needle bearing		$\frac{Coa}{2000}\leq$Famin$>1.8F_r+A\left(\frac{n}{1000}\right)^2$	n — Speed, r/min

5.3.5 The control of preload and design of preload structure

In actual operation, it's difficult to achieve optimal clearance by calculation and measurement. For the last mounting step of angular contact ball bearing, taper roller bearing and taper bore double row cylindrical roller bearing, it is required to adjust clearance precisely, that is to say to control the preload. Especially, for these shafts that have a strict requirement of running accuracy, noise and temperature increase, such as shafts of machine tools, clearance needs to be adjusted not only during first time mounting, but also in operation. There are many methods for controlling preload. Several methods for controlling preload and the issues related to the design of preload structures are explained below.

(1) Several methods for controlling preload.

1. Measure the bearing rotational torque during acceleration. Measure the relationship between the bearing rotational torque and axial load in advance, so that the preload can be adjusted by controlling rotational torque. This method is often applied for the preload of a mounted pair of tapered roller bearings
2. Measure the bearing axial displacement. For taper bore bearing, measure the relationship between axial load and axial displacement in advance, so that the preload can be adjusted by controlling the axial displacement.
3. Measure the deformation of preload spring. Measure the relationship between the spring preload and deformation beforehand, so that the constant pressure preload can be adjusted by controlling the deformation.
4. Measure the holding torque of the nut. Adjusting the preload to control the holding torque of the nut when a bearing preloaded with a nut is used
5. Pad with bearing end plates (No.4 diagram in Table 5-3). Tightening the one bearing end plate, not shimming another bearing, and screwing down the bolt. If the shaft can't rotate freely, it means that there is no clearance between bearing and shaft, so measure the gap between the end plate and housing cover using a gauge, then the thickness of shim can be calculated by adding this gap and necessary clearance.
6. The length of the spacer sleeve of the inner ring can be calculated based on the length of the spacer sleeve of the outer ring and bearing dimension, and it also can be directly measured.

(2) Measurement and control of preload. At present, it's difficult to measure a bearing's preload while in operation with common tools, the most common method of measuring axial and radial displacement or rotational torque is by using a dial gauge and rarely by using using special instruments. Some bearing companies overseas detect and adjust the preload by using special instruments and have some tools for controlling the preload, to achieve the optimal preload.

(3) Some problems should be paid attention in the design of preload structure.

1. Application of compressed spring to constant pressure preload, and the spring dimension and parameter can be decided by calculation, the design is convenient for adjusting preload.
2. Though the located preload can meet the preload requirement, but the precision of initial preload will be affected when the bearing is running due to friction.Therefore, the design of preload structure should be convenient to adjust.
3. To achieve a simple and convenient means for adjusting preload, a spacer sleeve is placed between two inner rings or two outer rings, and the preload can be adjusted by nuts.
4. When adjusting preload by nuts, the selection of the design of the nut and the precision of its manufacture have a great impact on the control of preload and the adjustment precision.

5.4 Rolling bearing fit

5.4.1 Purpose of the load

The purpose of the fit is to firmly seat the bearing inner ring and outer ring with shaft and housing, and prevent harmful axial direction slippage of mating surfaces.

This will cause abnormal high temperature, mating surface wear (wear particles will enter the bearing) and vibration and other problems which will prevent the full function of the bearing.

The bearing is generally rotating with the load.

5.4.2 Tolerances and fit of shaft and housing

Metric series tolerances of shaft and housing bore by GB/T275-93 <<roll bearings with shaft and shell fit>> standardization .

For shaft and housing fit tolerances for bearing precision class P0, see figure 5-5

5.4.3 Selection of fit

General principles are below:

It must be taken into account whether the inner or outer ring is rotating and whether the load itself is stationary or rotating. A ferrule is used when there is interference fit for rotating loads or the direction of loading is indeterminate as well as for transition fit and clearance fit with a stationary load.

When the bearings have too large of a load, vibration and shock, the interference must be increased. For a hollow shaft, thin-wall housing, light alloy or plastic housing, the interference must also be increased.

For high precision applications, which use a high-precision bearing, more carefully control shaft and housing tolerances and avoid too large of an interference. If it is too large, it could it can affect the precision of the shaft and housing and negatively affect bearing rotating precision.

Interference is used with a non-separable bearing but such a bearing is not easy to mount and dismount as one using a clearance fit on the inner ring.

5.4.3.1 Property of the load

Basic load types, there are three different conditions: inner ring rotating load, outer ring rotating load and direction of load indeterminate, see figure 5-12.

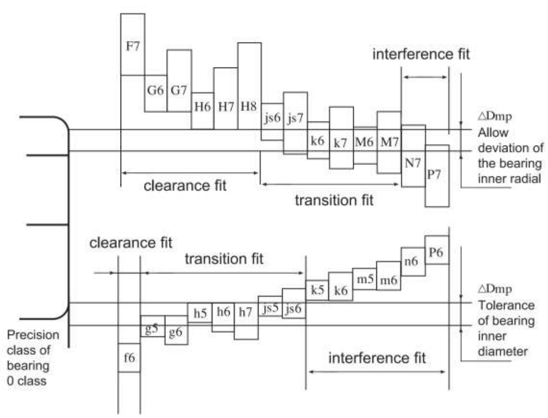
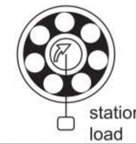
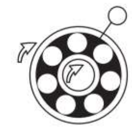
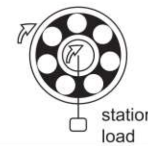
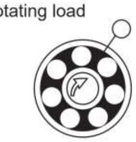


Figure 5-5 Shaft and shell fit relation of size tolerances
(Class P0 precision for bearing)

Table 5-12 Property of the load and fit of Relationship

Operating Conditions	Load Condition	Schematic Illustration	Recommended Fits
Rotating inner ring Stationary outer ring Constant load direction	 stationary load	Rotating load on inner ring Stationary load on outer ring	Interference fit for inner ring Loose fit for outer ring
Stationary inner ring Rotating outer ring Load rotates with outer ring	Rotating load 		
Stationary inner ring Rotating outer ring Constant load direction	 stationary load	Stationary load on inner ring Rotating load on outer ring	Loose fit for inner ring Interference fit for outer ring
Rotating inner ring Stationary outer ring Load rotates with outer ring	Rotating load 		

5.4.3.2 Magnitude of the load

The influence of a rotating load on a ring may cause it to creep, the degree of interference must therefore be related to the magnitude of the load.

Interference calculation:

[If $F_r \leq 0.25C_0$]

$$\Delta d_F = 0.08\sqrt{\frac{d}{B}\cdot F_r} \times 10^{-3} \quad \cdots\cdots (5\text{-}1)$$

[If $F_r > 0.25C_0$]

$$\Delta d_F = 0.02\frac{F_r}{B} \times 10^{-3} \quad \cdots\cdots (5\text{-}2)$$

Δd_F : Interference decrease of inner ring, mm
d : Nominal bore diameter , mm
B : Nominal width of inner ring, mm
F_r : Radial load , N(kgf)
C_0 : Rated stationary load , N(kgf)

So the heavier the load (C_0>25%), the greater the interference fit required, shock load needs to be considered.

5.4.3.3 Effect of surface roughness on mating surfaces

Taking into account the plastic deformation of matched surfaces, the quality of the surfaces will affect effective interference

See formula:

[ground shaft] $\Delta d_{eff} = \frac{d}{d+2} \Delta d$ .... (5-3) [turned shaft] $\Delta d_{eff} = \frac{d}{d+3} \Delta d$ .... (5-4)

Δd_{eff} : Effective interference, mm
Δd : Diametrical interference, mm
d : Nominal bore diameter , mm

5.4.3.4 Temperature influence

Generally speaking, the bearing's temperature is higher than its surroundings when running, and the inner ring temperature is higher than its shaft. So, the effective interference is diminished by heat expansion. If Δt is difference in temperature between the bearing inner and diminished, so (0.10-0.15) Δt is difference in temperature between inner and shaft.

So interference outer (Δdt) can be calculated by formula(5-5)

$$dt = (0.10\text{-}0.15)\,\Delta t \cdot a \cdot d \qquad \Delta dt = 0.0015\,\Delta t \cdot d \times 10^{-3} \text{......} \ (5\text{-}5)$$

Δdt: Interference reduction, mm
Δt: Difference in temperature between the bearing inner and shaft, °C
a: thermal expansion factor of bearing steel, (12.5×10^{-6})1/°C,
d : Nominal bore diameter , mm

So, when the bearing temperature is higher than shaft temperature, there must be an interference fit.
In addition, between the outer ring and the housing, due to the difference in temperature or different coefficient of thermal expansion, sometimes the interference will increase. Therefore, it is necessary to pay attention to this point when considering avoiding shaft's thermal expansion by taking advantage of the sliding between the outer ring and the housing mating surface.

5.4.3.5 Ideal fit produced by bearing inner ring

When mounting a bearing using an interference fit, and stress is produced by the shrinking and expansion of the ferrule.
The optimal stress for the bearing inner ring can be calculated by formula(table 5-13). In general, it is best if the interference is not more than 1/1000 shaft diameter or the max. stress σ calculated as per table 5-13 should not be more than 120MPa.

5.4.3.6 Others

When high precision is required, shaft and housing tolerances should be controlled more carefully but it is difficult to control housing bore tolerance, so a looser fit between housing bore and outer ring is allowable

When using hollow shaft, thin wall housing, light alloy and cast aluminum, that fitting must be tighter than others.

When using a separable housing, it should be a loose fit with the outer ring.

Table 5-13 The ideal stress produced by inner ring fit

shaft and Inner Ring		Crust Bore and Inner Ring	
(hollow shaft)	$\sigma = \frac{E}{2} \cdot \frac{\Delta d_{eff}}{d} \cdot \frac{\left[1 - \frac{d_o^2}{d^2}\right]\left[1 + \frac{d^2}{d_i^2}\right]}{\left[1 - \frac{d_o^2}{d_i^2}\right]}$	$(D_h \neq \infty)$	$\sigma = E \cdot \frac{\Delta D_{eff}}{D} \cdot \frac{\left[1 - \frac{D^2}{D_h^2}\right]}{\left[1 - \frac{D_e^2}{D_h^2}\right]}$
(solid shaft)	$\sigma = \frac{E}{2} \cdot \frac{\Delta d_{eff}}{d} \cdot \left[1 + \frac{d^2}{d_i^2}\right]$	$(D_h = \infty)$	$\sigma = E \cdot \frac{\Delta D_{eff}}{D} \cdot$

δ: Target stress, MPa(kgf/mm2)
d : Nominal bore diameter , mm
di: diameter of inner raceway, mm
Ball bearing…di=0.2(D+4d)
Roll bearing …di=0.25(D+3d)
Δd_{eff} : Effective interference of inner ring, mm
d_o: hollow shaft diameter, mm

D_e: Housing bore diameter,mm
Ball bearing…d_e=0.2(D+4d)
Roll bearing …d_e=0.25(D+3d)
D: Nominal outer diameter, mm
ΔD_{eff} : Effectual interference of outer ring, mm
D_h: Housing outside diameter, mm
E: elastic modulus, 2.08×10^5MPa(21200kgf/mm2)

5.5 Rolling bearings lubrication

During rolling bearing rotation,friction exists between the components, and the purpose of lubrication is to form lubricating film on contact surfaces to reduce friction, and lubricant also inhibits wear and protects the bearing surface against corrosion,and lowers vibration and cools the bearing. Therefore, if rolling bearings are to operate reliably they must be adequately lubricated to increase the working performance, and to prolong service life. It's very important to select appropriate lubricant, methods of lubrication and lubricant volume.

The main types of lubrication are greases, lubricating oil and dry lubricant used for rolling bearing lubrication.

5.5.1 Grease lubrication

5.5.1.1 The sorts, characteristics and applications of lubricating grease

Lubricating greases are a semisolid lubricant and is made of a base oil, thickener and additive, the base oil makes up 70 - 95 percent of the volume, thickener is 5 to 30 percent of the volume, and the proportion of additives is minimal. The base oil of lubricating grease is mineral oil or synthesized oil of silicone oil and diester oil, the viscosity of base oil plays a key role in lubricating greases.

The thickening ingredient has an important effect on grease performance, especially for temperature performance, water resisting property and decanted performance.

Thickeners can be divided into metal soap base and non-soap base.

The inclusion of additives is mainly used enhance the performance of the lubricating grease with regards to oxidation resistance,rust prevention and extreme pressure. A lubricating grease with extreme pressure additives should be employed for conditions of heavy or shock loading. If there is a requirement for the grease to last for a long time and not be replenished, then a oxidation-resisting grease is preferred.

The lubricating grease can be divided into calcium base, sodium base, calcium-sodium base, aluminum base, lithium base, barium base and alkyl base based on thickener type. The common lubricating grease types, general characteristics and applications are listed in table 5-14. We should pay attention to that, even among the same type grease, the performance varies because of the different designation.

Different types of greases generally should not be mixed in an application because the greases' performance will drop as a result of the mixing of different thickeners.

Calcium base lubricating grease: Water immiscible, lower drop point, and applicable to bearing components under lower temperature, environmental moisture.

Sodium base lubricating grease: Good water resistance property, higher drop point, and applicable to mechanical components exposed to moisture and in contact with water.

Aluminum base lubricating grease:Good water resistance property, and applicable to parts in water contact. Suitable for the lubrication and corrosion prevention for centralized lubrication system and parts of shipping machinery.

Barium base lubricating grease: Good water resistance, higher drop point, gasoline and alcohol immiscible and is applicable for lubrication of friction part of oil pump and water pump.

Lubricating grease can be divided into several classes based on liquidity.

The larger the liquidity, the softer the lubricating grease. The application of lubricating greases with different liquidities are listed in table 5-15. The application temperature range of special lubricating grease is listed in table 5-16.

Table 5-14 General characteristics and applications of lubricating grease

Grease			Penetration Number (10^{-1}mm)	Pour Point ℃≥	Components	Performance and Application
	Name	Designation				
Calcium base	Calcium base grease	ZG-1 ZG-2 ZG-3 ZG-4 ZG-5	310-340 265-295 220-250 170-205 130-160	75 80 85 90 95	Fatty acid calcium soap thickener, moderate viscosity mineral oil	Good water resistance,applicable for agriculture and transportation machine. Running temperature for types 1 and 2 grease no higher than 55℃, 3 and 4 grease no higherthan 60℃, 5 grease no higher than 65℃.
Calcium base	Synthesis calcium base grease	ZG-2H ZG-3H	270-330 220-270	75 85	Synthesis fatty acid calcium soap thickener with moderate viscosity mineral oil.	Application as above, Running temperature for type 1 grease no higher than 55℃, 2 grease no higher than 60℃,
Calcium base	Synthesis compound calcium base grease	ZFG-1H ZFG-2H	310-340 265-295	180 200		
Calcium base	Synthetic compound calcium base grease	ZFG-3H ZFG-4H	220-250 175-205	220 240		Good mechanical stability and colloid stability, applicable to high temperature condition
Calcium base	Compound calcium base grease	ZFG-1 ZFG-2 ZFG-3 ZFG-4	310-340 265-295 210-250 175-205	180 200 224 240	Fatty calcium soap compounded calcium acetate thickening oil	Applicable to running temperature between120℃-180℃ respectively, such as machines before rolling mill, dyeing, papermaking, plastic, roller for heating rubber.
Sodium base	Sodium base grease	ZN-1 ZN-2 ZN-3	265-295 220-250 175-205	140 140 150	natural fatty acid sodium soap thickening oil	Applicable to various machine, thermo stabilization and non water resisting the running temperature is 2 and 3 grease no higher than 120℃, 4 grease no higher than 135℃,
Sodium base	Synthetic sodium base grease	ZN-1H ZN-2H	225-275 175-225	130 150	synthetic fatty acid sodium soap thickening oil	Applicable for the lubrication of automobiles, tractors and other machinery that has no contact with moisture
Calcium -sodium base	Grease for rolling mill	ZGN40-1 ZGN40-2	310-355 250-295	80 85	Calcium-sodium soap thickening cylinder oil with hardened oil and sulfuration cotton seed oil	Good pump over and extreme pressure. Applicable to calendar which center supplied grease, 1 grease applied in winter, and 2 in summer.
Calcium -sodium base	Grease for rolling bearings		250-290	120	synthetic gas and engine oil with castor oil calcium-sodium soap thickening No.6.	Good mechanical stability and colloid stability, applicable to ball bearing under temperature less than 90℃ condition, such as bearings used in guide rod locomotive, auto and motor.
Aluminum base	Aluminum base grease	ZU	230-280	75	Fatty acid aluminum soap thickening oil.	Good water resistance, and applicable to application for lubrication for parts of shipping machinery. and rust prevention of metal.
Aluminum base	Synthetic compound aluminum base grease	ZFU-1H ZFU-2H ZFU-3H ZFU-4H	310-350 260-300	180 200 220 240	Low-molecular organics acid or aluminum soap thickening oil compounded benzoic acid and synthesis fatty acid.	High pour point, Good mechanical stability and colloid stability, and applicable for lubricating bearings used in railway machinery, auto, water pump, and motor, the running temperature is 150℃ -180℃.
Lithium base	Common lithium base grease	ZL-1 ZL-2 ZL-3	310-340 265-295 265-295	170 175 180	Antioxidant mixed into natural fatty acid lithium soap thickening with moderate viscosity oil.	Good water resistance, mechanical stability, rust prevention and outgassing stability, applicable to rolling and sliding bearings and others wearing part of various machine equipment with -20℃-120℃usage temperature.
Lithium base	Extreme pressure lithium base grease	0 1 2	355-385 310-340 265-295	170	As above	Good water resistance, mechanical stability, rust prevention, extreme pressure anti-wear and pumpability. Applicable to bearings and gears of rolling mill, forging machine, reducer and other heavy equipment with -20℃ -120℃ usage.
Lithium base	Synthetic lithium base grease	ZL-1H ZL-2H ZL-3H ZL-4H	310-340 265-295 220-250 175-205	170 180 190 200	Synthetic fatty acid lithium soap thickening with moderate viscosity oil	Base is natural lithium soap, and the same as usage condition.
Lithium base	Grease for shaft of precision machine tool	#2 #3	265-295 220-250	180 180	Lithium soap thickening oil with lower viscosity and lower solidifying point.	Antioxidant, colloid stability and mechanical stability, applicable to various precision machine tools.
Lithium base	Grease for precision instrument	ZT 53-7 ZT 53-75	35 45	160 140	Harden fatty acid lithium soap ozocerite thickening oil applied for instrument.	Applicable to precision instrument and instrument bearing. The running temperature is -70℃ -120℃ for special No.7, -75℃-80℃ for special No.75.

Rolling Bearing Lubrication and Seals UBC

Grease		Desig-nation	Penetration Number (10^{-1}mm)	Pour Point °C≥	Components	Performance and Application
Barium base	Barium base	ZB-3	200-260	150	Fatty acid barium soap thickening with moderate viscosity oil.	Resistant to water, and resistant to heat handles extreme pressure. Applicable to suction pump, marine propeller and heavy machines under high temperature, high pressure and wet working condition.
	Multi effective seal grease	ZB 10-2	260-330	110	Harden fatty acid barium soap thickening with lower solidifying point used for transformer.	Applied for junction seal between alcohol, engine oil, water and air, it also applied in rolling bearings with rapidly changing speed.
Alkyl base	Grease for instrument	ZT 53-3	230-265	60	Ozocerite thickening instrument oil.	Applicable to instruments with -45°C-160°C running temperature.
	Grease for precision instrument	ZT 53	30	70		
	Lubrication grease	ZT-11	160	70		Applicable to precision bearings with high speed and the running temperature is -45°C-160°C.
Grease for high speed bearings		7018	64-78	260		

Table5-15 Penetration number and usage condition

Penetration Number	0	1	2	3	4
Penetration Value/ 10^{-1}mm	385-355	340-310	295-265	250-220	205-175
Application circumstances	Easy to smear on	Low temperature and easy to smear on	Common sealed ball bearings	High temperature sealed ball bearings	High temperature and sealed by grease

Table5-16 Usage temperature range of special lubricating grease

Designation of Lubricating Grease	7001	7007	7008	7011	7012	7013	7014	7014-1
Usage Temperature Range (°C)	-60-+120	-60-+120	-60-+120	-60-+120	-60-+120	-70-+120	-60-+200	-40-+200
Designation of Lubricating Grease	7014-2	7015	7016	7017	7018	7019	7020	221
Usage Temperature Range (°C)	-50-+200	-70-+180	-60-+230	-60-+250	-45-+160	-20-+150	-20-+300	-60-+150

5.5.1.2 The injection volume of lubricating grease

The injection volume of lubricating grease has an important effect on bearing working performance, and It has been verified in theory and practice that it is acceptable to inject grease to 1/3 to 1/2 of the total free internal volume,If more lubricating grease is injected, there is a waste of grease, increased bearing friction and temperature, the grease softens due to frothing, the result is worsening lubrication.

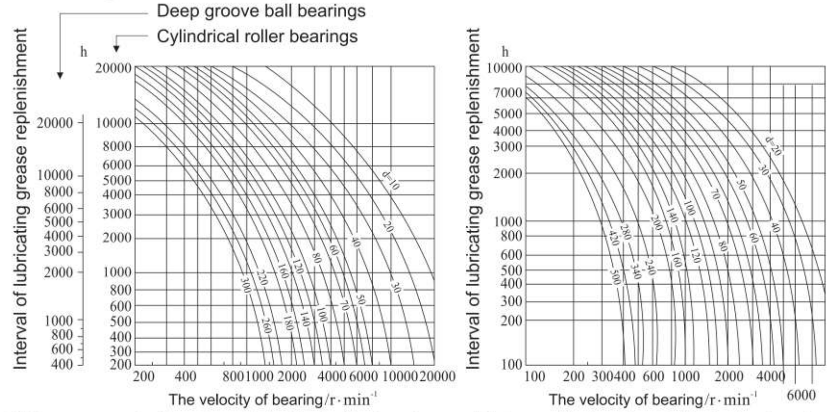
Generally the volume of grease applied should decrease as speed increases, the injection volume of grease should be only 1/3 or less when at high speed (>3000rpm). If speed is very low, pack the bearing full of grease to prevent external contaminants from penetrating.

5.5.1.3 The replenishment and renewing of lubricating grease

There is a limit of lubricating grease service life, and because of shearing force and ageing, its lubrication performance is gradually reduced and breakdown increases during operation, Therefore, lubricating grease must be replenished or renewed at a given interval. The cycle of replenishing grease is related to bearing structure, dimension, speed, temperature, environment condition.

Figure 5-6 is the cycle of replenishment for lubricating grease. The time for replenishment of lubricating grease can be found out based on bearing inside diameter and speed.

This figure was diagramed at conditions when the temperature of bearing outer diameter surface was 70°C, therefore this figure is applicable to the conditions in which the bearing's temperature is below 70° C,if the temperature exceeds 70°C, the replenishment cycle will be half for each increase of 15°C. The replenishment cycle will be shortened to 1/2-1/10 of illustrated value under significant contamination in the bearing and low seal reliability.



(a)Deep groove ball bearings,Cylindrical roller bearings (b)Taper roller bearings,Self-aligning bearings

Figure 5-6 The interval of replenishment of lubricating grease

5.5.2 Oil lubrication

5.5.2.1 Method of oil lubrication

(1) Oil bath. This method often applied for low and moderate speed bearing lubrication. Part of the bearing is soaked in the oil sink, the oil, which is picked up by the rotating components of the bearing, is distributed within the bearing and then flows back to the oil bath. The oil level should be such that it almost reaches the centre of the lowest rolling element when the bearing is stationary.

(2) Oil Wick This method often applied for high speed small size bearing lubrication, the oil transported by a rotating collar at given intervals. The minimum quantity can be obtained by test.

(3) Splash lubrication.Through the turning of gear or simple vane, the bearings are lubricated.This method is widely applied in auto gear box, differential gear box and machine tool gear-box. The surface velocity of splashing wheel does not exceed,12m/s, and oil immersion depth is 10-20mm.

(4) Circulating oil. The filtered lubrication is transported to bearing components by oil pump. Filtered lubrication oil which has passed through the bearing again,, and the lubricating oil can be reused after it has cooled.The bearing temperature decreases as the oil circulation removes some heat, so this method is applicable to bearings with high speed. Filter equipment of circulating oil system can eliminate debris and contamination from upper system, and can keep viscosity in optimal range by installation of a control valve for constant temperature.

The circulating oil quantity can be seen in figure 5-7. If the application of circulation oil is not needed for a larger system, but for bearing lubrication, a small quantity of oil is needed. If the application is for a larger system, a large quantity of oil needed to prevent oil from accumulating inside of the bearing because of resistance induced by oil passing through the bearing, the upper limit of oil quantity can be determined by b and c in diagram. The oil quantity supplied in a given time to achieve satisfactory working temperature depends on the rates of heat emission and radiation, and often needs test runs.

(5) Oil jet. High pressure oil applied by a jet into bearing by oil pump, and flowing into an oil sink after passing through the inside of the bearing.In a high-speed bearing, while rotating, rolling elements and cage also rotate at high speed so that an air flow is created, thus increasing resistance.

So this method must be used because it's very difficult to input oil into bearing by general method. The position of the nozzle should point to the gap between inner ring and cage.

The oil quantity required for oil injection mainly depends on heat emission from oil. Table 5-17 lists the approximate oil quantity that oil injection requires, and the quantity related to bearing diameter. The diameter of nozzle and oil pressure depends on the oil quantity. if oil pressure before nozzle isn't larger than 10MPa, ozzle diameter can be 0.7-2mm. In oil injection system, an oil filter is needed to avoid the nozzle becoming clogged

(6)Oil Mist. Clean, filtered, dried, compressed air is mixed into the lubricating oil to form mist, and then applied using a jet into bearing Airflow in bearing housing can cool the bearing, and the pressure induced in housing can prevent contamination entering.The quantity can be accurately adjusted, and the churning resistance is small. This method is applicable for lubricating bearings with high speed and high temperature.

(7) Oil metering system is applied to transport a small quantity of oil into compressed airflow in a pipe at given intervals, in order to form a continuous oil flow on pipe wall, to supply to the bearing. The oil should not be old as it must be replenished frequently. External contamination does not easily enter the bearing because of compressed air. The pollution to the environment is greatly decreased because a smaller quantity of oil is supplied in comparison to oil mist. Lubrication oil quantity is small and stable, smallrotational torque, low temperature increaseand this method is especially applicable to high speed bearing.

Attention should be paid to the oil pump effect, and the oil lubrication point should be placed between bearing cage and inner ring in the design and be directed to the contact of inner ring raceway and rolling elements.

5.5.2.2 The selection of oil lubrication

Generally, mineral oil without additives included is used for rolling bearing lubrication. Only in some special circumstances, a mineral oil with an additive is used to enhance lubrication performance, such as withstanding extremely high pressure and protecting against degradation, Synthetic oil is applied only in some special case,such as the temperature or speed is extremely high or low.

Viscosity is one of the important performance indexes, and is the main basis for selection suitable oil lubrication.

The viscosity of oil is temperature dependent, becoming lower as the temperature rises. In order for a sufficiently thick oil film to be formed in the contact area between rolling elements and raceways, the oil must retain a minimum viscosity at the operating temperature. If viscosity is too low, oil film can't be formed,and it can lead to abnormal bearing friction and service life lower. If viscosity is too high, the dynamic loss is increased because of the heat emission induced by viscosity resistance.

a-Lubrication with sufficient oil
b-The upper limitation of symmetrically bearing
c-The upper limitation of asymmetric bearing

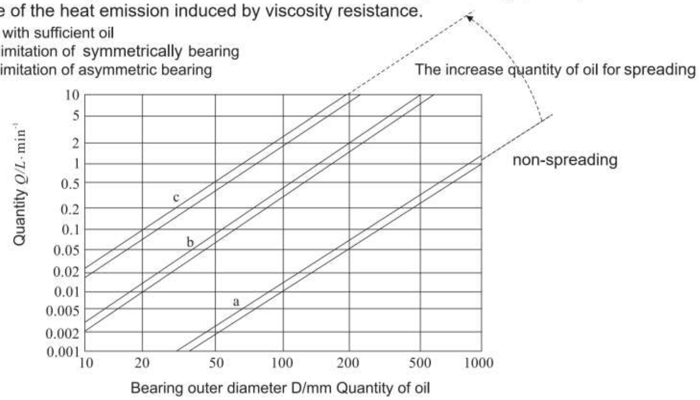


Figure5-7 The quantity of circulating oil

Table 5-17 Quantity of injection oil

Bearing inside diameter /mm	>		50	120
	≤	50	120	
Quantity of oil <	L/min	0.5-1.5	1.1-4.2	2.5

Generally speaking, low viscosity oil is applicable for high speed applications and viscosity changes as bearing size and applied load increase. Under bearing running temperature, the viscosity of lubricant is generally no less than 13mm^2/s for ball bearings, and 20mm^2/s for roller bearing, and 32mm^2/s for thrust self-aligning bearing.

The requirements of bearing dynamic viscosity at running temperature are listed in Figure 5-8. If running temperature is given, the viscosity of lubrication oil can be found by referring international standard reference temperature 40°C (or other temperatures) through figure5-9.The figure 5-9 diagramed at viscosity index VI is 85.

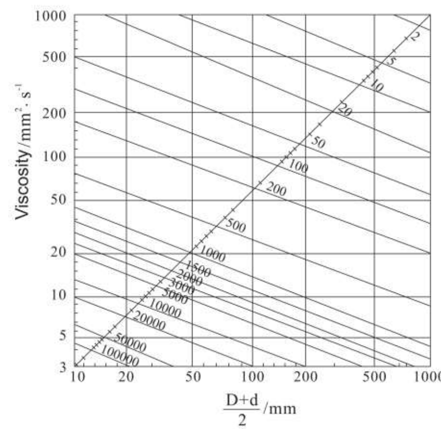


Figure5-8 Suitable lubricating oil (Left)

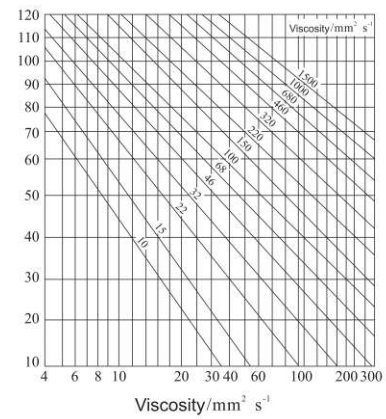


Figure5-9 The relationship of viscosity and temperature (Right)

5.5.2.3 Bearing oil

Bearing oil.Used for on a shaft, bearing and clutch, L-FC is the designation for anti-oxidant and anti-rust; L-FD is designation of antioxidant, antirust and anti-wear. The standard listed in Table 5-18.

Table 5-18 Bearing oil

Description	Quality Index										
Variety	L-FC										
The Class of Quality	One Level Production										
Motion level (GB 3141)	2	3	5	7	10	15	22	32	46	68	100
Dynamic viscosity (40℃)/$mm^2.s^{-1}$	1.98 - 2.42	2.88 - 3.52	4.14 - 5.06	6.12 - 7.48	9.00 - 11.0	13.5 - 16.5	19.8 - 24.2	28.8 - 35.2	41.4 - 50.6	61.2 - 74.8	90 - 110
Pour point/℃ No higher than			-18					-12			-6
Flash point (open point)/℃ No less than		-		115		114		160		180	
(close point) No less than	70	80	90								

The Class of Quality	One Level Production							Quality Production						
Motion level(GB 3141)	2	3	5	7	10	15	22	2	3	5	7	10	15	22
Dynamic viscosity (40℃) /mm^2 s^{-1}	1.98 - 2.42	2.88 - 3.52	4.14 - 5.06	6.12 - 7.48	9.00 - 11.0	13.5 - 16.5	19.8 - 24.2	1.98 - 2.42	2.88 - 3.52	4.14 - 5.06	6.12 - 7.48	9.00 - 11.0	13.5 - 16.5	19.8 - 24.2
Pour point/℃ No higher than				-12							-			
Flash point (open point)/℃No less than		-		115		140								
close point)No less than	70	80	90					60	70	80	90	100	110	120

5.5.2.4 The frequency of bearing oil replacement

The frequency with which it is necessary to change the oil depends mainly on the operating conditions and the quantity of oil.
With oil bath lubrication it is generally sufficient to change the oil once a year, provided the operating temperature does not exceed 50 °C and there is little risk of contamination. Higher temperatures call for more frequent oil changes, e.g. for operating temperatures around 100 °C, the oil should be changed every three months. Frequent oil changes are also needed if other operating conditions are arduous.
With circulating oil lubrication, the period between two oil changes is also determined by how frequently the total oil quantity is circulated and whether or not the oil is cooled. It is generally only possible to determine a suitable interval by test runs and by regular inspection of the condition of the oil. The same applies for oil jet lubrication. With oil mist and oil air lubrication the oil only passes through the bearing once and is not recirculated.

5.5.3 Solid lubricant

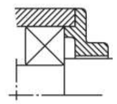
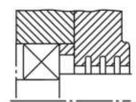
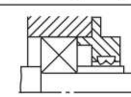
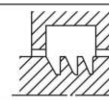
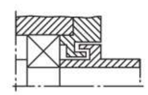
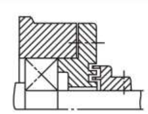
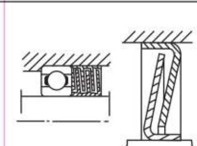
Solid lubricant is applied under some special situations such as applications which limit the use of lubricating grease and oil. This method can be divided into five types:
(1) Solid lubricant mixed into lubricant. Generally, 3% or 5% of No.1 supramoly mixed into lubricating grease.
(2) Lubricant adhered to the raceway, cage and rolling elements by adhesives to form solid lubrication film.
(3) Solid lubricant mixed into engineering plastics and powder metallurgy material, and made into bearing components with self lubrication function.
(4) Small groove or gouge carved on sliding part of bearing, then embedded in combined materials of solid lubricant with relevant shape, or directly inlaid into the combined material of solid lubricant on retaining surface or raceway.
(5) With techniques such as electroplating, high frequency sputtering, ion plating, chemical deposition and etc, solid lubricant or soft metal is formed into a uniform dense film on the rubbing surface of bearing components.

5.6 Rolling bearings seals

5.6.1 Type of seals and performance

The purpose of a seal is to help the bearing to reach its maximum service life and reliability, and to retain lubricants, preventing contamination and water entering into bearing.
Seals can be divided into static seals and dynamic seals, and the dynamic seals can be divided into rotation seals and moving seals, and the rotation seals also can be divided into contact rotation seals and non-contact rotation seals based on whether there is gap between two adjoining planes. There are many types of seal structure, and Table 5-19, Table 5-20, table 5-21 list common seal types and performances.
Additionally, there are bearings with shield or seal, and are prepacked with a suitable quantity of grease before mounting. These bearings can retain lubricant as well as prevent contamination from entering into bearing under normal working condition without external seals. These types of bearings have a simple structure and save space.

Table 5-19 Non-contact rotation seal type and performance

Seal Types		Diagram	Performance and Application
Slit seals	Gap type seal		The effectiveness of the seal increases as the gap between shaft and end plates gets smaller and the axial width becomes longer. It is suitable for clean running condition with grease lubrication. Generally the size of gap is 0.1-0.3mm.
	Seal groove type seals		There are 2-4 grooves on the cover arrangement surface, and prepacked grease to enhance seal effectiveness. The dimension can be found in Table 6-40, generally, radial gap is 0.1-0.3mm.
	W shape groove seals		Applied for oil lubrication. There is oil groove on the shaft or sleeve to return leaking oil. A return chute on the wall of the bore of the cover recovers it into the bearing (or housing) .
	Helical groove seals		The vertical surface of oil groove seals is perpendicular to the direction of oil flow. It's very suitable for shaft of machine tool.
Labyrinth seals	Axial labyrinth seals		Axial labyrinth seals feature a gap between sleeve and cover. But the labyrinth extends radially and so the number of circuits isn't able to be too many. The axial labyrinth seals are more widely used than radial labyrinth seals because of easy mounting and dismounting and not requiring a split housing.
	Radial labyrinth seals		Radial labyrinth seals are composed of gap between sleeve and cover and labyrinth extends axially but is radially compact. The effectiveness of seal reliability increase as the number if circuits rises. The radial labyrinth seals are applicable for dirty condition, such as working end of machine tool for metal cutting,seal dimension listed in Table 6-41.
	Sealing washers		Labyrinth seals made by thin steel plate,and it is possible to stack any number of labyrinth seals. They are simple in structure, low cost and space saving. The seals must be mounted with special care, and pay attention to whether there is interference between labyrinth seal and the axial space constraints of bearing,and whether there is interference between seals and shaft deflection when applied to self-aligning bearings.

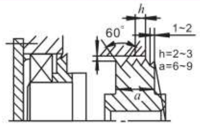
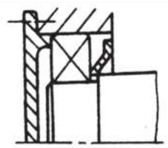
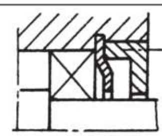
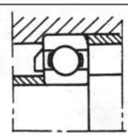
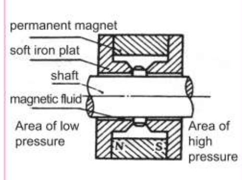
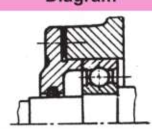
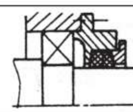
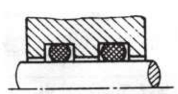
Seal Types		Diagram	Performance and Application
Sealing ring	Oil flange disk		Oil flange disk rotates with shaft, the effectiveness of the seals becomes greater with higher speed, and it can not only retain oil, but also exclude contamination entering into bearings, mainly applicable for bearing seals with grease lubrication.
	Dynamic seals		Stamped from thin metal plate, dynamic seal rings rotate with the shaft and are applicable to sealed bearings with oil lubrication, relying on centrifugal force to eject oil and impurities, to prevent external pollution.. The static seals ring fixed with outer ring are mainly applicable for bearing seals with grease lubrication. Seal rings integrated with the shaft by turning on a lathe also can act as an effective seal.
	Static seals		
	Spring seals		Stamped from thin spring steel plate, and fixed on inner ring or outer ring cover of bearing, held to another outer ring cover by it's own spring force. It is often applied for bearings with grease lubrication, and structure is compact, and has good effectiveness.
Magnetic fluid seals			It is a newly developed type of seal and the basic theory is to use ferromagnetism particulate (0.2-1)*102um to form a stable solvent gel (magnetic fluid) in lower volatility liquid, and can form tenacious liquid film by the action of a magnetic field in gap between seals to prevent leakage, its advantage is that it has almost unlimited service life, and no leakage under larger pressure difference, and no strict requirement on roughness of shaft surface and runout.

Table 5-20 Contact rotation seal type and performance

Seal Types		Diagram	Performance and Application
Felt seals	Single felt ring		Groove filled with felt ring to achieve seal contact surface between felt ring and shaft surface, and applicable to grease lubrication, the circular velocity is less than 5m/s, and relative groove dimension listed in Table 6-31.
	Double felt ring		The gap can be adjusted by felt ring, good effectiveness of seal, and convenient to replace.
Rubber ring	Rubber o-ring		The compression of the seal by the mounting groove, the effectiveness of loosening prevention and the mitigation against damage of the threads can be enhanced by the force of gravity. Rubber o-ring has sealing ability in both directions, and there are single seal ring and double seal ring. The effectiveness of prevention of loosening and mitigate against damage of the threads of double seal ring is greater than for a single ring, and the dimension of seal ring and groove listed in table 6-38,6-39 and 6-40.

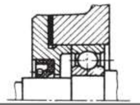
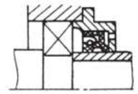
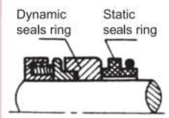
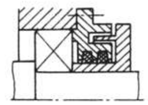
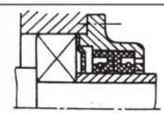
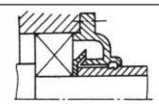
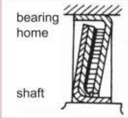
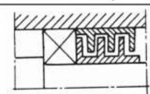
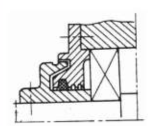
Seal Types		Diagram	Performance and Application
Rotary shaft lip seals	Single lip		Mainly applicable for oil lubrication seals for situations with a the shaft speed no larger than 7m/s and temperature no higher than 100℃. It is also applicable for grease lubrication seal. There are six basic types of rotary shaft lip seals (the basic types listed in table 6-43). The double lip should be applied under the condition of more external dust, water and contamination, seal ring is suitable for large scale and precision equipment.
	Double lip (Vice-lip)		
Mechanical seals			The dynamic ring is made of graphite or plastic and rotating with shaft, static ring is made of metal or ceramic. Under the axial force of the spring, magnetic force or fluid pressure, the dynamic ring and the static ring are tightly compressed to achieve sealing. The structure types and material varies depending on usage condition and types of seal structure structure. The mechanical seal has high seal reliability and less leakage, and can work under harsh conditions. The shaft speed should be no larger than 150 rpm,it can handle pressure larger than 35 MPa, the running temperature is [seems incorrect value]

Table 5-21 Compound seal

Seal Types	Diagram	Performance and Application
combination of labyrinth and felt seals		Good seal effectiveness, and applicable for oil or grease, the contact circular velocity no higher than 7m/s.
combination of oil flange and lip ring seals		Good seal effectiveness, and applicable to oil or grease, the contact circular velocity can be larger than 7-15m/s.
combination of oil slinger W shape and slit seals		No lose due to friction, Good seal effectiveness, and applicable to oil or grease seals, no limitation of circular velocity, the effectiveness of seal greater as circular velocity rises.
combination of stamped and labyrinth seals		Stamped from sheet metal, and there is contact seal laid in the middle. Good seal effectiveness, and complex structure, not applicable to high speed, and suitable for mass production.
combination labyrinth seals		Labyrinth seal combined by two "┌" shape gasket, compact size, lower cost, and suitable for mass production. The gaskets can be installed simultaneously.
combination of labyrinth,felt and oily groove seals		Combining the merits of labyrinth, felt and oil groove seals, Good seal effectiveness, contact seal, and isn't applicable to high shaft speed, and its structure is complex.

5.7 Mounting and dismounting of rolling bearings

The quality of rolling bearing mounting and dismounting will directly impact bearing precision, life and performance, so, bearing mounting and dismounting must be done according to requirements with the correct procedure and tools.

5.7.1 The preparation for bearing mounting.

1) Be familiar with installation drawing and technical files and be sure to be familiar with mounting techniques and have the proper tools. By analysis of drawing and technical file, it is possible to determine bearing characteristic and requirement, draw out a mounting scheme, plan, program and tools. When there is a special requirement for bearing mounting, choose the best mounting technique to guarantee mounting quality.

2) Checking bearing type. Check bearing casing type is the same as the installation drawing before mounting.

For a bearing with special requirements, for example: high temperature bearing, bearings with no basic clearance and bearings with special class, it is the same as with general bearings but they need to be checked more carefully and/or separated in storage.

3) Cleaning bearing. A bearing should be installed in a dry, clean environment. Mounting should be away from machining metalworking or other machines producing chips and dust.

The bearings need to be left in their original packages until immediately before mounting so that they will not be exposed to any contaminants, especially dirt.

Use gasoline or kerosene to clean corrosion-resistant bearings, but for corrosion-resistant bearings with anti-rust grease or thick oil, first clean by dissolving the grease / oil in 95 -100 C light mineral oil. After anti-rust grease has melted, then use gasoline or kerosene to clean.

When cleaning a few bearings, put immediately in an oil bath. When cleaning lots of small and medium bearings, put into a wire net and immerge this in an oil bath. When cleaning lots of large size bearings, the best method is using a cleaning machine.

4) In addition to cleaning the bearings, careful check if the face has a burr, markings or contaminants on the shaft bore, lining, end closure and separate ring, and these must be cleaned with gasoline or kerosene to prevent contaminants from entering the bearing.

5) Measuring and matching bearings and its parts. The precision of the fit between the bearing, inner ring and interrelated parts must be maintained. When mass produced, the the precision of fit is ensured in the manufacturing process.

For sensitive applications, such as the bearings of steel rolling machine, railway locomotive, high speed diesel engine, High-accuracy CNC machines and so on,it is important to carefully check that all parts match drawing prior to mounting.

For low-runout shaft, for example, the principle axis of a high-accuracy machine tool, so as to increase runout accuracy of principal axis parts, in addition to choosing a high-accuracy bearing, choose a high-accuracy shaft and more accurate housing bore to match accuracy of the bearing.

Measure the inner ring diameter and shaft prior to mounting, make a mark at the point of largest diameter, then match these with one another and install them to improve runout accuracy.

5.7.2 Rolling bearings mounting method

There are many methods for mounting rolling bearings, there is several methods for general use,①using hand hammer and sleeve ②using pressure③using temperature difference④the oil injection method

5.7.2.1 Mounting bearing with a cylindrical bore

1) Using pressure

The method is simple in that it is uses only hand tools, it can be used to mount a bearing with only a hammer and a sleeve or a pressure fitting.

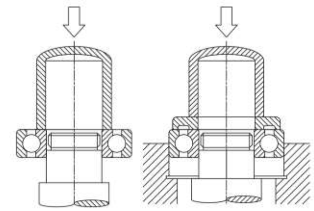
Mounting and Dismounting of Rolling Bearings

2) Mounting bearing using pressure method and note the proceeding:

1、To ensure mounting pressure and bearing fit, per Figure 6-14. Be sure not to damage the other bearing components during mounting and dismounting by causing deformation with the applied pressure.

2、Axial pressure can not be imposed on the bearing rings, Use a soft metal sleeve or pad to apply uniform pressure on the face, prevent a force which may cause tilting which can cause damage or failure.

3、Must be based bearing's structure、size、accuracy, type and location of the installation, considering bearing mounting tools and methods.



(a) Mounting with inner ring pressed

(b) Mounting with both inner ring and outer ring pressed

4、Bearing should be cleaned prior to installation and after then after some times, apply some lubricant in between to reduce the pressure during dismounting.

5、with separable cylindrical roller bearing、taper roller bearing、thrust ball bearing ,the outer rings and inner rings can be installed separately, so make sure there is no misalignment on the shaft.

5.7.2.2 Mounting and adjusting bearings with tapered bores

For bearing having a tapered bore, the degree of interference is not determined by the chosen shaft tolerance, as with bearing having a cylindrical bore, but by how far the bearing is driven up onto the tapered shaft seating, or onto the adapter or withdrawal sleeve. Generally, there are three methods for fitting this bearing.

1、Method of measure-fit for mounting a taper-bore bearing

1) Controlling the reduction in radial internal clearance .The bearing's internal clearance is reduced due to the expansion of the inner ring.

2) Directly control the axial movement. Figure 5-10, the bearing was pushed onto the cone shaft .Measuring inner ring side and axial drive-up A. Force the bearing to the appropriate location per requirements .

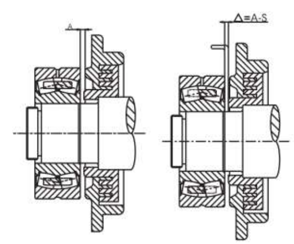


Figure 5-10 control of axial travel

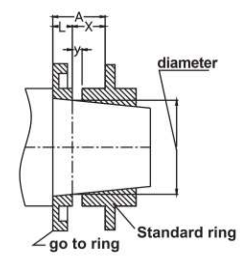


Figure 5-11 control orientation ring length

3) Control orientation ring length figure 5-11, orientation of the bearing per the seal ring. Check measurements, choose and control orientation ring length before mounting. Keep orientation ring A-A face shaft tolerance. To ensure the same as interference of the bearing.

L-orientation ring length

A-form standard ring measure face to shaft distance

x-form measure face to orientation ring face distance

y-measure clearance ,ensure positive tolerance of the taper

2、Notes for mounting tapered bore bearing

1)The fitting quality of tapered bore bearing and shaft diameter depends on the movement of the bearing up the shaft and as a result, it produces different measurements, it is very difficult to achieve the best quality fit and precise requirements using only the three methods listed above.

2) Tuning of the mounting and clearance adjustment is ideally performed using a lock nut as per Figure 5-12. Generally this method is used for the bearing of machine tool.

3) How to count number of turns.Formula relating interference and number of turns

$$s=\frac{\delta}{c}\times 10^{-3}$$

s- number of turns
δ- fitting interference
c –taper angle of inner bore c=1:12

Formula relating number of turns and bearing interference or clearance.

$$\Delta u=\frac{d}{d_E}\times 10^{3}$$

Δu- bearing diametric clearance / interference
d- bearing inner diameter
dE- Bearing inner diameter of the equivalent table 5-22 method

Self –aligning bearing : $\Delta u=\frac{s}{15}\times 10^{3}$

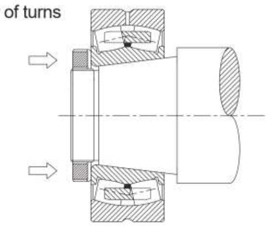


Figure 5-12 Use of lock nut for muting and to adjust clearance

Table 5-22 dE and DE formula

Bearing Type	d_E	D_E
Deep groove ball bearing, angular contact ball bearing, cylindrical roller thrust bearing no rib	$0.25D+0.75d$	$0.75D+0.25d$
Self-aligning ball bearing	$0.25D+0.75d$	$0.73D+0.27d$
Cylindrical roller bearing(rib), taper roller bearing	$0.30D+0.70d$	$0.70D+0.30d$
Cylindrical roller bearing(rib), taper roller bearing	$0.30D+0.70d$	$0.70D+0.30d$
Self-aligning roll bearing	$0.30D+0.70d$	$0.73D+0.27d$

When considering the uses of adapter sleeve or withdrawal sleeve, which has clearance between the outer ring and shaft and require preload, interference needs to increase 0.1 - 0.2 mm for calculating s. In the calculation of the radial clearance reduced to △u , it is still practical and effective to determine the value of 's'

To control and adjust the decrease in radial clearance, ensure the quality of the procedure for tapered-face bearings in accordance with technical drawing and conditions. Per Table 5-23 and 5-24, there are two kinds of relationships between bearing radial internal clearance and axial movement

Table 5-23 Tapered bore cylindrical (1:12) roll bearing Δu and s relationship

Bore Radial (mm)	Radial Internal Clearance (△u/μm)	axial movement s/mm	
		no taper sleeve	taper sleeve
45-50	25-30	0.40-0.50	0.55-0.60
50-65	30-35	0.50-0.55	0.60-0.70
65-80	30-40	0.50-0.65	0.60-0.75
80-100	35-45	0.55-0.70	0.70-0.85
100-120	40-50	0.65-0.80	0.75-0.90
120-140	45-55	0.70-0.85	0.85-1.00
140-160	45-60	0.70-0.95	0.85-1.05
160-180	50-65	0.80-1.00	0.90-1.15
180-200	55-70	0.85-1.10	1.00-0.20
200-225	65-80	1.00-1.25	1.15-1.35

Bore Radial (mm)	Radial Internal Clearance (△u/μm)	Axial Movement (s/mm)	
		No Taper Sleeve	Taper Sleeve
225-250	70-85	1.10-1.30	1.20-1.45
250-280	75-95	1.15-1.45	1.30-1.60
280-315	80-100	1.25-1.55	1.35-1.65
315-355	95-115	1.45-1.75	1.60-1.90
355-400	100-125	1.55-1.90	1.65-2.05
400-450	115-140	1.80-2.20	1.90-2.30
450-500	130-160	2.00-2.50	2.10-2.60
500-560	140-180	2.20-2.80	2.30-2.90
560-630	150-200	2.40-3.10	2.50-3.20
630-710	180-230	2.80-3.50	2.90-3.60
710-800	210-270	3.20-4.10	3.30-4.20
800-900	230-300	3.60-4.60	3.70-4.70
900-1000	260-340	4.00-5.20	4.10-5.20
1000-1120	280-370	4.30-5.60	4.40-6.70
1120-1250	300-400	4.60-6.10	4.70-6.20

Table 5-24 Tapered bore self-aligning (1:12) roll bearing Δu and s relationship

Bore Radial (mm)	Radial Internal Clearance (△u/μm)	Axial Movement (s/mm)	
		No Taper Sleeve	Taper Sleeve
45-50	30-35	0.50-0.55	0.60-0.70
50-65	35-40	0.55-0.65	0.70-0.75
65-80	40-50	0.65-0.80	0.75-0.90
80-100	50-60	0.80-0.95	0.90-1.05
100-120	55-65	0.85-1.00	1.00-1.15
120-140	60-70	0.95-1.10	1.05-1.20
140-160	70-85	1.10-1.30	1.20-1.45
160-180	75-90	1.15-1.40	1.30-1.50
180-200	85-100	1.30-1.55	1.45-1.65
200-225	100-115	1.55-1.75	1.65-1.90
225-250	105-25	1.60-1.90	1.75-2.05
250-280	120-140	1.80-2.15	1.95-2.25
280-315	130-150	2.00-2.30	2.10-2.50
315-355	150-170	2.20-2.60	2.50-2.70
355-400	160-190	2.40-2.90	2.55-3.00
400-450	180-210	2.60-3.20	2.85-3.30
450-500	200-240	3.05-3.65	3.15-3.75
500-560	220-270	3.30-4.10	3.50-4.20
560-630	250-300	3.80-4.50	3.90-4.70
630-710	290-350	4.40-5.30	4.50-5.40
710-800	330-400	5.00-6.00	5.10-6.20
800-900	360-450	5.40-6.80	5.60-6.90
900-1000	400-500	6.00-7.50	6.20-7.70
1000-1120	440-550	6.60-8.30	6.80-8.40
1120-1250	480-600	7.20-9.00	7.40-9.20

5.7.2.3 Mounting and Dismounting force calculation

With regards to the bearing mounting and dismounting force, it is important to choose the appropriate method and tools. Mounting and dismounting force can be calculated for critical bearings from the interference. Mounting and dismounting force of solid shaft and thick housing:

$$F=f_k f_f \delta_E B,\ \mathrm{N}$$

f_k- resistance coefficient of mounting and dismounting, data please check table 5-25;

f_f- geometry size coefficient of the bearing: $f_f=1-\frac{d^2}{d_E^2}$, when mounting and dismounting inner ring,

Calculation of d_E refer to table 5-22 $f_f=1-\frac{D^2}{D_E^2}$, when mounting and dismounting outer ring, Calculation of

D_E refer to table 5-22

δ_E -effective interference of the bearing after mounting ,μm.

B -the bearing width

Mounting and dismounting force of hollow shaft and thin-wall housing:

$$F=f_k f_f f_1 \delta_E B$$

the meaning of f_k, f_f, δ_E, B same as previous

coefficient for hollow shaft f_1, determined $\frac{d_0}{d}$ and $\frac{D}{d}$ by figure 5-13; thin-walled coefficient FEG of thin-walled steel housing,

determined $\frac{D_0}{d}$ and $\frac{D}{d}$ by figure 5-14; thin-walled coefficient f_{EG} of thin-walled cast iron housing,

determined $\frac{D}{d}$ and by figure 5-15;

when $d_0/d<0.5$, hollow shaft and solid shaft approximate as same ,$f_1=1$; when $D_0/D>2$, steel housing is greater than the bearing outer ring , $f_{EG}=f_{ET}=1$。

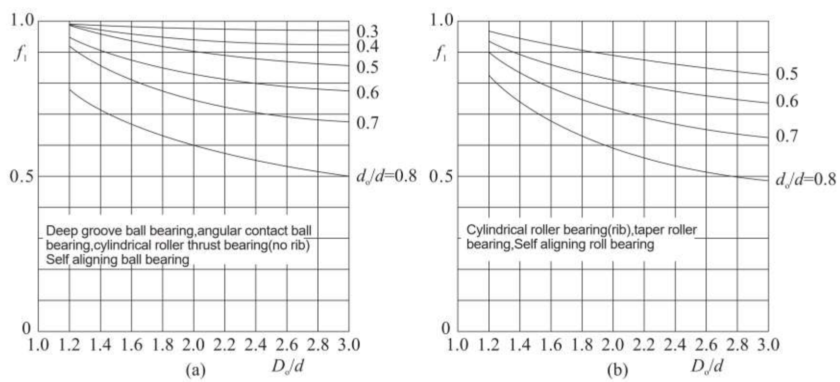


Figure 5-13 coefficient f_1

Table 5-25 Tapered bore self-aligning (1:12) roller bearing Δ_μ and s relationship

structural style of mating surface	process	f_k
Cylindrical bore bearing	mounting	40-50
	dismounting	60-80
Taper bore bearing(taper shaft radial and adapter sleeve)	mounting	55-65
	dismounting	45-70
withdrawal sleeve of taper bore bearing	mounting	100-120
	dismounting	110-150

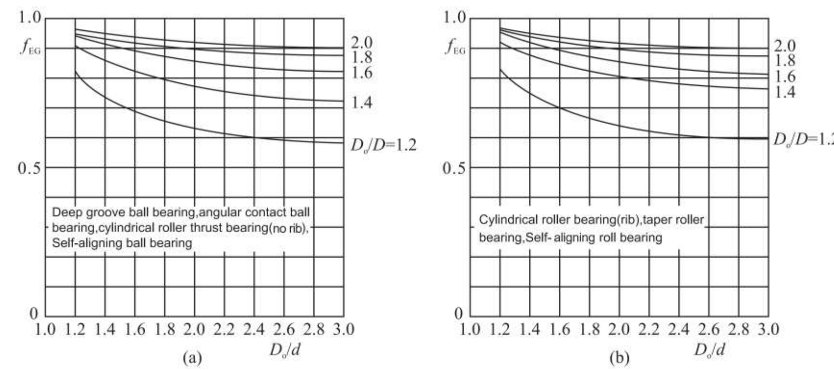


Figure 5-14 coefficient f_{EG}

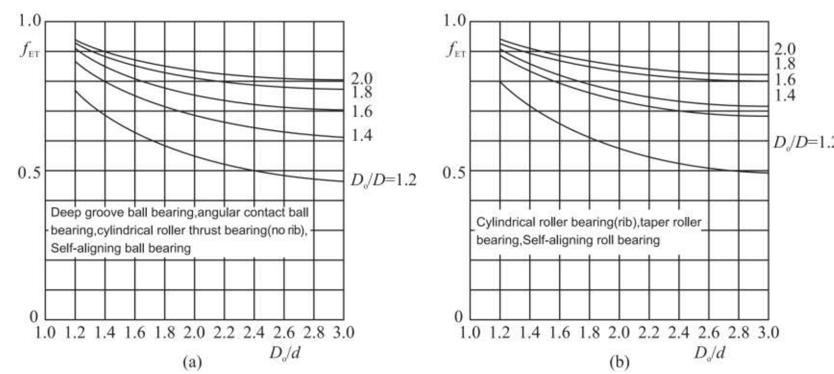


Figure 5-15 coefficient f_{ET}

5.7.2.4 Hot mounting

When the bearing is larger or the interference is large, the mounting pressure will increase, so many times for the mounting and removal or replacement of bearings, surface damage is possible particularly for bearings and housings without taper and with interference fit. Therefore these require the use of a shrink fit

The shrink fit method is based on the principle of thermal expansion and contraction in which the shaft or housing is set at a temperature different than the operating temperature. When the bearings are mounted to the shaft, the bearing expands as it is heated and is thus mounted as the bearing cools, the diameter reduces and produces an interference fit with the shaft.

When installing the bearing in a housing bore, the bearing can also be cooled so that when it returns to normal temperature an interference fit is produced.

The requisite difference in temperature between the bearing ring and shaft or housing depends on the degree of interference and the diameter of the bearing seating.

During operation, bearings are generally lower than the tempering temperature, about 60° - 70° C or else there may be deformation and a reduction in hardness. For ordinary bearings, heat to 80° -100° C and not more than 120° C

For cooling bearings, in order to prevent brittleness, the temperature should not usually be lower than -50° C but sometimes can as much as -80° C. See Table 5-26 for heating and cooling method.

Table 5-26 Heat and cool method see table

Heat and Cool Method	Feature and Applicable
Oven and hothouse heating	The bearing can be heated by oven and hothouse with temperature adjustment and strict control. The benefits of this method is that it is consistent, clean and has strict temperature control; it is used for general equipment on other occasions.The drawbacks of this method are long heating time, limited space capacity and difficulty heating large quantity or large-sized bearings
heater plate heating	Bearings can safely be heated on a heater plate with accurate temperature adjustment which provides even heating, convenience and gives signs of overheating. It is suitable for small bearings.
oil bath heating	The best oil is transformer oil, temperature controlled at 80 - 100° C, it offers even and fast heating and can be used for large bearings but not for bearings with seals, dust covers or prepacked grease
Induction heating	A fast and very efficient way to heat a bearing for mounting is to use an induction heater. At the end of each heating cycle, the bearings are automatically demagnetized.
Cold method	The bearings can be cooled by kinds of cryogenic box with refrigeration, and put in intermixture of dry ice and alcohol.

5.7.2.5 The oil injection method

When there is interference between the bearing and shaft, there is large surface friction. When the interference is large, there may be damage to the mating surfaces and as such it is necessary to reduce friction which can be done by pressure injecting oil. Figure 5-16 shows the method of injecting pressurized oil into a hole in the cone.

When mounting bearings, the bearing is first put onto the cone and when it is close to final position, tighten the nut, with a manual pump or oiling to meet the injection pressure between the surface of the oil, while pushing the bearing to the appropriate location by tightening the nut using a wrench

This method is typically used when mounting bearing directly on tapered journals. but is also used to mount bearings on adapter and withdrawal sleeves that have been prepared for the oil injection method .A pump or oil injector produces the requisite pressure the oil is injected between the mating surfaces via ducts and distributor grooves in the shaft or sleeve.

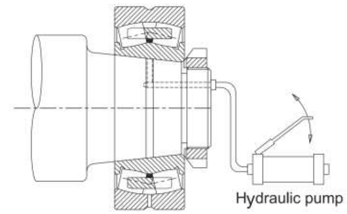


Figure 5-16 Mounting bearing using the oil injection method

5.7.3 Dismounting of rolling bearing

Choose the bearing dismounting method and tools according to the type, precision, mounting structure, position, size and if the bearing is to be used again.

It is more difficult dismounting than mounting, because of rust and deformation of the bearing. If the bearing must be used again, there must not be any force transmitted through the rolling elements but if it is not to be used, the cage and rolling elements are allowed to be damaged.

A puller is used in the center of the bearing with the pressure method. See figure 5-17

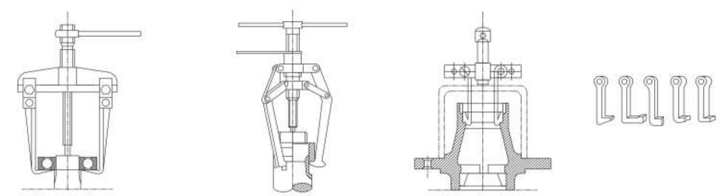
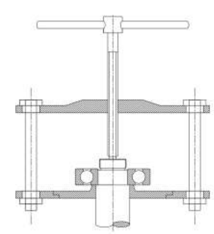
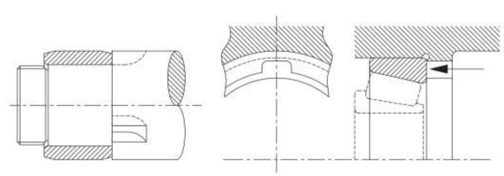


Figure 5-17 Puller disassembly

Larger bearings with an interference fit that must be dismounted generally require a greater force to remove them, See figure 5-18 dismounting cushion block. It is made up for two semi-circle cushion blocks and an outer ring. The method is to evenly distribute pressure to the bearing ferrule head face.

The ferrule must be must be locked with the pull rod when dismounting the bearings and so the physical design requires that there be space for that. See figure 5-19, a groove in the shaft and housing is made before installation.





(a) extraction grooves (b) bore shoulder

Figure 5-18 puller disassembly

Figure 5-19 extraction groove for outer ring disassembly

When dismounting bearings outer ring if the housing bore has a high enough shoulder, in which can be made a screw hole or unthreaded hole to push out the bearing, the outer ring can be conveniently pushed out, see Figures 5-19(b) and 5-20.

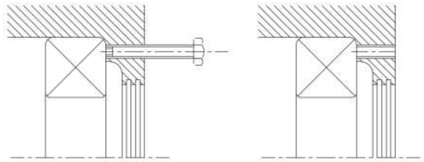


Figure 5-20 Outer ring disassembly bolt

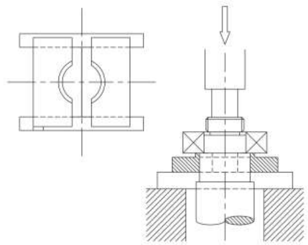


Figure 5-21 Press disassembly

When dismounting inner ring of separable bearings or with interference fit between inner ring and shaft, shaft and bearing inner bore is easily damaged due to high dismounting force. It's recommended to heat the bearings inner ring with Induction heater as figure 5-21.

For large bearings using hydraulic removal methods, per Figure 5-22, First, loosen the nut, then use the manual high-pressure pump to the cone axis of the hole to apply oil to expand the bearing inner ring to allow for removal.

For small to medium bearings installed using an adapter sleeve are removed by loosening the locking nut, placing a block on the edge of inner ring as shown in Figure 5-23(a), and tapping with a hammer. Bearings which have been installed with withdrawal sleeves can be disassembled by tightening down the lock nut as shown in Figure 5-23(b).

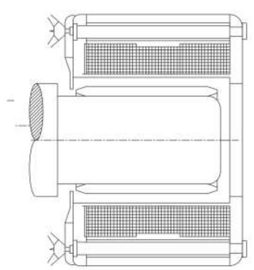
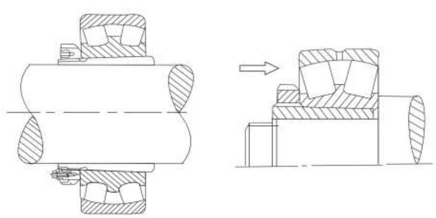


Figure 5-22 Induction heater



(a)disassembly of bearing with adapter sleeve (b)disassembly of bearing with withdrawal sleeve

Figure 5-23 Disassembly of bearing with tapered bore

5.8 Bearing damage and corrective measures

If handled correctly, bearings can generally be used for a long time before reaching their fatigue life. If damage occurs prematurely, the problem could base from improper bearing selection, handling or lubrication. If this occurs, take note of the type of machine on which the bearings is used, the place where it is mounted, service conditions and surrounding structure. By investigating several possible causes surmised from the type of damage and condition at the time the damage occurred, it is possible to prevent the same kind of damage from reoccurring. In the table below gives the main causes of bearing damage and remedies for correcting the problem.

Descpription		Causes	Corrective Measures
Flaking	Surface of the raceway and rolling elements peels away in flakes. Conspicuous hills and valleys form soon afterward.	· Excessive load, fatigue life, improper handling · Improper mounting. · Improper precision in the shaft or housing. · Insufficient clearance. · Contamination. · Rust. · Improper lubrication · Drop in hardness due to abnormally high temperatures.	· Select a different type of bearing. · Reevaluate the clearance. · Improve the precision of the shaft and housing. · Review application conditions. · Improve assembly method and handling. · Reevaluate the layout (design) of the area around the bearing. · Review lubricant type and lubrication methods.
Seizure	The bearing heats up and becomes discolored. Eventually the bearing will seize up.	· Insufficient clearance (including clearances made smaller by local deformation). · Insufficient lubrication or improper lubricant. · Excessive loads (excessive preload). · Skewed rollers. · Reduction in hardness due to abnormal temperature rise	· Review lubricant type and quantity. · Check for proper clearance. (Increase clearances.) · Take steps to prevent misalignment. · Review application conditions. · Improve assembly method and handling.
Cracking and notching	Localized flaking occurs. Little cracks or notches appear.	· Excessive shock loads. · Improper handling (use of steel hammer, scratching from large contaminant particles) ·Creation of a worn surface layer due to improper lubrication · Excessive interference. · Large flaking. · Friction cracking. · Imprecise mounting surfaces (oversized fillet radius)	· Review lubricant (friction crack prevention). · Select proper interference and review materials. · Review service conditions. · Improve assembly procedures and take more care in handling.
Cage damage	Rivets break or become loose resulting in cage damage.	· Excessive moment loading. · High speed or excessive speed fluctuations. · Inadequate lubrication. · Impact with foreign objects. · Excessive vibration. · Improper mounting. (Mounted misaligned)	· Reevaluation of lubrication conditions. · Review of cage type selection. · Investigate shaft and housing rigidity. · Review service conditions. · Improve assembly method and handling.
Rolling path skewing	Abrasion or an irregular, rolling path skewing left by rolling elements along raceway surfaces.	· Shaft or housing of insufficient accuracy. · Improper installation. · Insufficient shaft or housing rigidity. · Shaft runout caused by excessive internal bearing clearances.	· Reinspect bearing's internal clearances. · Review accuracy of shaft and housing finish. · Review rigidity of shaft and housing.
Smearing and scuffing	The surface becomes rough and some small deposits form. Scuffing generally refers to roughness on the race collar and the ends of the rollers.	· Inadequate lubrication. · Entrapped foreign particles. · Roller skewing due to a misaligned bearing. · Bare spots in the collar oil film due to large axial loading. · Surface roughness. · Excessive slippage of the rolling elements.	· Reevaluation of the lubricant type and lubrication method. · Improve sealing performance. · Review preload. · Review service conditions. · Improve assembly method and handling

Description		Causes	Corrective Measures
Rust and corrosion	The surface becomes either partially or fully rusted, and occasionally rust even occurs along the rolling element pitch lines.	· Poor storage conditions. · Poor packaging. · Insufficient rust inhibitor. · Penetration by water, acid, etc. · Handling with bare hands.	· Take measures to prevent rusting while in storage. · Periodically inspect the lubricating oil. · Improve sealing performance. · Improve assembly method and handling.
Fretting	There are two types of fretting. In one, a rusty wear powder forms on the mating surfaces. In the other, brinelling indentations form on the raceway at the rolling element pitch.	· Insufficient interference. · Small bearing oscillation angle. · Insufficient lubrication. (unlubricated) · Fluctuating loads. · Vibration during transport, vibration while stopped.	· Select a different kind of bearing. · Select a different type of lubricant. · Review the interference and apply a coat of lubricant to fitting surface. · Pack the inner and outer rings separately for transport.
Wear	The surfaces wear and dimensional deformation results. Wear is often accompanied by roughness and scratches.	· Entrapment of foreign particles in the lubricant. · Inadequate lubrication. · Skewed rollers.	· Review lubricant type and lubrication methods. · Improve sealing performance. · Take steps to prevent misalignment.
Electrolytic corrosion	Pits form on the raceway. The pits gradually grow into ripples.	· Electric current flowing through the rollers.	· Create a bypass circuit for the current. · Insulate the bearing.
Dents and scratches	Scoring during assembly, gouges due to hard foreign objects, and surface denting due to mechanical shock.	· Entrapment of foreign objects. · Galling on the flaked-off side. · Dropping or other mechanical shocks due to careless handling. · Assembled misaligned.	· Improve handling and assembly methods. · Bolster sealing performance. (measures for preventing foreign matter from getting in) · Check area surrounding bearing.(when caused by metal fragments)
Creeping	Surface becomes mirrored by sliding of inside and outside diameter surfaces. May by accompanied by discoloration or scoring.	· Insufficient interference in the mating section. · Sleeve not fastened down properly. · Abnormal temperature rise. · Excessive loads.	· Reevaluate the interference. · Reevaluate usage conditions. · Review the precision of the shaft and housing.
Speckles and discoloration	Luster of raceway surfaces is gone; surface is matted, rough, and / or evenly dimpled. Surface covered with minute dents.	· Infiltration of bearing by foreign matter. · Insufficient lubrication.	· Reevaluation of lubricant type an relubrication method. · Review sealing mechanisms. · Examine lubrication oil purity.(filter may be excessively dirty, etc.)
Peeling	Patches of minute flaking or peeling. Innumerable hair-line cracks visible though not yet peeling. (This type of damage frequently seen on roller bearings.)	· Infiltration of bearing by foreign matter. · Insufficient lubrication.	· Reevaluation of lubricant type and lubrication method. · Improve sealing performance. (to prevent infiltration of foreign matter) · Take care to operate smoothly.