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BALL & ROLLER BEARINGS

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

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BEARINGS
Reliability & Innovation

BALL & ROLLER BEARINGS

General Catalogue

An IKO Company

Discover UBC

UBC Foreword

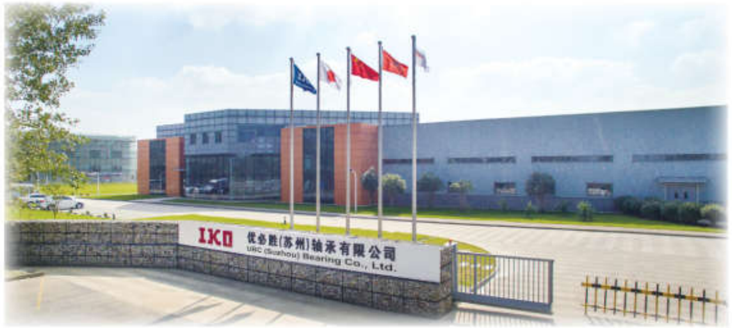
This catalogue contains technical information on UBC bearings that are typically used in industrial applications.

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 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 bearings' structure sketch, basic dimensions, load ratings, limiting speed, and reference weight.

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



UBC Precision Bearing Mfg. Company is a manufacturer of standard bearings for aftermarket & OEMs as well as specific design engineered bearings for special applications since year 2001.

Being as a dependable brand with reliable quality and professional service at competitive prices, UBC products are the perfect alternative for customers who intend to reduce costs without compromising bearing performance.

In April 2018, UBC became a 100% subsidiary of IKO Nippon Thompson Group of Japan, a world leading manufacturer of Needle Roller Bearings and Linear Motion Rolling Guides and Components. 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 an exceptional engineering support, before 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.co

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 applied for higher load and ball bearings for higher speed. The differences between radial bearing and thrust bearing is that radial bearings can take load from both radial and axial direction in most cases but thrust bearings can only take axial load. Based on above bearing categories, rolling bearings can also divided into radial ball bearings, radial roller bearings, thrust ball bearings and thrust roller bearings. Detailed rolling bearing ranges and their key features could found below table 1-1 and table 1-2.

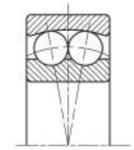
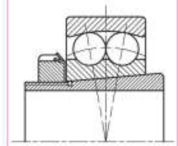
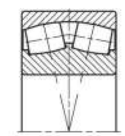
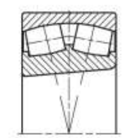
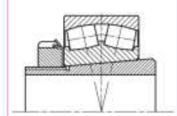
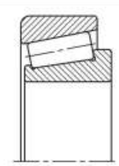
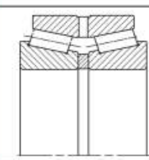
Table 1-1 Bearing ranges and their features

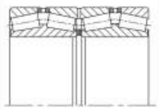
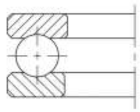
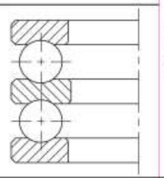
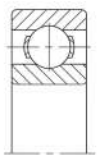
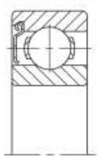
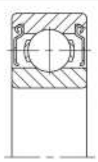
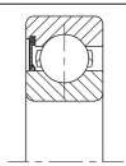
←	Single direction	√√√	Best
↔	Dual direction	√√	Good
×	Poor	√	Normal
××	Unapplicable		

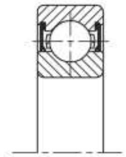
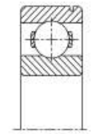
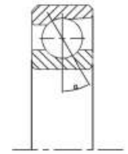
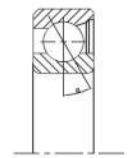
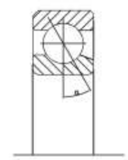
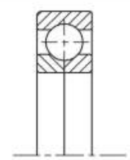
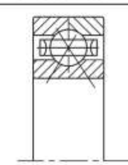
Bearing Ranges				Axial load	Radial load	High speed	High rotating precision	Low noise	High stiffness	Self-alignment	Axial displacement	Locating end	Non-locating end
Radial bearings	Ball bearings	DGBB	Single row	√ ↔	√	√√√	√√√	√√√	√	××	××	√√	√
			Double row	√ ↔	√	√	√	√	√	××	××	√	√
			Insert Bearing	√ ↔	√	√	√	√√	√	√√	××	√√	√
		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	××	√√	√√	√√	√√	√√	××	√√√	××	√√√
			Single row: One rib outer ring	√ ←	√√	√√	√√	√√	√√	××	√	√	√
			Single row: non-rib inner ring	××	√√	√√	√√	√√	√√	××	√√√	××	√√√
			Single row: One rib inner ring	√ ←	√√	√√	√√	√√	√√	××	√	√	√
			Single row: Flat rib	√ ↔	√√	√√	√√	√√	√√	××	××	√	×
			Double row: non-rib outer ring	××	√√√	√√	√√√	√√	√√√	××	√√√	××	√√√
			Double row: non-rib inner ring	××	√√√	√√	√√√	√√	√√√	××	√√√	××	√√√

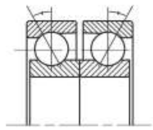
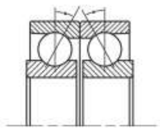
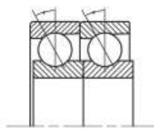
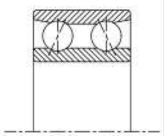
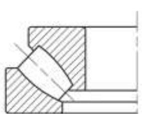
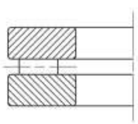
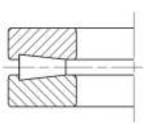
Radial bearings	Roller bearings	Taper roller bearing	Single row		√√ ←	√√	√	√√	√	√√	XX	XX	√√	XX
			Double row	2 inner rings	√√√ ↔	√√√	√	√	√	√√√	XX	XX	√√√	XX
				2 outer rings	√√√ ↔	√√√	√	√	√	√√√	XX	XX	√√√	XX
			4 row	2 inner rings	√√√ ↔	√√√	√	√	√	√√√	XX	XX	√√√	XX
		Spherical roller bearing			XX	√√	√	√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

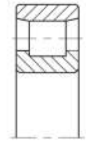
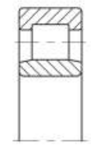
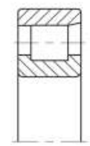
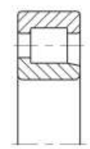
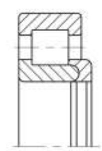
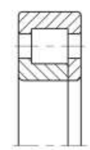
Table 1-2 Bearing categories, structure and characteristics

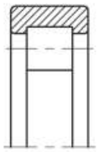
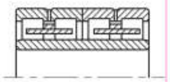
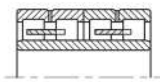
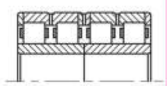
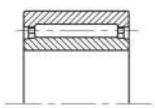
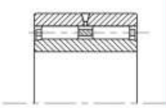
Bearing Types		Sketch	Characteristics
Self-aligning ball bearings	Self-aligning ball bearings		Its inner ring bore could be tapered or cylindrical bore; Accommodating radial load and limited axial load; Maximum shaft axial displacement must be less than its clearance; Self-aligning property, the permissible angular between inner and outer ring is no bigger than 3 degree;
	Self-aligning ball bearings with adapter sleeves		As above Adapter sleeves can be applied for shafts without any shoulder convenient for mounting and dismounting, and easy adjustment on radial clearance.
Spherical roller bearings	Spherical roller bearings		Accommodating high radial load and limited axial road; Good self-aligning property, the permissible angular between inner ring and outer ring is no less than 2.5 degree; Radial clearance can be adjusted by moving tapered bore inner ring in axial direction. Bearings with adapter sleeves are suitable for shaft without any shoulder, and applications that needs 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 big contact angle accommodating mainly axial loads combined radial loads; Additional axial load will generated by radial load, so two single bearings applied must be paired for combined loads. 313 Series bearing has big contact angle (27°~30°) for larger axial load and other series bearing with contact angle of 10°~18°
	Double row tapered roller bearings		Consisted by 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.

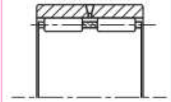
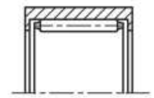
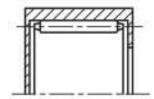
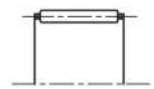
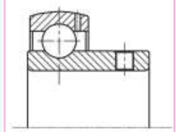
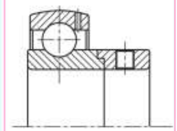
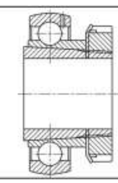
Bearing Types		Sketch	Characteristics
	Four row tapered roller bearings		A spacer ring between Inner ring and outer ring for clearance adjustment; Similar properties with double row taper roller bearing; High load capacity but lower Limiting speed; Applied for heavy machineries, eg. steel rolling mill.
Thrust ball bearings	Single direction thrust ball bearings		Only accommodating axial load and confining single direction axial displacement; Low limiting speed;
Thrust ball bearings	Double direction thrust ball bearings		Bidirectional thrust bearing applied for bidirectional axial loads and confining bio-directional axial displacement ; Low limiting speed.
Deep groove ball bearings	Single row deep groove ball bearing		Accommodating radial load and limited axial load, confining 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 fit 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 bigger friction and lower limiting speed.

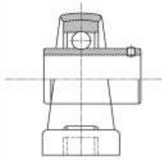
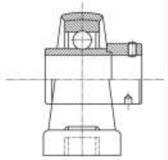
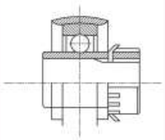
Bearing Types		Sketch	Characteristics
Deep groove ball bearings	Single row deep groove ball bearings with seals on both sides		Non-contact sealing type deep groove ball bearing's limiting speed is similar to that of open type. Already fit with grease for two-side-seald-type deep groove ball bearing, 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 for axial locating in bearing housing with 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 with the contact angle α increases; High limiting speed; Paired angular contact ball bearings mounted into the shaft, can confine bio-directional axial displace-ment. 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 inner ring lock up		
Angular contact ball bearings	Four-point contact ball bearings with double half inner rings		Inner ring and/or outer ring could be separated with each other with 35° contact angle; There are 4 contact points between balls and rings if bearing without loads or with pure radial load. There are 2 contact points between balls and rings if bearing with pure axial load. Carrying bio-direc-tional axial loads, torque loads, with functions of both single row angular contact ball bearing and double-row angular contact ball bearing. This type of bearing can only work properly when bearing with 2-point contact.
Angular contact ball bearings	Four-point contact ball bearings with double half 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 rest two arrange-ments can carry axial load from any direction. In general, manufacturer supply this type of bearings in pair. To improve bearing's stiffness and rotation precision, end user should set preload after mounted 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 torque load. It confines bio-directional axial displacement of shaft (housing).
Thrust spherical roller bearings	Spherical roller thrust 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, confining single direction axial displacement of shaft (housing).
	Thrust cylindrical roller bearings		Carrying higher single direction axial load. Confining 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 for 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 bigger intermittent axial load. Bearings with single rib can only carry axial load from one direction. Bearings without inner ring or outer ring can be applied for limited radial space where shaft journal or housing surface will be raceway of the bearing and the surface must be machined to similar quality of bearing inner ring or outer ring.
	Inner ring without rib		
	Outer ring with an rib		
	Inner ring with an rib		
	Inner ring with an rib and L-shaped loose rib		
	Inner ring with an rib and a loose 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 applied for Heavy machineries, e.g. steel rolling mill; Special designations differ to 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 loose 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 loose flange rings; The bore diameter of double row needle bearings d≥32mm
	Double row needle roller bearing		
	Without inner ring		Applied for limited radial mounting space; Shaft journal surface working as inner ring raceway and its hard -ness is among 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; Applied for limited mounting space and use shaft journal surface as raceway; Directly press it into bearing housing; Avoid axial position adjustment; Lubricated with grease before mounting; BK design is for the shaft without extend shaft end and accommodates 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 working as bearing raceway and their surface hardness is around 58~64HRC; Depth of surface hardened layer is 0.6~1mm; Surface roughness Ra is 0.32~0.20um
Insert bearings	Insert bearings with grub screws locking		Consisted by double shielded ball bearing and one cast iron housing; Internal structure is similar with ball bearing; The spherical outer ring can match with spherical housing for self-aligning; Often mounted the inning ring with shaft by grub 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 grub screws		Two designations with UC and UB; For changing rotating direction of the machine shaft; Have two designations with 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 represent 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.

The detail 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 transmutation 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	Conjurations	Others

Table 2-2

	Bearing Components
S	Stainless steel material
Code	Definition
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 side
RL	Light contact seal of acrylonitrile-butadiene rubber on one side
2RL	Light contact seal of acrylonitrile-butadiene rubber on both side
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 side, 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-grinded side surface
DC	Double row angular contact ball bearing with double outer ring
DI	Double row taper roller bearing without cone spacer, grinded side surface
DH	Single-direction thrust bearing with double housing washer
DS	Single-direction thrust bearing with double shaft washer

Seals, Shields and transmutation 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 notch
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	Glass fiber 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	Weld 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 bigger than Normal
/C4	Bearing internal clearance bigger than C3
/C5	Bearing internal clearance bigger than C4
/C9	Bearing internal clearance different with current standard
/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 fact-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, following with a data for specific preload value requested
GA	Light preload
GB	Middle 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°C
	LHT2: -40 to +200°C
	LHT3: -40 to +250°C
	LHT4: -40 to +300°C
/Y	Combination of Y and other letter or number to identify the special designs which can not represented by available suffixes
	YA: Changed structure
	YA1: The outer ring surface is different with standard design
	YA2: The bearing bore is different with standard design
	YA3: The ring side surface is different with standard design

UBC Bearing Designations

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

Bearing width series

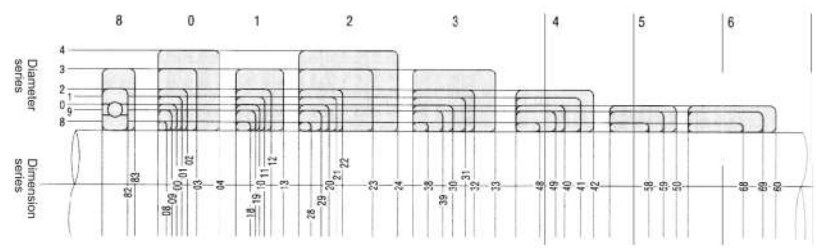


Figure 2-1 Dimension series of radial bearings (excluding TRB)

Bearing height series

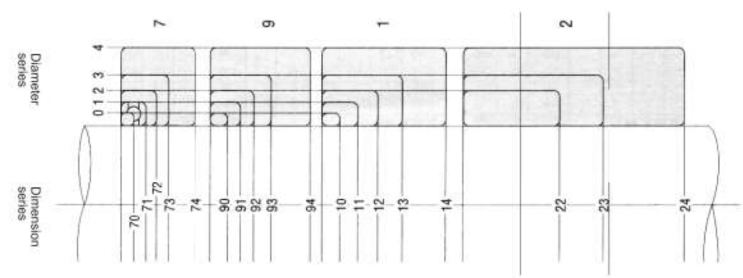


Figure 2-2 Dimension series of thrust bearings

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

$\Delta B_s,(\Delta C_s)$ ——— 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 inspected single width of taper roller bearing from the nominal

ΔT_{1s} ——— Deviation of inspected single width of cone from the nominal

ΔT_{2s} ——— Deviation of inspected 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 9	V_{dp} Diameter Series 0、1	V_{dp} Diameter Series 2、3、4	V_{dmp}	K_{ia}	ΔB_S all	ΔB_S Normal	ΔB_S Modify①	V_{Bs}
>	≤	h	l	max	max	max	max	max	h	l	l	max
0.6	2.5	0	-8	10	8	6	6	10	0	-40	-	12
2.5	10	0	-8	10	8	6	6	10	0	-120	-250	15
10	18	0	-8	10	8	6	6	10	0	-120	-250	20
18	30	0	-10	13	10	8	8	13	0	-120	-250	20
30	50	0	-12	15	12	9	9	15	0	-120	-250	20
50	80	0	-15	19	19	11	11	20	0	-150	-380	25
80	120	0	-20	25	25	15	15	25	0	-200	-380	25
120	180	0	-25	31	31	19	19	30	0	-250	-500	30
180	250	0	-30	38	38	23	23	40	0	-300	-500	30
250	315	0	-35	44	44	26	26	50	0	-350	-500	35
315	400	0	-40	50	50	30	30	60	0	-400	-630	40
400	500	0	-45	56	56	34	34	65	0	-450	-	50
500	630	0	-50	63	63	38	38	70	0	-500	-	60
630	800	0	-75	-	-	-	-	80	0	-750	-	70
800	1000	0	-100	-	-	-	-	90	0	-1000	-	80
1000	1250	0	-125	-	-	-	-	100	0	-1250	-	100
1250	1600	0	-160	-	-	-	-	120	0	-1600	-	120
1600	2000	0	-200	-	-	-	-	140	0	-2000	-	140

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} Close ① Bearing Diameter Series 2、3、4	V_{Dmp} ②	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

2) class P6 tolerances

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 Modify①	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} Close ① 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			

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 Modify[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	-	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	-380	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	-500	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}[①]	ΔC_s h	ΔC_s l	V_{Bs}
>	≤	h	l	max		max	max	max	max	h	l	max
2.5	6	0	-5	5	4	3	5	8	8			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	Values are identical to those for inner ring of same bearing (ΔB_s)		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 Modify[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}[②]	ΔC_s h	ΔC_s l	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			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	Values are identical to those for inner ring of same bearing (ΔB_s)		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
0.6[1]	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	-	-	-	-

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 applies 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 applies 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 double direction 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 bearing housing raceways for fundus ply
- *Note* —— Only applicable for thrust ball bearing (90°) and thrust cylindrical roller bearing
- S_i —— variation of shaft ring raceways for fundus ply
- *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 double direction bearing
- ΔT_s —— Deviation of inspected height of single direction bearing
- ΔT_{1s} —— Deviation of inspected height of double direction bearing
- V_{dp} —— diameter variation of single direction shaft ring in one radial plane
- V_{d2p} —— diameter variation of double direction 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 bio-direction 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 bio-direction 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 bio-direction 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 bio-direction 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 bio-direction 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 bio-direction 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 bio-direction 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 bio-direction bearings, 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.

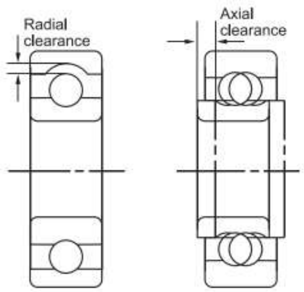


Fig 2 Bearing Clearance

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

Naminal 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

Naminal 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 Tab2-50

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

µm

Naminal 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

Naminal 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

Rolling Bearing Clearance UBC

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

Naminal 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

Naminal 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

Tbale 2-53 Radial clearance of double-row cylindrical roller bearing (tapered bore)

μm

nominal bore diameter d/mm		C1		C2	
>	⩽	min	max	min	max
-	24	10	20	20	30
24	30	15	25	25	35
30	40	15	25	25	40
-	-	-	-	-	-
40	50	17	30	30	45
50	65	20	35	35	50
65	80	25	40	40	60
-	-	-	-	-	-
80	100	35	55	45	70
100	120	40	60	50	80
120	140	45	70	60	90
-	-	-	-	-	-
140	160	50	75	65	100
160	180	55	85	75	110
180	200	60	90	80	120
-	-	-	-	-	-
200	225	60	95	90	135
225	25	65	100	100	150
250	280	75	110	110	165
-	-	-	-	-	-
280	315	80	120	120	180
315	355	90	135	135	200
355	400	100	150	150	225
-	-	-	-	-	-
400	450	110	170	170	255
450	500	120	190	190	285

2.3.5 Needle roller bearing clearance

The Needle roller bearings with inner ring, outer ring and cage, except the pressed outer ring and heavy bearing series, can refer to the radial clearance of cylindrical roller bearings. Depends on the diameter of inner ring raceway and the inscribed circle diameter of needle roller component, heavy bearing series with inner ring and outer ring, and needle roller bearings with cage, which inner ring can be supplied as a separate accessory, can refers to the radial clearance of cylindrical roller bearings.

2.3.6 Axial internal clearance of angular contact ball bearings in table 2-54

Table2-54 Axial internal clearance of double-row angular contact ball bearing

μm

Naminal 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 2-55

Table2-55 Radial internal clearance of double row and four row tapered roller bearings

µm

Naminal 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 2-56 and 2-57

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

µm

Naminal 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 2-57 Radial internal clearance of insert bearings (tapered bore)

µm

Naminal 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

Bearing Vibration UBC

2.4 Bearing vibration

The bearing vibration is defined that during the bearing rotation, all periodicity motion except some motion between the components, these motion are fixed and required by function.

Below is the vibration limit of each bearing. If you have any special requirement for bearing vibration you can directly contact UBC company.

2.4.1 The vibration limit of deep groove ball bearing in table 2-58,2-59,2-60,and 2-61

Table 2-58 The vibration (by velocity) limit

μm/s

Naminal 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 2-59 The vibration (by velocity) limit

μm/s

Naminal 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 2-61 The vibration acceleration (dB) limit

Naminal 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 2-62 to 2-63

Table 2-62 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 2-63 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 2-64 to 2-65

Table 2-64 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 2-65 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 by its various applications and the increasing needs of industry development. There are so many types of rolling bearings supplied to match different needs of various applications. How to select the right bearing has a significant impact to 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 illustrated the bearing selection process. Please contact UBC for support in the case of special applications.

Figure 3-1 Diagram of rolling bearing selection

Understand machine and bearing application conditions	Function and structure of machine; bearing positions; load and its direction; rotating speed; vibration and pulse; 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; permissablespeed and axial load; mounting space
Select bearing precision	Shaft tolerance; speed; torque range
Select bearing internal clearance	Material and type of shat/housing; fitness; 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 pulse load; instant load; lubricant and lubrication
Select lubricants, lubrication and seals	Operating temperature; speed; lubricant and lubrication; seal type; maintenance and detection
Select special bearing	Operating environment (high/low temperature, vacuum, chemical environment); high dependable requirement
Determine handling 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 one bearing for specific applications, both the characteristic properties and application condition of the bearing must be taken into consideration, including load, speed, self-alignment, permeable mounting space, accuracy, stiffness, noise and vibration and axial displacement, meanwhile without neglect of its cost and purchase convenience. 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 character usually determine the size of bearing.

(1) Magnitude and character of load. Most of ball bearings are usually applied for light or moderate and stable load, while roller bearings for heavy and high pulse 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 bearing and thrust needle bearing are normally applied for purely heavy axial load. Single direction thrust bearings can only accommodate axial loads acting in one direction; for axial loads acting in both directions, double direction 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 bearing 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) Couple load

When a load acts eccentrically on a bearing, a titling couple will occur. Double row bearings, e.g. deep groove or angular contact ball bearings, can accommodate titling couple, 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 condition.
The limiting speed is depended on bearing's type, dimension, accuracy, internal clearance, cage material and structure, lubrication and lubricants, the magnitude and direction of the load, and heat dissipation, etc.

The limiting speed of different bearings could be found in its parameter table, and it's measured under lubricated 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 changed, the limiting speed can also be calculated, e.g., when bearing accommodating 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 bearing running at equivalent dynamic load P > 0.1C, bearing contact stress increases and will generate more heat and worsen lubrication effect, thus reduce the limiting speed of the bearing.

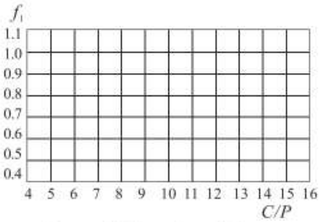


Figure 3-2 Load coefficient

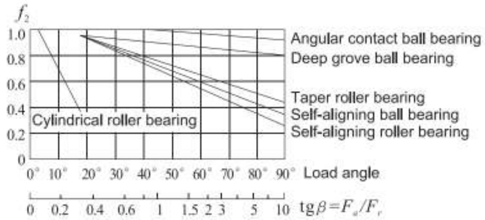


Figure 3-3 Load distribution coefficient

f_2: load distribution coefficient to Figure 3-3, when bearing running at combined loads, the number of roller taking load increases and will cause more friction with raceway and worsen lubrication effect, thus reduce the limiting speed of the bearing.

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

To run the bearing at higher speeds than limiting speed given in 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 bigger 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 of the bearing contact angle, the bigger of the centrifugal force undertaken by 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 bearing in tandem arrangement or wide width bearings could be applied if the carrying load is bigger than single bearing could take.

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

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 the misalignment from early bearing mounting process. Needle bearings and roller bearings are not recommended for the applications with a sloped shaft line.

3.2.1.4 Stiffness

Generally the stiffness of 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 the suitable for the applications which need the bearing moving forward or backward in 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 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 for long shaft.

3.2.1.8 Others

Whether the bearings are chosen with snap ring, seal, shield or quiet running is depended on actual application conditions and their prices and market supply condition.

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 related with the precision and quality of manufacturing and mounting of the fitted components.

Each types of bearings are supplied with tolerance grade 0 and widely applied. 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 to its load capacity, service life and temperature increase and noise level. Radial clearance can be defined as initial clearance, mounting clearance and 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 fitness 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 fitness. 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 preloaded 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 fitness grade of bearing rings with the range as Table 3-1.

Table 3-1 Fitness for Normal internal clearance

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

Rolling Bearing Load Ratings, Life and Limiting Speed UBC

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

Once the structure of material changed, the structure can't be recovered even if the temperature comeback to normal temperature.

Therefore, when the bearing is used in high temperature situation, it must be temperature adjusted to basic dynamic load rating in table of bearing dimension, that is to say, the dynamic load rating multiply by temperature factor list in table4-1.

Table 4-1 Temperature coefficient

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

To these bearings, that used in above 120 centigrade situation long time, the change of dimension will be large just encounter normal heat treatment. So the stabilization treatment to dimension must be taken.

The code of dimension stabilization treatment and the range of usage temperature listed in table4-2.But after the dimension stabilization treatment, the rigidity of bearing will be reduce, sometimes the basic rating dynamic load will decrease.

Table 4-2 Dimension stabilization treatment

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

4.1.2 Basic static load rating

The partly permanence distortion will occur between roller and the interface of raceway when the bearing encountered too large static load, or to be subjected to pulse load at very slow speed.

The basic static load rating is used in calculations tangency stress between roller and the raceway center of raceway, the roller is subjected to largest load.

- 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 permission value of bearing equivalent static load depends on the bearing basic load rating. But the limit of bearing usage that depends on the permanence distortion (partly sunken) will be changed, when the requirement of bearing performance and the usage condition of bearing varies.

Therefore, to analyze the safety degree of bearing basic load rating, the safety factor was established based on experience. The formula 4-1 is calculation method, and the safety factor of varies work environment list 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
Seldom rotation (sometimes oscillate)	General usage condition	0.5	1
	Shock load or non-uniformity load	1	2

Note: To Thrust self-aligning roller bearing, the $f_s \geq 4$

4.2 Rolling bearing equivalent load

4.2.1 Equivalent dynamic load

Many bearings encounter combined load which combined by radial load and axial load. Moreover, there are varies condition of load, for example, the value of load changed.

So, it can't direct compare reality bearing load with basic dynamic load rating.

Therefore, the supposed load can be used to analyze and compare, which through the center of bearing, and transformed by reality load, the value and direction are fixed. In the case of tentative load, the bearing has the life same as the situation of reality load and speed.

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

4.2.2 Equivalent static load

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

The radial load which go through the center of bearing and the axial load which 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 backstop, the transfer impetus of gear or belt and the load induced during machine rotation.

Due to the bearing load varies mostly, and the degree or value of change is hardly determined, so it's impossible to estimate the bearing load by simple calculation.

Therefore, we usually calculate the load of bearing by theoretical value multiplying experience factor.

(1) load factor

Though the radial load or axial load on bearing can be calculated by common mechanical method, but the actual load to which the bearing is subjected is larger than the calculated value due to the reason of vibration or shock. Therefore, we calculate the load of bearing by theoretical value multiplying load factor related 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 theoretical load multiplying load factor above and belt factor, which related to belt strain.

Table 4-4 Load factor f_w

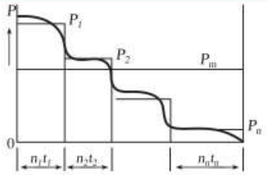
Usage Condition	Purpose	f_w
Almost non vibration or shock	Motor, Machine tool, Instrument	1.0-1.2
General rotation (Slight shock)	Railway vehicle, Auto, Paper machine, Fan, Compressor, Agriculture machine	1.2-2.0
Intensity vibration or shock	Rolling mill, Muller, Architecture machine, Vibration screen	2.0-3.0

4.2.4 Equivalent dynamic load in load change

When the bearing under the load which magnitude or direction variety, it need to calculate the averaging of equivalent dynamic load, which makes bearing having the same life as under actual condition.
The method for calculation of average equivalent dynamic load Pm illustrated in (1)-(4).

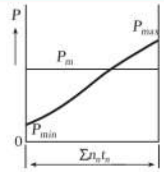
(3) Sine transformation

(1) Ladder transformation



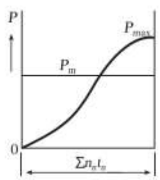
$$P_m = \sqrt[P]{\frac{P_1^P n_1 t_1 + P_2^P n_2 t_2 + \cdots\cdots + P_n^P n_n t_n}{n_1 t_1 + n_2 t_2 + \cdots\cdots n_n t_n}} \quad \cdots\cdots (5.2)$$

(2) humdrum transformation



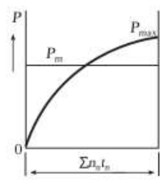
$$P_m = \frac{P_{min} + 2P_{max}}{3} \quad \cdots\cdots (5.3)$$

(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).

The identical bearings operating under identical conditions, such as dimension, structure, material, the method of manufacture, have different individual endurance lives. The life of bearing can only be predicted statistically, because the fatigue of material has discrete. Life calculations refer only to a bearing population in same running condition, and a given degree of reliability, i.e. 90 %.

Furthermore field failures are not generally caused by fatigue, but are more often caused by wear, corrosion, rupture, impress, burn.

4.3.1 The calculation of bearing life

Basic dynamic load rating

The basic dynamic load rating is the capability of enduring the rolling fatigue (the capability of load). It is assumed that the load is constant in magnitude and direction and is radial for radial bearings and axial, centrically acting (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 marked as Cr and Ca, and its value listed in the table of bearing dimension.

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 the higher reliability than 90% is needed based on the different usage.

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

Considered of these factors mentioned above, the basic life rating named modification rating life.

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

where:
- L_{na}: modification rating life, millions of revolutions. Lna is life at 100-n%reliability considered of bearing characteristic 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 intensity of shaft and shell, when selecting bearing dimension based on the reliability 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.

It tested that high quality vacuum carbon deoxidized steel, as a standard bearing material, can obviously extend the bearing life. All the basic dynamic load rating in the table of bearing dimension are base on this material, and now a_2=1.

Otherwise, to those materials which 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 when with excellent lubrication.

But to the below condition, 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 oblique compared with the outer ring, and the rigidity is decreasing 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 lower, as the pitch diameter of the roller element multiplied by the speed is less than 10000.

[Note] Even with special material (a_2>1), $a_2 \times a_3$>1 can not stand if without proper lubrication. Consequently, in this situation (a_3<1), $a_2 \leqslant 1$.

Because we can not separate a_2 with a_3, someone recommends correction factor a_{23} as combined.

4.4 Limit Speed of Rolling Bearing

The speed of bearing is restricted by the heat caused by friction. After over-speed, bearing will stop because of burned.

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

Consequently, the limit speed of 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 showed separately at bearing dimension table, the value represent 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 it's not applicable for high-speed.

4.4.1 Correction for Limit Speed

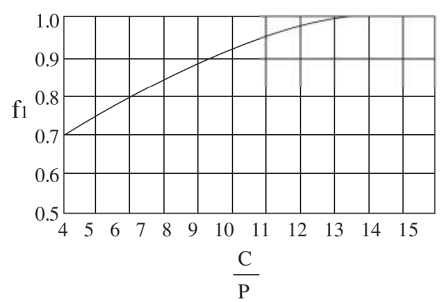
When C/P<13 (the equivalent dynamic load is larger than 8% of the basic load rating C), or the axial load is larger than 25% of the radial load in combined load, we use function 4-6 for correction.

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

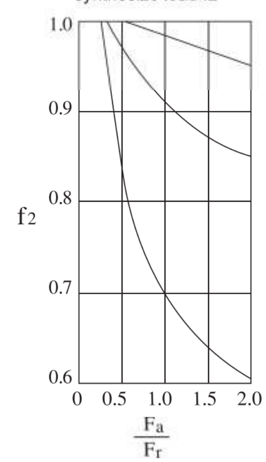
where:

- 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 Bearing

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

4.4.3 Attentions for High Speed Application

When bearing is in high speed, especially when it's approaching or over the speed limit, attentions are listed below:

(1) use precision bearings;

(2) analysis the inner clearance (the influence of the decreased inner clearance because of the temperature increasing)

(3) analysis 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) analysis the lubrication (we prefer lubrications 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 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, mN, 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 needle roller bearing	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

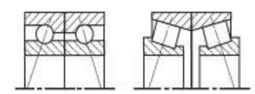
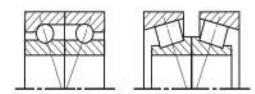
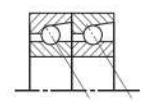
5. Application of rolling bearing

5.1 Rolling bearing arrangements and familiar type

5.1.1 Bearing arrangements

The arrangements of mechanical drive shaft, the shaft of machine tool, generally required 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 bearing 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 used together. The arrangements type listed in table 5-1.

Table 5-1 The basic arrangement of bearing

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 doesn't easy to block when thermal expansion and clearance increase.
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 to mounting and dismounting. It does easy to block when thermal expansion, generally, it applied in short support, and pay attention to adjust clearance.
Tandem (DT)		The center of load acting at same side of the center line of bearing, This arrangement usually applied in the situation that axial load is large, and need multi bearing to endure the load. It must be applied symmetrical, such as face-to-face or back-to-back.

5.1.2 The basic structure of bearing support

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

(1) Two locating supports.The position between bearing and shaft and bore of shell is fixed (See plot 1 in table 5-3). Under the axial load, one bearing surface will approaches the bearing end plates, and there is a gap Δ between another bearing surface and another bearing end plates, and the gap can be used compensated the thermal expansion. If the gap is too large, the chatter of shaft and shock will too intensity, on the other hand, if the gap is too small, it can't play the role of entirely compensate. To steel shaft, the value of Δ 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 cushion during mounting. This support is suitable where only radial load or small axial load is endured.

If the shaft accommodates the combined load, it's usually to use the two locating supports, which composed of the arrangement of face to face or back to back 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 movement of bearing cushion through bearing end plates. The structure is very suitable for machines that need high running accuracy.

(2) One locating and one floating support. On this structure, the position between bearing and shaft or shell bore is fixed at one shaft end, so the shaft can be axial located, (See plot 8 in table5-3). At another shaft end, there is relative movement between bearing and shaft or shell bore, so that the thermal expansion and the error of manufacture and mounting can be compensated.

In this support, the precision of axial locating depends on the axial clearance of 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 can be applied in widely condition, so this structure is widely applied in the shaft of diverse machine tool, shaft that worked in high temperature and long shaft.

(3) Two floating supports. On this structure, the axial position of shaft needn't to be precisely located by two bearings, such as in the herringbone gear driving, this structure is generally used in the pinion shaft. The suitable mesh position of shaft in gearwheel can be located itself by floating around, and it helps to have enough gap at the two sides of bearing.

Almost of all bearings that needn't to be adjusted can be used as 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.

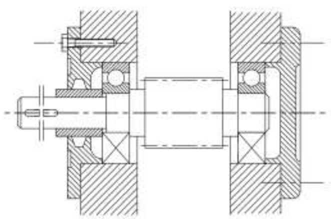
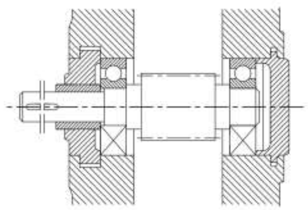
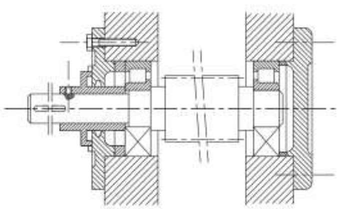
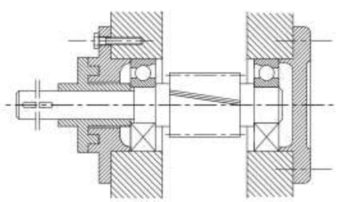
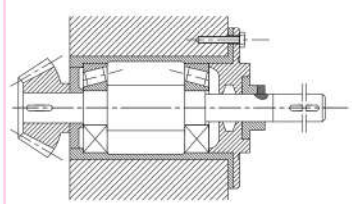
Table5-2 Familiar type and characteristics of support structure

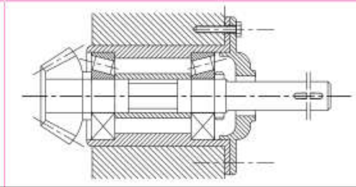
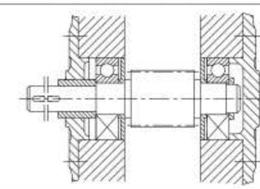
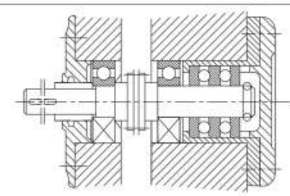
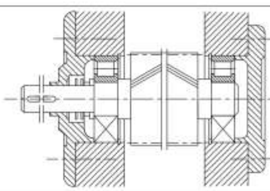
Support Type	Diagram	Bearing Arrangement	Axial Load	Accommodate Shaft Expansion	Others Characteristics
Two locating supports		A pair of deep groove ball bearings	Can accommodate axial loads in single direction (one side which has no clearance)	The clearance between outer ring cover and end plates	High speed, simple structure and convenience 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			Employed 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.	Employed shaft with high speed
		The combined of deep groove ball bearing, thrust ball bearing and double row cylindrical roller bearing with taper bore		Bearing clearance	Enhance the stiffness of support 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 to mounting and dismounting
		Deep groove ball bearing (at left side)	Cylindrical roller bearing (at left side)		Roller axial move relatively to outer ring raceway	Simple structure and convenience to mounting and dismounting
		Angular contact ball bearing paired mounted back-to-back (at right side)	Cylindrical roller bearing (at left side)			Enhance the 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 axial move relatively 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 convenience 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 have 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	Applied in shaft which under large radial load, and can self-aligning
Two non-locating supports		A pair of cylindrical roller bearings		Can not accommodate axial loads	Roller of two sides bearings move relatively to outer ring raceway	Applied in situation that have requirements of shaft moving in axial
		A pair of needle roller bearings without inner rings			Needle at two sides supports move relatively to shaft	

Table5-3 The typical structure of bearing support

Number	Structure Type	Characteristic and Application
1		Deep groove ball bearing, bearing axial 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 need felt seal and lubrication oil, it is suitable to light load, the sliding speed of felt seal is v<=4-5 m/s, and cleanness environment.
2		The design is basically same as Number 1 design, the difference is embedded housing cover; Bearing necessary axial clearance is ensured by adjusting shim between outer ring of right side bearing and housing shim; grope 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 to biggish pure radial load, bad working environment, and the bearing span 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 endures radial load and bidirectional axial load, It is suitable to light load, high speed, and the bearing span less than 300mm.
5		It is suitable to support with small taper gear, There are have below merits compared to Number 6 design 1, Bearing which endures small radial load endures 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 need round nut for axial fix.

Number	Structure Type	Characteristic and Application
6		There are merits below compared to Number5 design 1, The permission of shaft expansion is large. 2, The stiffness of structure is large, for example, if the bearing span equals, the distance between two bearings anti-force is 12>11.
7		The design is basically same as Number 6 design, the difference is the shaft bidirectional axial fixed by right side bearing; and can endure radial load and not large bidirectional axial load. Bearing inside adding flange to prevent grease to be diluted to loss. It applied in the support with 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 endure very large bidirectional axial load, and also endure radial load at the same time; and large move is permitted. The suitable axial clearance can be achieved through the adjustment shim between housing cover and box shell.
9		The outer ring of cylindrical roller bearing has no flange. To chevron gear driven, a shaft (normal high speed shaft) is needed, Application of this design in order to adjust automatic and force equality on the two sides teeth. Rejection oil seal is applied.

5.2 Axial fitting

The axial fitting includes axial locating and axial retained.

5.2.1 Axial locating

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

The height of abutment is not only to guarantee the fully contact between abutment and bearing end plates, but also convenient for the usage of mounting and dismounting tools. General, the minimum of abutment height should accord to requirements listed in the table 5-5.

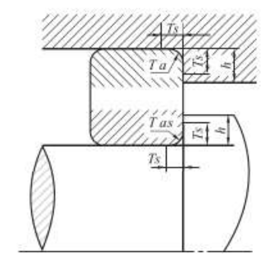


Diagram 5-1 The relationship between bearing fillet radius ra and height h of housing shoulder

Table 5-4 the Maximal of fillet radius of shaft and shell bore

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

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 Axial retained

The axial retained of bearing includes retained inner ring at shaft and outer ring in shell bore. Although the axial retained are required to both inner and outer ring, but it needn't to fix simultaneous. To the structure of two locating supports, it only needs to be fixed in one direction because of every bearing enduring single direction axial load just. To the structure of one locating and one floating support, due to the bearing in locating support under the bidirectional axial load, so it needs to be fixed in dual directions, and the fix structures for floating depend on the type of bearing and the mode of floating.

There are many types of apparatuses for axial retained, 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 retained. 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 fix type of bearing inner ring

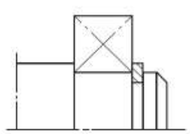
Diagram	Fix Type	Application and Characteristic
	Fixed by Spring collar	Simple structure, convenient to mounting and dismounting, cover small space, often applied for fixing radial bearings.

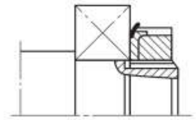
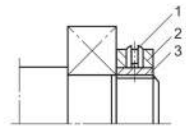
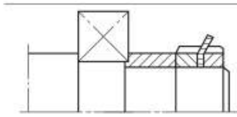
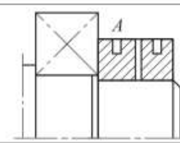
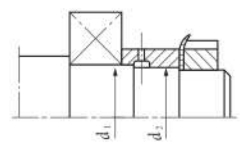
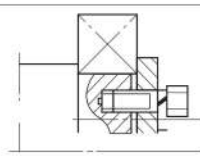
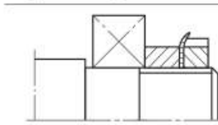
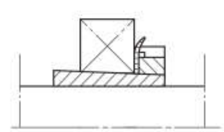
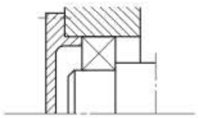
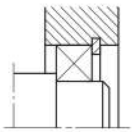
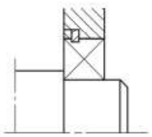
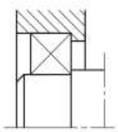
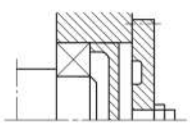
Diagram	Fix Type	Application and Characteristic
	Inner ring fixed by nut and snap ring	Simple structure, convenient to mounting and dismounting, and high fixed reliability.
	Inner ring fixed by nut-2,and prevention loosen by set screw-1, shim-3 is made of soft metal to enhance the effective of prevention loosen and thread damage.	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 high prevention loosen reliability, and sleeve can prevent tilted by nuts.
	Inner ring fixed by nut with two grooves, bolt used to prevent loosen.	It can guarantee the nut cover vertical to the center line of shaft, and applied in vertical shaft of machine tool.
	Inner ring fixed by ladder sleeve, interference fit for sleeve and shaft diameter d1 and d2.	This type fit to high speed shaft of high precision machine tool, it can overcome the changer induced by nut cover not plumping the center line. First mount the sleeve on shaft by heating, after cooled, expanding the sleeve by injecting pressure oil between sleeve and shaft. ,then adjust the position of sleeve by nuts.
	Bearing fixed by bolts and plate, and prevent loose by 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 arrange to the taper bearing, and fixed by shim and nuts.	The bearing radial clearance can be adjusted, and suitable to 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 to mounting and dismounting, often applied for fixing inner ring of self-aligning bearing. This type is applicable to supports with several pivot and difficult to process housing shoulder.

Table 5-7 Normal fix type of bearing outer ring

Diagram	Fix Type	Characteristic
	Outer ring fixed by cover	Simple structure, high fix reliability, convenient to mounting and dismounting
	Outer ring fixed by Spring collar	Simple structure, convenient to mounting and dismounting, cover small space, often applied on radial bearings.
	Outer ring fixed by snap ring	Simple structure, applied in axial dimension 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, shell bore can be a open bore, the axial position can be adjusted by shims, and has a good assembly procedure
	Outer ring fixed by bolt and top cover	Convenient to adjust clearance, and often applied of 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

The bearing preload is defined as a given volume initial force and elastic deformation are kept between rolling elements and raceway when mounting to reduce the actual bearing deformation under running load.

The suitable preload can increase the support stiffness, running accuracy, life, dampness, and can reduce running noise. The research shows that the preload has positive and negative effect on accuracy, life, dampness and noise. At the beginning, the preload has a obviously effect on running accuracy, stiffness, life, dampness and reducing noise, but on the contrary, when the preload reaches a given degree, the effect will not obvious if the preload farther enhanced, and the more the preload, the higher the temperature, and the bearing life declined. Therefore, the bearing preload should be appropriate.

To these bearings in each precision machine tool, their temperature increase has a limit, table 5-8 lists the permission temperature of the each precision machine tool bearing under high speed, unload and continuous running. The ambient temperature is 20 centigrade, and lubricated well. If the ambient temperature is not 20 centigrade, but t centigrade, the permission temperature 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 correct factor, and the K_T based on the selected lubricant. The K_T= 0.6~0.5 if L-HM-L-HV.HS 662 and 32 liquefaction oil are applied, and if applies 3~6 shaft lubricant, the K_T= 0.85~0.8, and K_T= 0.9 if lubricating greases applied.

Table 5-8 The permission temperature of machine tool bearing

The precise level of machine tool	
Normal Level	Mini type Machine tool 45 - 50 large-scale Machine tool 50 - 55
Precise Level	35 - 40
High Precise Level	28 - 30

The bearing preload depends on the relatively movement between inner ring and outer ring, and to thrust bearing, the preload depends on the relatively movement between bearing ring and seating. The preload can eliminate the clearance and achieve the interference. The preload can be divided into radial preload and axial preload based on the direction of preload, and the preload also can be divided into located preload and static preload. In the actual application, the located preload applied in ball bearing, and the static preload applied in cylindrical roller bearing.

5.3.2 Radial preload

The radial preload utilizes the 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 expansion or outer ring compressing.

To bearings with a tapered bore, the different expansion can be achieved depends 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 axial position statically, see figure 5-2. The preload can be achieved through the difference 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 axial preload force statically, see figure 5-3. The preload can be achieved through the spring compression.

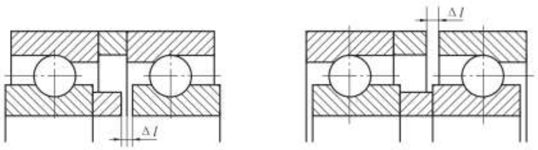


Diagram 5-2 Located preload

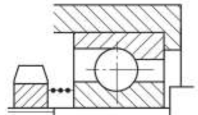


Diagram 5-3 Constant pressure preload

(3) The selection of located and constant pressure preload. On the same preload distortion, it can't obviously increase the axial stiffness of support by constant pressure preload, and the temperature has no impact on the distortion. On the located preload, the axial extension and radial expansion have impact on the preload distortion. The axial induced by the temperature difference between bearing and housing, and the radial expansion induced by 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 for high speed.

5.3.4 Determining preload

The preload is mainly used to adjust and control during the mounting, and this is a very carefulness task in bearing mounting procedure.

The suitable preload depends on the value of bearing load and the requirement of usage, and can be confirmed by calculation combined practical test and actual rotation. Generally it can be divided into below case.

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

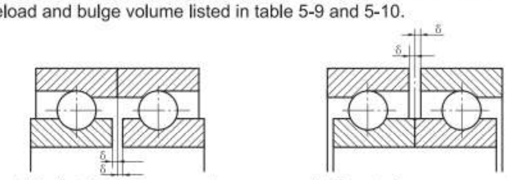
(2) The moderate and heavy preload are applied under moderate speed with middling load or low speed with heavy load, to improve the support stiffness.

(3) To same type angular contact ball bearing paired mounting (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) To same type taper roller bearing paired mounting, the additional axial preload Fa less than 2*Fao (Fao is preload). Otherwise, the situation of one bearing enduring entire axial preload should be avoided.

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

In order to the bulge volume is δ which is between one ring cover bulging another ring cover of single bearing, a certain deformation should be rubbed out on the cover of inner ring or outer ring of two bearing paired mounted. When the paired bearings mounted at the shaft and housing, the two bearing achieve the preload by pressing out the related end plates with retained tools, see figure 5-4. This bearing preload and bulge volume 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. To angular contact ball bearing, taper roller bearing, thrust ball bearing, thrust roller bearing, the roller under centrifugal effect when rotation, there is sliding opposite between roller and raceway. To ensure the bearing action normally, a certain axial preload must be brought, 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 that 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 bulge volume

μm

Δδ₁ + Δδ₂ (Face-to-Face or Back-to-Back), Δδ₁ − Δδ₂ (Tandem)

Preload d/mm	Bearing Series	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: To these paired bearing with inner diameter d>150mm, the tolerance of bulge volume between two bearings is △δ 1±△δ2, it is permitted that the bulge volume is larger 1μm than the value listed in the d=120~150mm.

Table5-11 Preload of angular contact ball bearing paired mounted

Bearing Types	Under Load *Famin*: Pure Axial Load	Under Load *Famin*: Combined Load	Description
Angular contact ball bearing	$\geq 0.35Fa$	$\geq 1.7F_r\text{I}+\tan\alpha\text{I} - \frac{F_a}{2}$ $\geq 1.7F_r\text{II}\tan\alpha\text{II} - \frac{F_a}{2}$	$F_r\text{I}$ —— Radial load that bearing Ⅰ endured, KN $F_r\text{II}$ —— Radial load that bearing Ⅱ endured, KN
Taper roller bearing	$\geq 0.5Fa$	$\geq 1.9F_r\text{I}\tan\alpha\text{I} - \frac{F_a}{2}$ $\geq 1.9F_r\text{II}\tan\alpha\text{II} - \frac{F_a}{2}$ Select larger one	αII、αI – Contact angle of bearing Ⅰ，Ⅱ
Thrust ball bearing	$=A\left(\frac{n}{1000}\right)^2$		F_a —— Axial load, KN F_r —— Radial load, KN
Cylindrical, taper roller thrust bearing	$\frac{Coa}{1000} \leq$ Famin> $A\left(\frac{n}{1000}\right)^2$		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 actually application, it's difficult to achieve optimal clearance by calculation and measurement. To the last mounting step of angular contact ball bearing, taper roller bearing and taper bore double row cylindrical roller bearing, it need to adjust clearance precisely, that is to say to control the preload. Especially, to these shafts that have a strict requirement of running accuracy, noise and temperature increase, such as shaft of machine tool, clearance need to be adjusted not only during first time mounting, but also in using. There are many methods for control preload. Several methods for control preload and problem in the design of preload structure are introduced below.

(1) Several methods for control preload.

1. Measure the bearing friction moment of run up. Measure the relationship between the bearing friction moment of run up and axial load in advance, so that the preload can be adjusted by control bearing friction moment of run up. This method is often applied for the preload of taper roller bearing paired mounted.
2. Measure the bearing axial displacement. To taper bore bearing, measure the relationship between axial load and axial displacement in advance, so that the preload can be adjusted by control 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 control the deformation.
4. Measure the retain moment of nut. Adjusting the preload to control the retain moment of nut, when bearing with nut preload 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, and measure the gap between the end plate and housing cover by gauge, the thickness of shim can be calculated by adding this gap and needed clearance.
6. Application of midst spacer sleeve (No.6 diagram in Table 5-3). The length of spacer sleeve in inner ring can be calculated depends on the length of spacer sleeve in outer ring and bearing dimension, and it also can be directly measured.

(2) Detect and control of preload. At present, it's difficult to detect bearing work preload in our country, the majority detecting axial and radial displacement or friction moment of run up by using dial gauge, and the few using special instrument. Some bearing companies overseas detect and adjust the preload by using special instrument and some structure for controlling the preload, to achieve the optimal preload.

(3) Some problems should be pay 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, and the structure which is convenience to adjust preload.
2. Though the located preload can meet the preload requirement, but the precision of initial preload will be impacted when bearing running because of friction. Therefore, the design of preload structure should be convenience to adjust.
3. To achieve simple structure and convenience to adjust preload, a spacer sleeve 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 structure of nut and manufacture precision have a greatly impact on the control of preload and the adjustment precision.

5.4 Rolling bearing fit

5.4.1 Purpose of the load

Fit purpose is firm set of bearing inner ring and outer ring with shaft and shell , and prevent harmful axial direction slippage of fit surface.

It will cause abnormal high temperature, fit surface fray (fray ferrous powder into the bearing) and vibration and so on problem by harmful axial direction slippage, and cannot full unleash action of the bearing.

The bearing is general rotating load.

5.4.2 Tolerances and fit of shaft and shell

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

Shaft and shell fit relation of size tolerances and class P0 precision for bearing, to meet figure 5-5

5.4.3 Selection of fit

Generally according to bellow principle.

Basis load direction, nature, inner and outer ring revolution direction, so there are three difference conditions: rotating load, stationary load and direction of load indeterminate. Ferrule is used interference fit of rotating load and direction of load indeterminate, and Ferrule is used transition fit and clearance fit of stationary load.

When the bearings have too large load, vibration and attack, So must to augment interference. For the hollow shaft, Thin wall bearing box, light alloy and plastics bearing box, the same to augment interference.

When keep high rotating precision, that use high precision bearing, and increase size precision of shaft and bearing box, prevent too large interference. If it is too large, that should influence shaft and bearing box precision, and cause to damage with bearing rotating precision.

It is used interference fit of no separate bearing. But bearing is not convenient with mounting and dismounting, that it is used clearance fit of one inner ring.

5.4.3.1 Property of the load

Basis load nature, there are three difference conditions: inner ring rotating load, outer ring rotating load and direction of load indeterminate, to meet figure 5-12.

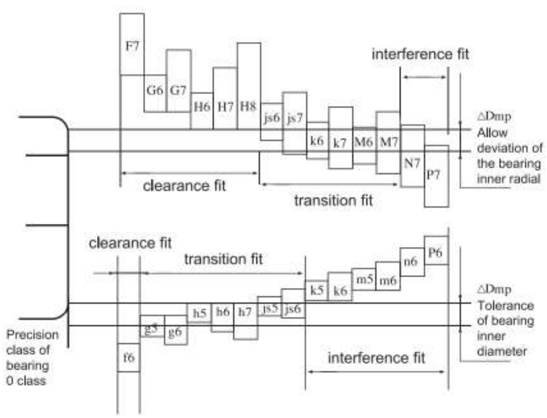
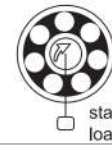
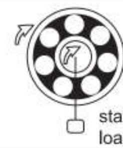


Figure 5-5 Shaft and shell fit relation of size tolerances
(Class P0 precision for bearing)

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	unbalance 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	unbalance load 		

5.4.3.2 Magnitude of the load

The influence of rotating load the ring may begin to creep , the degree of interference must therefore be related to the magnitude of the load.

Interference calculation:

[$F_r \leq 0.25C_0$时]

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

[$F_r > 0.25C_0$时]

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

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 need to be considered.

5.4.3.3 Roughness concentration of matching surface

If consideration plastic deformation of matching surface, So process quality of matching surface will influence effectual interference.

See formula:

[grinding shaft] $\triangle d_{eff} = \frac{d}{d+2} \triangle d$ .... (5-3)

[turning shaft] $\triangle d_{eff} = \frac{d}{d+3} \triangle d$ .... (5-4)

Δdeff : Effectual interference, mm
Δd : Metrical interference, mm
d : Nominal bore diameter , mm

5.4.3.4 Temperature influence

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

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

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

Δdt: Interference minish, mm
Δt: Difference in temperature between the bearing inner and crust,˚C
a: line swell factor of bearing steel, $(12.5\times10^{-6})1/^{\circ}C$,
d : Nominal bore diameter , mm

So, when the bearing is higher than shaft temperature, must be interference fit.
Because of difference in temperature and line swell factor is difference between outer ring and crust, and it is increased with interference fit.

That is noted, when consider and use between outer ring and crust surface glide to avoid shaft swell factor.

5.4.3.5 The best stress of bearing inner by fit produce

When mounting the bearing to use interference fit, and stress is produced by ferrule swell and shrink.
The best stress of bearing inner by fit produce can be calculated by formula (table 5-13). As reference, it is safe of the best interference not more than the shaft 1/1000 or see table 5-13 δnot more than 120MPa.

5.4.3.6 Others

When it require high with precision, and precision of shaft and crust by raise, crust is difficult process and low precision than shaft, so it is relaxed fit of outer ring and crust.

When using hollow shaft, thin wall crust, light alloy and cast aluminum, that fitting must be more tight than others.

When using separate crust, that it is loose fit with outer ring .

Table 5-13 The best stress of bearing inner by fit produce

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

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

D_e: outer rollaway nest ,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: crust outside diameter, mm
E: elastic modulus, 2.08×10^5MPa(21200kgf/mm2)

5.5 Rolling bearings lubrication

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

There are mainly lubricating 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 is semisolid lubricant, and are made of base oil, thickener and additive, base oil has 70-95 percents, thickener has 5-30 percents, the contents of additive is minim.

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 ingredients of thickener have important effect to grease performance, special to temperature performance, water resisting property and decanted performance.

The thickener can be divided into metal soap base and non-soap base.

The additive mainly used to enhance the lubricating grease performance of oxidation resistance, rust prevention and extreme pressure. The lubricating grease with extreme pressure should be applied under heavy load, shock load condition. If there is a requirement of grease long time acting and not replenishment grease, the oxidation resistance lubricating 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 usually 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 type of grease can't be applied mixed, because the grease performance will decline if two greases with different thickeners applied mixed.

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

Sodium base lubricating grease: Well water resisting property, higher drop point, and apply to mechanical components under moisture and contact water.

Aluminum base lubricating grease: Well water resisting property, and apply to part water contacted. The lubricating grease is applicable for lubricating and against corrosion of centralized lubrication system and shipping machine.

Barium base lubricating grease: Well water resisting property, higher drop point, gasoline and alcoholic 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 grease with different liquidity listed in table 5-15. The application temperature range of special lubricating grease 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 thickening, moderate viscosity mineral oil	Well water resistance, applied for agriculture and transportation machine. Running temperature is 1 and 2 grease no higher than 55℃, 3 and 4 grease no higher than 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, thickening with moderate viscosity mineral oil.	Application as above, Running temperature is 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		

Grease			Penetration Number (10^{-1}mm)	Pour Point /℃≥	Components	Performance and Application
	Name	Designation				
Calcium base	Synthesis compound calcium base grease	ZFG-3H ZFG-4H	220-250 175-205	220 240		Well 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 is 120℃-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	Nature 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	Synthesis sodium base grease	ZN-1H ZN-2H	225-275 175-225	130 150	Synthesis fatty acid sodium soap thickening oil	Applicable for lubrication auto, tractor and others machine which not contacting with moisture content.
Calcium-sodium base	Grease for calender	ZGN40-1 ZGN40-2	310-355 250-295	80 85	Calcium-sodium soap thickening cylinder oil with hardened oil and sulfuration cotton seed oil	Well 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	Synthesis gas and engine oil with castor oil calcium-sodium soap thickening No.6.	Well 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.	Well water resisting, and applicable to application for shipping machine and rust prevention of metal.
Aluminum base	Synthesis 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, well 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 nature fatty acid lithium soap thickening with moderate viscosity oil.	Well water resisting, mechanical stability, rust prevention and gasification stability, applicable to rolling and sliding bearings and others rub part of various machine equipment with -20℃-120℃ usage temperature.
Lithium base	Extremely pressure lithium base grease	0 1 2	355-385 310-340 265-295	170	As above	Well water resisting, mechanical stability, rust prevention, extreme pressure anti-wear and pump-over. Applicable to bearings and gears of calendar, forging machine, reducer and other heavy equipment with -20℃-120℃ usage.
Lithium base	Synthesis lithium base grease	ZL-1H ZL-2H ZL-3H ZL-4H	310-340 265-295 220-250 175-205	170 180 190 200	Synthesis fatty acid lithium soap thickening with moderate viscosity oil	Basic as nature lithium soap, and the same as usage condition.
Lithium base	Grease for shaft of precision machine tool	2号 3号	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.

Grease			Penetration Number (10^{-1}mm)	Pour Point °C≥	Components	Performance and Application
	Name	Designation				
Barium base	Barium base	ZB-3	200-260	150	Fatty acid barium soap thickening with moderate viscosity oil.	Water resisting, stand fire, and well extreme pressure. Applicable to suction pump, marine propeller and heavy machines under high temperature, high pressure and moist working condition.
Barium base	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 speed rapidly changed.
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.
Alkyl base	Grease for precision instrument	ZT 53	30	70		
Alkyl base	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 occasion	Easy to jiggle rub	Low temperature and easy to jiggle rub	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 important effect on bearing working performance, and testified by theory and practice that it's applicable to inject grease to 1/3 -1/2 of bearing and bearing shell. If more lubricating greases injected, there is a waste of grease, increasing bearing friction and temperature, soften the grease because of whisk. The result is worsening lubricating contrary.

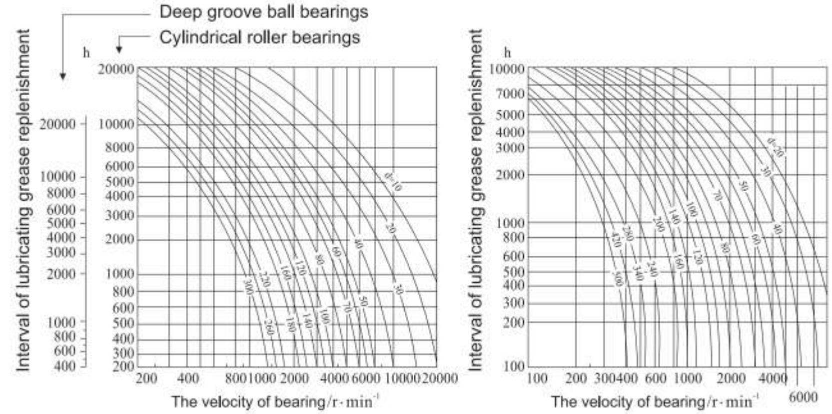
General injection volume of lubricating grease decrease when speed increase, the injection volume of grease should be only 1/3 or fewer when high speed (>3000rpm). If speed is very low, injection full of bearing space to prevent external contamination entering bearing inside.

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 reduced gradually and debris increased during working. Therefore, lubricating grease must be replenished or renewed at a given interval. The cycle of replenishment lubricating grease related to bearing structure, dimension, speed, temperature, environment condition.

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

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



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

Figure 5-6 The interval of lubricating grease replenishment

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 bearing marinated in 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-spot. This method often applied for high speed small size bearing lubrication, the oil transported by visualization oil cup at given intervals. The minimum quantity can be obtained by test.

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

(4) Circulating oil. The filtered lubrication oil transported to bearing components by oil pump. Filtering lubrication oil which went through bearing once more, and these lubrication oils can be circle used after cooled. The bearing temperature declined because of oil circulation removing some volume heat, so this method is applicable to bearing 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 control valve for constant temperature.

The circulating oil quantity can refer to figure 5-7. If the application of circulation oil is not for radiating, but for bearing lubrication, a small quantity of oil needed. If the application is for radiating, large quantity of oil needed to prevent oil amass inside bearing because of resistance induced by oil passing 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 satisfied working temperature depends on the rates of heat emission and radiation, and often needs trial running.

(5) Oil jet. High pressure oil jetted into bearing by oil pump, and flowing into oil sink after running through bearing inside. In high speed bearing, when bearing rotating, the rolling elements and cage also rotation with high speed, so that airflow formed and resistance increases.

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

The oil quantity that oil injection needed mainly depends on heat emission from oil. Table 5-17 lists the approximate oil quantity that oil injection needed, 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, nozzle diameter can be 0.7-2mm. In oil injection system, oil filter needed to avoid nozzle jam.

(6) Oil mist. Mixed very dry and cleanness and filtered compressed air into lubrication oil to form mist, and then jet into bearing. Airflow in bearing housing can cool bearing, and the pressure induced in housing can prevent contamination entering. The quantity can be accurately adjusted, and the stir resistance is small. This method is application for lubrication bearing part with high speed and high temperature.

(7) Oil air. Piston ration distributer is applied to transport minim oil into compresses airflow in pipe at given interval, and to form continue oil flow on pipe wall, and to supply to bearing. The oil not to be ageing because often renew oil. External contamination isn't easy to enter bearing inside because of compressed air. The pollution to environment greatly decreased because of supplying minim oil compared with oil mist. Lubrication oil quantity is small and stable, small friction moment, low rising of temperature, and this method is special applicable to high speed bearing.

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

5.5.2.2 The selection of oil lubrication

Generally, mineral oil without additive applied for rolling bearing lubrication. Only in some special occasion, the mineral oil with additive used to enhance lubrication performance, such as enduring extremely pressure and defending ageing. Synthesis oil applied only in some special occasion, such as temperature or speed is extremely high or low.

Viscosity is one of important performance index, and is a 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 too lower, oil film can't be formed, and it can lead bearing abnormal rubbing and service life lower. If viscosity too high, the dynamic lose enlarged because of the heat emission induced by viscosity resistance.

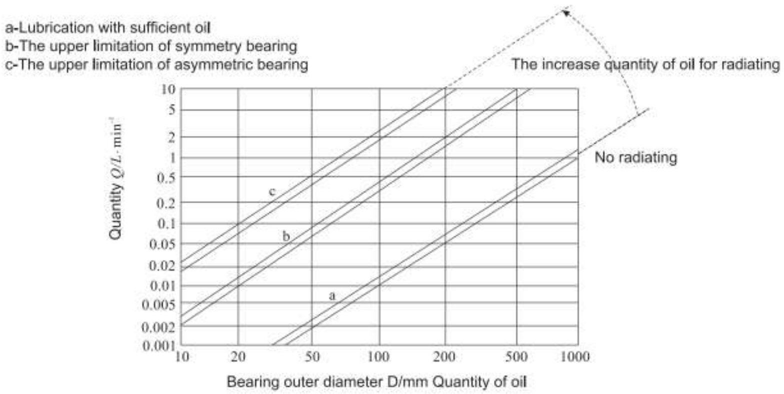


Figure5-7 The quantity of circulating oil

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 applied for high speed occasion, and the bearing size becoming larger as the load rises. Under bearing running temperature, the viscosity of lubricant is generally no less than $13mm^2/s$ to ball bearings, and $20mm^2/s$ to roller bearing, and $32mm^2/s$ to thrust self-aligning bearing.

The requirements of bearing dynamic viscosity at running temperature listed in figure5-8. 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.

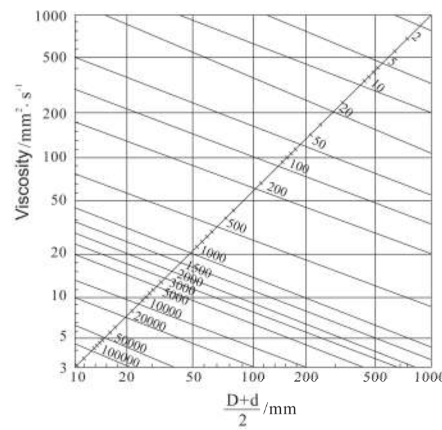


Figure5-8 Suitable lubricating oil (Left)

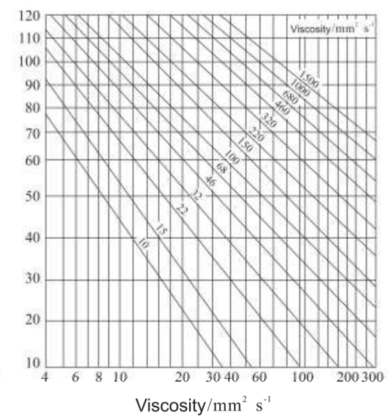


Figure5-9 The relationship of viscosity and temperature (Right)

5.5.2.3 Bearing oil

Bearing oil applied in shaft, bearing and clutch, L-FC is designation of antioxidant and antirust; L-FD is designation of antioxidant, antirust and anti-wear. The standard listed in table5-18.

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
Motion viscosity (40℃)/mm².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
Motion viscosity (40℃) /mm² 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

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 circulated.

5.5.3 Solid lubricant

The solid lubricant applied under some special occasion because of the application limitation 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 on 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 combined materials of solid lubricant with relevant shape, or directly inlay combined material of solid lubricant on retaining surface or raceway.
(5) With techniques of electroplate, high frequency sputtering, ion plating, chemical deposition and etc, solid lubricant or soft metal formed into uniform dense film on the rubbing surface of bearing components.

5.6 Rolling bearings seals

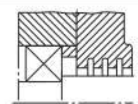
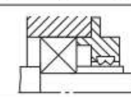
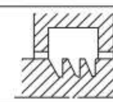
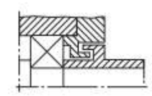
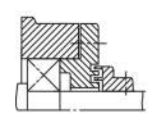
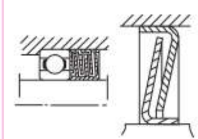
5.6.1 Type of seals and performance

The purpose of a seal is to help bearing to reach its maximum service life and reliability, and retaining lubricants, excluding contamination and water entering into bearing.

Seal can be divided into static seal and dynamic seal, and the dynamic seal can be divided into rotation seal and movement seal, and the rotation seal also can be divided into contact rotation seal and non-contact rotation seal based on whether there is gap between two adjoining planes. There are many seals structure, and table5-19, table5-20, table 5-21 list common seals types and performances.

Besides, there are bearings with shield or seal, and have infill suitable quantity lubricating grease when mounting. These bearings can retain lubricant exclude contamination entering into bearing under normal working condition without external seals. These type bearing have simple structure and saving space.

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

Seal Types		Diagram	Performance and Application
Slit seals	Gap type seal		The effective of seal well as the gap between shaft and end plates smaller and axial width longer. It is suitable for cleanness running condition with grease lubrication. Generally the value of gap is 0.1-0.3mm.
	oil groove seals		There are 2-4 grooves on the cover arrangement surface, and infill lubricating grease to enhance seal effective. The dimension can refer to table6-40, generally, radial gap is 0.1-0.3mm.
	W shape groove seals		Applied for oil lubrication. There is oil groove on shaft or sleeve to injection leak oil. Return chute on wall of bore of cover to recover into bearing (or box).
	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.
Labyrinthseals	Axial labyrinth seals		Axial labyrinth seals are made of gap between sleeve and cover. But labyrinth radial extends, and the number of circuitous isn't applicable too much. The axial labyrinth seals are widely applied than radial labyrinth seals because of easy to mounting and dismounting, and not splitting cover.
	Radial labyrinth seals		Radial labyrinth seals are made of gap between sleeve and cover and labyrinth axial extends, radial dimension is compactable. The effective of seal more reliability as the number of circuitous rises. The radial labyrinth seals are applicable for dirty condition, such as working end of machine tool for metal cutting, seal dimension listed in table6-41.
	Sealing washers		Labyrinth seals coined by thin steel plate, and can laminate arbitrary quantity of labyrinth seals. Simple structure, lower cost and small space. This seals mounted with special care, and pay attention to whether there is interference between labyrinth seal and the axial clutter of bearing, and whether there is interference between seals and shaft deflection when applied self-aligning bearings.

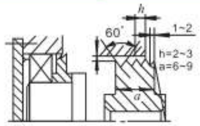
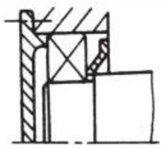
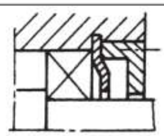
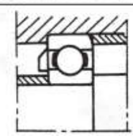
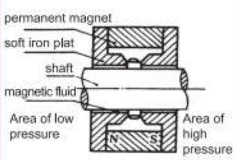
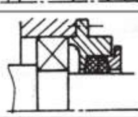
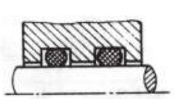
Seal Types		Diagram	Performance and Application
Sealing ring	Oil flange disk		Oil flange disk rotates with shaft, the effective of seals greater as speed higher, and it can not only retain oil, but also exclude contamination entering into bearings, mainly applied bearings seals with grease lubrication.
	Dynamic seals		Coined by thin metal plate, and dynamic seal rings rotation with shaft are applied for seals bearing with oil lubrication, and rejection oil and contamination depends on centrifugal force to prevent pollution environment. The static seals ring fixed with outer ring mainly applied for seals bearing with grease lubrication. The seal rings integrated with shaft by turning also act seal effective.
	Static seals		
	Spring seals		Coined by thin spring steel plate, and fixed on inner ring or outer ring cover of bearing, approach to another outer ring cover by self spring force. It often applied for bearing with grease lubrication, and structure is compactable, effective well.
Magnetic fluid seals			It's a new developing seal, and the theory is ferromagnetism particulate (0.2-1)*102um form to 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 merits is has almost non-limitation of service life, and no leakage under larger pressure difference, and no strict requirement of roughness of shaft surface and thrash.

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 table6-31.
	Double felt ring		The gap can be adjusted by felt ring, well effective of seal, and replace conveniently.
Rubber ring	Rubber o-ring		Compressing the seal by mounting groove, and the seal effective can be enhanced by gravity press. Rubber o-ring has seal ability on dual directions, and there are single seal ring and double seal ring. The effective of double seal ring greater than single ring, and the dimension of seal ring and groove listed in table 6-38, 6-39 and 6-40.

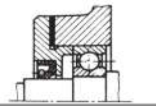
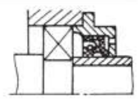
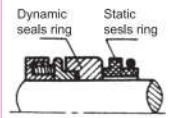
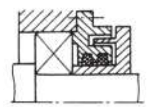
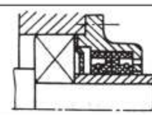
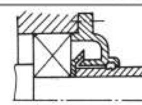
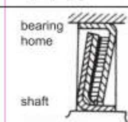
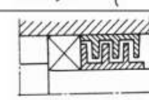
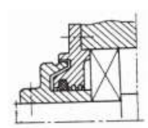
Seal Types		Diagram	Performance and Application
Rotary shaft lip seals	Single lip		Mainly applied for oil lubrication seal under the condition of the shaft speed no larger than 7m/s and temperature no higher than 100□. It also applied for grease lubrication seal. There are six basic types of rotary shaft 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, the arrangement seal ring is suitable for large scale and precision equipments.
	Double lip (Vice-lip)		
Mechanical seals			The dynamic ring is made of graphite or plastic and rotation with shaft, static ring is made of metal or ceramic. Depend on the axial force of dynamic ring and static ring under spring, magnet or hydrodynamic to achieve seal by tightly fitting between dynamic ring rub surface and static ring rub surface. The structure types and material varies depend on usage condition and difference structure. The mechanical seal has high seal reliability and less leakage, and can work under harsh condition. The shaft speed is no larger than 150rpm,can pressure is on larger than 35MPa, the running temperature is -250℃~1000℃.

Table 5-21 Compound seal

Seal Types	Diagram	Performance and Application
Combined of labyrinth and felt seals		The effective of seal well, and applicable to oil or grease, the contact circular velocity no large than 7m/s.
Combined of oil flange and lip ring seals		The effective of seal well, and applicable to oil or grease, the contact circular velocity can be larger than 7-15m/s.
Combined of oil slinger W shape and slit seals		No lose of friction, seal effective reliability, and applicable to oil or grease seals, no limitation of circular velocity, the effective of seal greater as circular velocity rises.
Combined of coining and labyrinth seals		Coined by sheet metal, and there is contact seal lay in the middle. The effective of seal well, and complex structure, not applicable to high speed, and suitable for mass production.
Combined labyrinth seals		Labyrinth seal combined by two ┌ shape gasket, small space, lower cost, and suitable for mass production. The gasket mass mounted.
Combined of labyrinth,felt and oily ditch seals		Combined the merits of labyrinth, felt and oil ditch seals, the effective of seal well, contact seal, and isn't applicable to high shaft speed, and its structure complex.

5.7 Mounting and dismounting of rolling bearings

The quality of rolling bearing mounting and dismounting will directly impact bearing precision, life and capability, so, bearing mounting and dismounting will strictly accord to rule, and take right means and tools.

5.7.1 The preparation for bearing mounting.

1) Be familiar with mounting drawing and technical file, and sure mounting technical and tools. By analysis of drawing and technical file , to determine bearing characteristic and requirement ,draw out mounting scheme 、plan、program and tools. When there is special request of bearing mounting, choose the best mounting technique to guarantee mounting quality.

2) Checking bearing type. Check bearing casing type if the same with mounting drawing before mounting.

For special require bearing, example: high temperature bearing, no basic clearance bearing and no basic class bearing, but it is the same with general bearing of package, so that need to seriously check or to separate storage.

3) Cleaning bearing. Bearing should be installed in a dry, clear environment. Mounting should be away from machining metalworking or other machines producing forge 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.

Using gasoline or kerosene to clean anti-rust's bearings, but to anti-rust bearing with anti-rust grease or thick oil, first hot dissolve clean with 950C-1000C light mineral oil. After anti-rust grease melted, then use gasoline or kerosene to clean.

When cleaning a few bearings, it is immediate put into oil sink. When cleaning lots of small and medium bearings, it is put into wire netting and by sway immerge oil sink. When cleaning lots of large size bearing, the best method using cleaning machine.

4) Expect cleaning the bearings, careful check coordinate with face if have burr, pocking and sundries of shaft radial, lining, end closure and separate ring, and must be clean with gasoline or kerosene, to prevent sundries to enter the bearings.

5) Measuring and matching bearings and its parts. The match precision must be kept strictly between the bearing and shaft ring & interrelated parts. When mass produced, the match precision is guarantee by the parts process precision.

In the important occasion, such as the bearings of steel rolling machine, railway locomotive, high speed diesel engine, accuracy numerical control machine and so on, it must overall check strictly with the kinds of parts technical requirement of drawing before mounting.

For whirl accuracy requirement high shaft , example accuracy machine tool principal axis, so as to increase whirl accuracy of principal axis parts, except choose high accuracy bearing , increase principal axis and prop up hole accuracy, reasonable choose bearing, may matching bearing.

Measuring roll bearing inner ring and shaft radial before mounting, and make sign at the most highest, then grouping with practical pulse, to take the similar pulse mounting , they are contrary with the high point ,and increase whirl accuracy.

5.7.2 Rolling bearings mounting method

Roll bearing mounting method is very more, 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

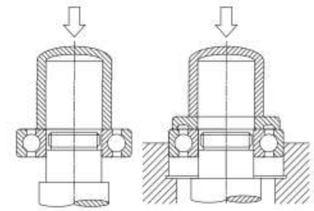
The method is simply in using tools and operating, basis bearing measure 、fit quality and mounting's place, It can take bearing mounted in shaft and shell with using hand hammer and sleeve or pressure fitting.

2) Mounting bearing using pressure method and notation proceeding:

1、To ensure mounting pressure and bearing fit piece, Figure 6-14 .It is not allowed to be harmful to the bearing's other part of mounting and dismounting force caused damage and deformation.

2、Axial pressure can not be imposed on the bearing rings，But through the soft metal sleeve or pad to impose average on the lap, Preventing ring unilateral force to tilt, mounting process cause damage and clip death.

3、Must be based bearing's structure、size、accuracy, character and location of the installation of an integrated to consider bearing mounting methods and used tools.



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

4、Bearing pre-installed should be carefully cleaned ,after using bearing some times and with some lubricant between the trickle-down to reduce the pressure of dismounting.

5、with separable cylindrical roller bearing、taper roller bearing、thrust ball bearing ,the outer ring and inner ring can installing the shaft, make sure misalignment.

5.7.2.2 Mounting and adjustment bearing with a tapered bore

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. General there is three methods of this bearing fit.

1、Mounting taper bore bearing measure fit method

1) Controlling the reduction in radial internal clearance .The bearing internal clearance because the process due to the expansion of the inner ring.

2) Directly control the axial movement. Figure 5-10, the bearing was pushed into the cone shaft .Measuring inner ring side and axial drive-up A. According to the request to push the bearing with appropriate location .

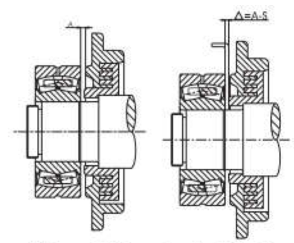


Figure 5-10 control axial trip

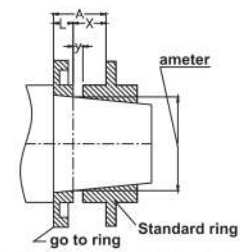


Figure 5-11 control orientation ring lenth

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

L-orientation ring long

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 tapered

2、Notes for mounting tapered bore bearing

1)The fitting quality of tapered bore bearing and shaft diameter depends on the bearing movement up to shaft , as a result of produce difference, measure and account difference , it's very difficult to meet the best fitting quality and high precise requirement only using the three method above.

2) Tunable of mounting place is very ideal method for, figure 5-12, Mounting and adjustment clearance use lock nut. Generally this method is used for the bearing of machine tool.

3) To count course of mounting. Relation formula of Interference and course

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

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

Relation formula of course and the bearing diameter interference clearance .

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

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

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

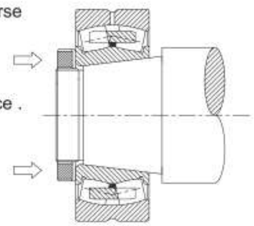


Figure 5-12 Mounting and adjustment clearance use lock nut

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(unrib)	$0.25D+0.75d$	$0.75D+0.25d$
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 consider uses of adaptive sleeve or withdrawal sleeve, that have clearance of coat and shaft and bearing in between, and need preload ,so in the same interference ,and need increase 0.1~0.2mm for step S. In the calculation of the radial clearance reduced to Δu , still take practical and effective step s .

To control radial clearance decrement and step, that be to ensure the quality of the important methods with taper face, so that give us in the drawing in the technical conditions. Table 5-23 and 5-24,Two kinds of bearing radial internal clearance and axial movement relationship.

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

Bore Radial (mm)	Radial Internal Clearance (Δu/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
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 (Δu/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

The bearing mounting and dismounting force is important according to choose sure method and tools. According interference to the calculated of important bearing with mounting and dismounting force.

Mounting and dismounting force of solid shaft and thick shell:

$$F=f_k f_f \delta_E B,\ N$$

f_k- resistance coefficient of mounting and dismounting

f_f- geometry size coefficient of the bearing: $f_f=1-\frac{d^2}{d_E^2}$, when mounting and dismounting inner ring, d_E calculated see table 6-50 , $f_f=1-\frac{D^2}{D_E^2}$, when mounting and dismounting outer ring, D_E calculated to meet table 5-25

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

B -the bearing width

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

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

the meaning of f_k, f_f, δ_E, B before

f- hollow coefficient f1 of hollow shaft, determined $\frac{d_0}{d}$ and $\frac{D}{d}$ by figure 5-13; thin-walled coefficient FEG of thin-walled steel shell ,

determined $\frac{D_0}{d}$ and $\frac{D}{d}$ by figure 5-14; thin-walled coefficient FEG of thin-walled cast iron shell , 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 of shell is greater than the bearing outer ring , $f_{EG}=f_{ET}=1$。

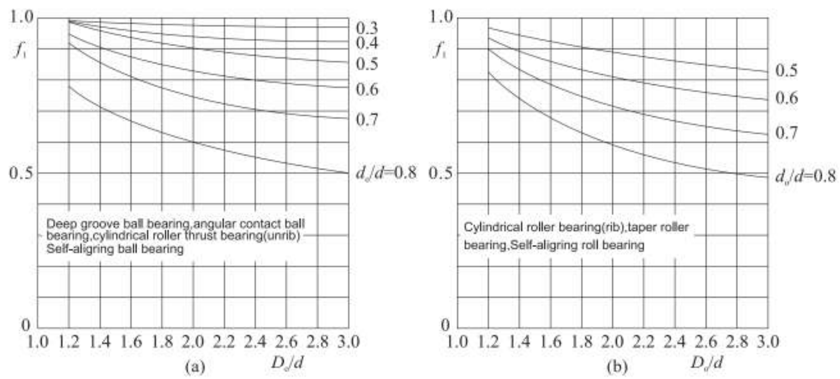


Figure 5-13 coefficient f_1

Table 5-25 Tapered bore self-aligning (1:12) roller bearing Δ_a 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

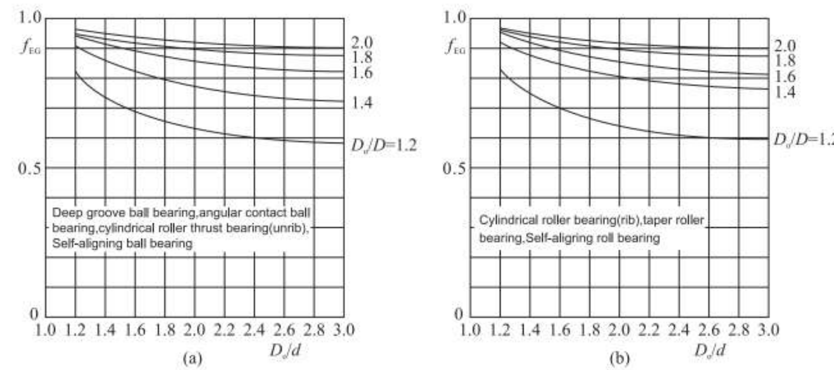


Figure 5-14 coefficient f_{EG}

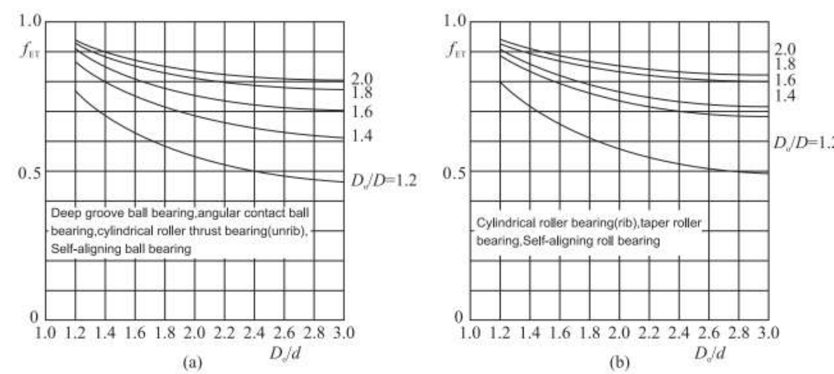


Figure 5-15 coefficient f_{ET}

5.7.2.4 Hot mounting

When the bearing is larger or the interference is large, the mounting will increase the pressure, so many times in the mounting and removal or replacement of bearings, particularly bearing and metal seat empty flat, interference fit, easy to lead with the pressure method Surface damage. Therefore requires the use of temperature difference method.

Temperature difference method is to use the principle of expansion and contraction so that bearing ring and shaft or hole temperature difference between the production installation. When the bearings are mounted to the shaft, the bearing heating, diameter swell, set in the journal, the other bearing cooling, the diameter reduced the amount of interference resume, work closely with the shaft bearings.

When the bearing mount of bearing home, heated bearing, if the body such as seat hole is large, bearing cooling can also be installed, when bearings recovery room, they get the interference fit.

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.

When heated bearings are generally lower than the tempering temperature is about 60-70℃, or bearing deformation and reduce the hardness, heat at 80-100℃ for ordinary bearings, not more than 120℃

Bearing cooling, in order to prevent the bearings cold brittle behavior, the temperature is not lower than -50℃, sometimes can also be used -80℃. Heat and cool method see table 5-26

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 feature is safe, cleaning and temperature strict control; it is use other occasion of general equipment. That fault is long times of heat, space limitation, no method lot heating and large bearing heating
heater plate heating	The bearing can be heated by heater plate with temperature accurate adjustment and control, and even-heating ,handiness, safe , signs of overheating if no person to look after, be applicable to small bearings.
oil bath heating	the oil is transformer oil with better ,to control 80~1000C of oil temperature, even-heating ,flash heat, heat large bearing. But it isn't heat bearing of seal ring and dust cap with grease lubricant.
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

Interference with the shaft and bearings, the friction with the surface large. When the interference is large, and may damage mating surfaces, as reduce friction between mating surfaces, the protection with the surface, can be used in injection pressure between the surface of the oil with the method, Figure 5-16 is a hole in this way mounting cone bearing Example.

mounting bearings, the first bearing into the cone surface, with surface Press closer, tightening the nut, with a manual pump or oiling to meet the injection pressure between the surface of the oil, while moving with the nut wrench nut, push forward bearing until appropriate location.

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.

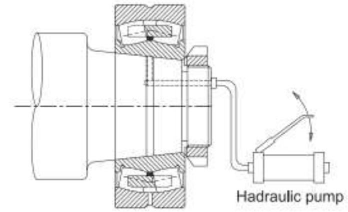


Figure 5-16 Mounting bearing of the oil injection method

5.7.3 Dismounting of rolling bearing

To choose fitting method and tools of dismounting bearing , and according to type, precision, mounting structure, position, size and if use to future.

It is more difficult dismounting than mounting, because the part rust and deform. if the bearing again be use, That not must be allow to transitive dismounting force with rolling element, if not it isn't used for rollaway nest and rolling element damage.

The puller is used of center bearing with pressure method. See figure 5-17

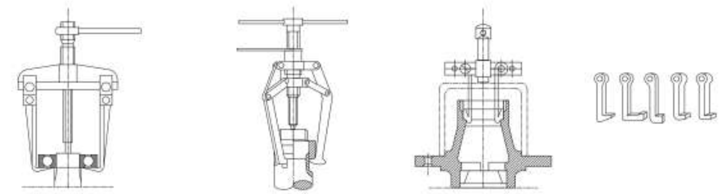


Figure 5-17 Puller disassembly

Larger bearing dismounted with an interference fit generally require greater force to remove them, See figure 5-18 dismounting cushion block. It makes up of two semicircle cushion block and outer ring. The method is evenness distributing press of bearing ferrule head face.

The ferrule must be lock dismounting bearings with pull rod, that is require have enough space for physical design. See figure 5-19, processing groove of shaft and seat bore beforehand.

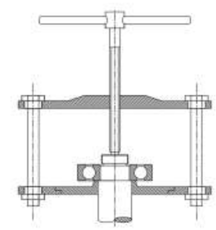
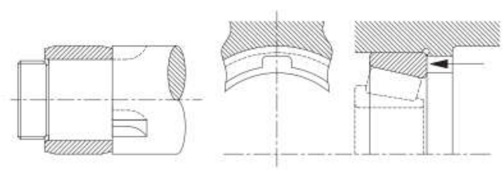


Figure 5-18 puller disassembly



(a) extraction grooves (b) bore shoulder

Figure 5-19 extraction groove for outer ring disassembly

When dismounting bearings outer ring if no enough bore shoulder high , that screw hole and unthreaded hole be process in the circumference of bore shoulder, and the outer ring is push-out convenient with crew hole and unthreaded hole , see figure 5-19(b) and 5-20

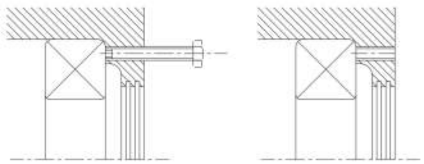


Figure 5-20 Outer ring disassembly bolt

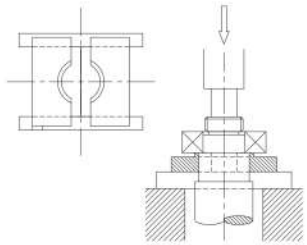


Figure 5-21 Press disassembly

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 to hydraulic demolition methods, figure 5-22,First, loosen the nut, then use the manual high-pressure pump to the cone axis of the hole to send oil to make bearing removal bearing inner ring expansion.

For small to medium bearings installed using an adapter sleeve are removed by loosening the locle nut, plaesing 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 fightening down the look nut as shown in Figure 5-23(b).

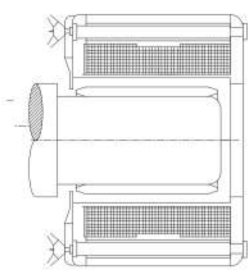
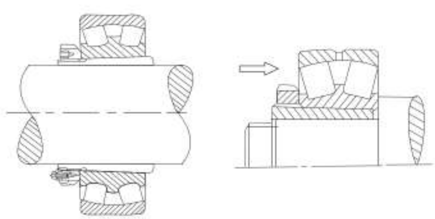


Figure 5-22 Induction heater



(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 fromimproper bearing selection, handling or lubrication. In thisoccurs, take note of the type of machine on which thebearings is used, the place where it is mounted, serviceconditions and surrounding structure. By investigatingseveral possible causes surmised from the type ofdamage and condition at the time the damage occurred, it is possible to prevent the same kind of damage fromreoccurring. In the table below gives the main causes of bearingdamage 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, improperhandling · 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 (includingclearances made smaller by localdeformation). · Insufficient lubrication or improperlubricant. · Excessive loads (excessive preload). · Skewed rollers. · Reduction in hardness due toabnormal temperature rise	· Review lubricant type and quantity. · Check for proper clearance. (Increase clearances.) · Take steps to prevent misalignment. · Review application conditions. · Improve assembly method andhandling.
Cracking and notching	Localized flaking occurs. Little cracks or notches appear.	· Excessive shock loads. · Improper handling (use of steel hammer,cutting by large particles of foreign matter) · Formation of decomposed surface layer due to improper lubrication · Excessive interference. · Large flaking. · Friction cracking. · Imprecision of mounting mate (oversized fillet radius)	· Review lubricant (friction crack prevention). · Select proper interference and reviewmaterials. · Review service conditions. · Improve assembly procedures andtake 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 whirling caused by excessive internal bearing clearances.	· Reinspect bearing's internal clearances. · Review accuracy of shaft and housingfinish. · 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 tolarge axial loading. · Surface roughness. · Excessive slippage of the rolling elements.	· Reevaluation of the lubricant type andlubrication method. · Bolster 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 occasionallyrust 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 rustingwhile 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 formson 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, vibrationwhile stopped.	· Select a different kind of bearing. · Select a different type of lubricant. · Review the interference and apply acoat 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 thelubricant. · Inadequate lubrication. · Skewed rollers.	· Review lubricant type and lubricationmethods. · 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. · Bite-in on the flaked-off side. · Dropping or other mechanical shocksdue to careless handling. · Assembled misaligned.	· Improve handling and assembly methods. · Bolster sealing performance. (measures for preventing foreignmatter from getting in) · Check area surrounding bearing.(when caused by metal fragments)
Creeping	Surface becomes mirrored by sliding of inside and outside diametersurfaces. May by accompanied by discoloration or score.	· Insufficient interference in the matingsection. · Sleeve not fastened down properly. · Abnormal temperature rise. · Excessive loads.	· Reevaluate the interference. · Reevaluate usage conditions. · Review the precision of the shaft andhousing. · Raceway end panel scuffing
Speckles and discoloration	Luster of raceway surfaces is gone; surface is matted, rough, and / orevenly dimpled. Surface covered with minute dents.	· Infiltration of bearing by foreign matter. · Insufficient lubrication.	¡Reevaluation of lubricant type andlubrication method. ¡Review sealing mechanisms. ¡Examine lubrication oil purity.(filtermay 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 andlubrication method. · Improve sealing performance. (to prevent infiltration of foreign matter) · Take care to operate smoothly.