6 Fit and clearance of bearings

6.1 Fit

When mounting installation, the fit between Inner diameter and shaft, outer diameter and housing is very important. If the fit is too loose, relative sliding will occur to the fit surface, which is called creep deformation. Creep deformation will cause abrasion to the fitting surface, and damage the shaft or housing. Furthermore, sometimes abrasion metal particles will penetrate into the bearing, and bring about premature failure .

When the magnitude of interference is too large, outer ring outer diameter decreases or inner ring inner diameter increases, the internal clearance of the bearing will decrease. In addition, the geometric accuracy of shaft and housing will also affect the bearing ring's original accuracy, and then affect the bearing's performance.

The relations between shaft bore diameter tolerance and inner /outer diameter fit are as shown. Fig. 6.1.

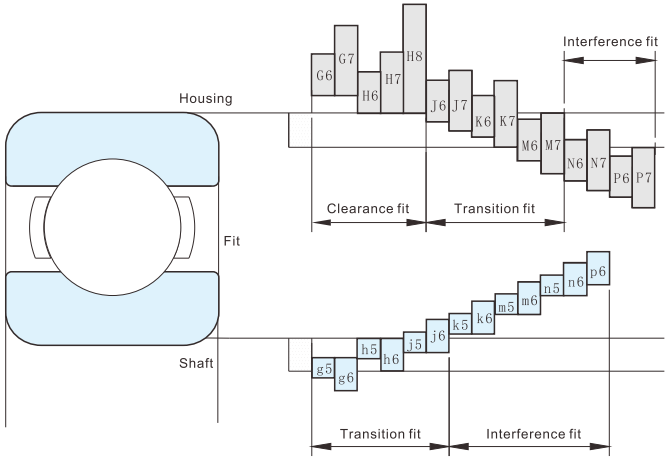


Fig. 6.1 Dimensional tolerances and fit of shaft and outer bore

6.1.1 Load characteristic and fit

The following principles are often been used to select fit.

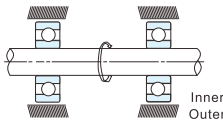
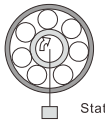
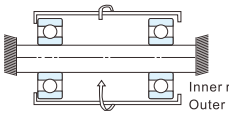
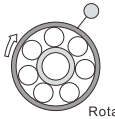
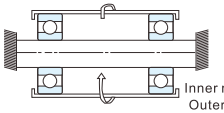
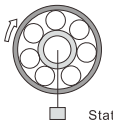
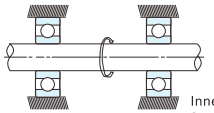
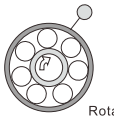
According to the direction and characteristic of bearing load, and the rotation direction of inner/outer ring, to determine whether the load carried by each ring is rotation load, static load or indeterminate direction load. Rotation load indeterminate directional load shall adopt interference fit, static load can adopt transition fit or clearance fit. See Table 6.1.

In case of large load or shock/impact load, its magnitude of interference shall be increased properly. When using hollow shaft, thin wall case or light alloy or bearing housing made of plastics, the allowance of interference shall also be properly increased.

When the working condition requires to keep high running accuracy, it is necessary to adopt high precision bearing, and increase the dimension accuracy of shaft and bearing housing, to avoid too large allowance of interference. If the allowance of interference is too large, the geometry of the shaft or bearing housing might affect the geometric shape of the bearing ring, and then affect the bearing's running accuracy.

If the inner ring and the outer ring is inseparable (such as deep groove ball bearings) both adopt allowance fit, bearing mounting and dismounting will be very inconvenient. In this case, it is better to adopt clearance fit to either inner ring or outer ring.

Table 6.1 Examples of selecting fit according to the characteristic of radial load

Bearing rotation condition	Direction of load	Load conditions	Method
 Inner ring : rotation Outer ring : static	 Static load	Inner ring rotation load	Inner ring : adopt interference fit
 Inner ring : static Outer ring : rotation	 Rotation load	Outer ring static load	Outer ring : clearance fit available
 Inner ring :static Outer ring : rotation	 Static load	Inner ring static load	Inner ring : clearance fit available
 Inner ring :rotation Outer ring :static	 Rotation load	Outer ring rotation load	Outer ring : adopt interference fit
Where load direction varies, or the direction of unbalanced load, etc. is uncertain	Rotation or static	Indeterminate direction load	Interference fit

6.1.2 Calculation of interference allowance

1) Load and interference

When the bearing carries radial load, the interference of the inner ring will decrease. The decrease of the interference of the inner ring can be determined with the following two formulas:
When

$$F_r \leqslant 0.3C_{0r}$$

$$\Delta d_F = 0.08\sqrt{d \cdot F_r / B}$$

$$F_r > 0.3C_{0r}$$

$$\Delta d_F = 0.02(F_r / B)$$

In the formula,

Δd_F : Decrease of the interference allowance of the inner ring μm

d : Bearing inner diameter mm

B : Inner ring width mm

F_r : Radial load N

C_{0r} : Basic static load rating N

2) Interference allowance caused by the temperature difference of bearing, shaft and housing

The interference allowance of the fitting surface of the bearing inner ring decreases along with the increase of the bearing temperature in operation. $\triangle T$ (° C) is supposed to be the difference between the bearing internal temperature and surrounding environment temperature. The temperature difference of the shaft and the fitting surface of the inner ring can be (0.1 ~ 0.15) $\triangle T$.Therefore, $\triangle d_T$, the decrease of the inner ring interference allowance caused by this temperature difference can be determined with the following formula:

$$\Delta d_T = (0.1 \sim 0.15)\Delta T \cdot a \cdot d$$
$$= 0.0015\Delta T \cdot d$$

In the equations:

Δd_T : Decrease of the interference allowance due to temperature difference μm

ΔT : Temperature difference between bearing internal and surrounding environment ℃

α : Linear expansion coefficient of bearing steel

(12.5×10^{-6}) 1/℃

d : Bearing nominal bore mm

In addition, since the temperature difference and expansion coefficient is not the same between outer rings and bearing housings , the interference allowance sometimes will increase instead.

3) Effective interference allowance and target interference allowance

Due to the roughness of the fitting surface, damage due to pressing is very often during fit, therefore effective interference allowance sometimes is smaller than target interference allowance. The decrease of target interference allowance differs according to the working accuracy of the fitting surface. Generally , effective interference allowance can be determined with the following formula:

Grindled shaft $\Delta d_{eff} = \frac{d}{d+2} \Delta d_a$

Machined shaft $\Delta d_{eff} = \frac{d}{d+3} \Delta d_a$

In the equations:

Δd_{eff}	Effective interference allowance	mm
Δd_a	Target interference allowance	mm
d	Bearing nominal bore	mm

The effective interference allowance of bearings whose nominal bores are between 30mm ~ 150mm is approximately 95% of the target interference allowance.

4) Maximum interference allowance

Rings mounted on the shaft or bearing housing by using interference fit may generate tension stress or compression stress. Over interference allowance may bring about ring's fracture or shorten bearing life. Therefore, the maximum interference allowance is generally below 1/1000 of the shaft diameter or outside diameter.

6.1.3 Recommended fit

To select suitable fit, the characteristic and magnitude of the bearing load, etc., the mounting and dismounting of the bearing, and the factors of temperature etc. shall be considered. When mounting the bearing to thin wall housing or hollow shaft, the interference need to be larger than that in normal situation; release bearing housing is easy to cause the deformation of bearing outer ring, therefore, care shall be taken when outer ring requires interference fit; where the vibration is large, inner ring and outer ring shall adopt interference fit.

See Table 6.2 ~ 6.9 for general recommend fits.

In case of any particular service requirement, please contact the technical center of C&U Group. Please see the chapter on shaft and housing for the accuracy and roughness of shaft and housing.

Table 6.2 Fit of radial bearing and shaft

Condition		Application example (reference)	Bearing nominal bore diameter d (mm)			Shaft tolerance zone	Remarks
			Ball bearing	Cylindrical roller bearingTaper roller bearing	Spherical roller bearing		
Outer ring rotation load	Demand inner ring to be prone to move on the shaft	Wheel of stationary axle	All dimensions			g6	When there are requirements for accuracy, use g5 and h5. f6 can also be used for large bearings and where convenience for inner ring movement is required.
	Not demand inner ring to be prone to move on the shaft	Tensioner rack, rope pulley				h6	
Inner ring rotation load or indeterminate direction Load	Light load: Load below 0.06 Cr Varying load	Household appliance, pump, blower transition vehicles, precise machines, machine tool	≤18	—	—	js5	When there are requirements for accuracy, use class p5 bearing. Use h5 for precision ball bearings whose inner diameters are below 18mm
			18～100	≤40	—	js6(j6)	
			100～200	40～140	—	k6	
			—	140～200	—	m6	
	Normal load: Load (0.06 ~ 0.13 Cr)	Some large or medium-sized electric motors, turbine, pump, engine axes, cogwheel gearing, Woodworking machinery	≤18	—	—	js5	For single-row tapered roller bearings and single row radial-thrust ball bearings, k6 and m6 can be used to substitute for k5 and m5
			18～100	≤40	≤40	k5	
			100～140	40～100	40～65	m5	
			140～200	100～140	65～100	m6	
			200～280	140～200	100～140	n6	
			—	200～400	140～280	p6	
			—	—	280～500	r6	
			—	—	>500	r7	
	Heavy load: 0.13 Cr load or impact load	Railway, industrial automotive, trolley main motor, construction machinery, disintegrator	—	50～140	50～100	n6	Bearings greater than normal clearance are recommended
			—	140～200	100～140	p6	
			—	>200	140～200	r6	
			—	—	200～500	r7	
Only take axial load		Different kinds of bearing use positions	All dimensions			js6(j6)	—

Table 6.3 Fit of radial bearing and outer bore

Condition			Application example (reference)	Outer bore tolerance zone	Movement of outer ring	Remarks
One-piece housings	Outer ring rotation load	Thin-wall bearing heavy load	Automobile wheel (roller bearing) Lifter traveling wheel	P7	Outer ring is incapable of movement in the axial direction	—
		Normal load, heavy load	Automobile wheel (ball bearing) Vibration screen	N7		
		Light or varying load	Transporter wheel, trochleae, tensioner	M7		
	Indeterminate direction load	Heavy shock loads	Trolley mainframe	M7		
		Normal load or light load	Pump Crankshaft principal axes	K7	Outer ring is incapable of movement in the axial direction in principle	Outer ring does not need to move in the axial direction
One-piece or split housings		Normal load or light load	Large and medium-sized electric motors	JS7(J7)	Outer ring can move in the axial direction	Demand outer ring to move in the axial direction
	Inner ring rotation load	Various load	Ordinary Bearing housing of rolling stock	H7	Outer ring is easy to move in the axial direction	—
		Normal load or light load	Bearing with housing	H8		
		The temperature of shaft and inner ring is high	Paper manufacture drier	G7		
One-piece housings	Indeterminate direction load	Normal load, light load, especially demand accuracy rotation	Ball bearing for grinding axle and fixed bearing for high speed centrifugation compressor	JS6(J6)	Outer ring can move in the axial direction	—
			Ball bearing for grinding axle and fixed bearing for high speed centrifugation compressor	K6	Outer ring is fixed to axial direction in principle	For large load, use interference fit larger than K. If high class is specially required, it is necessary to further use small allowable difference fit according to usage respectively.
	Inner ring rotation load	Varying load, especially demand precision rotation and large rigidity	Cylindrical roller bearings for machine tool spindles	M6或N6	Outer ring is fixed to axial direction	
		Require noiseless running	Household electrical appliances	H6	Outer ring move in the axial direction	—

Remarks:
1. This table is applicable for cast iron or steel housings. Larger interference allowance will be used for light alloy housing;
2.Special fit like pressed outer rings in roller bearing, please and contact with C&U Group.

6.4 Fit of thrust bearing and shaft

Condition		Application example	Nominal bore(mm)	Shaft tolerance zone	Remarks
Only take axial load		Lathe principal axes	All dimensions	H6 or js6(j6)	
Resultant load Thrust self-aligning roller bearing	Inner ring static load	Crusher	All dimensions	js6(j6)	(1) When requiring small interference, j6, k6 and m6 can be used to substitute for k6, m6 and n6 respectively
	Inner ring rotation load or indeterminate direction load	Fine extruding machine	＜200	k6(1)	
			200～400	m6	
			＞400	n6	

Table 6.5 Fit of thrust bearing and outer bore

Condition		Applicable bearing	Outer bore tolerance zone	Remarks
Only take axial load		Thrust ball bearing	Space above 0.25mm	Normal situation
			H8	Where precision is required
		Thrust self-aligning bearing Steep angle tapered roller bearing	Space in the radial direction of the outer ring	Other bearing radial load situations
Combined load	Outer ring static load	Spherical thrust roller bearing	H7 or JS7 (J7)	
	Outer ring rotation load or indeterminate direction load		K7	Normal working conditions
			M7	With large radial load

Table 6.6 Fit of Inch system series taper roller bearing and shaft run-out

(1) Bearings with accuracy classes Class 4 and Class 2

Unit: μm

Condition		Bearing nominal bore d mm		Bearing inner diameter deviation $\triangle_{ds}$		Shaft dimensional tolerance		Remarks
		Over	Up to	Upper	Lower	Upper	Lower	
Inner ring rotation load	Normal load	—	76.200	+13	0	+38	+25	Bearings d＜152.4mm, applicable for bearings whose operation clearance is greater than normal.
		76.200	304.800	+25	0	+64	+38	
		304.800	609.600	+51	0	+127	+76	
		609.600	914.400	+76	0	+190	+114	
	Heavy load Impact load	—	76.200	+13	0	+64	+38	Generally applicable for bearings whose operation normal clearance is greater than ordinary clearance *As average interference, adopt the value around 0.0005d.
		76.200	304.800	+25	0	*	—	
	High speed load	304.800	609.600	+51	0	*	—	
		609.600	914.400	+76	0	+381	+305	
Outer ring rotation load	Without impact normal load	—	76.200	+13	0	+13	0	——
		76.200	304.800	+25	0	+25	0	
		304.800	609.600	+51	0	+51	0	
		609.600	914.400	+76	0	+76	0	
	Without impact normalload	—	76.200	+13	0	0	−13	Inner ring can move in the axial direction
		76.200	304.800	+25	0	0	−25	
		304.800	609.600	+51	0	0	−51	
		609.600	914.400	+76	0	0	−76	

(2) Bearings with accuracy classes, Class 3 and Class 0 ([1])

Unit: μm

Condition		Bearing nominal bore diameter d mm		Bearing bore diameter deviation Δ_{ds}		Shaft dimensional tolerance		Remarks
		over	up to	Upper	Lower	Upper	Lower	
Rotating inner ring load	Precision machine tool spindles	—	76. 200	+13	0	+30	+18	——
		76. 200	304. 800	+13	0	+30	+18	
		304. 800	609. 600	+25	0	+64	+38	
		609. 600	914. 400	+38	0	+102	+64	
	Heavy load Impact load High speed rotation	—	76. 200	+13	0	—	—	As average interference, allowance adopt the value around 0.0005d.
		76. 200	304. 800	+25	0	—	—	
		304. 800	609. 600	+51	0	—	—	
		609. 600	914. 400	+76	0	—	—	
Rotating outer ring load	Precision machined tool spindles axes	—	76. 200	+13	0	+30	+18	——
		76. 200	304. 800	+13	0	+30	+18	
		304. 800	609. 600	+25	0	+64	+38	
		609. 600	914. 400	+38	0	+102	+64	

Note: ([1]) Bearing's d exceeding 304.800mm do not have Class 0.

Table 6.7 Fit of Inch system series tapered roller bearing and housing bore

(1) Bearings with accuracy classes Class 4 and Class 2

Unit: μm

Condition		Bearing nominal outer diameter D mm		Bearing outside diameter deviation Δ_{Ds}		Shaft dimensional tolerance		Remarks
		over	up to	Upper	Lower	Upper	Lower	
Rotating inner ring load	Used for free end or fixed end	—	76. 200	+25	0	+76	+51	Outer ring is easy to move in the axial direction
		76. 200	127. 000	+25	0	+76	+51	
		127. 000	304. 800	+25	0	+76	+51	
		304. 800	609. 600	+51	0	+152	+102	
		609. 600	914. 400	+76	0	+229	+152	
	Outer ring position can be adjusted in the axial direction	—	76. 200	+25	0	+25	0	Outer ring can move in the axial direction
		76. 200	127. 000	+25	0	+25	0	
		127. 000	304. 800	+25	0	+51	0	
		304. 800	609. 600	+51	0	+76	+25	
		609. 600	914. 400	+76	0	+127	+25	
	Outer ring position cannot be adjusted in the axial direction	—	76. 200	+25	0	−13	−38	In principle outer ring is fixed to axial direction
		76. 200	127. 000	+25	0	−25	−51	
		127. 000	304. 800	+25	0	−25	−51	
		304. 800	609. 600	+51	0	−25	−76	
		609. 600	914. 400	+76	0	−25	−102	
Rotating outer ring load	Normal load or outer ring position cannot be adjusted in axial direction	—	76. 200	+25	0	−13	−38	Outer ring is fixed to axial direction
		76. 200	127. 000	+25	0	−25	−51	
		127. 000	304. 800	+25	0	−25	−51	
		304. 800	609. 600	+51	0	−25	−76	
		609. 600	914. 400	+76	0	−25	−102	

(2) Bearings with accuracy classes, Class 3 and Class 0 ([1])

Unit: μm

Condition		Bearing nominal outer diameter D mm		Bearing outside diameter deviation Δ_{Ds}		Shaft dimensional tolerance		Remarks
		Over	Up to	Upper	Lower	Upper	Lower	
Rotating inner ring load	Used for free end	—	76. 200	+13	0	+38	+25	Outer ring is easy to move in the axial direction
		76. 200	304. 800	+13	0	+38	+25	
		304. 800	609. 600	+25	0	+64	+38	
		609. 600	914. 400	+38	0	+89	+51	
	Used for fixed end	—	76. 200	+13	0	+25	+13	Outer ring can move in the axial direction
		76. 200	304. 800	+13	0	+25	+13	
		304. 800	609. 600	+25	0	+51	+25	
		609. 600	914. 400	+38	0	+76	+38	
	Outer ring position can be adjusted in the axial direction	—	76. 200	+13	0	+13	0	In principle outer ring is fixed to axial direction
		76. 200	304. 800	+13	0	+25	0	
		304. 800	609. 600	+25	0	+25	0	
		609. 600	914. 400	+38	0	+38	0	
	Outer ring position cannot be adjusted in the axial direction	—	76. 200	+13	0	0	−13	Outer ring is fixed to axial direction
		76. 200	304. 800	+13	0	0	−25	
		304. 800	609. 600	+25	0	0	−25	
		609. 600	914. 400	+38	0	0	−38	
Rotating outer ring load	Normal load or outer ring position cannot be adjusted in axial direction	—	76. 200	+13	0	−13	−25	Outer ring is fixed to axial direction
		76. 200	152. 400	+13	0	−13	−25	
		152. 400	304. 800	+13	0	−13	−38	
		304. 800	609. 600	+25	0	−13	−38	
		609. 600	914. 400	+38	0	−13	−51	

Note: ([1]) Bearing's D exceeding 304.800mm do not have Class 0.

6.2 Bearing clearance

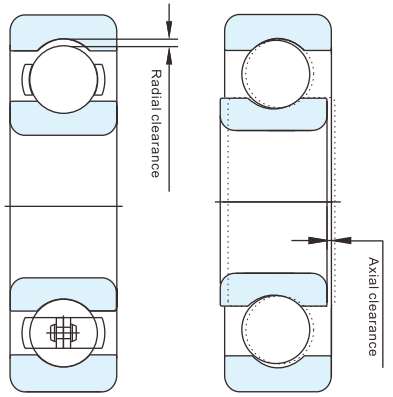


Fig. 6.2 Bearing clearance

Clearance (i.e. internal clearance) is a very important operation characteristic of bearings. Clearance's magnitude has an quite effect on the fatigue life, vibration, noise, temperature rise and mechanical movement accuracy of the bearings. When selecting, both the structure dimension and the clearance of the bearings need to be determined.

Bearing's clearance refers to the space between the inner/outer ring and the rolling element, i.e. the distance of movement from this end to the opposite end by fixing either inner ring or outer ring , and then move the other ring in the up-and-down (radial direction) or left-and-right (axial direction) direction. The radial distance of movement is called radial clearance, and axial distance of movement is called axial clearance. See Fig. 6.2.