7. Bearing Fits

7.1 Interference

For rolling bearings the bearing rings are fixed on the shaft or in the housing so that slip or movement does not occur between the mated surface during operation or under load. This relative movement (sometimes called creep) between the fitted surfaces of the bearing and the shaft or housing can occur in a radial direction, or in an axial direction, or in the direction of rotation. This creeping movment under load causes damage to the bearing rings, shaft or housing in the form of abrasive wear, fretting corrosion or friction crack. This, in turn, can also lead to abrasive particles getting into the bearing, which can cause vibration, excessive heat, and lowered rotational efficiency. To ensure that slip does not occur between the fitted surfaces of the bearing rings and the shaft or housing, the bearing is usually installed with an interference fit.

The most effective interference fit is called a tight fit (or shrink fit). The advantage of this “tight fit” for thin walled bearings is that it provides uniform load support over the entire ring circumference without any loss in load carrying capacity.

However, with a tight interference fit, ease of mounting and dismounting the bearings is lost; and when using a non-separable bearing as a non-fixing bearing, axial displacement is impossible.

7.2 Calculation of interference

1) Load and interference

The minimum required amount of interference for inner rings mounted on solid shafts when acted on by radial loads, is found by formula (7.1) and (7.2).

When $F_r \leq 0.3C_{or}$

$$\Delta_{dF} = 0.08\sqrt{\frac{d \bullet F_r}{B}} \cdots\cdots\cdots\cdots\cdots\cdots (7.1)$$

When $F_r > 0.3C_{or}$

$$\Delta_{dF} = 0.02\frac{F_r}{B} \cdots\cdots\cdots\cdots\cdots\cdots (7.2)$$

where,

Δ_{dF} : Required effective interference (for load) μm
d : Nominal bore diameter mm
B : Inner ring width mm
F_r : Radial load N
C_{or} : Basic static rated load N

2) Temperature rise and interference

To prevent loosening of the inner ring on steel shafts due to temperature increases (difference between bearing temperature and ambient temperature) caused by bearing rotation, an interference fit must be given. The required amount of interference can be found by formula (7.3).

$$\Delta_{dT} = 0.0015 \bullet d \bullet \Delta T \cdots\cdots\cdots\cdots\cdots\cdots (7.3)$$

where,

Δ_{dT} : Required effective interference (for temperature) μm
ΔT : Difference between bearing temperature and ambient temperature °C
d : Bearing bore diameter mm

3) Effective interference and apparent interference

The effective interference (the actual interference after fitting) is different from the apparent interference derived from the dimensions measured value. This difference is due to the roughness or slight variations of the mating surfaces, and this slight flattening of the uneven surfaces at the time of fitting is taken into consideration. The relation between the effective and apparent interference, which varies according to the finish given to the mating surfaces, is expressed by formula (7.4).

$$\Delta d_{eff} = \Delta d_f - G \cdots\cdots\cdots\cdots\cdots\cdots (7.4)$$

where,

Δd_{eff} : Effective interference μm
Δd_f : Apparent interference μm
G =1.0~2.5 μm for ground shaft
=5.0~7.0 μm for turned shaft

4) Maximum interference

When bearing rings are installed with an interference fit on shafts or housings, the tension or compression stress may occur. If the interference is too large, it may cause damage to the bearing rings and reduce the fatigue life of the bearing. For these reasons, the maximum amount of interference should be less than 1/1000 of the shaft diameter, or outside diameter.

7.3 Fit selection

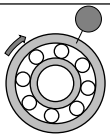
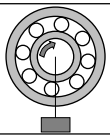
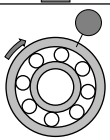
Selection of the proper fit is generally based on the following factors: 1) the direction and nature of the bearing load, 2) whether the inner ring or outer ring rotates, 3) whether the load on the inner or outer ring rotates or not, 4) whether there is static load or direction indeterminate load or not. For bearings under rotating loads or direction indeterminate loads, a tight fit is recommended; but for static loads, a transition fit or loose fit should be sufficient (see Table 7.1).

The interference should be tighter for heavy bearing loads or vibration and shock load conditions. Also, a tighter than normal fit should be given when the bearing is installed on hollow shafts or in housings with thin walls, or housings made of light allows or plastic.

In applications where high rotational accuracy must be maintained, high precision bearings and high tolerance shafts and housings should be employed instead of a tighter interference fit to ensure bearing stability. High interference fits should be avoided if possible as they cause shaft or housing deformities to be induced into the bearing rings, and thus reduce bearing rotational accuracy.

Because mounting and dismounting become very difficult when both the inner ring and outer ring of a non-separable bearing (for example a deep groove ball bearing) are given tight interference fits, one or the other rings should be given a loose fit.

Table 7.1 Radial load and bearing fit

Bearing rotation and load	Illustration	Ring load	Fit
Inner ring : Rotating Outer ring : Stationary Load direction : Constant	 Static load	Rotating inner ring load	Inner ring : Tight fit
Inner ring : Stationary Outer ring : Rotating Load direction : Rotates with outer ring	 Unbalanced load	Static outer ring load	Outer ring : Loose fit
Inner ring : Stationary Outer ring : Rotating Load direction : Constant	 Static load	Static inner ring load	Inner ring : Loose fit
Inner ring : Rotating Outer ring : Stationary Load direction : Rotates with outer ring	 Unbalanced load	Rotating outer ring load	Outer ring : Tight fit

7.4 Recommended fits

Metric size standard dimension tolerances for bearing shaft diameters and housing bore diameters are governed by ISO 286 and JIS B 0401 (dimension tolerances and fits). Accordingly, bearing fits are determined by the precision (dimensional tolerance) of the shaft diameter and housing bore diameter. Widely used fits for various shaft and housing bore diameter tolerances, and bearing bore and outside diameters are shown in Fig. 7.1.

Generally-used, recommended fits relating to the primary factors of bearing shape, dimensions, and load conditions are listed in Tables 7.2 through 7.5. Table 7.6 gives the numerical values for housing and shaft fits.

The bore and outside diameter tolerances and tolerance ranges for inch and metric tapered roller bearings are different. Recommended fits and numerical values for inch tapered roller bearings are shown in Table 7.8. For special fits or applications, please consult NTN.

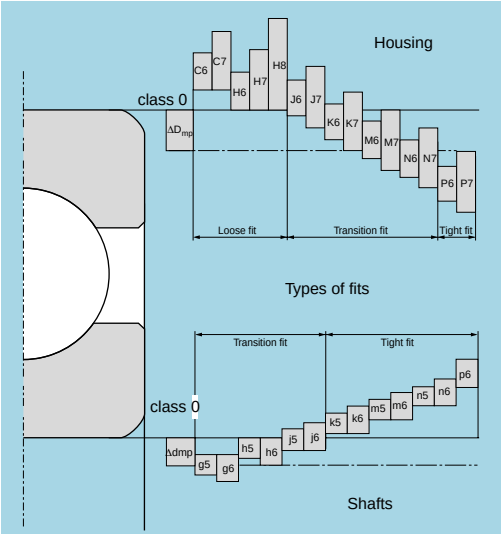


Fig. 7.1

Table 7.2 General standards for radial bearing fits (JIS class 0, 6, 6X)

Table 7.2 (1) Housing fits

Housing type	Load condition		Housing fits
Solid or split housing	Outer ring static load	All load conditions	H7
		Heat conducted through shaft	G7
Solid housing	Direction indeterminate load	Light to normal	JS7
		Normal to heavy load	K7
		Heavy shock load	M7
	Outer ring rotating load	Light or variable load	M7
		Normal to heavy load	N7
		Heavy load (thin wall housing) Heavy shock load	P7

Note: Fits apply to cast iron or steel housings. For light alloy housings, a tighter fit than listed is normally required.

Table 7.2 (2) Shaft fit

Bearing type	Load conditions		Ball bearings	Cylindrical and tapered roller bearings	Spherical roller bearings	Shaft fits
			Shaft diameter mm			
Cylindrical bore bearings	Rotating inner ring or indeterminate direction load	Light or fluctuating variable load	~ 18	—	—	h5
			18~100	~ 40	—	js6
			100~200	40~140	—	k6
			—	140~200	—	m6
		Normal to heavy load	~ 18	—	—	js5
			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
		Very heavy or shock load	—	50~140	50~100	n6
			—	140~200	100~140	p6
			—	200~	140~	r6
	Static inner ring load	Inner ring axial displacement required	All shaft diameters			g6
		Easy axial displacement of inner ring not required	All shaft diameters			h6
Tapered bore bearings (With sleeve)	All load		All shaft diameters			h9/IT5

Note: 1. All values and fits listed are for solid steel shafts.
2. For radial bearings under axial loads, all shaft tolerance range classes are js6.
3. Load classifications are as follows:
LIght load: $P_r \leq 0.06\ C_r$
Normal load: $0.06\ C_r < P_r \leq 0.12\ C_r$
Heavy load: $P_r > 0.12\ C_r$

where,

P_r: Bearing equivalent load
C_r: Bearing basic dynamic load rating

Table 7.3 Solid type needle roller bearing fits

Table 7.3 (1) Shaft fit

Conditions			Shaft fits
Load type	Scale of load	Shaft diameter *d* mm	
Rotating inner ring or indeterminate direction load	Light load	~ 50	j5
	Normal load	~ 50	k5
		50~150	m5
		150~	m6
	Heavy load and shock load	~ 150	m6
		150~	n6
Static inner ring load	Medium & low speed revolution, light load	All sizes	g6
	General application	All sizes	h6
	When high rotation accuracy is required	All sizes	h5

Table 7.3 (2) Housing fit

Conditions		Housing fits
Static inner ring load	Normal to heavy load	J7
	Normal loads with split housings	H7
Outer ring rotating load	Light loads	M7
	Normal loads	N7
	Heavy and normal loads	P7
Direction indeterminate load	Light loads	J7
	Normal load	K7
	Very heavy or shock load	M7
High demands on running accuracy with light load		K6

Table 7.4 Standard fits for thrust bearings

Table 7.4 (1) Shaft fits

Load conditions		Shaft diameter	Shaft fits
“Pure” axial load (All thrust bearings)		All sizes	js6
Combined load: spherical roller thrust bearings	Static inner ring loads	All sizes	js6
	Inner ring rotating load or direction indeterminate	~200	k6
		200~400	m6
		400~	n6

Table 7.4 (2) Housing fits

Load conditions		Housing fits	Remarks
“Pure” axial load: All thrust bearings	When another bearing is used to support radial load	—	Clearance given between outer ring and housing
		H8	Accuracy required with thrust ball bearings
Combined load: spherical roller thrust bearings	Static outer ring load	H7	—
	Outer ring rotating load or direction indeterminate load	K7	Normal usage conditions
		M7	Relatively heavy

Table 7.5 Fits for electric motor bearings

Shaft or housing	Deep groove ball bearings			Cylindrical roller bearings		
	Shaft or housing bore diameter mm		Fits	Shaft or housing bore diameter mm		Fits
	over	incl.		over	incl.	
Shaft	—	18	j5	—	40	k5
	18	100	k5	40	160	m5
	100	160	m5	160	200	n5
Housing	All Sizes		H6 or J6	All sizes		H6 or J6

Table 7.6 Fitting values for radial bearings, Class 0

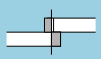
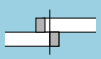
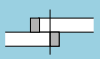
Table 7.6 (1) Shaft fit

Nominal bore diameter of bearing d (mm) over	incl.	Δ_{dmp} high	low	g5 bearing	shaft	g6 bearing	shaft	h5 bearing	shaft	h6 bearing	shaft	j5 bearing	shaft	js5 bearing	shaft	j6 bearing	shaft
3	6	0	–8	4T~9L		4T~12L		8T~5L		8T~8L		11T~2L		10.5T~2.5L		14T~2L	
6	10	0	–8	3T~11L		3T~14L		8T~6L		8T~9L		12T~2L		11T~3L		15T~2L	
10	18	0	–8	2T~14L		2T~17L		8T~8L		8T~11L		13T~3L		12T~4L		16T~3L	
18	30	0	–10	3T~16L		3T~20L		10T~9L		10T~13L		15T~4L		14.5T~4.5L		19T~4L	
30	50	0	–12	3T~20L		3T~25L		12T~11L		12T~16L		18T~5L		17.5T~5.5L		23T~5L	
50	80	0	–15	5T~23L		5T~29L		15T~13L		15T~19L		21T~7L		21.5T~6.5L		27T~7L	
80	120	0	–20	8T~27L		8T~34L		20T~15L		20T~22L		26T~9L		27.5T~7.5L		33T~9L	
120 140 160	140 160 180	0	–25	11T~32L		11T~39L		25T~18L		25T~25L		32T~11L		34T~9L		39T~11L	
180 200 225	200 225 250	0	–30	15T~35L		15T~44L		30T~20L		30T~29L		37T~13L		40T~10L		46T~13L	
250 280	280 315	0	–35	18T~40L		18T~49L		35T~23L		35T~32L		42T~16L		46.5T~11.5L		51T~16L	
315 355	355 400	0	–40	22T~43L		22T~54L		40T~25L		40T~36L		47T~18L		52.5T~12.5L		58T~18L	
400 450	450 500	0	–45	25T~47L		25T~60L		45T~27L		45T~40L		52T~20L		58.5T~13.5L		65T~20L	

Table 7.6 (2) Housing fit

Nominal bore diameter of bearing D (mm) over	incl.	Δ_{dmp} high	low	G7 housing	bearing	H6 housing	bearing	H7 housing	bearing	J6 housing	bearing	J7 housing	bearing	Js7 housing	bearing	K6 housing	bearing
6	10	0	–8	5L~28L		0~17L		0~23L		4T~13L		7T~16L		7.5T~15.5L		7T~10L	
10	18	0	–8	6L~32L		0~19L		0~26L		5T~14L		8T~18L		9T~17L		9T~10L	
18	30	0	–9	7L~37L		0~22L		0~30L		5T~17L		9T~21L		10.5T~19.5L		11T~11L	
30	50	0	–11	9L~45L		0~27L		0~36L		6T~21L		11T~25L		12.5T~23.5L		13T~14L	
50	80	0	–13	10L~53L		0~32L		0~43L		6T~26L		12T~31L		15T~28L		15T~17L	
80	120	0	–15	12L~62L		0~37L		0~50L		6T~31L		13T~37L		17.5T~32.5L		18T~19L	
120	150	0	–18	14L~72L		0~43L		0-~58L		7T~36L		14T~44L		20T~38L		21T~22L	
150	180	0	–25	14L~79L		0~50L		0~65L		7T~43L		14T~51L		20T~45L		21T~29L	
180	250	0	–30	15L~91L		0~59L		0~76L		7T~52L		16T~60L		23T~53L		24T~35L	
250	315	0	–35	17L~104L		0~67L		0~87L		7T~60L		16T~71L		26T~61L		27T~40L	
315	400	0	–40	18L~115L		0~76L		0~97L		7T~69L		18T~79L		28.5T~68.5L		29T~47L	
400	500	0	–45	20L~128L		0~85		0~108		7T~78L		20T~88L		31.5T~76.5L		32T~53L	

Unit μm

js6	k5	k6	m5	m6	n6	p6	r6
bearing shaft 	bearing shaft 	bearing shaft 	bearing shaft 	bearing shaft 	bearing shaft 	bearing shaft 	bearing shaft 
12T~4L	14T~1T	17T~1T	17T~4T	20T~4T	24T~8T	28T~12T	—
12.5T~4.5L	15T~1T	18T~1T	20T~6T	23T~6T	27T~10T	32T~15T	—
13.5T~5.5L	17T~1T	20T~1T	23T~7T	26T~7T	31T~12T	37T~18T	—
16.5T~6.5L	21T~2T	25T~2T	27T~8T	31T~8T	38T~15T	45T~22T	—
20T~8L	25T~2T	30T~2T	32T~9T	37T~9T	45T~17T	54T~26T	—
24.5T~9.5L	30T~2T	36T~2T	39T~11T	45T~11T	54T~20T	66T~32T	—
31T~11L	38T~3T	45T~3T	48T~13T	55T~13T	65T~23T	79T~37T	—
37.5T~12.5L	46T~3T	53T~3T	58T~15T	65T~15T	77T~27T	93T~43T	113T~63T 115T~65T 118T~68T
44.5T~14.5T	54T~4T	63T~4T	67T~17T	76T~17T	90T~31T	109T~50T	136T~77T 139T~80T 143T~84T
51T~16L	62T~4T	71T~4T	78T~20T	87T~20T	101T~34T	123T~56T	161T~94T 165T~98T
58T~18L	69T~4T	80T~4T	86T~21T	97T~21T	113T~37T	138T~62T	184T~108T 190T~114T
65T~20L	77T~5T	90T~4T	95T~23T	108T~23T	125T~40T	153T~68T	211T~126T 217T~132T

Unit μm

K7	M7	N7	P7
housing bearing 	housing bearing 	housing bearing 	housing bearing 
10T~13L	15T~8L	19T~4L	24T~1T
12T~14L	18T~8L	23T~3L	29T~3T
15T~15L	21T~9L	28T~2L	35T~5T
18T~18L	25T~11L	33T~3L	42T~6T
21T~22L	30T~13L	39T~4L	51T~8T
25T~25L	35T~15L	45T~5L	59T~9T
28T~30L	40T~18L	52T~6L	68T~10T
28T~37L	40T~25L	52T~13L	68T~3T
33T~43L	46T~30L	60T~16L	79T~3T
36T~51L	52T~35L	66T~21L	88T~1T
40T~57L	57T~40L	73T~24L	98T~1T
45T~63L	63T~45L	80T~28L	108T~0

Table 7.7 Fits for inch series tapered roller bearing (ANSI class 4)

Unit μm
0.0001 inch

Table 7.7 (1) Fit with shaft

Load conditions		Shaft diameter d mm, inch over	incl.	Cone bore tolerance[2] Δ_{dS} high	low	Shaft tolerance high	low	Extreme fits[3] max	min
Rotating cone load	Normal loads, no shock	—	76.200	+13	0	+38	+26	38T~13T	
		—	3.0000	+5	0	+15	+10	15T~5T	
		76.200	304.800	+25	0	+64	+38	64T~13T	
		3.0000	12.0000	+10	0	+25	+15	25T~5T	
	Heavy loads or shock loads	—	76.200	+13	0	Use average tight cone fit of 0.5μm/mm, (0.0005 inch/inch) of cone bore, use a minimum fit of 25μm, 0.0010 inch tight.			
		—	3.0000	+5	0				
		76.200	304.800	+25	0				
		3.0000	12.0000	+10	0				
Stationary cone load	Cone axial displacement on shaft necessary[1]	—	76.200	+13	0	0	–13	0~26L	
		—	3.0000	+5	0	0	–5	0~10L	
		76.200	304.800	+25	0	0	–25	0~51L	
		3.0000	12.0000	+10	0	0	–10	0~20L	
	Cone axial displacement on shaft unnecessary	—	76.200	+13	0	+13	0	13T~13L	
		—	3.0000	+5	0	+5	0	5T~5L	
		76.200	304.800	+25	0	+25	0	25T~25L	
		3.0000	12.0000	+10	0	+10	0	10T~10L	

1) Applies only to ground shafts.
2) For bearings with negation deviation indicated in bearing tables, same fit applies.
3) T=tight, L=loose, d=cone bore, mm, inch
Note: For bearings higher than class 2, consult NTN.

Unit μm
0.0001 inch

Table 7.7 (2) Fit with housing

Load conditions		Housing bore diameter mm, inch over	incl.	Cup O.D. tolerance[1] high	low	Housing bore tolerance high	low	Extreme fits[2] max	min
Stationary cup load	Light and normal loads: cup easily axially displaceable	—	76.200	+25	0	+76	+50	25L~76L	
		—	3.0000	+10	0	+30	+20	10L~30L	
		76.200	127.000	+25	0	+76	+50	25L~76L	
		3.0000	5.0000	+10	0	+30	+20	10L~30L	
		127.000	304.800	+25	0	+76	+50	25L~76L	
		5.0000	12.0000	+10	0	+30	+20	10L~30L	
	Light and normal loads: cup axially adjustable	—	76.200	+25	0	+25	0	25T~25L	
		—	3.0000	+10	0	+10	0	10T~10L	
		76.200	127.000	+25	0	+25	0	25T~25L	
		3.0000	5.0000	+10	0	+10	0	10T~10L	
		127.000	304.800	+25	0	+51	0	25T~51L	
		5.0000	12.0000	+10	0	+20	0	10T~20L	
	Heavy loads: cup not axially displaceable	—	76.200	+25	0	–13	–39	64T~13T	
		—	3.0000	+10	0	–5	–15	25T~5T	
		76.200	127.000	+25	0	–25	–51	76T~25T	
		3.0000	5.0000	+10	0	–10	–20	30T~10T	
		127.000	304.800	+25	0	–25	–51	76T~25T	
		5.0000	12.0000	+10	0	–10	–20	30T~10T	
Rotating cup load	Cup not axially displaceable	—	76.200	+25	0	–13	–39	64T~13T	
		—	3.0000	+10	0	–5	–15	25T~5T	
		76.200	127.000	+25	0	–25	–51	76T~25T	
		3.0000	5.0000	+10	0	–10	–20	30T~10T	
		127.000	304.800	+25	0	–25	–51	76T~25T	
		5.0000	12.0000	+10	0	–10	–20	30T~10T	

1) For bearings with negation deviation indicated in bearing tables, same fit applies.
2) T=tight, L=loose
Note: For bearings higher than class 2, consult NTN.

Table 7.8 Fits for inch series tapered roller bearing (ANSI classes 3 and 0)

Unit μm
0.0001 inch

Table 7.8 (1) Fit with shaft

Load conditions		Shaft diameter mm, inch over	Shaft diameter mm, inch incl.	Cone bore[2] tolerance high	Cone bore[2] tolerance low	Shaft tolerance high	Shaft tolerance low	Extreme fits[3] max	Extreme fits[3] min
Rotating cone load	precision machine tool spindles	—	304.800	+13	0	+31	+18	31T~5T	
		—	12.0000	+5	0	+12	+7	12T~2T	
	heavy loads, or high speed or shock	—	76.200	+13	0	Use minimum tight cone fit of 0.25μm/mm (0.00025 inch/inch) of cone bore.			
		—	3.0000	+5	0				
		76.200	304.800	+13	0				
		3.0000	12.0000	+5	0				
Stationary cone load	precision machine tool spindles	—	304.800	+13	0	+31	+18	31T~5T	
		—	12.0000	+5	0	+12	+7	36T~2T	

Note: Must be applied for maximum bore dia. 241.300mm (9.500 inch) in case of class 0 product.

Note 1) T=tight, L=loose
2) Must be applied for maximum cup OD 304.800mm (12.000 inch) case of class 0 product.

Unit μm
0.0001 inch

Table 7.8 (2) Fit with housing

Load conditions		Housing bore diameter mm, inch over	Housing bore diameter mm, inch incl.	Cup O.D. tolerance high	Cup O.D. tolerance low	Housing bore tolerance high	Housing bore tolerance low	Extreme fits[2] max	Extreme fits[2] min
Stationary cup load	Floating	—	152.400	+13	0	+38	+26	13L~38L	
		—	6.0000	+5	0	+15	+10	5L~15L	
		152.400	304.800	+13	0	+38	+26	13L~38L	
		6.0000	12.0000	+5	0	+15	+10	5L~14L	
	Clamped	—	152.400	+13	0	+25	+13	0~25L	
		—	6.0000	+5	0	+10	+5	0~10L	
		152.400	304.800	+13	0	+25	+13	0~25L	
		6.0000	12.0000	+5	0	+10	+5	0~10L	
	Adjustable	—	152.400	+13	0	+13	0	13T~13L	
		—	6.0000	+5	0	+5	0	5T~5L	
		152.400	304.800	+13	0	+25	0	13T~25L	
		6.0000	12.0000	+5	0	+10	0	5T~10L	
	Nonadjustable or in carriers	—	152.400	+13	0	0	–12	25T~0	
		—	6.0000	+5	0	0	–5	10T~0	
		152.400	304.800	+13	0	0	–25	38T~0	
		6.0000	12.0000	+5	0	0	–10	15~0	
Rotating cup load	Nonadjustable or in carriers	—	152.400	+13	0	–13	–25	38T~13T	
		—	6.0000	+5	0	–5	–10	15T~5T	
		152.400	304.800	+13	0	–13	–38	51T~13T	
		6.0000	12.0000	+5	0	–5	–15	20T~5T	

Note 1) T=tight, L=loose
2) Must be applied for maximum cup OD 304.800mm (12.000 inch) case of class 0 product.