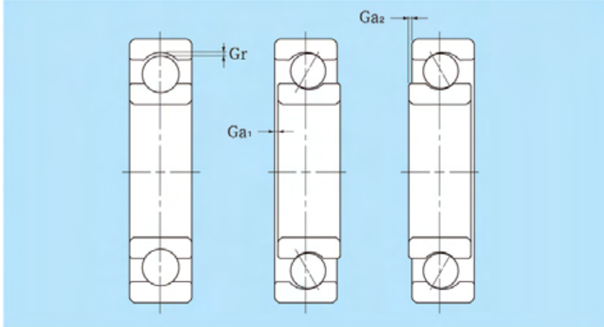
BEARING INTERNAL CLEARANCE

Bearing internal clearance is defined as the total distance through which one bearing ring can be moved relative to the other in the radial direction (radial internal clearance) or in the axial direction (axial internal clearance).

● Internal Clearances of deep groove ball bearings

Deep groove ball bearings having an internal clearance other than Normal are identified by the suffixes C2 to C5. Meanwhile the axial internal clearances will vary accordingly. Following diagrams show the relationship between radial internal clearance and axial internal clearance for four series of deep groove ball bearing.



Radial Internal Clearance Δ_r and Axial Internal Clearance Δ_a in Single-Row Deep Groove Ball Bearings

$$\Delta_a = K \Delta_r^{\frac{1}{2}}$$

$$K = 2\left(r_e + r_i - D_w\right)^{\frac{1}{2}}$$

where

K : Constant determined by internal design of bearing (mm)

r_e : Groove radius of outer ring

r_i : Groove radius of inner ring

D_w : Nominal rolling element diameter

Note: Please check the charts in next page for the relationship of radial clearance and axial clearance of deep goove ball bearings.

● Internal clearance of tapered roller bearing clearance

In tapered roller bearings, internal clearance is usually defined as a specific amount of either end play or preload. Establishing this clearance, or setting, at the time of assembly is an inherent advantage of tapered roller bearings. Unlike deep groove ball bearing, tapered roller bearings do not rely strictly on housing or shaft fits to obtain a certain bearing setting. One race can be moved axially relative to the other to obtain the desired bearing setting. They can be set to provide optimum performance in almost any application.

At assembly, the conditions of bearing setting are defined as:

End play

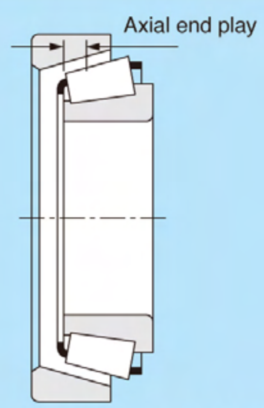
An axial clearance between rollers and races producing a measurable axial shaft movement when a small axial force is applied - first in one direction, then in the other, while oscillating or rotating the shaft.

Preload

An axial interference between rollers and races such that there is no measurable axial shaft movement when a small axial force is applied - in both directions, while oscillating or rotating the shaft.

Line-to-line

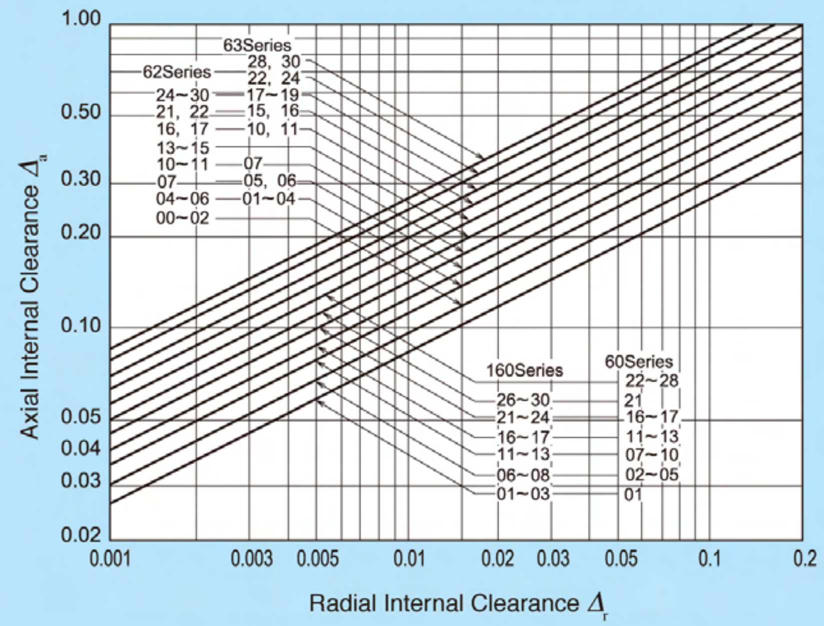
A zero setting condition; the transitional point between end play and preload.



Axial force is applied in both directions while rotating the shaft

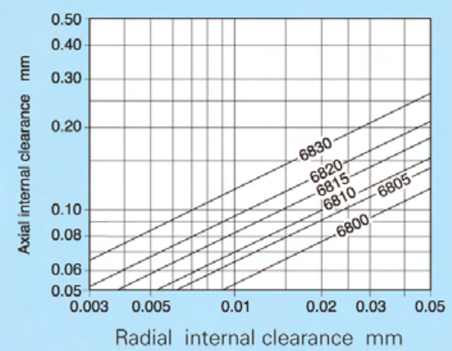
Note: The tapered roller bearings are usually applied with axial load. Under this condition, bearing will have an increased displacement. Please check the charts in next page for the relationship of displacement value and the load amount of tapered roll bearings.

● Deep groove ball bearing radial internal clearance and axial internal clearance

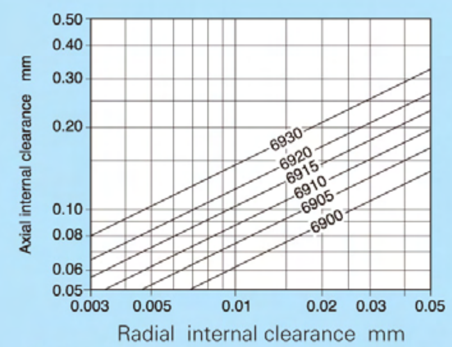


Δ_r and Δ_a in Single-Row Deep Groove Ball Bearings

Bore No.	Values of K 160XX	60XX	62XX	63XX
00	–	–	0.93	1.14
01	0.80	0.80	0.93	1.06
02	0.80	0.93	0.93	1.06
03	0.80	0.93	0.99	1.11
04	0.90	0.96	1.06	1.07
05	0.90	0.96	1.06	1.20
06	0.96	1.01	1.07	1.19
07	0.96	1.06	1.25	1.37
08	0.96	1.06	1.29	1.45
09	1.01	1.11	1.29	1.57
10	1.01	1.06	1.33	1.64
11	1.06	1.20	1.40	1.70
12	1.06	1.20	1.50	2.09
13	1.06	1.20	1.54	1.82
14	1.16	1.29	1.57	1.88
15	1.16	1.29	1.57	1.95
16	1.20	1.37	1.64	2.01
17	1.20	1.37	1.70	2.06
18	1.29	1.44	1.76	2.11
19	1.29	1.44	1.82	2.16
20	1.29	1.44	1.88	2.25
21	1.37	1.54	1.95	2.32
22	1.40	1.64	2.01	2.40
24	1.40	1.64	2.06	2.40
26	1.54	1.70	2.11	2.49
28	1.54	1.70	2.11	2.59
30	1.57	1.76	2.11	2.59

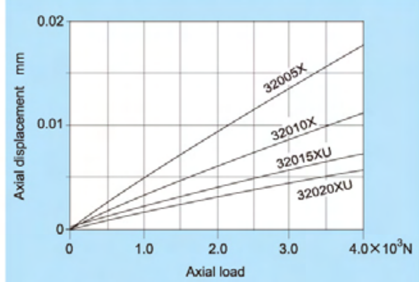


Series 68 radial internal/axial internal clearances

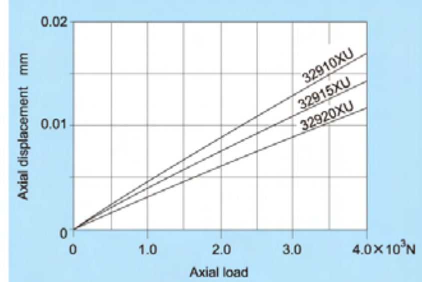


Series 69 radial internal/axial internal clearances

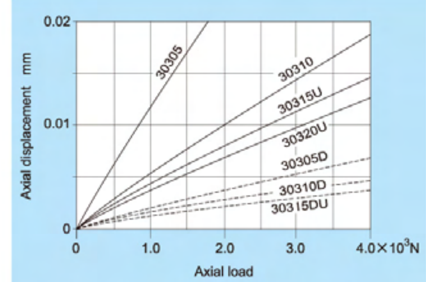
● Tapered roller bearing axial load and axial displacement



Series 320 axial load and axial displacement



Series 329 axial load and axial displacement



Series 303/303 D axial load and axial displacement

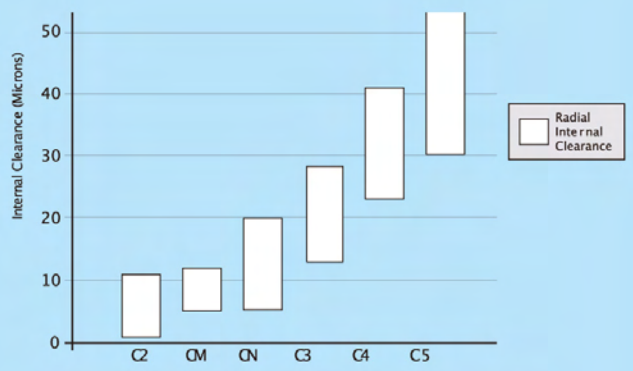
Bearing radial internal clearance

Internal clearance is determined so that appropriate clearance will remain after the bearing is mounted to the shaft with an interference fit. Typical clearance groups for the deep groove ball bearings are C2, CN, C3, C4, and C5. CN(Normal)

C2: less than Normal clearance
C3: more than Normal clearance
C4: more than C3
C5: more than C4

CM: clearance for EMQ Bearings

MC: clearance for Miniature Bearings



Example of Radial Internal clearances for a single row radial ball bearing with a bore diameter

● Data of standard radial clearances for bearings under no load

Tolerance in μm.

Bore				C2		Normal		C3		C4		C5	
Over		Including											
mm	Inch	mm	Inch	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
2.5	0.0984	10	0.3937	0	7	2	13	8	23	14	29	20	37
10	0.3937	18	0.7087	0	9	3	18	11	25	18	33	25	45
18	0.7887	24	0.9449	0	10	5	20	13	28	20	36	28	48
24	0.9449	30	1.1811	1	11	5	20	13	28	23	41	30	53
30	1.1811	40	1.5748	1	11	6	20	15	33	28	46	40	64
40	1.5748	50	1.9685	1	11	6	23	18	36	30	51	45	73
50	1.9685	65	2.5591	1	15	8	28	23	43	38	61	55	90

● The radial clearances of bearings with electric motor quality

Tolerance in μm.

Bore				CM	
Over		Including		Min.	Max.
mm	Inch	mm	Inch	μm	μm
10	0.3937	18	0.7087	4	11
18	0.7087	24	0.9449	5	12
24	0.9449	30	1.1811	5	12
30	1.1811	40	1.5748	9	17
40	1.5748	50	1.9685	9	17
50	1.9685	65	2.5591	12	22

● Data of the mini-deep groove ball bearing under no load

Tolerance in μm.

Clearance Code	MC1		MC2		MC3		MC4		MC5		MC6	
Clearance	min	max	min	max	min	max	min	max	min	max	min	max
	0	5	3	8	5	10	8	13	14	21	21	29

● Clearance correction under loads

When the internal clearance of a bearing is measured, a slight measurement load is applied to the raceway so the internal clearance may be measured accurately. However, at this time, a slight amount of elastic deformation of the bearing occurs under the measurement load, and the clearance measurement value (measured clearance) is slightly larger than the true clearance. This discrepancy due to the elastic deformation must be compensated for.

● Clearance correction for standard radial clearance

Units: μm.

Nominal Bore Dia ***d*** (mm)		Measuring Load		Radial Clearance Correction Amount				
over	incl	(N)	{kgf}	C2	CN	C3	C4	C5
10(incl)	18	24.5	{2.5}	3 to 4	4	4	4	4
18	50	49	{5}	4 to 5	5	6	6	6
50	280	147	{15}	6 to 8	8	9	9	9

● Clearance correction for miniature radial clearance

Units: μm.

Clearance Symbol	MC1	MC2	MC3	MC4	MC5	MC6
Clearance Correction Value	1	1	1	1	2	2

● The measuring loads are as follows:

Units: mm

Design	Miniature Ball Bearigs		Extra Miniature Ball Bearigs		Measuring loads
Metric size bearings	Outside diameter Bore diameter	***D*** ≥ 9 ***d*** < 10	Outside diameter	***D*** < 9	2.5N {0.25kgf}
Inch size bearings	Outside diameter Bore diameter	***D*** ≥ 9.525 ***d*** < 10	Outside diameter	***D*** < 9.525	4.4N {0.45kgf}

Bearing internal clearance selection standards

Under normal operating conditions (e.g. normal load, fit, speed, temperature, etc.), a standard internal clearance will give a very satisfactory operating clearance. Customers should pay attention when coming across the following conditions.

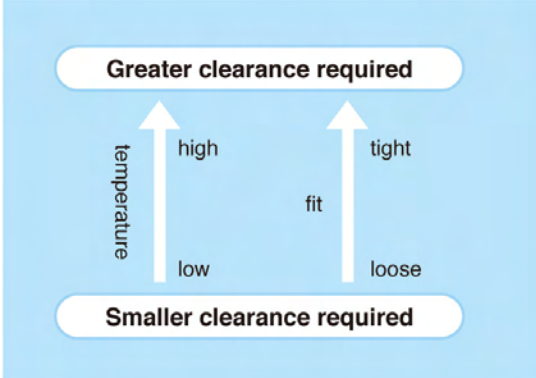
● Example of selection of clearance other than CN (Normal) clearance

Service Conditions	Clearance	Application Example(reference)
Large interference for heavy or impact load	C3 clearance or larger	Railroad car axle
Inner ring is exposed to high temperature Outer ring is exposed to low temperature		Traction motor
When shaft has a large deflation For increasing axial load capacity by increasing contact angle		Pulp and paper machine dryer For outdoor use in cold area
Interference is required for both inner and outer rings due to indeterminate heavy impact load		Semi-floating axle of automobile Bearing of railroad car axle for carrying axial load Thrust bearing of axles of rolling machine
When both inner and outer rings are clearance-fitted for controlling vibration and sound	C2 clearance or smaller	Roll neck of rolling machine Small, special electric motors

Selection of bearing internal clearance

The internal clearance of rolling contact bearings during operation (the operating clearance) is a factor that can affect bearing life, vibration, heat, sound, etc.. Therefore, to prevent clearance problems, unmounted bearing clearance should be selected so that operating clearance will be slightly positive.

Usually the bearing internal clearance refers to as Normal when the recommended and operating conditions are normal. Where interference fits are used for both bearing rings, where unusual temperatures prevail etc., bearings with greater or smaller internal clearance than Normal are required.



● Operating clearance

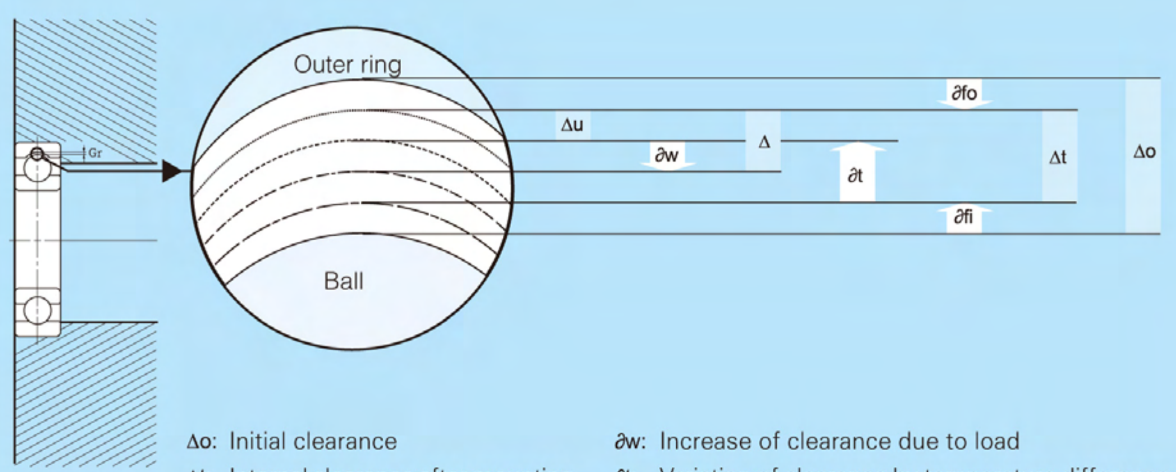
Operating clearance is defined as the clearance of a bearing operating in a machine at the operating temperature and load.

$$\Delta = \Delta o - (\delta t + \delta f) + \delta w$$

where,

- Δ: Operating clearance (mm)
- Δo: Unmounted bearing clearance
- δt: Variation of clearance from temperature difference between inner and outer rings (mm)
- δf: Reduction in clearance due to the fit of inner and outer rings (mm)
- δw: Increase of clearance due to load (mm)

● Operating clearance & clearance influence factors



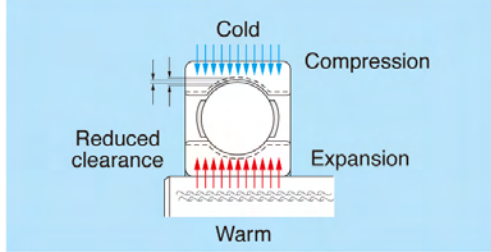
- Δo: Initial clearance
- Δt: Internal clearance after mounting
- Δu: Effective clearance
- Δ: Operating clearance
- δw: Increase of clearance due to load
- δt: Variation of clearance by temperature difference
- δfi: Reduction in clearance due to the fit of inner ring and shaft
- δfo: Reduction in clearance due to the fit of outer ring and housing

a) Increase of clearance due to load (δw)

When a bearing is subjected to a load, elastic deformation will occur and this deformation will cause an increase in internal clearance.

b) Temperature effects on radial internal clearance (δt)

Under normal operation, the radial internal clearance of a bearing will decrease because of the temperature difference between the inner and outer rings. Typically, the temperatures of the inner ring and the rolling elements are higher than that of the outer ring. When the shaft is heated or the housing is cooled, the difference between the inner and outer rings is even larger.



$$\delta t = \alpha \cdot \Delta T \cdot Do$$

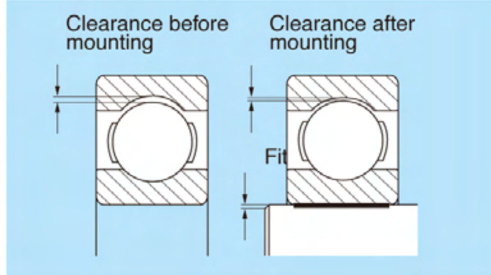
where,

- δt: Reduction in clearance due to temperature difference between inner and outer rings(mm)
- α : Linear expansion coefficient of bearing steel: 1.12×10^{-5} (1/ ℃) for operating temperature 300℃ or less
- ΔT: Temperature difference between the inner and outer rings (℃)
- Do: Outer ring raceway diameter (mm)
- Do= 0.2(4D+d) for deep groove ball bearings

Notes: Any increase in speed above the reference speed without taking any of these precautions could cause bearing temperatures to rise excessively. At the same time, the operational clearance in the bearing is reduced because of increased inner ring temperature, the final consequence would be bearing seizure. Usually, therefore, a bearing with a C3 internal clearance, which is greater than Normal, is required.

c) Decrease in radial clearance due to fit (δf, δfi, δfo)

The initial internal clearance (before mounting) is greater than the operational clearance because different degrees of interference in the fits and differences in thermal expansion of the bearing rings and the associated components cause the rings to be expanded or compressed. Therefore, when the inner or outer ring is tight-fitted to the shaft or the house, a decrease of radial internal clearance is caused by the expansion or contraction of the bearing rings.



$$\delta f = \delta fi + \delta fo$$

$$\delta fi = \Delta de \, \frac{d}{di} \, \frac{1-\left(\frac{dh}{d}\right)^2}{1-\left(\frac{dh}{di}\right)^2}$$

(In the case of solid shaft)

$$\delta fi = \Delta de \, \frac{d}{di}$$

$$\delta fo = \Delta De \, \frac{De}{D} \, \frac{1-\left(\frac{D}{Dh}\right)^2}{1-\left(\frac{De}{Dh}\right)^2}$$

(In the case of Dh=∞)

$$\delta fo = \Delta De \, \frac{De}{D}$$

where,

- δf: Reduction in clearance due to fit (mm)
- δfi: Reduction in clearance due to expansion of the inner ring (mm)
- δfo: Reduction in clearance due to contraction of the outer ring (mm)

- Δde: Effective interference of the inner ring (mm)
- d: Bearing bore diameter (mm)
- di: Mean outside diameter of inner ring (mm)
- dh: Inside diameter of hollow shaft (mm) Note: For solid shaft, dh=0

- ΔDe: Effective interference of the outer ring (mm)
- D: Bearing outside diameter (mm)
- De: Mean inside diameter of outer ring (mm)
- Dh: Housing outside diameter (mm) Note: If the housing is a rigid body, Dh=∞

$di \approx 0.1\,(3D+7d)$ $De \approx 0.1\,(7D+3d)$

For estimating δf, the following may be used:
$\delta f = 0.7\,(\Delta de + \Delta De)$ to $0.9\,(\Delta de + \Delta De)$
with smaller values for heavy-section bearings (e.g. bearings of diameter series 4) and larger values for light-section bearing rings. (e.g. bearings of diameter series 9)