

6. Bearing Internal Clearance

6.1 Bearing internal clearance

Bearing internal clearance (initial clearance) is the amount of internal clearance a bearing has before being installed on a shaft or in a housing.

As shown in Fig. 6.1, when either the inner ring or the outer ring is fixed the other ring is free to move, displacement can take place in either an axial or radial direction. This amount of displacement (radially or axially) is termed the internal clearance and, depending on the direction, is called the radial internal clearance or the axial internal clearance.

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 between the true bearing clearance and the increased amount due to the elastic deformation must be compensated for. These compensation values are given in Table 6.1.

The internal clearance values for each bearing class are shown in Table 6.3.

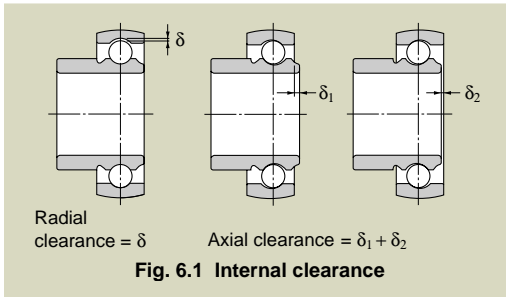


Table 6.1 Adjustment of radial internal clearance based on measured load Unit: μm

Nominal Bore Diameter d (mm)		Measuring Load (N)	Radial Clearance Increase				
over	incl.		C2	CN	C3	C4	C5
10	18	24.5	3~4	4	4	4	4
18	50	49	4~5	5	6	6	6
50	200	147	6~8	8	9	9	9

6.2 Internal clearance selection

The internal clearance of a bearing under operating conditions (effective clearance) is usually smaller than the same bearing's initial clearance before being installed and operated. This is due to several factors including bearing fit, the difference in temperature between the inner and outer rings, etc. As a bearing's operating clearance has an effect on bearing life, heat generation, vibration, noise, etc.; care must be taken in selecting the most suitable operating clearance.

Effective internal clearance:

The internal clearance differential between the initial clearance and the operating (effective) clearance (the amount of clearance reduction caused by interference fits, or clearance variation due to the temperature difference between the inner and outer rings) can be calculated by the following formula:

$$\delta_{\text{eff}} = \delta_o - (\delta_f + \delta_t) \dots \dots \dots (6.1)$$

where,

δ : Effective internal clearance, mm

δ_{eff} : Bearing internal clearance, mm

δ_f : Reduced amount of clearance due to interference, mm

δ_t : Reduced amount of clearance due to temperature differential of inner and outer rings, mm

Reduced clearance due to interference:

When bearings are installed with interference fits on shafts and in housings, the inner ring will expand and the outer ring will contract; thus reducing the bearings' internal clearance. The amount of expansion or contraction varies depending on the shape of the bearing, the shape of the shaft or housing, dimensions of the respective parts, and the type of materials used. The differential can range from approximately 70% to 90% of the effective interference.

$$\delta_f = (0.70 \sim 0.90) \bullet \Delta d_{\text{eff}} \dots \dots \dots (6.2)$$

where,

δ_f : Reduced amount of clearance due to interference, mm

Δd_{eff} : Effective interference, mm

Reduced internal clearance due to inner/outer ring temperature difference:

During operation, normally the outer ring will be from 5° to 10°C cooler than the inner ring or rotating parts. However, if the cooling effect of the housing is large, the shaft is connected to a heat source, or a heated substance is conducted through the hollow shaft; the temperature difference between the two

rings can be even greater. The amount of internal clearance is thus further reduced by the differential expansion of the two rings.

$$\delta_t = \alpha \cdot \Delta_T \cdot D_o \dots\dots\dots (6.3)$$

where,

δ_t : Amount of reduced clearance due to heat differential, **mm**

α : Bearing steel linear expansion coefficient $12.5 \times 10^{-6}/^\circ\text{C}$

Δ_T : Inner/outer ring temperature differential, $^\circ\text{C}$

D_o : Outer ring raceway diameter, **mm**

Outer ring raceway diameter, D_o , values can be approximated by using formula 6.4.

$$D_o = 0.20(d + 4.0D) \dots\dots\dots (6.4)$$

where,

d : Bearing bore diameter, **mm**

D : Bearing outside diameter, **mm**

6.3 Bearing internal clearance selection standards

Theoretically, in regard to bearing life, the optimum operating internal clearance for any bearing would be a slight negative clearance after the bearing had reached normal operating temperature.

Unfortunately, under actual operating conditions, maintaining such optimum tolerances is often difficult at best. Due to various fluctuating operating conditions this slight minus clearance can quickly become a large minus, greatly lowering the life of the bearing and causing excessive heat to be generated. Therefore, an initial internal clearance which will result in a slightly greater than negative internal operating clearance should be selected.

Under normal operating conditions (e.g. normal load, fit, speed, temperature, etc.), a standard internal clearance will give a very satisfactory operating clearance.

Table 6.2 lists non-standard clearance recommendations for various applications and operating conditions.

Table 6.2 Examples of applications where bearing clearances other than normal clearance are used

Operating conditions	Applications	Selected clearance
Shaft is heated and housing is cooled.	Conveyor of casting machine	C5
Shaft or inner ring is heated.	Annealing pit, Drying pit, Curing pit	C4
Allows for shaft deflection and fitting errors.	Disc harrows	C4
	Combines	C3
Tight-fitted for both inner and outer rings.	Large blowers	C3
To reduce noise and vibration when rotating.	Multi-wing fan of air conditioners	C2

Table 6.3 (1) Cylindrical bore bearings

Unit: mm/0.0001 inch

Nominal bore diameter <i>d</i>				Radial internal clearance															
				C2		CN		C3		C4									
over		incl.		min.		max.		min.		max.		min.		max.					
mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch				
10	0.3937	18	0.7087	0	0	9	4	3	1	18	7	11	4	25	10	18	7	33	13
18	0.7087	24	0.9449	0	0	10	4	5	2	20	8	13	5	28	11	20	8	36	14
24	0.9449	30	1.1811	1	0	11	4	5	2	20	8	13	5	28	11	23	9	41	16
30	1.1811	40	1.5748	1	0	11	4	6	2	20	8	15	6	33	13	28	11	46	18
40	1.5748	50	1.9685	1	0	11	4	6	2	23	9	18	7	36	14	30	12	51	20
50	1.9685	65	2.5591	1	0	15	6	8	3	28	11	23	9	43	17	38	15	61	24
65	2.5591	80	3.1496	1	0	15	6	10	4	30	12	25	10	51	20	46	18	71	28
80	3.1496	100	3.9370	1	0	18	7	12	5	36	14	30	12	58	23	53	21	84	33
100	3.9370	120	4.7244	2	1	20	8	15	6	41	16	36	14	66	26	61	24	97	38
120	4.7244	140	5.5118	2	1	23	9	18	7	48	19	41	16	81	32	71	28	114	45

Note: Heat-resistant bearings with suffix HT1 or HT2 have C4 clearances.

Table 6.3 (2) Tapered bore bearings

Unit: mm/0.0001 inch

Nominal bore diameter <i>d</i>				Radial internal clearance															
				C2		CN		C3		C4									
over		incl.		min.		max.		min.		max.		min.		max.					
mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch	mm	inch				
24	0.9449	30	1.1811	5	2	20	8	13	5	28	11	23	9	41	16	30	12	53	21
30	1.1811	40	1.5748	6	2	20	8	15	6	33	13	28	11	46	18	40	16	64	25
40	1.5748	50	1.9685	6	2	23	9	18	7	36	14	30	12	51	20	45	18	73	29
50	1.9685	65	2.5591	8	3	28	11	23	9	43	17	38	15	61	24	55	22	90	35
65	2.5591	80	3.1496	10	4	30	12	25	10	51	20	46	18	71	28	65	26	105	41
80	3.1496	100	3.9370	12	5	36	14	30	12	58	23	53	21	84	33	75	30	120	47
100	3.9370	120	4.7244	15	6	41	16	36	14	66	26	61	24	97	38	90	35	140	55
120	4.7244	140	5.5118	18	7	48	19	41	16	81	32	71	28	114	45	105	41	160	63