5 Clearance

5.1 Internal clearance

Internal clearance of a bearing is the amount of internal clearance a bearing has before being installed on a shaft or in a housing.

As in Fig.5.1, when either the inner ring or the outer ring is fixed and 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 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 5.1. For roller bearings the amount of elastic deformation can be ignored.
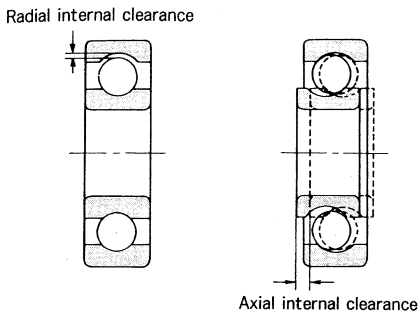

Fig. 5.1 Internal clearance

Table 5.1 Adjustment of radial internal clearance based on measured load Unit μm

Nominal bore diameter of bearing d (mm)		Measuring Load (N)	Radial Clearance Increase				
over	incl		C2	Normal	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

5.2 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 serveral 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 selectng 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:

When $\delta_{eff} = \delta_o - (\delta_f + \delta_t)$ 5.1

Where,

δ_{eff} : Effective internal clearance mm
δ_o : 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 shap of the shaft or housing, dimensions of the respective parts, and the type of material used. The differential can range from approximately 70% to 90% of the effective interference.

$\delta_f = (0.70 \sim 0.90) \cdot \Delta_{deff}$ 5.2

Where,

δ_f : Reduced amount of clearance due to interference mm
Δ_{deff} : Effective interference mm

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

During operation, normally the outer ring will be from 5x to 10xC cooler than the inner ring or rotating parts. However, if the colling 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.

$$\delta_t = \alpha \cdot \varDelta_r \cdot D_o \dots 5.3$$

Where,

- δ_t : Amount of reduced clearance due to heat differential mm
- α : Bearing steel linear expansion coefficietn $12.5 \times 10^{-6}/X C$
- $\varDelta_r$: Inner/outer ring temperature differential XC
- D_o : Outer ring raceway diameter mm

Outer ring raceway diameter, Do, values can be approximated by using formula (8.4) or (8.5).
For ball bearings and self-aligning roller bearings,

$$D_o = 0.20\,(d + 4.0D) \dots 5.4$$

For roller bearings (except self-aligning)

$$D_o = 0.25\,(d + 3.0D) \dots 5.5$$

Where, d : Bearing bore diameter mm
  D : Bearing outside diameter mm

5.3 Bearing internal clearance seletion standards

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

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 teh bearing and causing excessive heat to be generated. Therefore, an initial internal clearance which will result in a slightly greater than minus internal operating clearance should be selected.

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

Table 5.2. lists non-standard clearance recommendations for various applications and operating conditions.

Table 5.2 Examples of applications where bearing clearances other than normal clearance are used

Operating conditions	Applications	Selected clearance
With heavy or shock load, clearance is great.	Railway vehicle axles	C3
	Vibration screens	C3, C4
With direction indeterminate load both inner and outer rings are tight-fitted.	Railway vehicle traction motors	C4
	Tractors and final speed regulators	C4
Shaft or inner ring is heated	Paper making machines and driers	C3, C4
	Rolling mill table rollers	C3
Clearance fit for both inner and outer rings	Rolling mill roll rollers	C2
to reduce noise and vibration when rotating.	Micromotors	C2

Table 5.3 Radial internal clearance of bearing for electric motor

Unit μm

Nominal bore diameter d mm		Radial internal clearance, E			
		Deep groove ball bearings		Cylindrical[2] roller bearings	
over	incl.	min	max	min	max
10	18	4	11	-	-
18	24	5	12	-	-
24	30	5	12	15	30
30	40	9	17	15	30
40	50	9	17	20	35
50	65	12	22	25	40
65	80	12	22	30	45
80	100	18	30	35	55
100	120	18	30	35	60
120	140	24	38	40	65
140	160	24	38	50	80
160	180	-	-	60	90
180	200	-	-	65	100

1) Suffix E is added to bearing numbers.
2) Non-interchargeable clearance.

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Table 5.4. Radial internal clearance of deep groove ball bearings.

Unit μm

Nominal bore diameter d mm		C2		Normal		C3		C4		C5	
over	incl.	min	max	min	max	min	max	min	max	min	max
-	2.5	0	6	4	11	10	20	-	-	-	-
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
18	24	0	10	5	20	13	28	20	36	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	4	32	32	82	82	132	132	187	197	255
225	250	4	36	36	92	92	152	152	217	217	290
250	280	4	39	39	97	97	162	162	237	237	320
280	315	8	50	50	110	110	180	180	260	260	350
315	355	8	50	50	120	120	200	200	290	290	380
355	400	8	60	60	140	140	230	230	330	330	430
400	450	10	70	70	160	160	260	260	370	-	-
450	500	10	80	80	180	180	290	290	410	-	-
500	560	20	90	90	200	200	320	320	460	-	-
560	630	20	100	100	220	220	350	350	510	-	-

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Table 5.5 Radial internal clearance of self-aligning ball bearings, cylindrical bore   Unit μm

Nominal bore diameter d mm		C2		Normal		C3		C4		C5	
over	incl.	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	36	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	89	124
100	120	10	31	25	56	50	83	75	114	105	145
120	140	10	38	30	68	60	100	90	135	125	175
140	160	15	44	35	80	70	120	110	161	150	210

Table 5.5 Radial clearance of self-aligning ball bearings, tapered bore   Unit μm

C2		Normal		C3		C4		C5		Nominal bore diameter d mm	
min	max	min	max	min	max	min	max	min	max	over	incl.
-	-	-	-	-	-	-	-	-	-	2.5	6
-	-	-	-	-	-	-	-	-	-	6	10
-	-	-	-	-	-	-	-	-	-	10	14
-	-	-	-	-	-	-	-	-	-	14	18
7	17	13	26	20	33	28	42	37	55	18	24
9	20	15	28	23	39	33	50	44	62	24	30
12	24	19	35	29	46	40	59	52	72	30	40
14	27	22	39	33	52	45	65	58	79	40	50
18	32	27	47	41	61	56	80	73	99	50	65
23	39	35	57	50	75	69	98	91	123	65	80
29	47	42	68	62	90	84	116	109	144	80	100
35	56	50	81	75	108	100	139	130	170	100	120
40	68	60	98	90	130	120	165	155	205	120	140
45	74	65	110	100	150	140	191	180	240	140	160

Table 5.6.1 Radial internal clearance of spherical roller bearings, cylindrical bore

Unit μm

Nominal bore diameter d mm		C2		Normal		C3		C4		C5	
over	incl.	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	45	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	80	110	110	145	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	260
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	18	0240	240	310	310	390
180	200	70	130	130	200	200	260	260	340	340	430
200	225	80	14	014	0220	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	550	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	260	410	410	550	550	720	720	900
500	560	150	280	280	440	440	600	600	780	780	1 000
560	630	170	310	310	480	480	650	650	850	850	1 100
630	710	190	350	350	530	530	700	700	920	920	1 190
710	800	210	390	390	580	580	770	770	1 010	1 010	1 300
800	900	230	430	430	650	650	860	860	1 120	1 120	1 440
900	1 000	260	480	480	710	710	930	930	1 220	1 220	1 570
1 000	1 120	290	530	530	530	780	780	1 020	1 330	1 330	1 720
1 120	1 250	320	580	580	860	860	1 120	1 120	1 460	1 460	1 870
1 250	1 400	350	640	640	950	950	1 240	1 240	1 620	1 620	2 080

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Table 5.6.2 Radial internal clearance of spherical roller bearigns, tapered bore   Unit μm

C2		Normal		C3		C4		C5		Nominal bore diameter d mm	
min	max	min	max	min	max	min	max	min	max	over	incl.
-	-	-	-	-	-	-	-	-	-	14	18
15	25	25	35	35	45	45	60	60	75	18	24
20	30	30	40	40	55	55	75	75	95	24	30
25	35	35	50	50	65	65	85	85	105	30	40
30	45	45	60	60	80	80	100	100	130	40	50
40	55	55	75	75	95	95	120	120	160	50	65
50	70	70	95	95	120	120	150	150	200	65	80
55	80	80	110	110	140	140	180	180	230	80	100
65	100	100	135	135	170	170	220	220	280	100	120
80	120	120	160	160	200	200	260	260	330	120	140
90	130	130	180	180	230	230	300	300	380	140	160
100	140	140	200	200	260	260	340	340	430	160	180
110	160	160	220	220	290	290	370	370	470	180	200
120	180	180	250	250	320	320	410	410	520	200	225
140	200	200	270	270	350	350	450	450	570	225	250
150	220	220	300	300	390	390	490	490	620	250	280
170	240	240	330	330	430	430	540	540	680	280	315
190	270	270	360	360	470	470	590	590	740	315	355
210	300	300	400	400	520	520	650	650	820	355	400
230	330	330	440	440	570	570	720	720	910	400	450
260	370	370	490	490	630	630	790	790	1 000	450	500
290	410	410	540	540	680	680	870	870	1 100	500	560
320	460	460	600	600	760	760	980	980	1 230	560	630
350	510	51	0670	670	850	850	1 090	1 090	1 360	630	710
390	570	570	750	750	960	960	1 220	1 220	1 500	710	800
440	640	640	840	840	1 070	1 070	1 370	1 370	1 690	800	900
490	710	710	930	930	1 190	1 190	1 520	1 520	1 860	900	1 000
530	770	770	1 030	1 030	1 300	1 300	1 670	1 670	2 050	1 000	1 120
570	830	830	1 120	1 120	1 420	1 420	1 830	1 830	2 250	1 120	1 250
620	910	910	1 230	1 230	1 560	1 560	2 000	2 000	2 470	1 250	1 400

*In some critical applications, it is necessary to use bearings with controlled vibration and frequency. In such case, please contact your FBJ sales or engineering department.