15. TECHNICAL DATA

Page

DEFINIONS OF SYMBOLS AND THEIR UNITS

Symbols	Nomenclature	Units
a	Contact Ellipse Major Axis	(mm)
b	Contact Ellipse Major Axis	(mm)
C_r	Basic Dynamic Load Rating of Radial Bearings	(N){kgf}
C_{0r}	Basic Static Load Radial of Radial Bearings	(N){kgf}
C_a	Basic Dynamic Load Rating of Thrust Bearings	(N){kgf}
C_{0a}	Basic Static Load Rating of Thrust Bearings	(N){kgf}
d	Shaft Diameter, Nominal Bearing Bore Diameter	(mm)
D	Housing Bore Diameter, Nominal Bearing Outside Diameter	(mm)
D_e	Outer Ring Raceway Diameter	(mm)
D_i	Inner Ring Raceway Diameter	(mm)
D_0	Housing Outside Diameter	(mm)
D_{pw}	Rolling Element Pitch Diameter	(mm)
D_w	Nominal Rolling Element Diameter	(mm)
e	Contact Position of Tapered Roller End Face with Rib	(mm)
E	Modulus of Longitudinal Elasticity (Bearing Steel) 208 000 MP_a{21 200 kgf/mm²}	
$E(k)$	Complete elliptic integral of the 2nd kind for which the population parameter is $k=\sqrt{1-\left(\frac{b}{a}\right)^2}$	
f_0	factor which depends on the geometry of the bearing components and on the applicable stress level	
$f(\varepsilon)$	Function of ε	
F_a	Axial Load, Preload	(N){kgf}
F_r	Radial Load	(N){kgf}
h	D_e/D	
h_0	D/D_0	
k	d/D_i	
K	Constant Determined by Internal Design of Bearing	
L	Fatigue Life when Effective Clearance is 0	
L_{we}	Effective Leng of Roller	(mm)
L_ε	Fatigue Life when Effective Clearance is Δ	
m_0	Distance between Centers of Curvature of Inner and Outer Rings $r_i+r_e-D_w$	(mm)
M	Frictional Torque	(N·mm){kgf·mm}
M_s	Spin Friction	(N·mm){kgf·mm}

Symbols	Nomenclature	Units
n_a	Rotating Speed of Rolling Elements	(min^{-1})
n_c	Revolving Speed of Rolling Elements (Cape Speed)	(min^{-1})
n_e	Speed of Ouder Ring	(min^{-1})
n_i	Speed of Inner Ring	(min^{-1})
p_m	Surface Pressure on Fitted Surface	(MP_a){kgf/mm²}
P	Bearing Load	(N){kgf}
Q	Rolling Element Load	(N){kgf}
r_e	Groove Radius of Outer Ring	(mm)
r_i	Groove Radius of Inner Ring	(mm)
v_a	Circumferential Speed of Rolling Element about Its Center	(m/sec)
v_c	Circumferential Speed of Rolling Element about Beaing Center	(m/sec)
Z	Number of Rolling Elements per Row	
α	Contact Angle (when axial load is applied on Radial Ball Bearning	(°)
α_0	Initial Confact Angle (Geometri) (when inner and outer rings of Angular Contact Ball Bearings are pushed axially)	(°)
α_R	Initial Contact Angle (Geometric) (when inner and outer rings Angular Contact Ball Bearing are pushed radially)	(°)
β	1/2 of Conical Angle of Roller	(°)
δ_a	Relative Axial Displacement of Inner and Outer Rings	(mm)
Δ_a	Axial Internal Clearance	(mm)
Δd	Effective Interference of Inner Ring and Shaft	(mm)
Δ_r	Radial Internal Clearance	(mm)
ΔD	Effective Interference of Outer Ring and Housing	(mm)
ΔD_e	Contraction of Outer Ring Raceway Diameter due to Fit	(mm)
ΔD_i	Expansion of Inner Ring Raceway Diameter dus to Fit	(mm)
ε	Load Factor	
μ	Coefficient of Dynamic Friction of Rolling Bearing	
μ_e	Coefficient of Friction between Roller End Face and Rib	
μ_s	Coefficient of Sliding Friction	
$\sigma_{t\,max}$	Maximum Stress on Fitted Surfaces	(MP_a){kgf/mm²}

15. 1 Axial Displacement of Bearings

(1) Contact Angle α and Axial Displacement δ_a of Deep Groove Ball Bearing and Angular Contact Ball Bearings
(Figs. 15.1 to 15.3)

$$\left.\begin{aligned}\delta_a &= \frac{0.00044}{\sin\alpha}\left(\frac{Q^2}{D_w}\right)^{\frac{1}{3}} \quad \text{.................. (N)}\\ \delta_a &= \frac{0.002}{\sin\alpha}\left(\frac{Q^2}{D_w}\right)^{\frac{1}{3}} \quad \text{.................... \{kgf\}}\end{aligned}\right\}(\text{mm})$$

$$Q = \frac{F_a}{Z\sin\alpha} \qquad \text{(N), \{kgf\}}$$

(2) Axial Load F_a and Axial Displacement δ_a of Tapered Roller Bearings
(Fig. 15.4)

$$\left.\begin{aligned}\delta_a &= \frac{0.000077\,F_a^{0.9}}{(\sin\alpha)^{1.9}\,Z^{0.9}\,L_{we}^{0.8}} \quad \text{................ (N)}\\ \delta_a &= \frac{0.0006\,F_a^{0.9}}{(\sin\alpha)^{1.9}\,Z^{0.9}\,L_{we}^{0.8}} \quad \text{............. \{kgf\}}\end{aligned}\right\}(\text{mm})$$

Remarks:
Actual axial displacement may vary depending on the shaft/housing thickness, material, and fitting interference with the bearing. Please contact NSK about such factors of axial displacement which are not discussed in detail in this catalog.

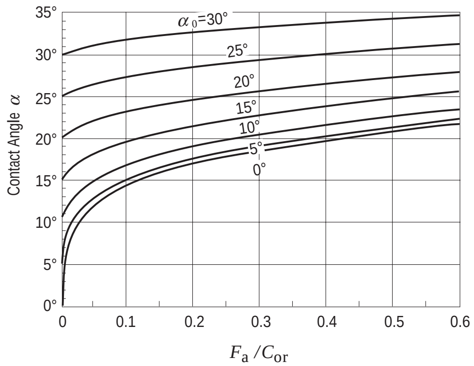

Fig. 15.1 F_a/C_{or} **and Contact Angle of Deep Groove and Angular Contact Ball Bearings**

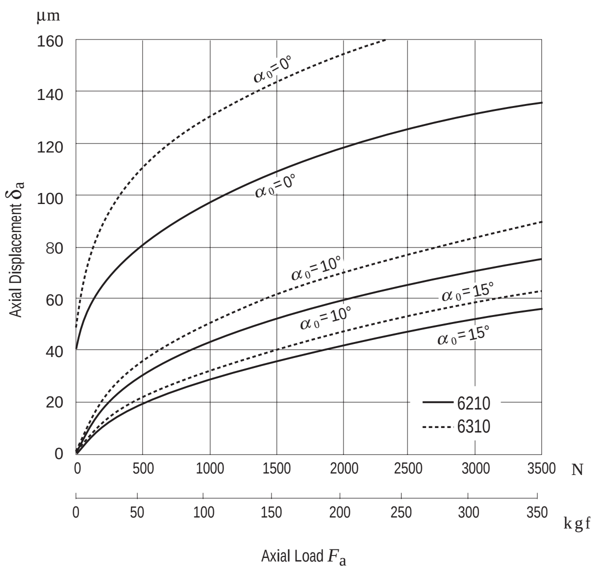

Fig. 15.2 Axial Load and Axial Displacement of Deep Groove Ball Bearings

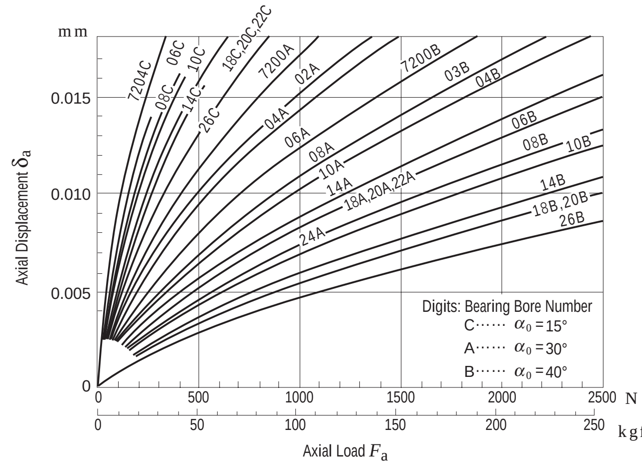

Fig. 15.3 Axial Load and Axial Displacement of Angular Contact Ball Bearings

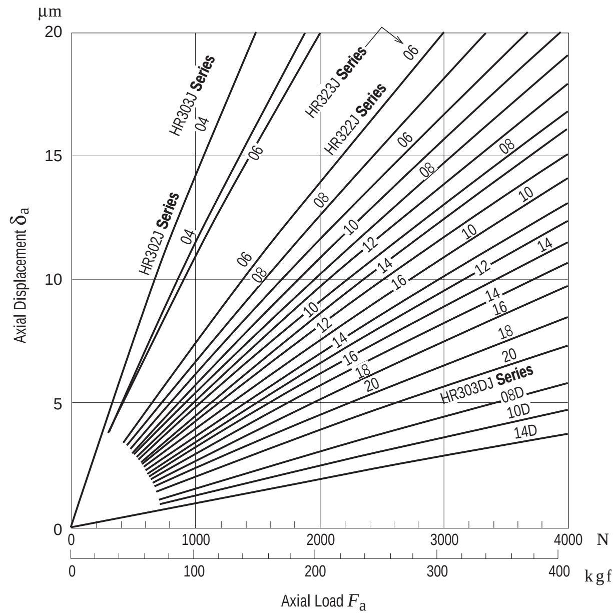

Fig. 15.4 Axial Load and Axial Displacement of Tapered Roller Bearings

15.2 Fits

(1) Surface Pressure p_m, Maximum Stress σ_{tmax} on Fitted Surfaces and Expansion of Inner Ring Raceway Diameter ΔD_i or Contraction of Outer Ring Raceway Diameter ΔD_e
(Table 15.1, Figs. 15.5 and 15.6)

(2) Interferences or Clearances of Shafts and Inner Rings (Table 15.2)

(3) Interferences or Clearances of Housing Bores and Outer Rings (Table 15.3)

Table. 15. 1 Surface Pressure, Maximum Stress on Fitted Surfaces and Expansion or Contraction

Items	Shaft & Inner Ring	Housing & Bore & Outer Ring
Surface Pressure p_m (MPa) {kgf/mm²}	(In case of sold shaft) $p_m = \frac{E}{2}\frac{\Delta d}{2}(1-k^2)$	In case of housing outside dia. $D_0 \neq \infty$: $p_m = \frac{E}{2}\frac{\Delta D}{D}\frac{(1-h^2)(1-h_0^2)}{1-h^2 h_0^2}$ In case $D_0 = \infty$: $p_m = \frac{E}{2}\frac{\Delta D}{D}(1-h^2)$
Maximum stress $\sigma_{t\,max}$ (MPa) {kgf/mm²}	Maximum circumferential stress on fitted surface of inner ring bore is $\sigma_{t\,max} = p_m \frac{1+k^2}{1-k^2}$	Maximum circumferential stress on outer ring bore surface is $\sigma_{t\,max} = p_m \frac{2}{1-h^2}$
Expansion of inner ring raceway dia. ΔD_i (mm) Contraction of outer ring raceway dia. ΔD_e (mm)	In case of solid shaft $\Delta D_i = \Delta d \cdot k$	In case $D_0 \neq \infty$: $\Delta D_e = \Delta D \cdot h \frac{1-h_0^2}{1-h^2 h_0^2}$ In case $D_0 = \infty$: $\Delta D_e = \Delta D \cdot h$

Remarks The modulus of longitudinal elasticity and Poisson's ratio for the shaft and housing material are the same as those for inner and outer rings.

Reference 1 MPa=1 N/mm²=0.102 kgf/mm²

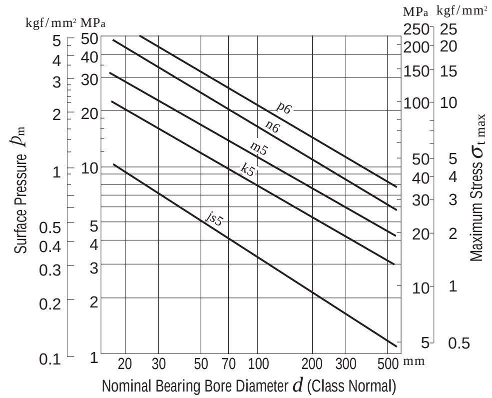

Fig. 15.5 Surface Pressure p_m and Maximum Stress $\sigma_{t\,max}$ for Average Fitting Interference

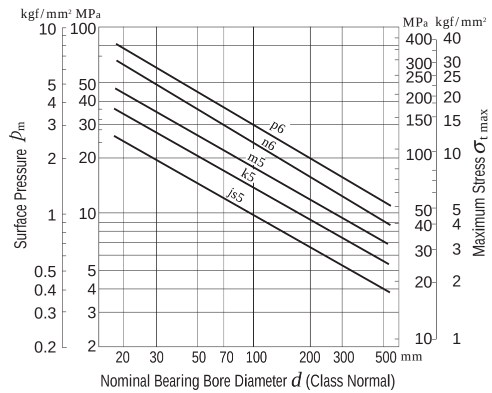

Fig. 15.6 Surface Pressure p_m and Maximum Stress $\sigma_{t\,max}$ for Maximum Fitting Interference

Table 15. 2 Interferences or Clearances of Shafts and Inner Rings

Units : μm

Size Classification (mm)		Single Plane Mean Bore Dia. Deviation (Normal) Δd_{mp}		Interferences or Clearances for Each Fitting Class													
				f6		g5		g6		h5		h6		js5		j5	
				Clearance		Clearance	Interference	Clearance	Interference	Clearance	Interference	Clearance	Interference	Clearance	Interference	Clearance	Interference
over	incl.	high	low	max.	min.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.	max.
3	**6**	0	−8	18	2	9	4	12	4	5	8	8	8	—	—	—	—
6	**10**	0	−8	22	5	11	3	14	3	6	8	9	8	3	11	2	12
10	**18**	0	−8	27	8	14	2	17	2	8	8	11	8	4	12	3	13
18	**30**	0	−10	33	10	16	3	20	3	9	10	13	10	4.5	14.5	4	15
30	**50**	0	−12	41	13	20	3	25	3	11	12	16	12	5.5	17.5	5	18
50	**65**	0	−15	49	15	23	5	29	5	13	15	19	15	6.5	21.5	7	21
65	**80**	0	−15	49	15	23	5	29	5	13	15	19	15	6.5	21.5	7	21
80	**100**	0	−20	58	16	27	8	34	8	15	20	22	20	7.5	27.5	9	26
100	**120**	0	−20	58	16	27	8	34	8	15	20	22	20	7.5	27.5	9	26
120	**140**	0	−25	68	18	32	11	39	11	18	25	25	25	9	34	11	32
140	**160**	0	−25	68	18	32	11	39	11	18	25	25	25	9	34	11	32
160	**180**	0	−25	68	18	32	11	39	11	18	25	25	25	9	34	11	32
180	**200**	0	−30	79	20	35	15	44	15	20	30	29	30	10	40	13	37
200	**225**	0	−30	79	20	35	15	44	15	20	30	29	30	10	40	13	37
225	**250**	0	−30	79	20	35	15	44	15	20	30	29	30	10	40	13	37
250	**280**	0	−35	88	21	40	18	49	18	23	35	32	35	11.5	46.5	16	42
280	**315**	0	−35	88	21	40	18	49	18	23	35	32	35	11.5	46.5	16	42
315	**355**	0	−40	98	22	43	22	54	22	25	40	36	40	12.5	52.5	18	47
355	**400**	0	−40	98	22	43	22	54	22	25	40	36	40	12.5	52.5	18	47
400	**450**	0	−45	108	23	47	25	60	25	27	45	40	45	13.5	58.5	20	52
450	**500**	0	−45	108	23	47	25	60	25	27	45	40	45	13.5	58.5	20	52

Interferences or Clearances for Each Fitting Class																		Size Classification (mm)	
js6		j6		k5		k6		m5		m6		n6		p6		r6			
Clearance	Interference	Clearance	Interference	Interference		Interference		Interference		Interference		Interference		Interference		Interference			
max.	max.	max.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	over	incl.
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	**3**	**6**
4.5	12.5	2	15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	**6**	**10**
5.5	13.5	3	16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	**10**	**18**
6.5	16.5	4	19	2	21	2	25	—	—	—	—	—	—	—	—	—	—	**18**	**30**
8	20	5	23	2	25	2	30	9	32	9	37	—	—	—	—	—	—	**30**	**50**
9.5	24.5	7	27	2	30	2	36	11	39	11	45	—	—	—	—	—	—	**50**	**65**
9.5	24.5	7	27	2	30	2	36	11	39	11	45	20	54	—	—	—	—	**65**	**80**
11	31	9	33	3	38	3	45	13	48	13	55	23	65	37	79	—	—	**80**	**100**
11	31	9	33	3	38	3	45	13	48	13	55	23	65	37	79	—	—	**100**	**120**
12.5	37.5	11	39	3	46	3	53	15	58	15	65	27	77	43	93	63	113	**120**	**140**
12.5	37.5	11	39	3	46	3	53	15	58	15	65	27	77	43	93	65	115	**140**	**160**
12.5	37.5	11	39	3	46	3	53	15	58	15	65	27	77	43	93	68	118	**160**	**180**
14.5	44.5	13	46	4	54	4	63	17	67	17	76	31	90	50	109	77	136	**180**	**200**
14.5	44.5	13	46	4	54	4	63	17	67	17	76	31	90	50	109	80	139	**200**	**225**
14.5	44.5	13	46	4	54	4	63	17	67	17	76	31	90	50	109	84	143	**225**	**250**
16	51	16	51	4	62	4	71	20	78	20	87	34	101	56	123	94	161	**250**	**280**
16	51	16	51	4	62	4	71	20	78	20	87	34	101	56	123	98	165	**280**	**315**
18	58	18	58	4	69	4	80	21	86	21	97	37	113	62	138	108	184	**315**	**355**
18	58	18	58	4	69	4	80	21	86	21	97	37	113	62	138	114	190	**355**	**400**
20	65	20	65	5	77	5	90	23	95	23	108	40	125	68	153	126	211	**400**	**450**
20	65	20	65	5	77	5	90	23	95	23	108	40	125	68	153	132	217	**450**	**500**

Remarks 1. The figures for tolerance classes where stress caused by the fitting of the shaft and inner ring becomes excessive are omitted.
2. The tolerance range js is now recommended instead of j.

Table 15. 3 Interferences or Clearances of Housing Bores and Outer Rings

Units : μm

Size Classification (mm) over	Size Classification (mm) incl.	Single Plane Mean O. D. Deviation (Normal) ΔD_{mp} high	ΔD_{mp} low	G7 Clearance max.	G7 Clearance min.	H6 Clearance max.	H6 Clearance min.	H7 Clearance max.	H7 Clearance min.	H8 Clearance max.	H8 Clearance min.	J6 Clearance max.	J6 Interference max.	JS6 Clearance max.	JS6 Interference max.	J7 Clearance max.	J7 Interference max.
6	**10**	0	– 8	28	5	17	0	23	0	30	0	13	4	12.5	4.5	16	7
10	**18**	0	– 8	32	6	19	0	26	0	35	0	14	5	13.5	5.5	18	8
18	**30**	0	– 9	37	7	22	0	30	0	42	0	17	5	15.5	6.5	21	9
30	**50**	0	– 11	45	9	27	0	36	0	50	0	21	6	19	8	25	11
50	**80**	0	– 13	53	10	32	0	43	0	59	0	26	6	22.5	9.5	31	12
80	**120**	0	– 15	62	12	37	0	50	0	69	0	31	6	26	11	37	13
120	**150**	0	– 18	72	14	43	0	58	0	81	0	36	7	30.5	12.5	44	14
150	**180**	0	– 25	79	14	50	0	65	0	88	0	43	7	37.5	12.5	51	14
180	**250**	0	– 30	91	15	59	0	76	0	102	0	52	7	44.5	14.5	60	16
250	**315**	0	– 35	104	17	67	0	87	0	116	0	60	7	51	16	71	16
315	**400**	0	– 40	115	18	76	0	97	0	129	0	69	7	58	18	79	18
400	**500**	0	– 45	128	20	85	0	108	0	142	0	78	7	65	20	88	20
500	**630**	0	– 50	142	22	94	0	120	0	160	0	—	—	72	22	—	—
630	**800**	0	– 75	179	24	125	0	155	0	200	0	—	—	100	25	—	—
800	**1 000**	0	–100	216	26	156	0	190	0	240	0	—	—	128	28	—	—

Interferences or Clearances for Each Fitting Class (continued)

JS7 Clearance max.	JS7 Interference max.	K6 Clearance max.	K6 Interference max.	K7 Clearance max.	K7 Interference max.	M6 Clearance max.	M6 Interference max.	M7 Clearance max.	M7 Interference max.	N6 Clearance max.	N6 Interference max.	N7 Clearance max.	N7 Interference max.	P6 Interference max.	P6 Interference max.	P7 Interference min.	P7 Interference max.	Size Classification (mm) over	Size Classification (mm) incl.
15	7	10	7	13	10	5	12	8	15	1	16	4	19	4	21	1	24	**6**	**10**
17	9	10	9	14	12	4	15	8	18	1*	20	3	23	7	26	3	29	**10**	**18**
19	10	11	11	15	15	5	17	9	21	2*	24	2	28	9	31	5	35	**18**	**30**
23	12	14	13	18	18	7	20	11	25	1*	28	3	33	10	37	6	42	**30**	**50**
28	15	17	15	22	21	8	24	13	30	1*	33	4	39	13	45	8	51	**50**	**80**
32	17	19	18	25	25	9	28	15	35	1*	38	5	45	15	52	9	59	**80**	**120**
38	20	22	21	30	28	10	33	18	40	2*	45	6	52	18	61	10	68	**120**	**150**
45	20	29	21	37	28	17	33	25	40	5	45	13	52	11	61	3	68	**150**	**180**
53	23	35	24	43	33	22	37	30	46	8	51	16	60	11	70	3	79	**180**	**250**
61	26	40	27	51	36	26	41	35	52	10	57	21	66	12	79	1	88	**250**	**315**
68	28	47	29	57	40	30	46	40	57	14	62	24	73	11	87	1	98	**315**	**400**
76	31	53	32	63	45	35	50	45	63	18	67	28	80	10	95	0	108	**400**	**500**
85	35	50	44	50	70	24	70	24	96	6	88	6	114	28	122	28	148	**500**	**630**
115	40	75	50	75	80	45	80	45	110	25	100	25	130	13	138	13	168	**630**	**800**
145	45	100	56	100	90	66	90	66	124	44	112	44	146	0	156	0	190	**800**	**1 000**

Note (*) Indicates the minimum interference
Remarks The tolerance range JS is now recommended instead of J.

15.3 Radial and Axial Internal Clearances

(1) Radial Internal Clearance Δ_r and Axial Internal Clearance Δ_a in Single-Row Deep Groove Ball Bearings
(Fig. 15.7)

$$\Delta_a \doteqdot K \Delta_r^{\frac{1}{2}} \qquad \text{(mm)}$$

where

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

(2) Radial Internal Clearance Δ_r and Axial Internal Clearance Δ_a in Double-Row Angular Contact Ball Bearings
(Fig. 15.8)

$$\Delta_a = 2\sqrt{m_0^2 - \left(m_0 \cos\alpha_R - \frac{\Delta_r}{2}\right)^2} - 2\,m_0 \sin\alpha_R \qquad \text{(mm)}$$

Table 15. 4 Constant *K*

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	1.11	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

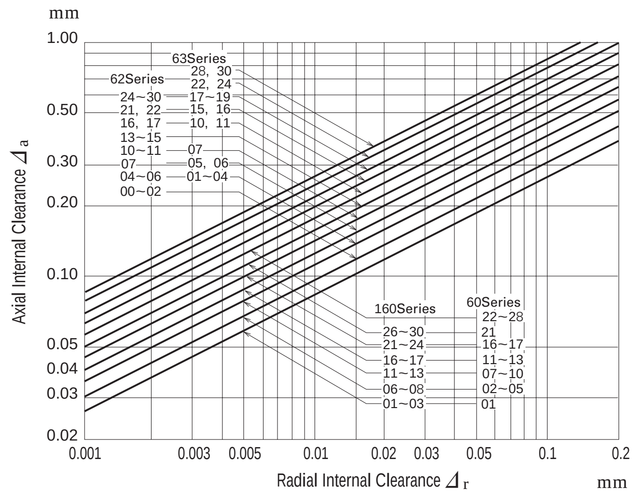

Fig. 15.7 Δ_r **and** Δ_a **in Single-Row Deep Groove Ball Bearings**

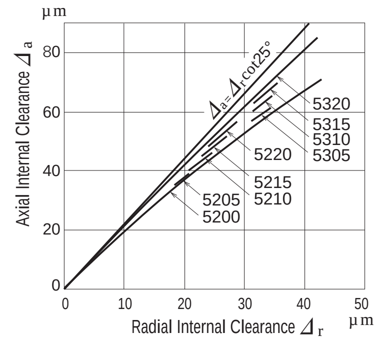

Fig. 15.8 Δ_r **and** Δ_a **in Double-Row Angular Contact Ball Bearings (52, 53 Series)**

15. 4 Preload and Staring Torque

(1) Axial Load F_a and Starting Torque M of Tapered Roller Bearings (Figs. 15.9 and 15.10)

$$M = e\,\mu_e\,F_a \cos\beta \qquad (\text{N·mm}),\ \{\text{kgf·mm}\}$$

where

μ_e : 0.20

When bearings with the same number are used in opposition, the torque M caused by the preload becomes $2M$.

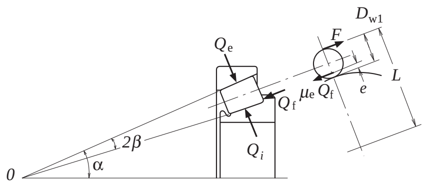

Fig. 15.9 Relation between e and β

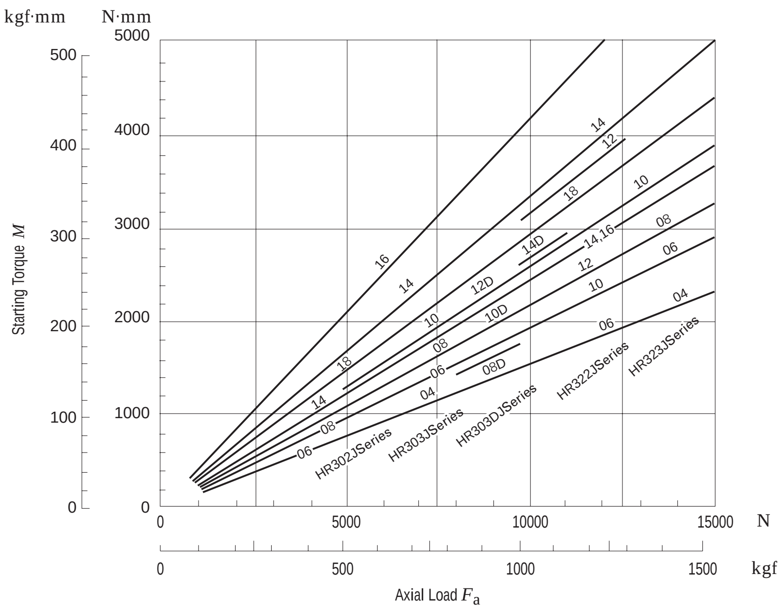

Fig. 15.10 Relation between Axial Load and Starting Torque of Tapered Roller Bearings

(2) Preload F_a and Starting Torque M of Angular Contact Ball Bearings and Double-Direction Angular Contact Thrust Ball Bearings (Figs. 15.11 and 15.12)

$$M = M_s\,Z \sin\alpha \qquad (\text{N·mm}),\ \{\text{kgf·mm}\}$$

where M_S is spin friction

$$M_S = \frac{3}{8}\mu_s\,Q\,a\,E(k) \qquad (\text{N·mm}),\ \{\text{kgf·mm}\}$$

where

μ_s = 0.15

When bearings with the same number are used in opposition, the torque M caused by the preload becomes $2M$.

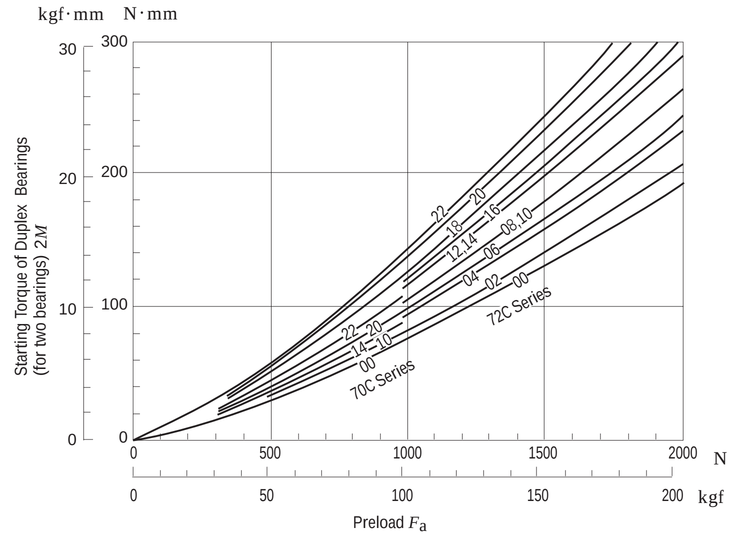

Fig. 15.11 Preload and Starting Torque for Back-to-Back or Face-to-Face Arrangements of Angular Contact Ball Bearings (α =15°)

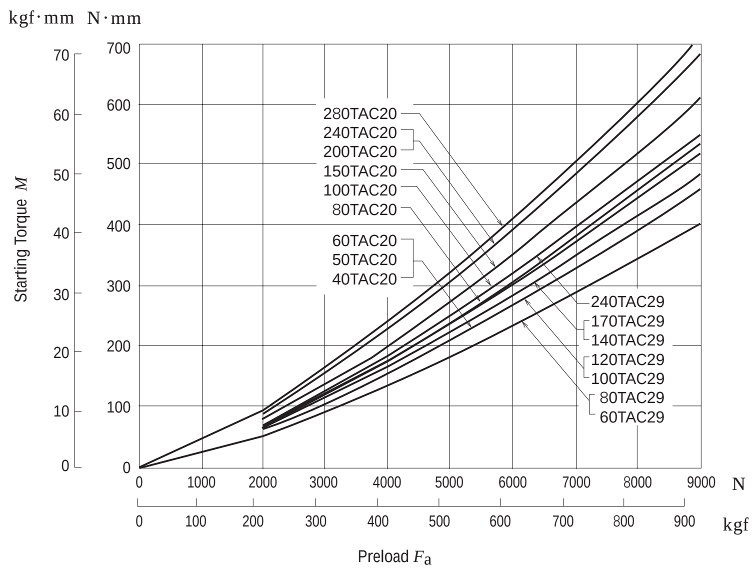

Fig. 15.12 Preload and Starting Torque of Double-Direction Angular Contact Thrust Ball Bearings

15.5 Coefficients of Dynamic Friction and Other Bearing Data

(1) Bearing Types and Their Coefficients of Dynamic Friction μ

$$\mu = \frac{M}{P \cdot \frac{d}{2}}$$

Table 15.5 Coefficients of Dynamic Friction

Bearing Types	Approximate values of μ
Deep Groove Ball Bearings	0.0013
Angular Contact Ball Bearings	0.0015
Self-Aligning Ball Bearings	0.0010
Thrust Ball Bearings	0.0011
Cylindrical Roller Bearings	0.0010
Tapered Roller Bearings	0.0022
Spherical Roller Bearings	0.0028
Needle Roller Bearings with Cages	0.0015
Full Complement Needle Roller Bearings	0.0025
Spherical Thrust Roller Bearings	0.0028

(2) Circumferential Speeds of Rolling Elements about Their Centers and Bearing Center

Table 15.6 Circumferential Speeds of Rolling Elements about Their Centers and Bearing Center

Items	Rotating inner ring, fixed outer ring	Rotating outer ring, fixed inner ring
Ball rotating speed n_a (min^{-1})	$-\left(\frac{D_{pw}}{D_w}-\frac{\cos^2\alpha}{D_{pw}/D_w}\right)\frac{n_i}{2}$	$+\left(\frac{D_{pw}}{D_w}-\frac{\cos^2\alpha}{D_{pw}/D_w}\right)\frac{n_e}{2}$
Cicumferential speed around bearing ball's center υ_a (m/sec)	$-\frac{\pi \cdot D_w}{60\times10^3}\left(\frac{D_{pw}}{D_w}-\frac{\cos^2\alpha}{D_{pw}/D_w}\right)\frac{n_i}{2}$	$+\frac{\pi \cdot D_w}{60\times10^3}\left(\frac{D_{pw}}{D_w}-\frac{\cos^2\alpha}{D_{pw}/D_w}\right)\frac{n_e}{2}$
Revolving speed around bearing center n_c (min^{-1})	$+\left(1-\frac{\cos\alpha}{D_{pw}/D_w}\right)\frac{n_i}{2}$	$+\left(1-\frac{\cos\alpha}{D_{pw}/D_w}\right)\frac{n_e}{2}$
Cicumferential speed around bearing center υ_c (m/sec)	$-\frac{\pi \cdot D_{pw}}{60\times10^3}\left(1-\frac{\cos\alpha}{D_{pw}/D_w}\right)\frac{n_i}{2}$	$+\frac{\pi \cdot D_{pw}}{60\times10^3}\left(1-\frac{\cos\alpha}{D_{pw}/D_w}\right)\frac{n_e}{2}$

Remarks 1. + sign indicates CW rotation and – sign CCW
2. The revolving speed and circumferential speed of the rolling elements are the same as those of the cage.

(3) Radial Internal Clearance Δ_r and Fatigue Life L (Fig. 15.13)

For the radial internal clearance Δ_r and the function $f(\varepsilon)$ of the load factor, the following equations are valid:

For Deep Groove Ball Bearings

$$f(\varepsilon) = \frac{\Delta_r \cdot D_w^{\frac{1}{3}}}{0.00044\left(\frac{F_r}{Z}\right)^{\frac{2}{3}}} \quad \text{.........(N)}$$

$$f(\varepsilon) = \frac{\Delta_r \cdot D_w^{\frac{1}{3}}}{0.002\left(\frac{F_r}{Z}\right)^{\frac{2}{3}}} \quad \text{.........\{kgf\}}$$

For Cylindrical Roller Bearings

$$f(\varepsilon) = \frac{\Delta_r \cdot L_{we}^{0.8}}{0.000077\left(\frac{F_r}{Z}\right)^{0.9}} \quad \text{.........(N)}$$

$$f(\varepsilon) = \frac{\Delta_r \cdot L_{we}^{0.8}}{0.0006\left(\frac{F_r}{Z}\right)^{0.9}} \quad \text{.........\{kgf\}}$$

The relation between the load factor ε and $f(\varepsilon)$ and L_ε/L, when the radial internal clearance is Δ_r is as shown in Table 15.7.
From the above equations, first obtain $f(\varepsilon)$ and then ε and L_ε/L can be obtained.

Table 15. 7 ε and $f(\varepsilon)$, L_ε/L

ε	Deep Groove Ball Bearings $f(\varepsilon)$	Deep Groove Ball Bearings $\frac{L_\varepsilon}{L}$	Cylindrical Roller Bearings $f(\varepsilon)$	Cylindrical Roller Bearings $\frac{L_\varepsilon}{L}$
0.1	33.713	0.294	51.315	0.220
0.2	10.221	0.546	14.500	0.469
0.3	4.045	0.737	5.539	0.691
0.4	1.408	0.889	1.887	0.870
0.5	0	1.0	0	1.0
0.6	– 0.859	1.069	– 1.133	1.075
0.7	– 1.438	1.098	– 1.897	1.096
0.8	– 1.862	1.094	– 2.455	1.065
0.9	– 2.195	1.041	– 2.929	0.968
1.0	– 2.489	0.948	– 3.453	0.805
1.25	– 3.207	0.605	– 4.934	0.378
1.5	– 3.877	0.371	– 6.387	0.196
1.67	– 4.283	0.276	– 7.335	0.133
1.8	– 4.596	0.221	– 8.082	0.100
2.0	– 5.052	0.159	– 9.187	0.067
2.5	– 6.114	0.078	–11.904	0.029
3	– 7.092	0.043	–14.570	0.015
4	– 8.874	0.017	–19.721	0.005
5	–10.489	0.008	–24.903	0.002
10	–17.148	0.001	–48.395	0.0002

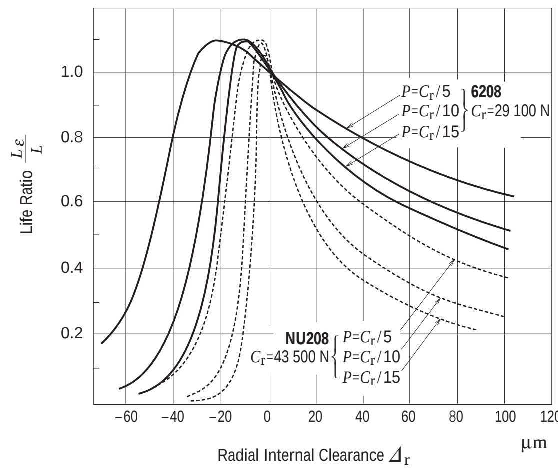

Fig. 15.13 Radial Internal Clearance and Life Ratio

15. 6 BRANDS AND PROPERTIES OF LUBRICATING GREASES

Table 15. 8 Brands of Lubricating Greases and Comparison of Properties

Brands	Thickeners	Base Oils	Dropping Point (°C)	Consistency	Working Temperature Range(1)(°C)	Pressure Resistance	Usable Limit Compared to Listed Limiting Speed(2)(%)
ADLEX	Lithium	Mineral oil	198	300	0 to +110	Good	70
APOLOIL AUTOLEX A	Lithium	Mineral oil	198	280	−10 to +110	Fair	60
ARAPEN RB 300	Lithium/Calcium	Mineral oil	177	294	−10 to + 80	Fair	70
EA2 GREASE	Urea (3)	Poly-α-olefin oil	≧260	243	−40 to +150	Fair	100
EA3 GREASE	Urea (3)	Poly-α-olefin oil	≧260	230	−40 to +150	Fair	100
EA5 GREASE	Urea (3)	Poly-α-olefin oil	≧260	251	−40 to +160	Good	60
EA7 GREASE	Urea (3)	Poly-α-olefin oil	≧260	243	−40 to +160	Fair	100
ENC GREASE	Urea (3)	Polyol ester oil + Mineral oil (4)	≧260	262	−40 to +160	Fair	70
ENS GREASE	Urea (3)	Polyol ester oil (4)	≧260	264	−40 to +160	Poor	100
ECE GREASE	Lithium	Poly-α-olefin oil	≧260	235	−10 to +120	Fair	100
ISOFLEX NBU 15	Barium Complex	Ester oil + Mineral oil (4)	≧260	280	−30 to +120	Poor	100
ISOFLEX SUPER LDS 18	Lithium	Ester oil (4)	195	280	−50 to +110	Poor	100
ISOFLEX TOPAS NB 52	Barium Complex	Poly-α-olefin oil	≧260	280	−40 to +130	Poor	90
DOW CORNING SH 33 L GREASE	Lithium	Silicone oil (5)	210	310	−60 to +120	Poor	60
DOW CORNING SH 44 M GREASE	Lithium	Silicone oil (5)	210	260	−30 to +130	Poor	60
NS HI-LUBE	Lithium	Polyol ester oil + Diester oil (4)	192	250	−40 to +130	Fair	100
NSC GREASE	Lithium	Alkyldiphenyl ether oil + Polyol ester oil (4)	192	235	−30 to +140	Fair	70
NSK CLEAN GREASE LG2	Lithium	Poly-α-olefin oil + Mineral oil	201	199	−40 to +130	Poor	100
EMALUBE 8030	Urea (3)	Mineral oil	≧260	280	0 to +130	Good	60
MA8 GREASE	Urea (3)	Alkyldiphenyl ether oil + Poly-α-olefin oil	≧260	283	−30 to +160	Fair	70
KRYTOX GPL-524	PTFE	Perfluoropolyether oil	≧260	265	0 to +200	Fair	70
KP1 GREASE	PTFE	Perfluoropolyether oil	≧260	280	−30 to +200	Fair	60
COSMO WIDE GREASE WR No.3N	Sodium Terephtalamate	Polyol ester oil + Mineral oil (4)	≧230	227	−40 to +130	Poor	100
G-40M	Lithium	Silicone oil (5)	223	252	−30 to +130	Poor	60
SHELL GADUS S2 V220 2	Lithium	Mineral oil	187	276	0 to + 80	Good	60
SHELL ALVANIA GREASE S1	Lithium	Mineral oil	182	323	−10 to +110	Fair	70
SHELL ALVANIA GREASE S2	Lithium	Mineral oil	185	275	−10 to +110	Fair	70
SHELL ALVANIA GREASE S3	Lithium	Mineral oil	185	242	−10 to +110	Fair	70
CASSIDA GREASE RLS 2	Aluminum Complex	Poly-α-olefin oil	≧240	280	0 to +120	Fair	70
SHELL SUNLIGHT GREASE 2	Lithium	Mineral oil	200	274	−10 to +110	Fair	70
WPH GREASE	Urea (3)	Poly-α-olefin oil	259	240	−40 to +150	Fair	70
DEMNUM GREASE L-200	PTFE	Perfluoropolyether oil	≧260	280	−30 to +200	Fair	60
NIGACE WR-S	Urea (3)	Synthetic oil	≧260	230	−30 to +150	Poor	70
NIGLUBE RSH	Sodium Complex	Polyalkylene Glycol oil	≧260	270	−20 to +120	Fair	60

Notes (1) If grease will be used at the upper or lower limit sufficient of the temperature range or in a special environment such as vacuum, it is advisable to consult NSK.
(2) For short-term operation or when cooling is grease may be used at speeds exceeding the above limits provided the supply of grease is appropriate.
(3) Urea-based grease causes fluorine-based material to deteriorate.
(4) Ester-based grease causes acrylic rubber material to swell.
(5) Silicone-based grease causes silicone-based material to swell.

(continued on next page)

Brands	Thickeners	Base Oils	Dropping Point (˚C)	Consistency	Working Temperature Range(1)(°C)	Pressure Resistance	Usable Limit Compared to Listed Limiting Speed(2)(%)
PALMAX RBG	Lithium Complex	Mineral oil	216	300	−10 to +130	Good	70
BEACON 325	Lithium	Diester oil (4)	190	274	−50 to +100	Poor	100
MULTEMP PS No.2	Lithium	Poly-α-olefin oil + Diester oil (4)	190	275	−50 to +110	Poor	100
MOLYKOTE FS-3451 GREASE	PTFE	Fluorosilicone oil (5)	≧260	285	0 to +180	Fair	70
UME GREASE	Urea	Mineral oil	≧260	268	−10 to +130	Fair	70
RAREMAX AF-1	Urea	Mineral oil	≧260	300	−10 to +130	Fair	70

Notes
(1) If grease will be used at the upper or lower limit sufficient of the temperature range or in a special environment such as vacuum, it is advisable to consult NSK.
(2) For short-term operation or when cooling is grease may be used at speeds exceeding the above limits provided the supply of grease is appropriate.
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