Main Spindle Bearings

12. Tapered Roller Bearings CONTENTS

12. Tapered Roller Bearings

Tapered roller bearings are designed so that the apexes of the inner ring, outer ring, and rollers are located at a common point on the bearing center line. Accordingly, the rollers roll on the raceway surfaces and slide along the back rib of the inner ring cone, guided by the combined force from the inner ring and outer ring raceways.

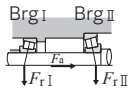
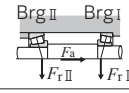
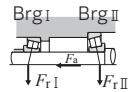
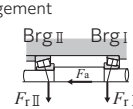
This bearing is suitable for handling a radial load, an axial load in one direction, and the combined load. Also, it has a large load capacity.

In general, pressed cages are used in tapered roller bearings. Care must be taken when designing the shaft and housing for such a bearing, because the cage protrudes from the side of the raceway surface.

12.1 Load calculation

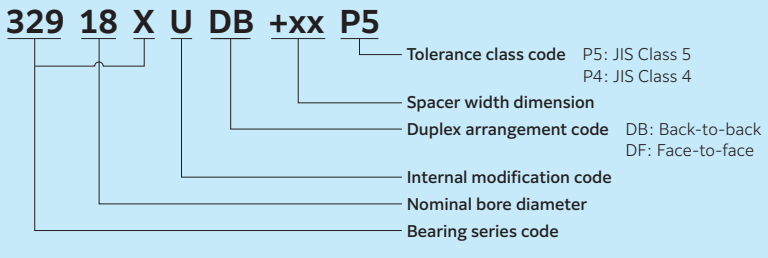
Tapered roller bearings are generally used in pairs, so their dynamic equivalent load can be calculated according to **Table 12.1**.

Table 12.1 Bearing arrangement and equivalent load

Bearing arrangement	Load condition	Axial load	Equivalent radial load
DB arrangement 	$\frac{0.5F_{r\,I}}{Y_I} \le \frac{0.5F_{r\,II}}{Y_{II}} + F_a$	$F_{a\,I} = \frac{0.5F_{r\,II}}{Y_{II}} + F_a$	$P_{r\,I} = XF_{r\,I} + Y_I\left[\frac{0.5F_{r\,II}}{Y_{II}} + F_a\right]$
		$F_{a\,II} = \frac{0.5F_{r\,II}}{Y_{II}}$	$P_{r\,II} = F_{r\,II}$
DF arrangement 	$\frac{0.5F_{r\,I}}{Y_I} > \frac{0.5F_{r\,II}}{Y_{II}} + F_a$	$F_{a\,I} = \frac{0.5F_{r\,I}}{Y_I}$	$P_{r\,I} = F_{r\,I}$
		$F_{a\,II} = \frac{0.5F_{r\,I}}{Y_I} - F_a$	$P_{r\,II} = XF_{r\,II} + Y_{II}\left[\frac{0.5F_{r\,I}}{Y_I} - F_a\right]$
DB arrangement 	$\frac{0.5F_{r\,II}}{Y_{II}} \le \frac{0.5F_{r\,I}}{Y_I} + F_a$	$F_{a\,I} = \frac{0.5F_{r\,I}}{Y_I}$	$P_{r\,I} = F_{r\,I}$
		$F_{a\,II} = \frac{0.5F_{r\,I}}{Y_I} + F_a$	$P_{r\,II} = XF_{r\,II} + Y_{II}\left[\frac{0.5F_{r\,I}}{Y_I} + F_a\right]$
DF arrangement 	$\frac{0.5F_{r\,II}}{Y_{II}} > \frac{0.5F_{r\,I}}{Y_I} + F_a$	$F_{a\,I} = \frac{0.5F_{r\,II}}{Y_{II}} - F_a$	$P_{r\,I} = XF_{r\,I} + Y_I\left[\frac{0.5F_{r\,II}}{Y_{II}} - F_a\right]$
		$F_{a\,II} = \frac{0.5F_{r\,II}}{Y_{II}}$	$P_{r\,II} = F_{r\,II}$

Note 1: The above are valid when the bearing internal clearance and preload are zero.
2: Radial load in the opposite direction to the arrow in the above illustration are also regarded as positive.

12.2 Bearing designations



12.3 Accuracy

Table 12.2 Inner rings Unit: μm

Nominal bore diameter d mm		Deviation of mean bore diameter in a single plane Δ_{dmp}				Variation of bore diameter in a single plane V_{dsp}		Variation of mean bore diameter V_{dmp}		Radial runout of inner ring of assembled bearing K_{ia}		Perpendicularity of inner ring face with respect to the bore S_d		Axial runout of inner ring of assembled bearing S_{ia}	Deviation of a single inner ring width Δ_{Bs}				Deviation of the actual assembled bearing width Δ_{Ts}			
		Class 5		Class 4 [1]		Class 5	Class 4	Class 5	Class 4	Class 5	Class 4	Class 5	Class 4	Class 4	Class 5		Class 4		Class 5		Class 4	
over	incl.	high	low	high	low	max		max		max		max		max	high	low	high	low	high	low	high	low
18	30	0	−8	0	−6	6	5	5	4	5	3	8	4	4	0	−200	0	−200	+200	−200	+200	−200
30	50	0	−10	0	−8	8	6	5	5	6	4	8	4	4	0	−240	0	−240	+200	−200	+200	−200
50	80	0	−12	0	−9	9	7	6	5	7	4	8	5	4	0	−300	0	−300	+200	−200	+200	−200
80	120	0	−15	0	−10	11	8	8	5	8	5	9	5	5	0	−400	0	−400	+200	−200	+200	−200
120	180	0	−18	—		14	—	9	—	11	—	10	—	—	0	−500	—		+350	−250	—	
180	250	0	−22	—		17	—	11	—	13	—	11	—	—	0	−600	—		+350	−250	—	

1) The dimensional difference Δ_{ds} of the measured bore diameter applied to Class 4 is the same as the tolerance of dimensional difference Δ_{dmp} of the mean bore diameter within a plane.

Table 12.3 Outer rings Unit: μm

Nominal outside diameter D mm		Deviation of mean outside diameter in a single plane Δ_{Dmp}				Variation of outside diameter in a single plane V_{Dsp}		Variation of mean outside diameter V_{Dmp}		Radial runout of outer ring of assembled bearing K_{ea}		Perpendicularity of outer ring outside surface with respect to the face S_D		Axial runout of outer ring of assembled bearing S_{ea}	Deviation of a single outer ring width Δ_{Cs}		
		Class 5		Class 4 [2]		Class 5	Class 4	Class 5	Class 4	Class 5	Class 4	Class 5	Class 4	Class 4	Class 5		Class 4	
over	incl.	high	low	high	low	max		max		max		max		max	high		low	
30	50	0	−9	0	−7	7	5	5	5	7	5	8	4	5	Depends on tolerance of Δ_{Bs} in relation to d of the same bearing			
50	80	0	−11	0	−9	8	7	6	5	8	5	8	4	5				
80	120	0	−13	0	−10	10	8	7	5	10	6	9	5	6				
120	150	0	−15	0	−11	11	8	8	6	11	7	10	5	7				
150	180	0	−18	0	−13	14	10	9	7	13	8	10	5	8				
180	250	0	−20	—		15	—	10	—	15	—	11	—	—				
250	315	0	−25	—		19	—	13	—	18	—	13	—	—				

2) The dimensional difference Δ_{Ds} of the measured outside diameter applied to Class 4 is the same as the tolerance of dimensional difference Δ_{Dmp} of the mean outside diameter within a plane.

12.4 Recommended fits for high-precision tapered roller bearings

Table 12.4 Shaft fits Unit: μm

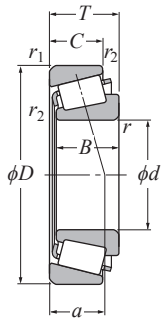
Nominal bore diameter d (mm)		Fits between inner ring and shaft	
		Fixed side	Floating side
over	incl.	Targeted [1] interference	Targeted [1] interference
18	30	0– 5T	0–1T
30	50	0– 6T	0–2T
50	80	0– 7T	0–3T
80	120	0– 8T	0–4T
120	180	0–10T	0–5T
180	250	0–13T	0–6T
250	315	0–15T	0–6T
315	400	0–18T	0–8T

1) It is recommended to use the median value.
T: Tight (Interference) fit

Table 12.5 Housing fits Unit: μm

Nominal outside diameter D (mm)		Fits between outer ring and housing
over	incl.	Targeted interference [1]
30	50	3L–3T
50	80	3L–3T
80	120	4L–4T
120	150	5L–5T
150	180	5L–5T
180	250	6L–6T
250	315	7L–7T
315	400	8L–8T
400	500	9L–9T

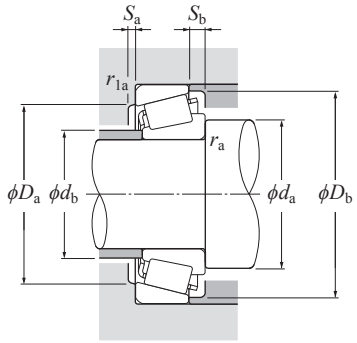
1) For high precision main spindles, the tight (interference) fit side of the targeted interference is recommended for the main spindle tool side.
L: Loose fit T: Tight (Interference) fit



d 20–90 mm

Part number	ISO Dimension series	Boundary dimensions mm								Basic load ratings dynamic kN		static kN		dynamic kgf		static kgf	Allowable speed min^{-1} grease lubrication	oil lubrication
		d	D	T	B	C	$r_{s\,min}$ 1)	$r_{1s\,min}$ 1)	$r_{2s\,min}$ 1)	C_r	C_{0r}	C_r	C_{0r}	C_r	C_{0r}			
4T-32004X	3CC	20	42	15	15	12	0.6	0.6	0.15	27.6	27.9	2 820	2 840	9 500	13 000			
4T-32005X	4CC	25	47	15	15	11.5	0.6	0.6	0.15	31	33.5	3 150	3 450	7 900	11 000			
4T-32006X	4CC	30	55	17	17	13	1	1	0.3	41.5	46	4 200	4 700	6 900	9 200			
4T-32007X	4CC	35	62	18	18	14	1	1	0.3	46	52.5	4 700	5 350	6 100	8 100			
4T-32008X	3CD	40	68	19	19	14.5	1	1	0.3	55.5	65.5	5 700	6 650	5 300	7 100			
4T-32009X	3CC	45	75	20	20	15.5	1	1	0.3	64	76.5	6 500	7 800	4 800	6 400			
32910XU	2BC	50	72	15	15	12	0.6	0.6	0.15	39.5	57	4 050	5 800	4 700	6 300			
32010XU	3CC	50	80	20	20	15.5	1	1	0.3	69.5	88	7 100	9 000	4 400	5 800			
32911XU	2BC	55	80	17	17	14	1	1	0.3	49.5	73.5	5 050	7 500	4 300	5 700			
4T-32011X	3CC	55	90	23	23	17.5	1.5	1.5	0.6	89	118	9 100	12 000	4 000	5 400			
32912XA 2)		60	85	17	17	14	1	1	0.3	56.5	83	5 750	8 450	4 000	5 300			
32012XU	4CC	60	95	23	23	17.5	1.5	1.5	0.6	91	123	9 250	12 500	3 700	4 900			
32913XU	2BC	65	90	17	17	14	1	1	0.3	53.5	85	5 450	8 700	3 700	4 900			
32013XU	4CC	65	100	23	23	17.5	1.5	1.5	0.6	92	128	9 400	13 000	3 400	4 600			
32914XU	2BC	70	100	20	20	16	1	1	0.3	76	110	7 750	11 200	3 400	4 600			
32014XU	4CC	70	110	25	25	19	1.5	1.5	0.6	116	160	11 800	16 400	3 200	4 200			
32915XU	2BC	75	105	20	20	16	1	1	0.3	77	114	7 850	11 600	3 200	4 300			
32015XU	4CC	75	115	25	25	19	1.5	1.5	0.6	118	167	12 000	17 000	3 000	4 000			
32916XU	2BC	80	110	20	20	16	1	1	0.3	79.5	121	8 150	12 400	3 000	4 000			
32016XU	3CC	80	125	29	29	22	1.5	1.5	0.6	154	216	15 700	22 000	2 800	3 700			
32917XU	2BC	85	120	23	23	18	1.5	1.5	0.6	104	157	10 600	16 100	2 800	3 800			
32017XU	4CC	85	130	29	29	22	1.5	1.5	0.6	157	224	16 000	22 900	2 600	3 500			
32918XU	2BC	90	125	23	23	18	1.5	1.5	0.6	108	168	11 000	17 100	2 700	3 600			
32018XU	3CC	90	140	32	32	24	2	1.5	0.6	187	270	19 100	27 600	2 500	3 300			

1) Minimum allowable value for corner radius dimension r, r_1 or r_2.
2) This bearing does not incorporate the subunit dimensions.



Dynamic equivalent radial load

$P_r = XF_r + YF_a$

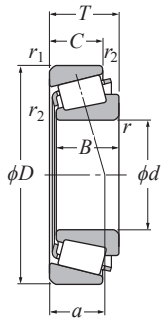
$\frac{F_a}{F_r} \le e$		$\frac{F_a}{F_r} > e$	
X	Y	X	Y
1	0	0.4	Y_2

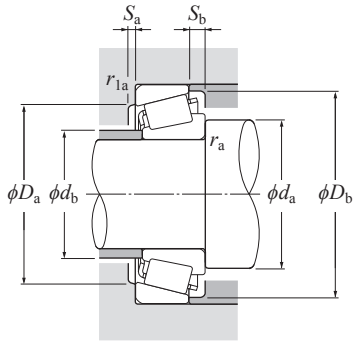
Static equivalent radial load

$P_{0r} = 0.5F_r + Y_0F_a$

Note that when $P_{0r} < F_r$, $P_{0r} = F_r$.
The values for e, Y_2 and Y_0 are given in the table below.

Part number	Abutment and fillet dimensions mm								Load center mm	Factor	Axial load factor		Mass kg
	d_a min	d_b max	D_a max	D_a min	D_b min	S_a min	S_b min	r_{as} max	r_{1as} max	a	e	Y_2	Y_0	(approx.)
4T-32004X	24.5	25	37.5	33.5	39.5	3	3	0.6	0.6	10.5	0.37	1.6	0.88	0.097
4T-32005X	29.5	29.5	42.5	38.5	44.5	3	3.5	0.6	0.6	12	0.43	1.39	0.77	0.113
4T-32006X	35.5	35.5	49.5	45.5	52.5	3	4	1	1	13.5	0.43	1.39	0.77	0.172
4T-32007X	40.5	40.5	56.5	51.5	59.5	4	4	1	1	15.5	0.45	1.32	0.73	0.223
4T-32008X	45.5	45.5	62.5	58	65	4	4.5	1	1	15	0.38	1.58	0.87	0.272
4T-32009X	50.5	51	69.5	64	72.5	4	4.5	1	1	16.5	0.39	1.53	0.84	0.341
32910XU	54.5	55	67.5	63.5	69	3	3	0.6	0.6	13.5	0.34	1.76	0.97	0.192
32010XU	55.5	55.5	74.5	68.5	77.5	4	4.5	1	1	17.5	0.42	1.42	0.78	0.373
32911XU	60.5	61	74.5	70.5	76.5	3	3	1	1	14.5	0.31	1.94	1.07	0.274
4T-32011X	63.5	63	81.5	77.5	87	4	5.5	1.5	1.5	20	0.41	1.48	0.81	0.56
32912XA 2)	65.5	66	79.5	76.5	82.5	3	3	1	1	15.5	0.33	1.8	0.99	0.281
32012XU	68.5	67.5	86.5	81.5	91.5	4	5.5	1.5	1.5	21	0.43	1.39	0.77	0.596
32913XU	70.5	70.5	84.5	80	86	3	3	1	1	16.5	0.35	1.7	0.93	0.315
32013XU	73.5	72.5	91.5	86	97	4	5.5	1.5	1.5	22.5	0.46	1.31	0.72	0.631
32914XU	75.5	76.5	94.5	90	96.5	4	4	1	1	18	0.32	1.9	1.05	0.475
32014XU	78.5	78	101.5	94.5	105.5	5	6	1.5	1.5	24	0.43	1.38	0.76	0.863
32915XU	80.5	81	99.5	94	101	4	4	1	1	19	0.33	1.8	0.99	0.508
32015XU	83.5	83	106.5	99.5	111	5	6	1.5	1.5	25.5	0.46	1.31	0.72	0.912
32916XU	85.5	86	104.5	99	106.5	4	4	1	1	20	0.35	1.71	0.94	0.54
32016XU	88.5	89	116.5	108.5	120.5	6	7	1.5	1.5	27	0.42	1.42	0.78	1.28
32917XU	93.5	92	111.5	107.5	115.5	4	5	1.5	1.5	21	0.33	1.83	1.01	0.773
32017XU	93.5	93.5	121.5	113	126	6	7	1.5	1.5	28.5	0.44	1.36	0.75	1.34
32918XU	98.5	97	116.5	112.5	120.5	4	5	1.5	1.5	22	0.34	1.75	0.96	0.815
32018XU	100	100	131.5	121	134.5	6	8	2	1.5	30	0.42	1.42	0.78	1.78





Dynamic equivalent radial load

$P_r = XF_r + YF_a$

$\frac{F_a}{F_r} \leq e$		$\frac{F_a}{F_r} > e$	
X	Y	X	Y
1	0	0.4	Y_2

Static equivalent radial load

$P_{0r} = 0.5F_r + Y_0F_a$

Note that when $P_{0r} < F_r$, $P_{0r} = F_r$.

The values for e, Y_2 and Y_0 are given in the table below.

d 95–190 mm

Part number	ISO Dimension series	Boundary dimensions mm								Basic load ratings dynamic kN	Basic load ratings static kN	Basic load ratings dynamic kgf	Basic load ratings static kgf	Allowable speed min^{-1} grease lubrication	Allowable speed min^{-1} oil lubrication	Abutment and fillet dimensions mm									Load center mm	Factor	Axial load factor		Mass kg
		d	D	T	B	C	$r_{s\,min}$ [1]	$r_{1s\,min}$ [1]	$r_{2s\,min}$ [1]	C_r	C_{0r}	C_r	C_{0r}			d_a min	d_b max	D_a max	D_a min	D_b min	S_a min	S_b min	r_{as} max	r_{1as} max	a	e	Y_2	Y_0	(approx.)
32919XU	2BC	95	130	23	23	18	1.5	1.5	0.6	112	178	11 400	18 200	2 500	3 400	103.5	102	121.5	117	125.5	4	5	1.5	1.5	23.5	0.36	1.68	0.92	0.851
32019XU	4CC	95	145	32	32	24	2	1.5	0.6	190	280	19 400	28 600	2 300	3 100	105	105	136.5	126	140	6	8	2	1.5	31.5	0.44	1.36	0.75	1.85
32920XU	2CC	100	140	25	25	20	1.5	1.5	0.6	134	206	13 700	21 000	2 400	3 200	108.5	109	131.5	127.5	135.5	4	5	1.5	1.5	24.5	0.33	1.82	1	1.12
32020XU	4CC	100	150	32	32	24	2	1.5	0.6	188	281	19 200	28 600	2 200	3 000	110	109.5	141.5	130.5	145	6	8	2	1.5	32.5	0.46	1.31	0.72	1.91
32921XA [2]		105	145	25	25	20	1.5	1.5	0.6	139	219	14 200	22 400	2 300	3 000	113.5	113.5	136.5	131.5	140.5	5	5	1.5	1.5	25	0.34	1.76	0.97	1.2
32021XU	4DC	105	160	35	35	26	2.5	2	0.6	223	335	22 800	34 000	2 100	2 800	117	115.5	150	138.5	153.5	6	9	2	2	34.5	0.44	1.35	0.74	2.44
32922XA [2]		110	150	25	25	20	1.5	1.5	0.6	141	226	14 400	23 100	2 200	2 900	118.5	118.5	141.5	136.5	146	5	5	1.5	1.5	26.5	0.36	1.69	0.93	1.24
32022XU	4DC	110	170	38	38	29	2.5	2	0.6	261	390	26 600	39 500	2 000	2 700	122	122	160	147.5	164	7	9	2	2	36.5	0.43	1.39	0.77	3.07
32924XU	2CC	120	165	29	29	23	1.5	1.5	0.6	180	294	18 400	30 000	2 000	2 600	128.5	129.5	156.5	150	160	6	6	1.5	1.5	29.5	0.35	1.72	0.95	1.76
32024XU	4DC	120	180	38	38	29	2.5	2	0.6	272	420	27 700	43 000	1 800	2 500	132	131	170	156	174.5	7	9	2	2	39	0.46	1.31	0.72	3.29
32926XU	2CC	130	180	32	32	25	2	1.5	0.6	215	350	21 900	36 000	1 800	2 400	140	140.5	171.5	163	174	6	7	2	1.5	31.5	0.34	1.77	0.97	2.41
32026XU	4EC	130	200	45	45	34	2.5	2	0.6	350	545	36 000	55 500	1 700	2 200	142	144	190	173.5	193.5	8	11	2	2	43.5	0.43	1.38	0.76	5
32928XU	2CC	140	190	32	32	25	2	1.5	0.6	221	375	22 600	38 000	1 700	2 200	150	150	181.5	172.5	184	6	6	2	1.5	34	0.36	1.67	0.92	2.5
32028XU	4DC	140	210	45	45	34	2.5	2	0.6	365	580	37 500	59 500	1 600	2 100	152	153	200	182.5	203	8	11	2	2	46	0.46	1.31	0.72	5.32
32930XU	2DC	150	210	38	38	30	2.5	2	0.6	297	490	30 500	50 000	1 600	2 100	162	162	200	189.5	202	7	8	2	2	36.5	0.33	1.83	1.01	3.93
32030XU	4EC	150	225	48	48	36	3	2.5	1	410	655	42 000	67 000	1 400	1 900	164	164	213	195	217.5	8	12	2.5	2	49.5	0.46	1.31	0.72	6.45
32932XU	2DC	160	220	38	38	30	2.5	2	0.6	305	520	31 500	53 000	1 500	1 900	172	172	210	199	213	7	8	2	2	38.5	0.35	1.73	0.95	4.14
32032XU	4EC	160	240	51	51	38	3	2.5	1	485	790	49 500	80 500	1 400	1 800	174	174.5	228	208	231.5	8	13	2.5	2	52.5	0.46	1.31	0.72	7.86
32934XU	3DC	170	230	38	38	30	2.5	2	0.6	315	560	32 500	57 000	1 400	1 800	182	181	220	208	223.5	7	8	2	2	42.5	0.38	1.56	0.86	4.4
32034XU	4EC	170	260	57	57	43	3	2.5	1	555	895	56 500	91 000	1 300	1 700	184	187	248	224.5	250	10	14	2.5	2	56	0.44	1.35	0.74	10.6
32936XU	4DC	180	250	45	45	34	2.5	2	0.6	390	700	40 000	71 500	1 300	1 700	192	192	240	219.5	241.5	8	11	2	2	54	0.48	1.25	0.69	6.55
32938XU	4DC	190	260	45	45	34	2.5	2	0.6	390	710	40 000	72 000	1 200	1 600	202	201.5	250	230	251	8	11	2	2	55	0.48	1.26	0.69	6.82

1) Minimum allowable value for corner radius dimension r, r_1 or r_2.
2) This bearing does not incorporate the subunit dimensions.