Autodesk Inventor Engineer s Handbook

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Engineer s Handbook

Bearing Calculator

alculation of bearing

Dynamic Equivalent Radial Load:

That constant stationary load under the influence of which a rolling bearing has the same life as it attains under the actual load conditions. The dynamic equivalent radial load for radial and angular contact ball bearings and radial roller bearings, under constant radial, and axial loads, is given by

$P_r = (X F_r + Y F_a). f_d$

The dynamic equivalent radial load for radial roller bearings with $\alpha = 0$, and subjected to radial load only, is given by

$P_r = F_r f_d$

Dynamic Equivalent Axial Load:

That constant centric axial load under the influence of which a rolling bearing has the same life as it attains under the actual load conditions. The dynamic equivalent axial load for thrust ball bearings and thrust roller bearings with $\alpha \neq 0$ is given by

$P_a = (X F_r + Y F_a). f_d$

Thrust ball and roller bearings with $\alpha = 90$ deg. can support axial loads only. The dynamic equivalent axial load for this type of bearings is given by

$P_a = F_a f_d$

Static Equivalent Radial Load:

Static radial load which causes the same contact stress at the center of the most heavily loaded rolling element/raceway contact as the contact that occurs under the actual load conditions. The static equivalent radial load for radial and angular contact ball bearing and radial roller bearing is the greater of the two values given by

$P_{0r} = X_0 F_r + Y_0 F_a$

$P_{0r} = F_r$

Static Equivalent Axial Load:

Static centric axial load which would cause the same contact stress at the center of the most heavily loaded rolling element/raceway contact as the contact that occurs under the actual load conditions. The static equivalent axial load for thrust ball bearing and thrust roller bearing is given by

$P_{0a} = X_0 F_r + Y_0 F_a$

Resultant Equivalent Load

When the bearing load is constant, the equivalent load is given according to bearing type by.

$P = P_r$ or $P = P_a$

When the bearing load during service life is not constant, the equivalent load is given by.

$$P = \sqrt[3]{\frac{\sum^{i}\left[P_i^3 \cdot n_i \cdot t_i\right]}{\sum^{i}\left[n_i \cdot t_i\right]}}$$

where:

i index of service life time period

n_i service life time period rotates

t_i service life time period duration $\sum_{1}^{i} t = 1$, bearing load P_i and rotates n_i are constant

P_i service life time period equivalent radial or axial load (according to bearing type)

Basic Rating Life:

For an individual rolling bearing, or a group of apparently identical rolling bearings operating under the same conditions, the life associated with 90% reliability, with contemporary, commonly used material and manufacturing quality, and under conventional operating conditions. The basic rating life for radial ball bearing is given by

$L_{10} = \left(\frac{C_r}{P_r}\right)^3$ or $L_{10} = \left(\frac{C_r}{P_r}\right)^3 \cdot \frac{10^6}{60 \cdot n}$ for rating life in hours

The basic rating life for radial roller bearing is given by

$$L_{10} = \left(\frac{C_r}{P_r}\right)^{\frac{10}{3}} \text{ or } L_{10} = \left(\frac{C_r}{P_r}\right)^{\frac{10}{3}} \cdot \frac{10^6}{60 \cdot n}$$ for rating life in hours

The basic rating life for thrust ball bearing is given by

$$L_{10} = \left(\frac{C_a}{P_a}\right)^{3} \text{ or } L_{10} = \left(\frac{C_a}{P_a}\right)^{3} \cdot \frac{10^6}{60 \cdot n}$$ for rating life in hours

The basic rating life for thrust roller bearing is given by

$$L_{10} = \left(\frac{C_a}{P_a}\right)^{\frac{10}{3}} \text{ or } L_{10} = \left(\frac{C_a}{P_a}\right)^{\frac{10}{3}} \cdot \frac{10^6}{60 \cdot n}$$ for rating life in hours

Adjusted Rating Life:

The rating life obtained by adjustment of the basic rating life for an appropriate reliability level, special bearing properties, and specific operating conditions. The basic rating life for radial ball bearing is given by

for ANSI/AFBMA 9 (ISO 281) calculation method: $L_{nar} = L_{10r}\, a_1\, a_2\, a_3$ or $L_{na} = L_{10}\, a_1\, a_2\, a_3$ for rating life in hours

for SKF AG calculation method: $L_{nar} = L_{10r}\, a_1\, a_{skf}\, f_t$ or $L_{na} = L_{10}\, a_1\, a_{skf}\, f_t$ for rating life in hours

Life Adjustment Factor for Reliability, a1

For a group of apparently identical rolling bearings, operation under the same conditions, the percentage of the group that is expected to attain or exceed a specified life. The reliability of an individual rolling bearings is the probability that the bearing attains or exceeds a specified life. Values of the life adjustment factor a1 are given in next table:

Reliability [%]	**L_{na}**	**a1**
90	L_{10}	1
95	L_5	0.62
96	L_4	0.53
97	L_3	0.44
98	L_2	0.33
99	L_1	0.21

Life Adjustment Factor for Special Bearing Properties, a2

The bearing life is extended or shortened according to the quality of the material, the manufacturing technology of the bearing and its internal design. For these bearing life properties, the life value is corrected by the life adjustment factor for special bearing properties a2.

Life Adjustment Factor for Operating Conditions, a3

Using this factor you take into account the effects of operating conditions, especially lubrication on the bearing. the bearing life is affected by the phenomenon of fatigue which occurs, in general, beneath surfaces subjected to repeated stresses. When the lubrication conditions are good when the rolling element and raceway surfaces are separated by an oil film and surface damage can be disregarded, a_3 is set to 1. When conditions of lubrication are not good, for example, when the viscosity of the lubricating oil is low or the peripheral speed of the rolling elements is especially low, and so on, $a_3 < 1$ is used.

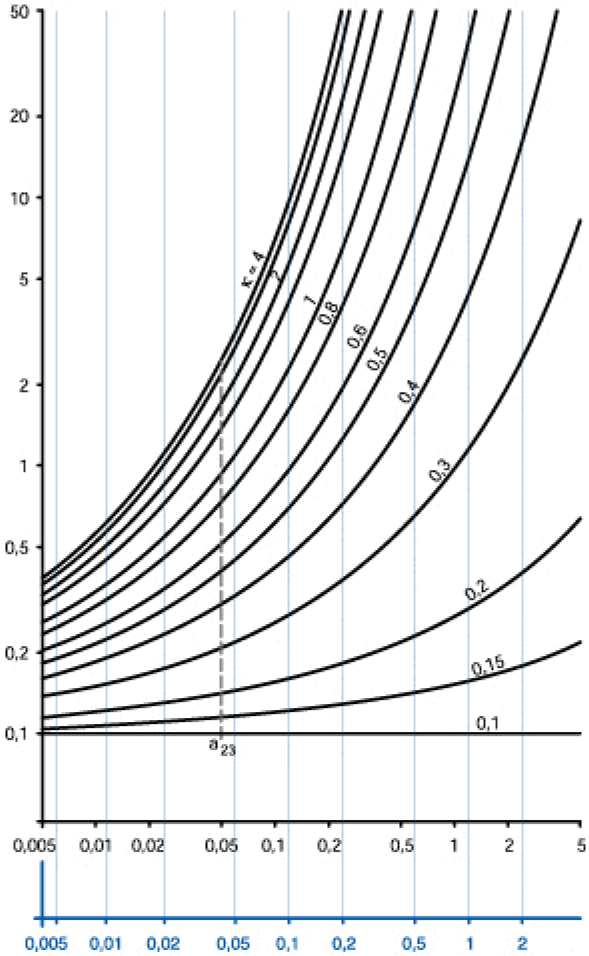
On the other hand, when lubrication is especially good, a value of $a_3 > 1$ can be used. When lubrication is not good and $a_3 < 1$ is used, the life adjustment factor a2 cannot be bigger than 1. When you select a bearing according to the basic dynamic load rating, we recommend that a suitable value for reliability factor a1 is chosen for each application. Make the selection using the C/P determined by machine type and based upon the actual conditions of lubrication, temperature, mounting, and so on.

SKF Life modification Factor, aSKF

This factor represents the relationship between the fatigue load limit ratio (Pu/P), the lubrication condition (viscosity ratio) and the contamination level in the bearing (ηc). Values for the factor aSKF can be obtained from four diagrams, depending on bearing type, as a function of ηc(Pu/P) for SKF standard and SKF Explorer bearings and different values of the viscosity ratio κ.

Diagram 1: Factor a_{SKF} for radial ball bearings:

a_{SKF}



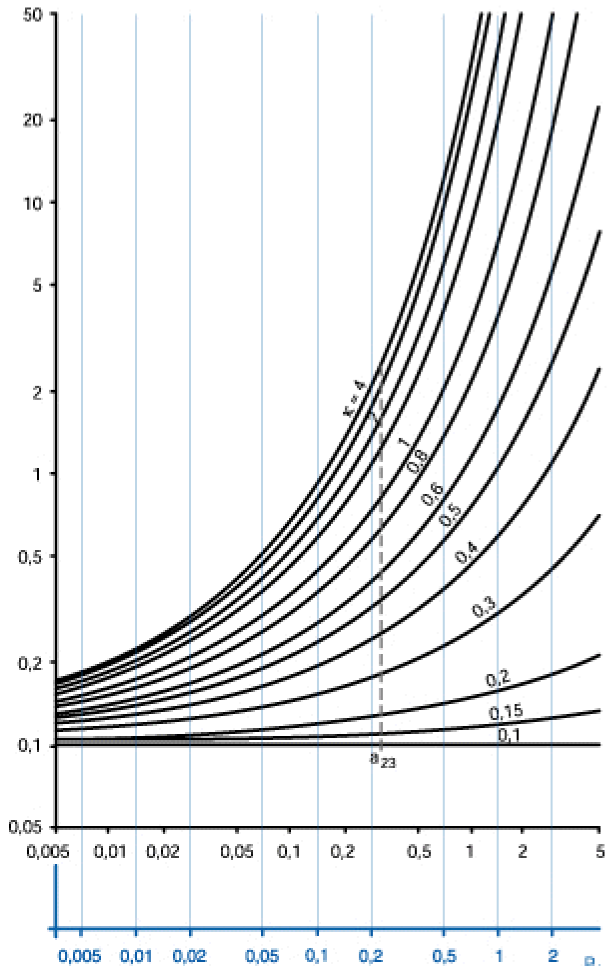
$\eta_c (P_u / P)$

—Other SKF Standard Bearings

—SKF Explorer Bearings

Diagram 2: Factor a_{SKF} for radial roller bearings:

a SKF



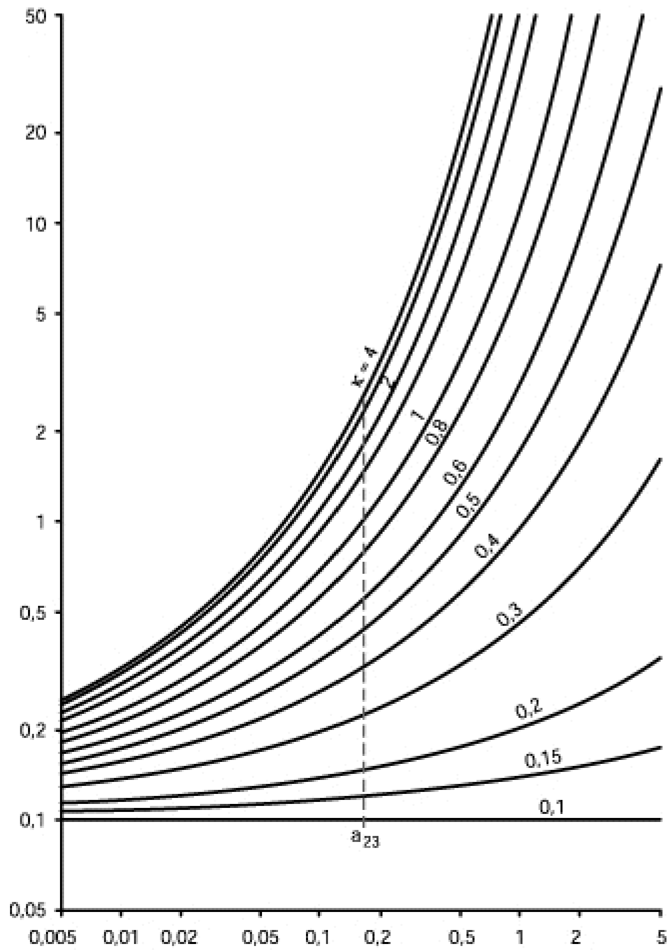
$\eta_c (P_u / P)$

—Other SKF Standard Bearings

—SKF Explorer Bearings

Diagram 3: Factor a_{SKF} for thrust ball bearings:

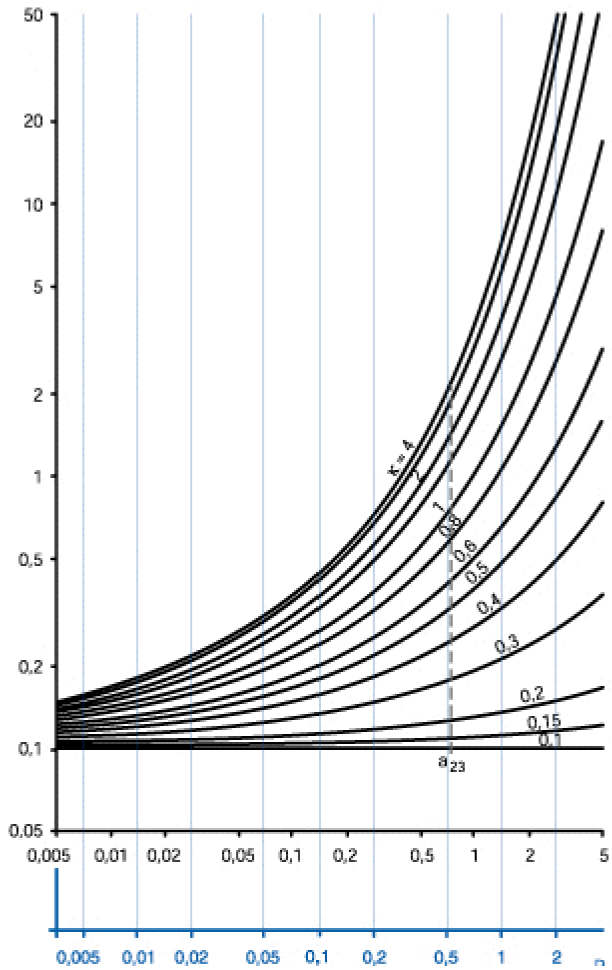
a_{SKF}



$\eta_c (P_u / P)$

Diagram 4: Factor a_{SKF} for radial thrust roller bearings:

a_{SKF}



$\eta_c (P_u / P)$

Other SKF Standard Bearings

SKF Explorer Bearings

Temperature Factor, ft

The operating temperature for each bearing is determined based on its material and structure. If special heat treatment is performed, bearings can be used at temperatures higher than +150 ºC. The allowable contact stress decreases gradually as the operating temperature increases. The rating life is lowered accordingly.

Power lost by friction

For $\kappa > 4$, use curve for $\kappa = 4$. As the value of $\eta_c (P_u / P)$ tends to zero, a_{SKF} tends to 0.1 for all values of κ. The dotted line marks the position of the old a_{23} (κ) scale where $a_{SKF} = a_{23}$.

The diagrams represent typical values and safety factors of the type normally associated with fatigue load limits for other mechanical components. Considering the simplifications inherent of the SKF rating life equations, even if the operating conditions are accurately identified, it is not meaningful to use values of a_{SKF} in excess of 50.

$$P_z = \mu \cdot P \cdot \pi \cdot d \cdot \frac{n}{60000}$$

Meaning of used variables:

C_r basic dynamic radial load rating, [lbforce, N]

C_{or} basic static radial load rating, [lbforce, N]

C_a basic dynamic axial load rating, [lbforce, N]

C_{oa} basic static axial load rating, [lbforce, N]

Fa bearing axial load = axial component of the actual bearing load, [lbforce, N]

F_r bearing radial load = radial component of the actual bearing load[lbforce, N]

n shaft rotates, [rpm]

L_{regr} required rating life, in 10^6 revolutions, [Mr]

L_{10r} basic rating life, in 10^6 revolutions, [Mr]

L_{nar} adjusted rating life, in 10^6 revolutions, [Mr]

L_{reg} required rating life, in 10^6 revolutions, [h]

L_{10} basic rating life, in 10^6 revolutions, [h]

L_{na} adjusted rating life, in 10^6 revolutions, [h]

P_r dynamic equivalent radial load, [lbforce, N]

P_{or} static equivalent radial load, [lbforce, N]

P_a dynamic equivalent axial load, [lbforce, N]

P_{oa} static equivalent axial load, [lbforce, N]

X dynamic radial load factor

X_0 static radial load factor

Y dynamic axial load factor

Y_0 static axial load factor

R_{reg} required reliability, [%]

a_1 life adjustment factor for reliability

a_2 life adjustment factor for special bearing properties

a_3 life adjustment factor for operating conditions

a_{SKF} life adjustment factor based on SKF Life Method

e limit value of F_a / F_r for the applicability of different values of factor X and Y

P exponent for determining life

α nominal contact angle of the bearing, in degrees

s_0 required static safety factor

s_{0c} calculated static safety factor

f_t temperature factor

f_d factor of additional forces

l_t lubrication type

T maximum working temperature

f_z power lost by friction

μ Friction Factor [MPA,psi]

Calculation according to the bearing type selected by user

All bearing output values are calculated and if the required life is greater than calculated life, it is displayed in red color. If F_{min} is less than P, then also F_{min} are displayed in red.

L_h (calculated) $\geq$ L_h (required)

$F_{min} > P$

Selection of bearing type

Bearing type	purely radial load	purely axial load	combined load	moment load	high speed	high running accuracy	high stiffness	quiet running	low friction	compensation for missallignment in operation	compensation for errors of alignment (initial)	locating bearing arrangements	non-locating bearing arrangements	axial displacement possible in bearing
Ball single-row	+	+	+	-	+++	+++	+	+++	+++	-	-	+++	+	--
Ball double-row	+	+	+	-	+++	+++	+	+++	+++	-	-	+++	+	--
Ball self-aligning	+	+	+	-	+++	+++	+	+++	+++	-	-	+++	+	--
Ball angular contact	+	+	++	-	++	+++	+	++	++	-	-	++	--	--
Ball (back-to-back)	++	+	++	+	+	++	++	+	+	--	--	++	+	--
Ball four-point contact	-	+	+	+	++	+	+	+	+	--	--	++	-	--
Cylindrical roller N,NU	++	--	--	--	+++	++	++	++	++	-	--	-	+++	+++
NU, NUP	++	+	+	--	+++	++	++	+	++	-	-	+	+	+
double-row	+++	--	--	+	+++	+++	+++	++	++	--	--	--	+++	+++
Full complement	+++	+	-	--	-	+	+++	-	-	-	-	+	+	+

cyl. roller double-row	+++	--	--	+	+++	+++	+++	++	++	--	--	+	+	+
Needle roller	++	--	--	--	+	+	++	+	-	--	--	--	+++	+++
Spherical roller	+++	+	+++	--	+	+	++	+	+	+++	++	++	+	--
Taper roller	++	++	+++	--	+	++	++	+	+	-	-	++	--	--
(face-to-face)	+++	++	+++	-	+	+	+++	+	+	-	-	+++	+	--
Thrust ball	--	+	--	--	+	++	+	-	+	--	--	+	--	--
with spherical housing washer	--	+	--	--	+	+	+	-	+	--		+	--	--
Thrust cylindrical roller	--	++	--	--	-	++	++	-	-	--	--	+	--	--
Thrust needle roller	--	++	--	--	-	+	++	-	-	--	--	+	--	--
Thrust spherical roller	--	+++	+	--	+	+	++	-	+	+++	++	++	--	--

Used Symbols

+++ excellent
++ good
+ satisfactory
- wrong
-- inconvenient

Standards

ANSI/AFBMA Std 9 : 1990	Load Ratings and Fatigue Life for Ball Bearings
ANSI/AFBMA Std 11 : 1990	Load Ratings and Fatigue Life for Roller Bearings
ISO 281 : 1990	Rolling bearings - Dynamic load ratings and rating life
ISO 76 : 1990	Rolling bearings - Static load ratings

Related international standards

JIS B 1518 : 1992	Dynamic load ratings and rating life for rolling bearings
JIS B 1519 : 1989	Static load ratings for rolling bearings
ISO 1132 :1980	Rolling bearings - Tolerances - Definitions
ISO 5593	Rolling bearings - Vocabulary
ISO/TR 9724 :1991	Rolling bearings - Measuring and gauging principles and method
ISO 5753 :1991	Rolling bearings - Radial internal clearance
ISO 578 :1987	Tapered roller bearings - Inch series - Tolerances
ISO 582 :1979	Rolling bearings - Metric series - Chamfer dimension limits
ISO 1123 :1987	Tapered roller bearings - Inch series - Chamfer dimension limits
ISO 15 :1981	Rolling bearings - Radial bearings - Boundary dimensions - General plan
ISO 104 :1994	Rolling bearings - Thrust bearings - Boundary dimensions, general plan
ISO 355 :1977	Rolling bearings - Metric tapered roller bearings - Boundary dimensions and series designation
ISO 15 :1985	Radial bearings - Boundary dimensions - General plan

Analogous foreign standards

DIN 617Wälzlager. Nadellager mit Käfig Massreihen 48 und 49

Guiding values of basic life Lh [hours]

Type of machine	*L_h [hours]*
Instruments and tools seldom used	1000
Electrical household machines, small fans	2000 - 4000
Machines for intermittent operation, hand tools, workshop cranes,agricultural machines	4000 - 8000
Machines for intermittent operation with demands for high reliability: auxiliary machines in power stations, belt conveyors, transport trucks, elevators	8000 - 15000
Rolling mills	6000 - 12000
Machines designed for 8 to 16 hours operation: stationary electric motors, gear drives, spindles of textile machines, machines for processing plastics, cranes	15000 - 30000
Cutting machines generally	20000 - 30000
Machines for permanent operation: stationary electric machines, transport equipment, roller beds, pumps, centrifuges, blowers, compressors, hammer mills, breakers, briquetting presses, mining elevators, rope disks	40000 - 60000
Machines for permanent operation with high operating safety: paper machines, power stations, water works, ship machines	100000 - 200000

imiting speed

Single-row radial ball and roller bearings have a favorable factor of rolling friction and can be used for higher speeds than other bearing types. Limiting speed is also affected by the type of lubricant used and the cage material is also important. Common pressed sheet steel cages are convenient for regular speed and brass or other materials used more for higher speeds. The guiding speed for bearings with ordinary degree of precision are presented in the tables. It is necessary to consider the falling of limiting speed in radial bearings which are constantly loaded with axial force. In this case limiting speed depends on F_a/F_r ratio. The table presents values of f_n factor, by which it is necessary to multiple limiting speed presented in the table.

Bearing type	F_a/F_r									
	0.25	0.40	0.60	1.00	1.60	2.50	4.00	6.00	10.00	> 10
Ball single-row	1.0	0.98	0.96	0.92	0.89	0.86	0.82	0.82	0.81	0.80
Ball single-row with angular-contact	1.0	1.0	1.0	1.0	0.98	0.97	0.96	0.96	0.95	0.95
Ball double-row self-aligning	0.98	0.93	0.85	0.72	0.62	0.58	0.45	0.43	0.38	0.33
Spherical-roller double-row	0.99	0.95	0.90	0.82	0.77	0.72	0.67	0.64	0.62	0.60
Tapered roller single-row	0.98	0.93	0.88	0.78	0.69	0.61	0.55	0.51	0.48	0.45

Allowable tilting

Allowable tilting angle of bearing ε:

Bearing type	ε
Ball single-row	6'
Ball double-row self-aligning	3 deg.
Roller single-row(NU2, NU3, NU4, N2, N3, N4)	6'
Other roller	2'
Spherical-roller double-row	1.5 deg.
Tapered-roller single-row	2'
Spherical-roller thrust bearing	2 deg.

Tolerances of shaft diameters for radial bearings

		Shaft diameter [mm]			
Operating conditions	*Examples of mounting*	*ball*	*roller*	*spherical - roller*	*Tolerance*
		taper - roller			
Point load of inner ring					
Small and variable load	electrical instruments, fans	18 - 100	< 40	-	j6
	cutting machines, conveyors	100 - 200	40 - 140	-	k6
Medium and high load	common loading, cutting machines	< 18	-	-	j5
	turbines, electrical motors	18 - 140	< 40	< 40	k5
	gear boxes, comb. engines	100 - 140	40 - 100	40 - 65	m5
	pumps	140 - 200	100 - 140	65 - 100	m6
	-	200 - 280	140 - 200	100 - 140	n6
High load, shocks	bearing for axles of rail trucks	-	50 - 140	50 - 100	n6
	traction motors, rolling mills	-	140 - 500	100 - 500	p6
High mounting precision	cutting machines	< 18	-	-	h5
	-	18 - 100	< 40	-	j5
	-	100 - 200	40 - 140	-	k5
Only axial load		All diameters			j6

NoteLoading is small for C / P > 15, common for C / P = 7 - 15, high for C / P < 7.

Tolerances of housing bores for radial bearings

Operating conditions	*Assembly conditions*	*Housing*	*Examples of mounting*	*Tolerance*
circumferential loading of outer ring				
high shock loading	outer ring is not sliding	one-part	wheel hubs, connecting rod bearing	P7
ordinary and high loading			pulleys, bearing of crankshafts	N7
small and variable load			transport and tightening pulleys	M7
indeterminate way of load				
high shock load	outer ring non-sliding	one-part	traction motors	M7
high and ordinary load	outer ring non-sliding from the right		pump electrical motors, crankshafts	K7
ordinary and small load	outer ring sliding from the right		pump electrical motors, fans	J7
precision mountings				
ordinary and small loading	outer ring non-slid. from the right, outer ring sliding, outer ring easily sliding	one-part	bearings for cutting machines	K6
			ball bearing for grinding spindles	J6
			small electric motors	H6
point loading of outer ring				
high ordinary and small loading	outer ring is easily sliding	1-2 parts	common machinery, axle bear.	H8
		two parts	transmission shaftings	H8
heat supply through shaft		1 - 2 parts	great electrical motors with spherical roller bearings	G7

NoteLoading is small for C / P > 15, common for C / P = 7 - 15, high for C / P < 7.

olerances of shaft diameters for radial bearings

Bearing type	*Way of loading*		*Shaft diameter*	*Tolerance*
thrust ball	only axial loading		all diameters	j6
	only axial loading			j6
thrust spherical-roller	axial and radial loading simultaneously	point load		j6
		circumferential loading of shaft ring or non-determined	< 200	k6
			200 - 400	m6
			> 400	n6

Tolerances of housing bores for axial bearings

Bearing type	*Way of loading and note*		*Tolerance*
thrust ball	only axial load, in ordinary mount. seat ring can be with radial clearance		H8
thrust spherical-roller	only axial load, seat ring is mounted with radial clearance		H8
	axial and radial loading simultaneously	point or indeterminated way of load of seat ring	H7
		circumferential load of seat ring	M7

Factor of temperature influence ft

Effect of temperature on reducing of bearing dynamic load capacity, according to the ZKL (1978) catalog:

Temp. degrees C	100	125	150	175	200	225	250	275	300
f_t	1	0.95	0.9	0.85	0.8	0.7	0.6	0.55	0.5

according to the SKF (1994) catalog:

Temp. degrees C	150	200	250	300
f_t	1	0.9	0.75	0.6

Factor of tooth influence fd1

Influence of a gear drive to increasing the radial force (the factor of additional forces originated from inaccuracy of teeth):

Type of gear wheel	f_{d1}
Precision gear wheels (pitch and shape deviations up to 0.02)	1.05 - 1.1
Common gear wheel (pitch and shape deviations 0.02 - 0.1)	1.1 - 1.3

Factor of tooth influence fd2

Influence of a gear drive to increasing the radial force (the factor of additional forces originated from acting of machines between which the gear drive is incorporated).

Machine type	f_{d2}
Electric rotary machines, turbines, turbo-compressors(machines working without shocks)	1 - 1.2
Railway and piston engines	1.2 - 1.5
Belt conveyors, rope ways, pumps, fans	1 - 1.2
Cranes, elevators, mine fans	1.2 - 1.4
Mine elevators and pumps	1.5 - 1.8
Piston pumps and compressors	1.2 - 1.5
Ball, tube, and hammer mills, breakers	1.5 - 1.8
Machines for soil removing, deep drilling machines	1.5 - 2.5
Drying drums	1.3 - 1.5
Paper and textile machines	1 - 1.5
Machines for food processing	1.1 - 1.5
Grinding, drilling and milling machines, circular, band and frame saws, wood-working machines	1.1 - 1.3
Lathes, planers, cutting machines with reversible movement	1.4 - 1.6
Roller beds with reversed movement, machines for wire drawing, cold rolling mills, rubber calendars, hammers, sheet shears, stamping machines	1.3 - 2
Roughing mills, sheet mills (load with gear shocks)	

Factor of belt transmission influence fd3

Influence of belt drives to increasing the radial force:

Type of belt drive	*fd* 3
V-belts	2 - 2.5
Single-ply belts with tightening pulley	2.5 - 3
Single-ply belts	

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