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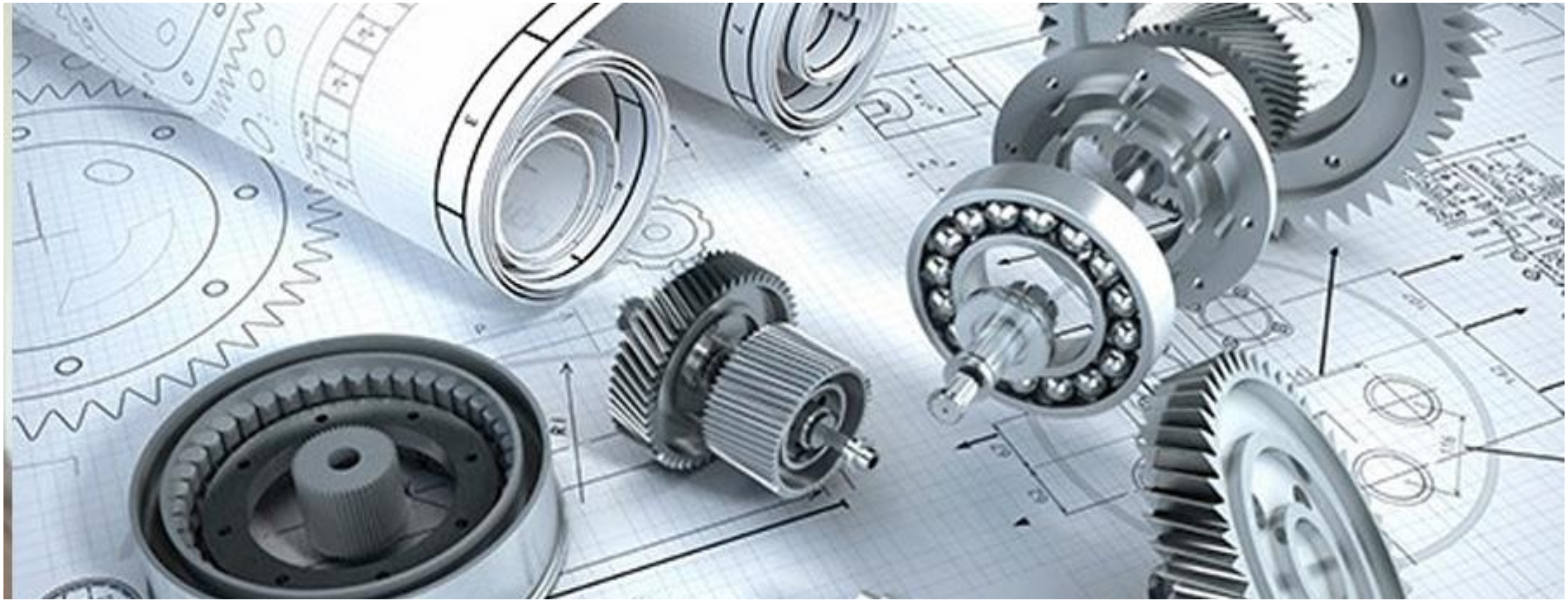
Machine Design 2
ENME 436

Department of Mechanical and Mechatronics Engineering

Dr. Rashad Mustafa



Fundamentals of Mechanics of Material

Fatigue strength means the property of a design or component, the casual occurrences during the operation elasto-plastic cyclic, quasi-static and sudden loads taking into account the environmental conditions, such as corrosion, and to maintain a high temperature and safe operation for the intended period of use.

Requirements for the fatigue strength of components and systems

- Designed for customer-specific operating and operating conditions
- Ensuring the required service life
- Ensuring the lowest possible probability of failure
- Consideration of special events and misuse

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Faculty of Engineering and Technology
Department of Mechanical and Mechatronics Engineering

Machine Design 2 – ENME436

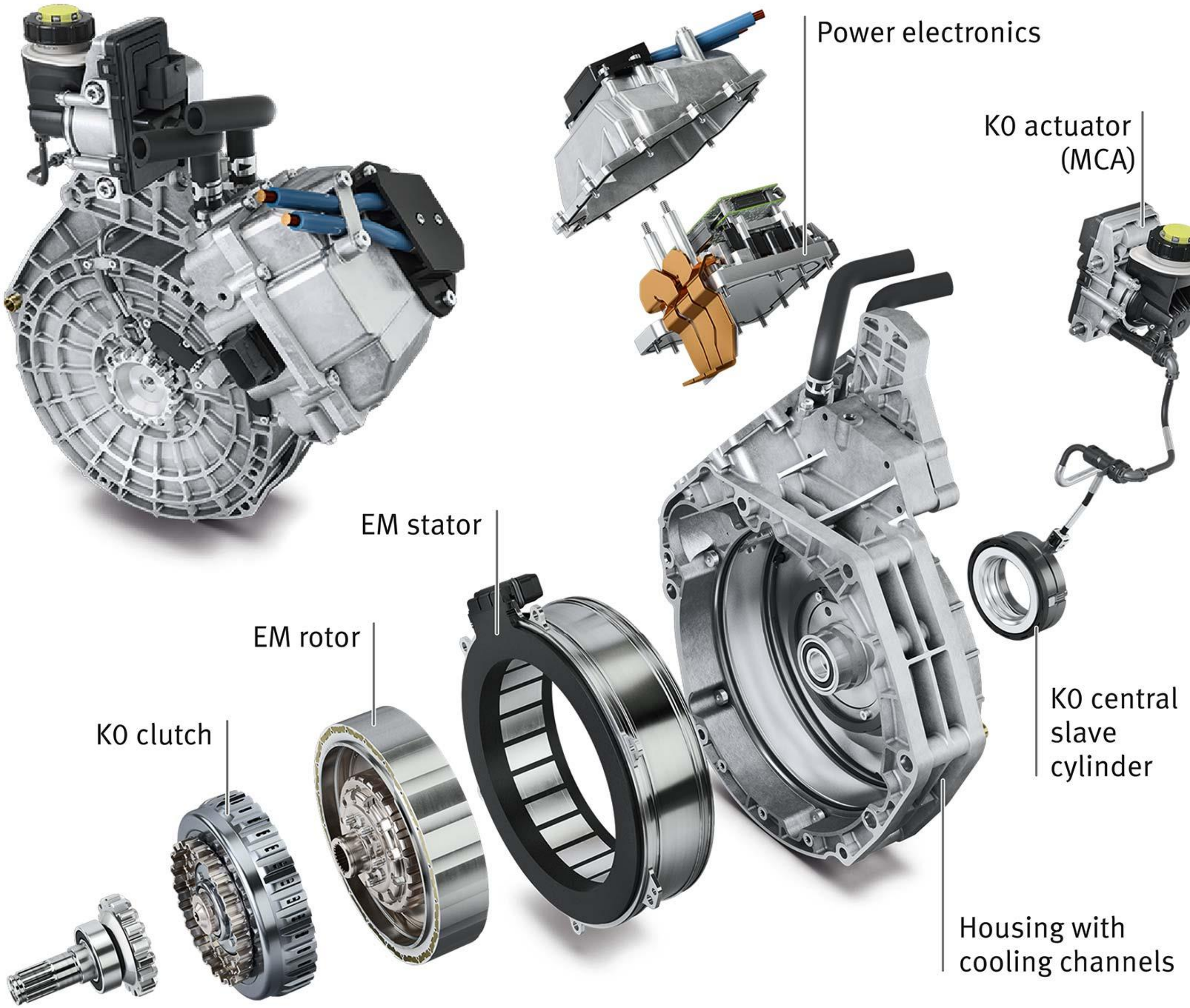
Text Book:

Mechanical Engineering Design, 10th Edition, Joseph E. Shigley & Charles R. Mischke

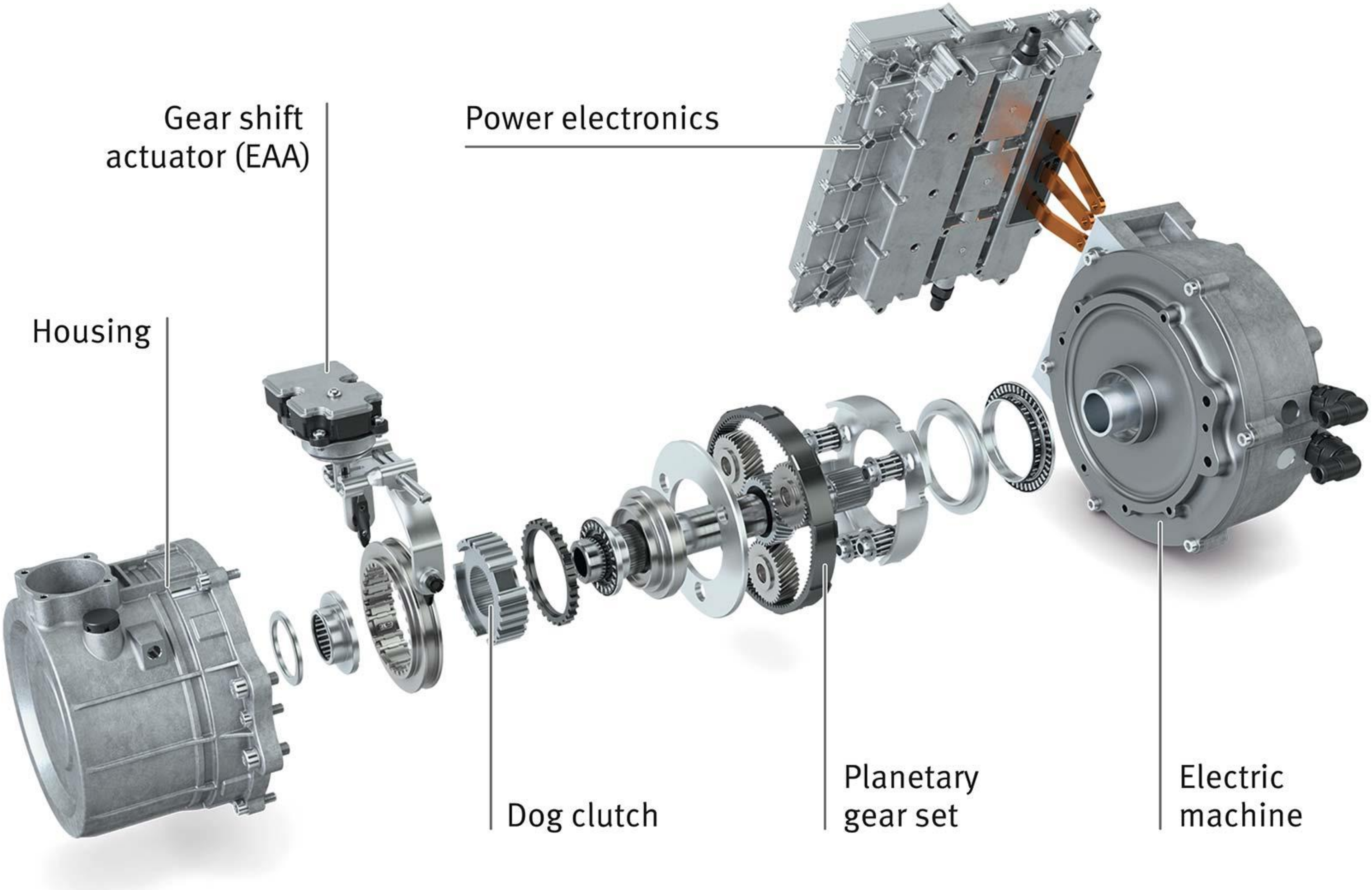
Course Content:

1. Friction, wear and lubrication; systems of lubrication.
2. Design of sliding bearings; journal and thrust bearings.
3. Antifriction bearings; types, selection criteria and calculation procedure.
4. Power transmission; Prime mover characteristics and types.
5. Design of gear drives; Spur gears, helical gears, bevel gears, worm gears.
6. Design of belt drives; Flat belts, V-belts.
7. Design of chain drives and rope drives.

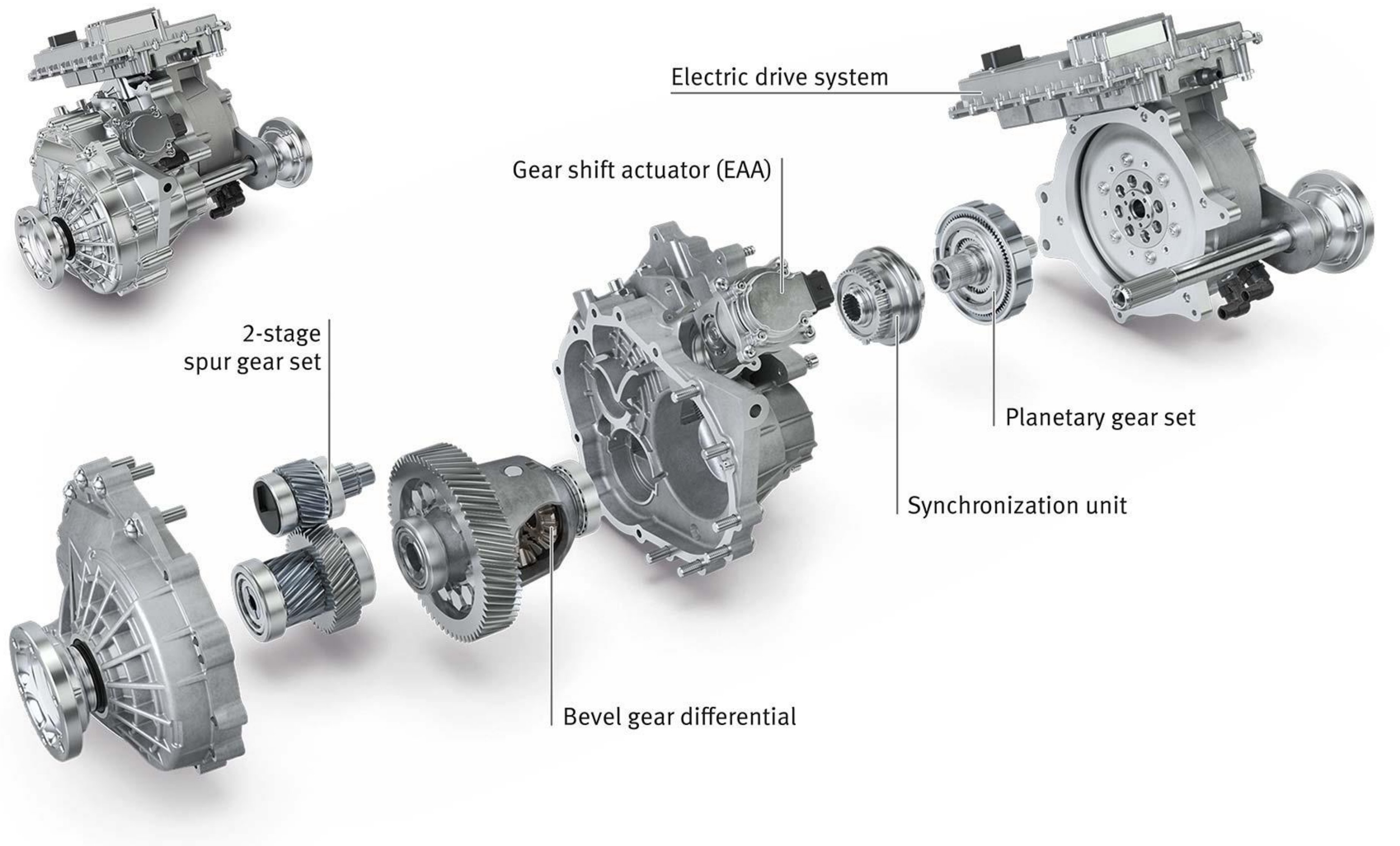
Introduction



Introduction



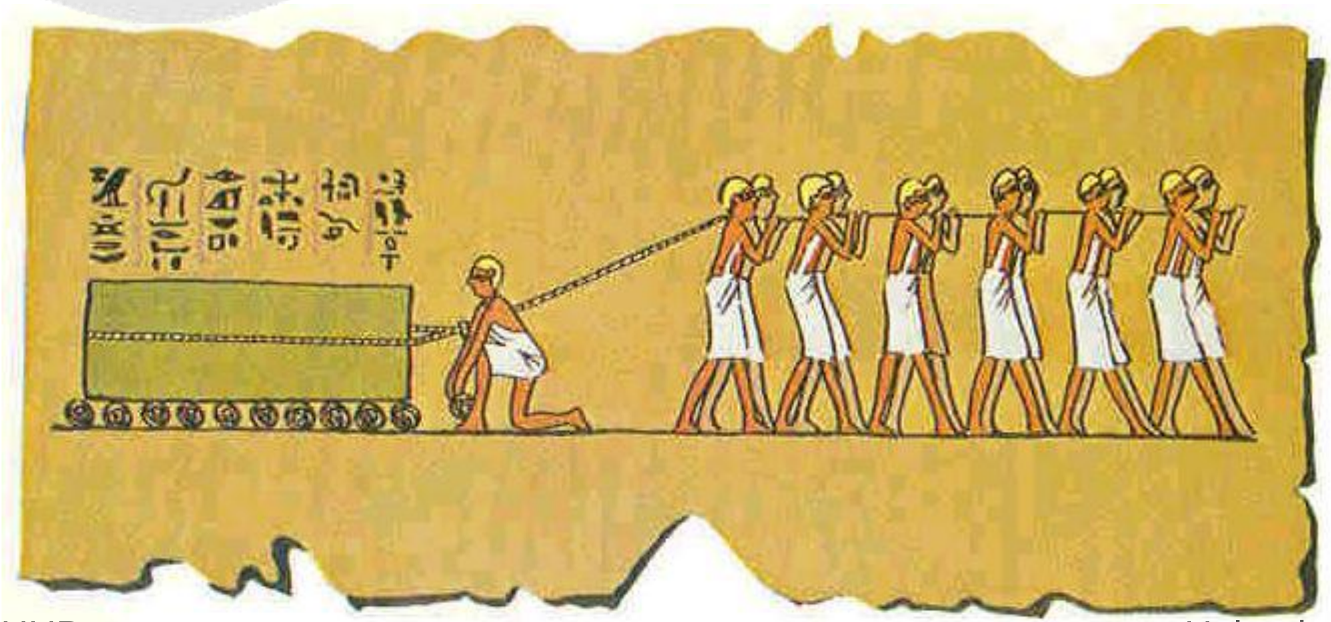
Introduction



History

Introduction

Ancient Egyptians used timbers for transportation of stones for pyramid building. This was roller bearings start.



Introduction

Introduction

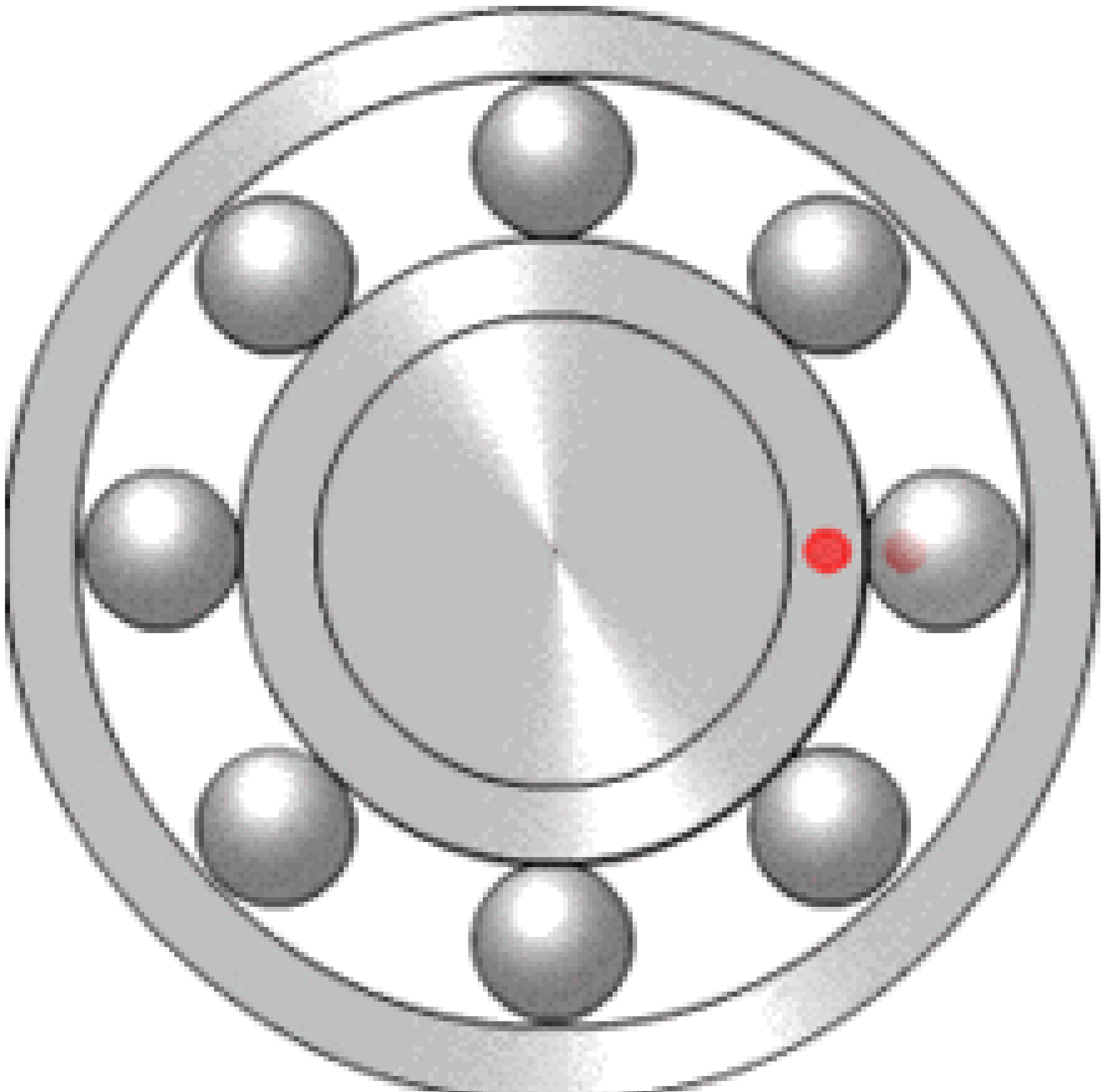
The terms "***rolling-contact bearing***", "***antifriction bearing***", and "***rolling bearing***" are all used to describe that class of bearing in which the main load is transferred through elements in rolling contact rather than in sliding contact.

Types of rolling contact bearing:

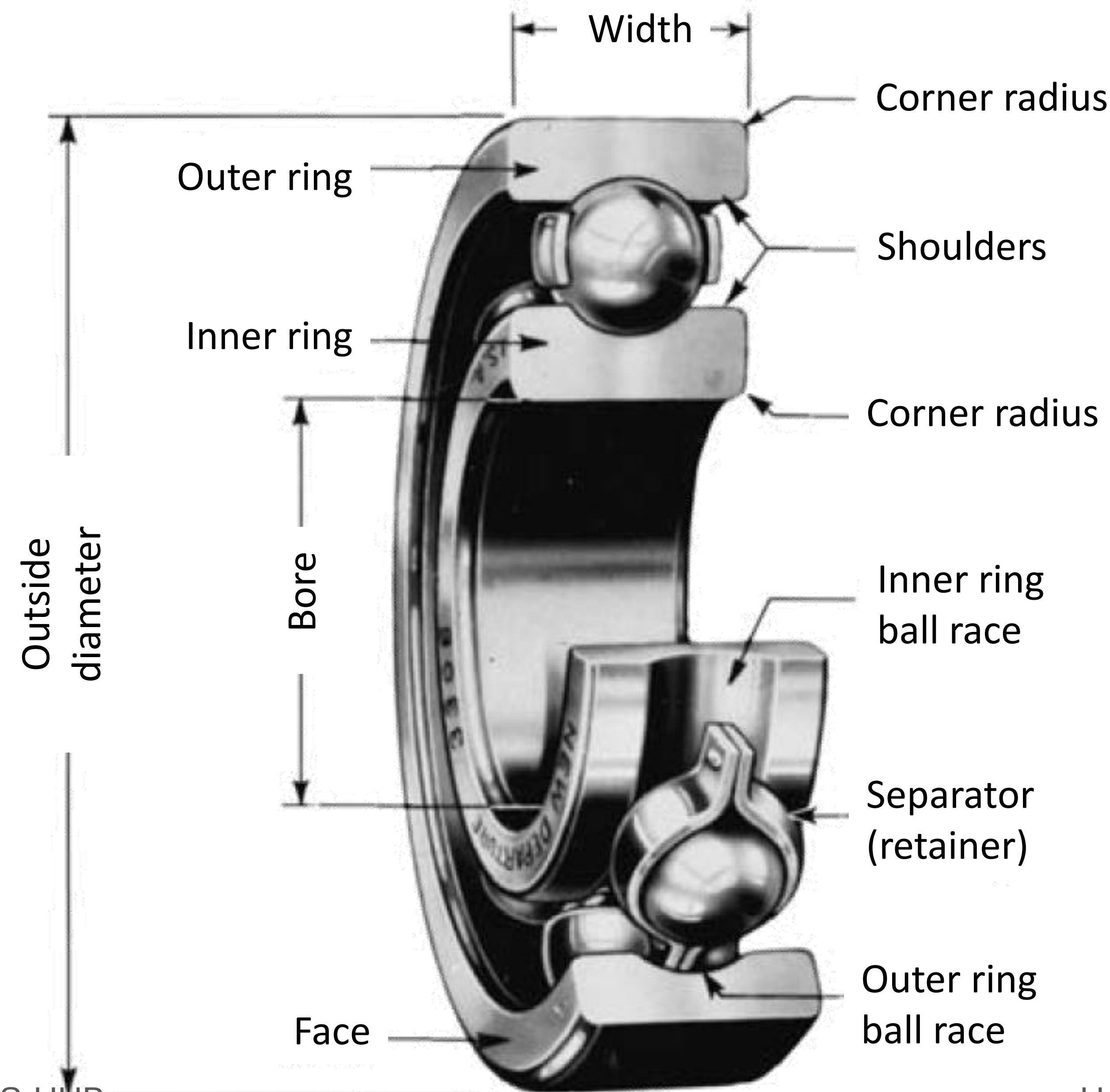
- Ball bearing

- Roller bearing

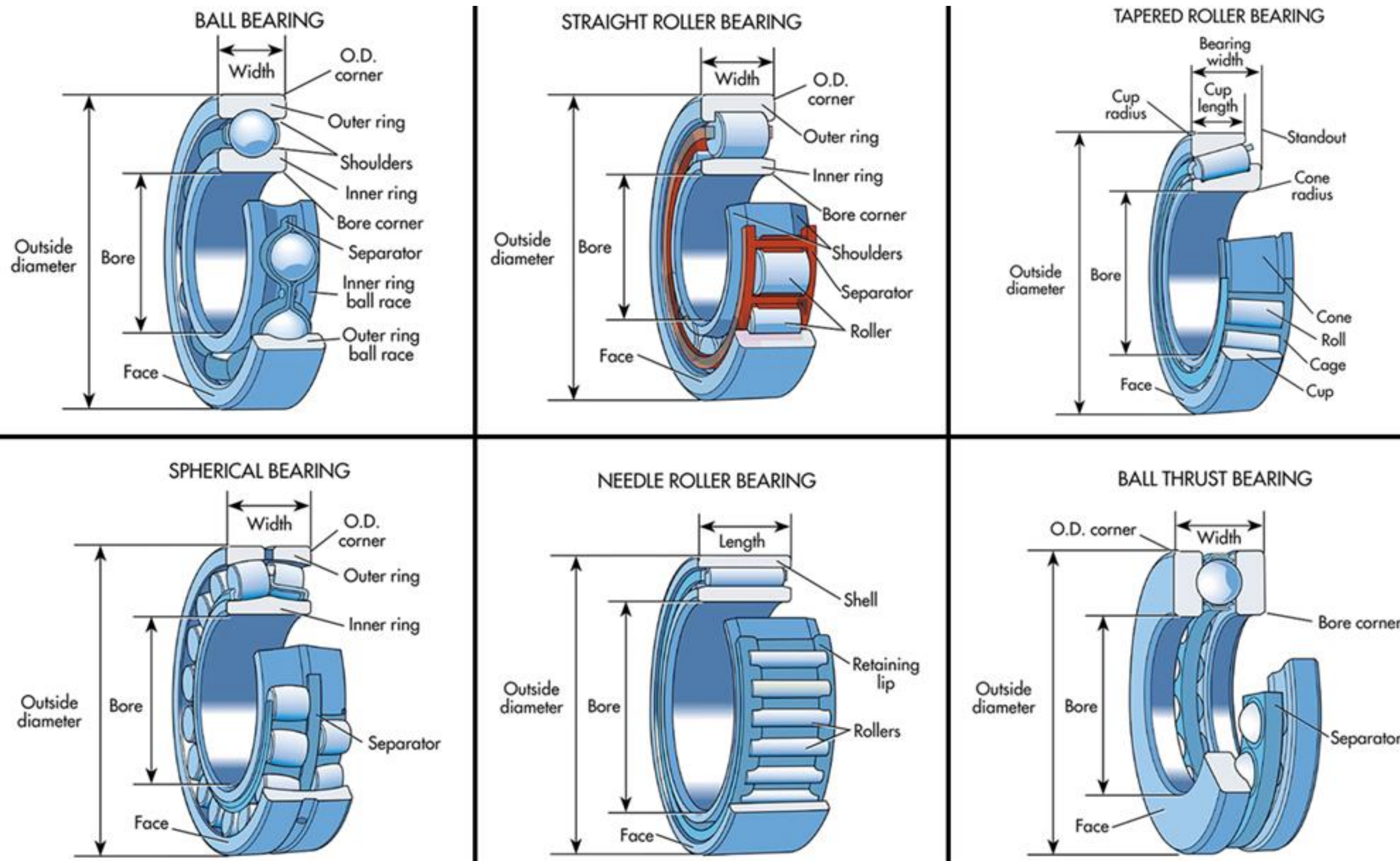
Introduction



Main Components



11.1 Bearing Types



11.1 Classification of Bearing Loads

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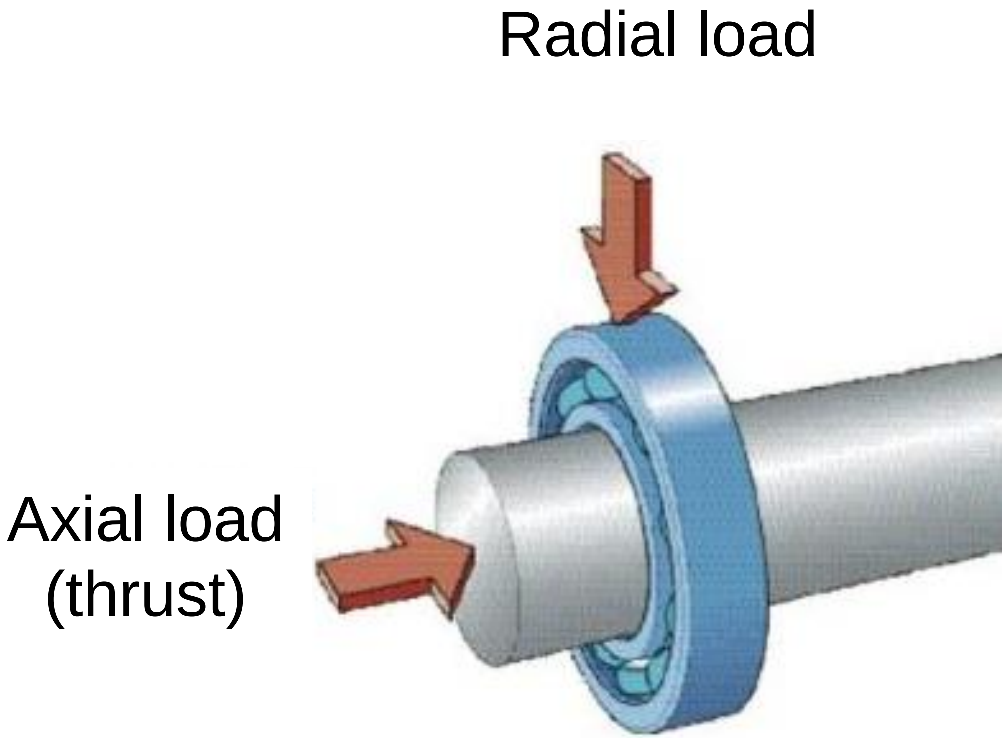
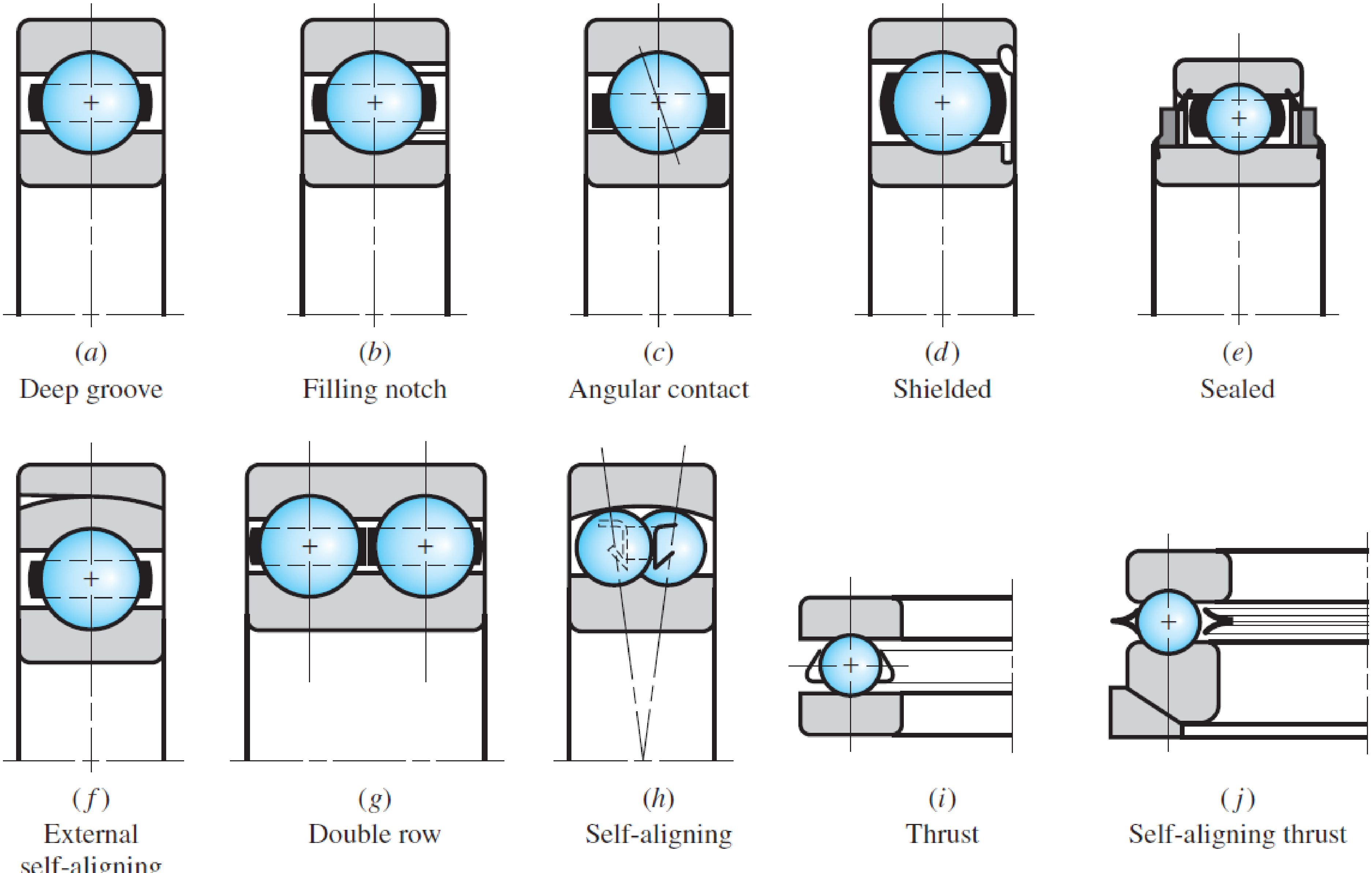
- Radial (Carry radial load)
- Thrust, axial contact (carry axial loads)
- Angular-contact (curry axial and radial loads)

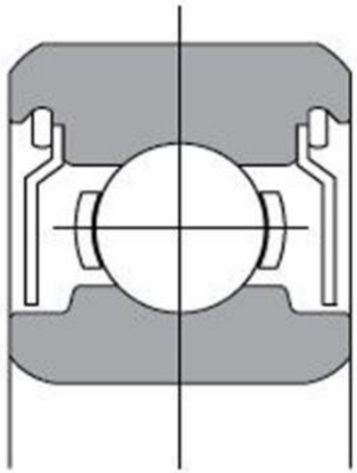


11.1 Ball Bearing Types

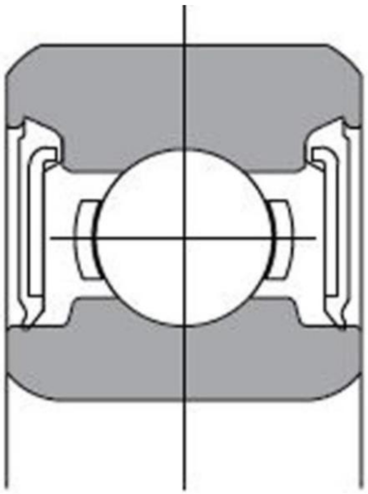


11.1 Ball Bearing Types

Shield Bearing



Sealed Bearing



11.1 Ball Bearing Types

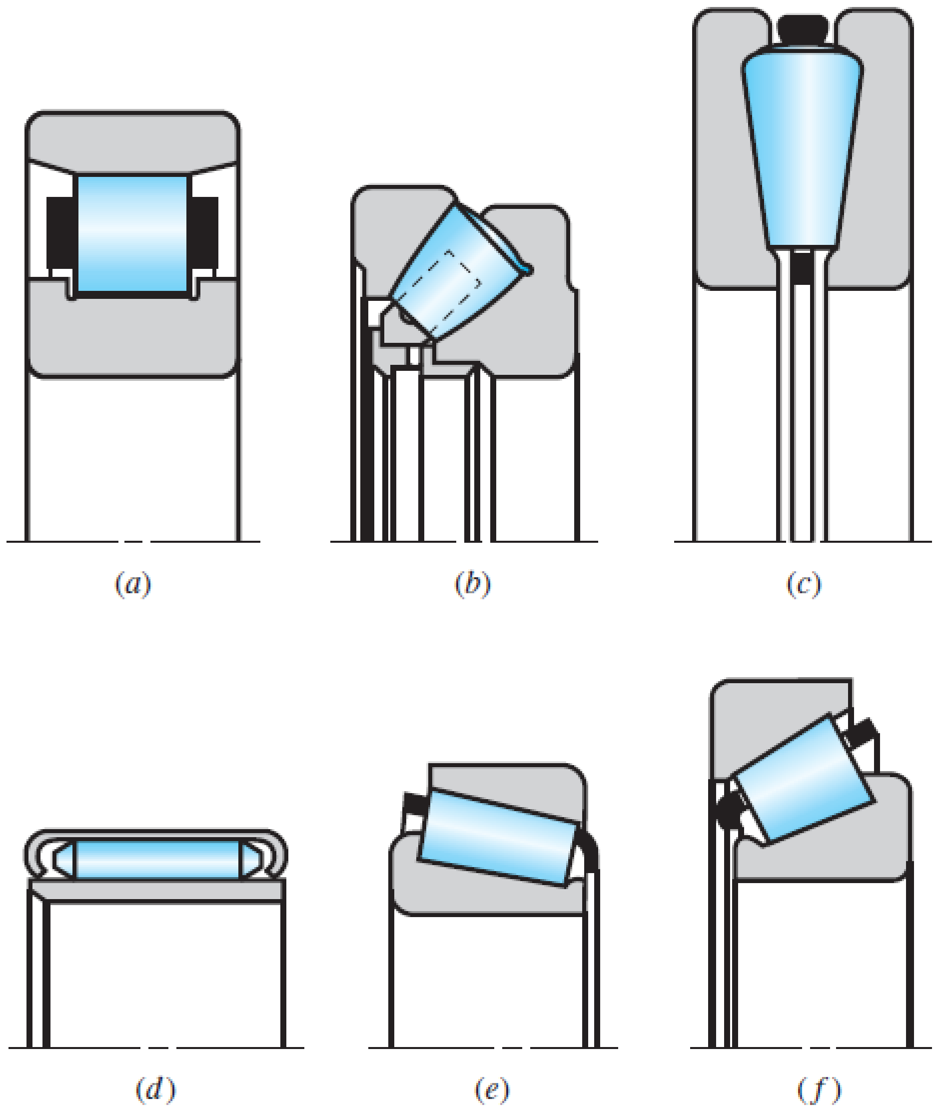
External Self-Aligning

Internal Self-Aligning

11.1 Ball Bearing Types

Figure 11–3

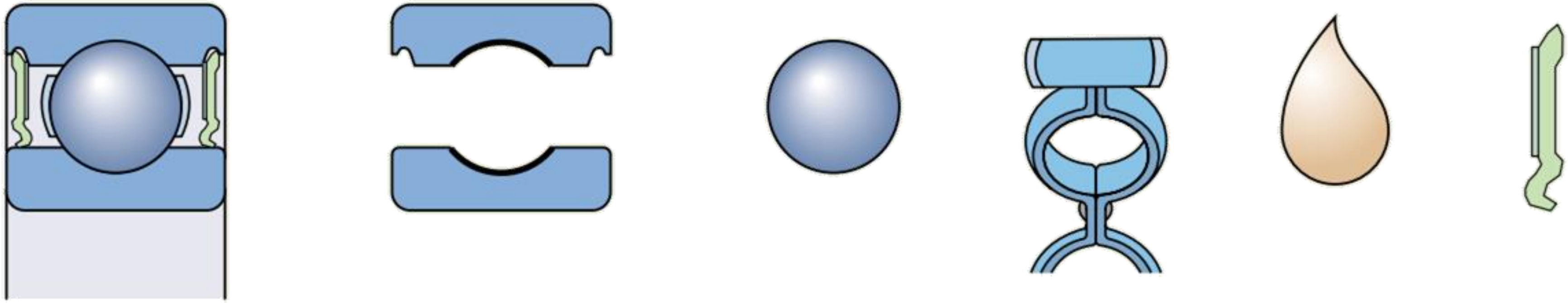
Types of roller bearings: (*a*) straight roller; (*b*) spherical roller, thrust; (*c*) tapered roller, thrust; (*d*) needle; (*e*) tapered roller; (*f*) steep-angle tapered roller. *(Courtesy of The Timken Company.)*



11.3 Bearing Load Life at Rated Reliablity

Bearing system life

$$L_{bearing} = f\,(L_{raceways}, L_{rolling\ elements}, L_{cage}, L_{lubricant}, L_{seals})$$



$$C_{10} = F_R = F_D\left(\frac{L_D}{L_R}\right)^{1/a} = F_D\left(\frac{\mathcal{L}_D n_D 60}{\mathcal{L}_R n_R 60}\right)^{1/a}$$

11.3 Bearing Load Life at Rated Reliablity

Bearing system life: Example:

Roller bearing is to withstand radial load $\mathbf{F_r = 4\ kN}$ and have a life $\mathbf{L_D = 1200\ hr}$ at $\mathbf{n_D = 600\ rpm}$. What value of load rating you will select from TimKen Engineering Company catalog

11.5 Relating Load, Life, and Reliability

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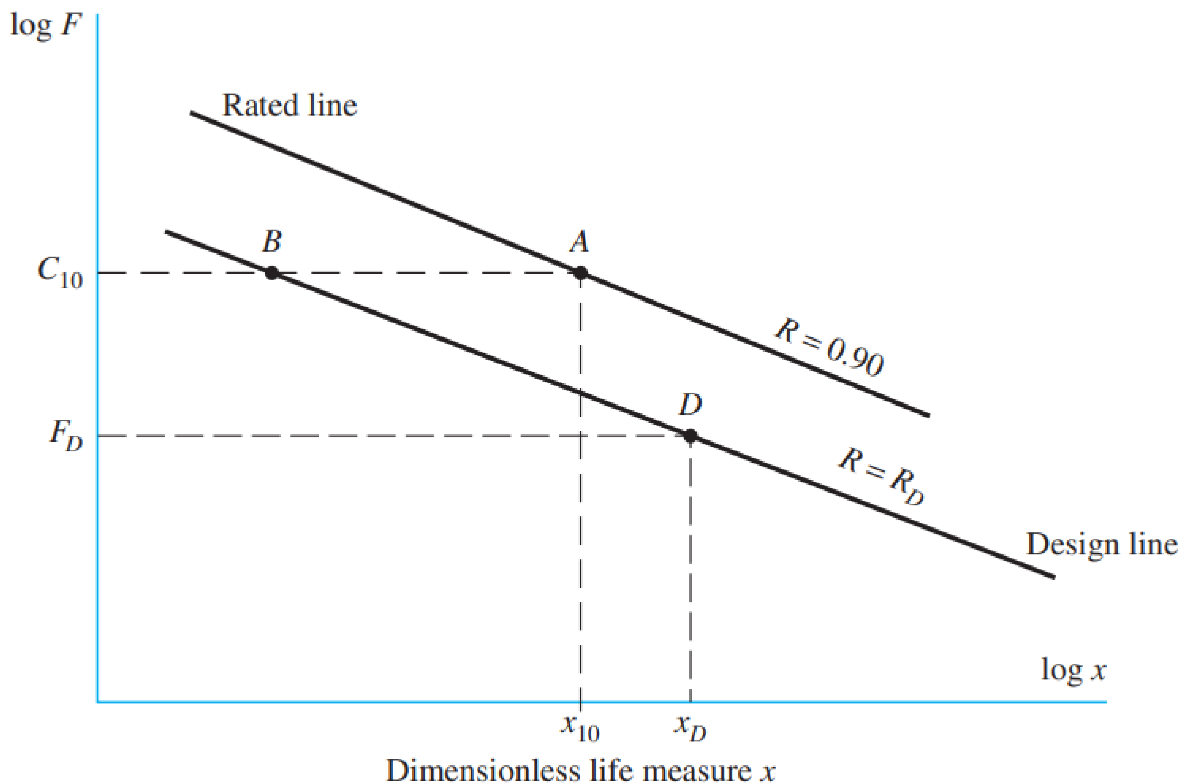
Figure 11–5

Constant reliability contours. Point A represents the catalog rating C_{10} at $x = L/L_{10} = 1$. Point B is on the target reliability design line R_D, with a load of C_{10}. Point D is a point on the desired reliability contour exhibiting the design life $x_D = L_D/L_{10}$ at the design load F_D.



$$C_{10} \approx a_f F_D \left[\frac{x_D}{x_0 + (\theta - x_0)(1 - R_D)^{1/b}} \right]^{1/a} \qquad R \geq 0.90 \qquad (11\text{–}10)$$

11.5 Relating Load, Life, and Reliability

$$C_{10} \approx a_f F_D \left[\frac{x_D}{x_0 + (\theta - x_0)(1 - R_D)^{1/b}} \right]^{1/a} \qquad R \geq 0.90 \qquad (11\text{–}10)$$

Table 11–6

Typical Weibull Parameters for Two Manufacturers

Manufacturer	Rating Life, Revolutions	Weibull Parameters Rating Lives x_0	θ	b
1	$90(10^6)$	0	4.48	1.5
2	$1(10^6)$	0.02	4.459	1.483

11.5 Relating Load, Life, and Reliability

Application factor and **Life** should be taken into account in the Bearing application

Table 11–4

Bearing-Life Recommendations for Various Classes of Machinery

1- Life

Type of Application	Life, kh
Instruments and apparatus for infrequent use	Up to 0.5
Aircraft engines	0.5–2
Machines for short or intermittent operation where service interruption is of minor importance	4–8
Machines for intermittent service where reliable operation is of great importance	8–14
Machines for 8-h service that are not always fully utilized	14–20
Machines for 8-h service that are fully utilized	20–30
Machines for continuous 24-h service	50–60
Machines for continuous 24-h service where reliability is of extreme importance	100–200

Table 11–5

Load-Application Factors

2 – Application factor

Type of Application	Load Factor
Precision gearing	1.0–1.1
Commercial gearing	1.1–1.3
Applications with poor bearing seals	1.2
Machinery with no impact	1.0–1.2
Machinery with light impact	1.2–1.5
Machinery with moderate impact	1.5–3.0

11.6 Combined Radial and Thrust Loading

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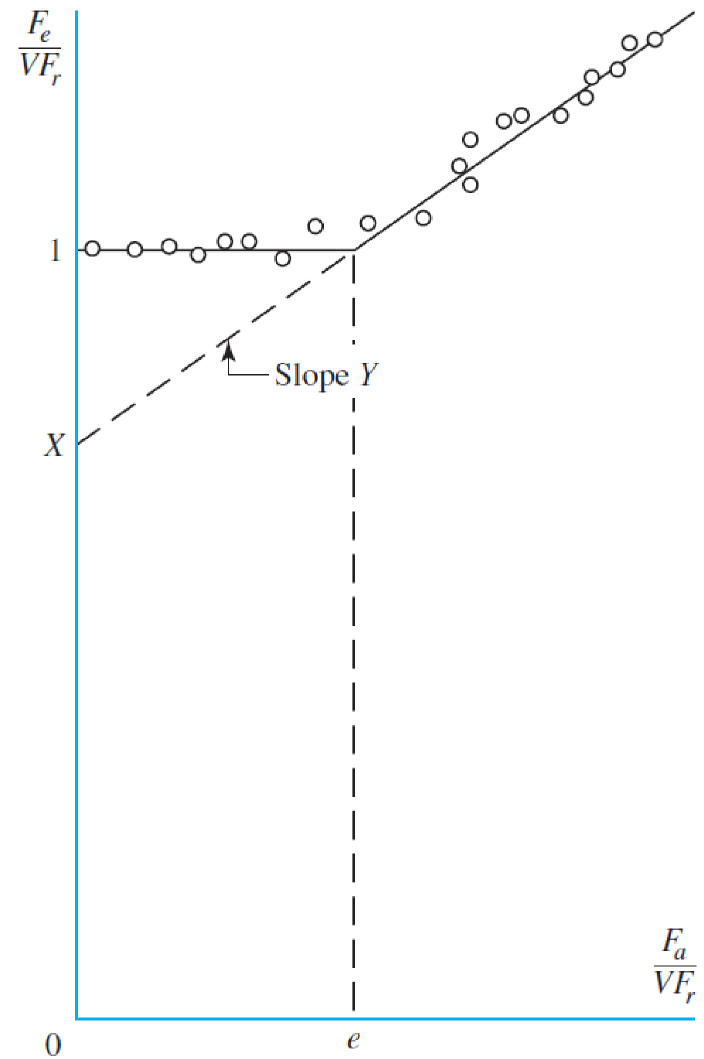
Figure 11–6

The relationship of dimensionless group $F_e/(VF_r)$ and $F_a/(VF_r)$ and the straight-line segments representing the data.



$$\frac{F_e}{VF_r} = 1 \qquad \text{when } \frac{F_a}{VF_r} \le e$$

$$\frac{F_e}{VF_r} = X + Y\frac{F_a}{VF_r} \qquad \text{when } \frac{F_a}{VF_r} > e$$

A **rotation factor** ***V*** is defined such that ***V* = 1** when the inner ring rotates and ***V* = 1.2** when the outer ring rotates

11.6 Combined Radial and Thrust Loading

$$F_e = X_i V F_r + Y_i F_a \qquad (11\text{–}12)$$

Table 11–1

Equivalent Radial Load Factors for Ball Bearings

		$F_a/(VF_r) \le e$		$F_a/(VF_r) > e$	
F_a/C_0	e	X_1	Y_1	X_2	Y_2
0.014*	0.19	1.00	0	0.56	2.30
0.021	0.21	1.00	0	0.56	2.15
0.028	0.22	1.00	0	0.56	1.99
0.042	0.24	1.00	0	0.56	1.85
0.056	0.26	1.00	0	0.56	1.71
0.070	0.27	1.00	0	0.56	1.63
0.084	0.28	1.00	0	0.56	1.55
0.110	0.30	1.00	0	0.56	1.45
0.17	0.34	1.00	0	0.56	1.31
0.28	0.38	1.00	0	0.56	1.15
0.42	0.42	1.00	0	0.56	1.04
0.56	0.44	1.00	0	0.56	1.00

*Use 0.014 if $F_a/C_0 < 0.014$.

11.6 Combined Radial and Thrust Loading

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Table 11–2

Dimensions and Load Ratings for Single-Row 02-Series Deep-Groove and Angular-Contact Ball Bearings

Bore, mm	OD, mm	Width, mm	Fillet Radius, mm	Shoulder Diameter, mm d_S	Shoulder Diameter, mm d_H	Load Ratings, kN Deep Groove C_{10}	Load Ratings, kN Deep Groove C_0	Load Ratings, kN Angular Contact C_{10}	Load Ratings, kN Angular Contact C_0
10	30	9	0.6	12.5	27	5.07	2.24	4.94	2.12
12	32	10	0.6	14.5	28	6.89	3.10	7.02	3.05
15	35	11	0.6	17.5	31	7.80	3.55	8.06	3.65
17	40	12	0.6	19.5	34	9.56	4.50	9.95	4.75
20	47	14	1.0	25	41	12.7	6.20	13.3	6.55
25	52	15	1.0	30	47	14.0	6.95	14.8	7.65
30	62	16	1.0	35	55	19.5	10.0	20.3	11.0
35	72	17	1.0	41	65	25.5	13.7	27.0	15.0
40	80	18	1.0	46	72	30.7	16.6	31.9	18.6
45	85	19	1.0	52	77	33.2	18.6	35.8	21.2
50	90	20	1.0	56	82	35.1	19.6	37.7	22.8
55	100	21	1.5	63	90	43.6	25.0	46.2	28.5
60	110	22	1.5	70	99	47.5	28.0	55.9	35.5
65	120	23	1.5	74	109	55.9	34.0	63.7	41.5
70	125	24	1.5	79	114	61.8	37.5	68.9	45.5

11.6 Combined Radial and Thrust Loading

Table 11–3

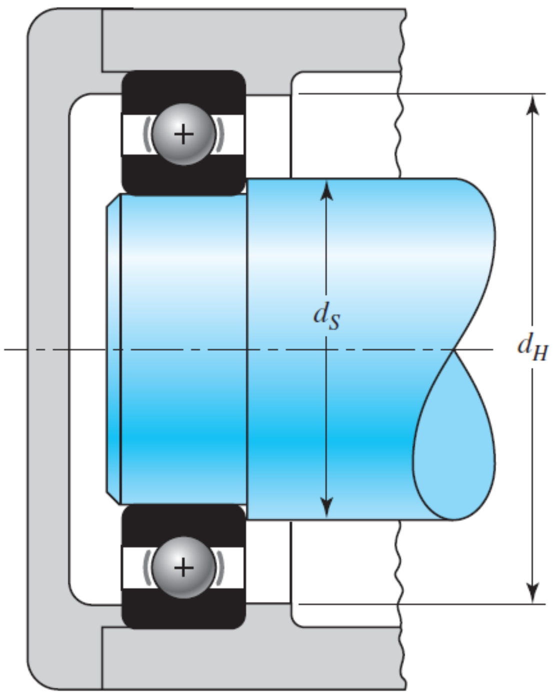
Dimensions and Basic Load Ratings for Cylindrical Roller Bearings

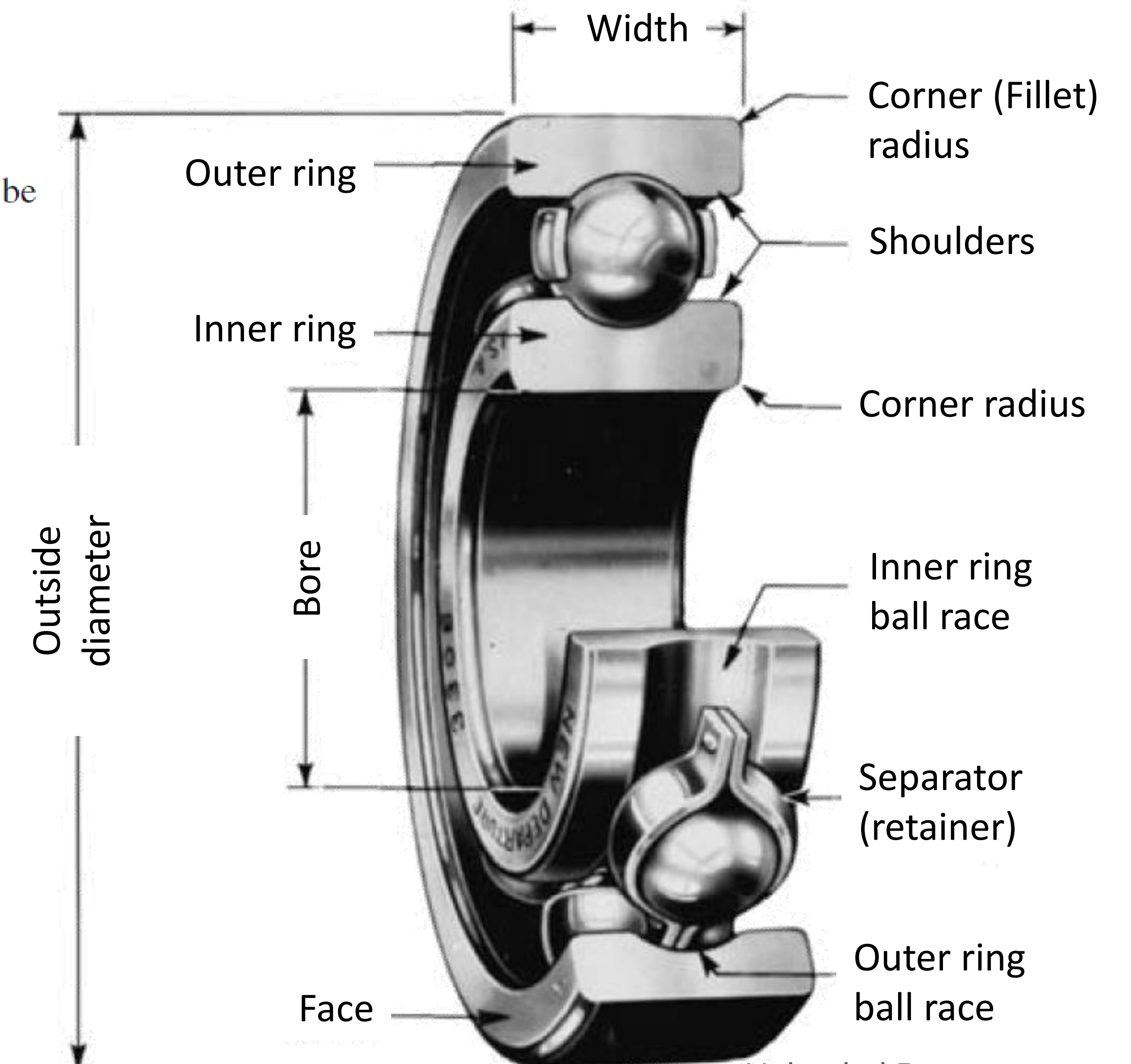
	02-Series				03-Series			
Bore, mm	OD, mm	Width, mm	Load Rating, kN C_{10}	Load Rating, kN C_0	OD, mm	Width, mm	Load Rating, kN C_{10}	Load Rating, kN C_0
25	52	15	16.8	8.8	62	17	28.6	15.0
30	62	16	22.4	12.0	72	19	36.9	20.0
35	72	17	31.9	17.6	80	21	44.6	27.1
40	80	18	41.8	24.0	90	23	56.1	32.5
45	85	19	44.0	25.5	100	25	72.1	45.4
50	90	20	45.7	27.5	110	27	88.0	52.0
55	100	21	56.1	34.0	120	29	102	67.2
60	110	22	64.4	43.1	130	31	123	76.5
65	120	23	76.5	51.2	140	33	138	85.0
70	125	24	79.2	51.2	150	35	151	102
75	130	25	93.1	63.2	160	37	183	125
80	140	26	106	69.4	170	39	190	125
85	150	28	119	78.3	180	41	212	149
90	160	30	142	100	190	43	242	160
95	170	32	165	112	200	45	264	189
100	180	34	183	125	215	47	303	220

11.6 Combined Radial and Thrust Loading

Figure 11–8

Shaft and housing shoulder diameters d_S and d_H should be adequate to ensure good bearing support.

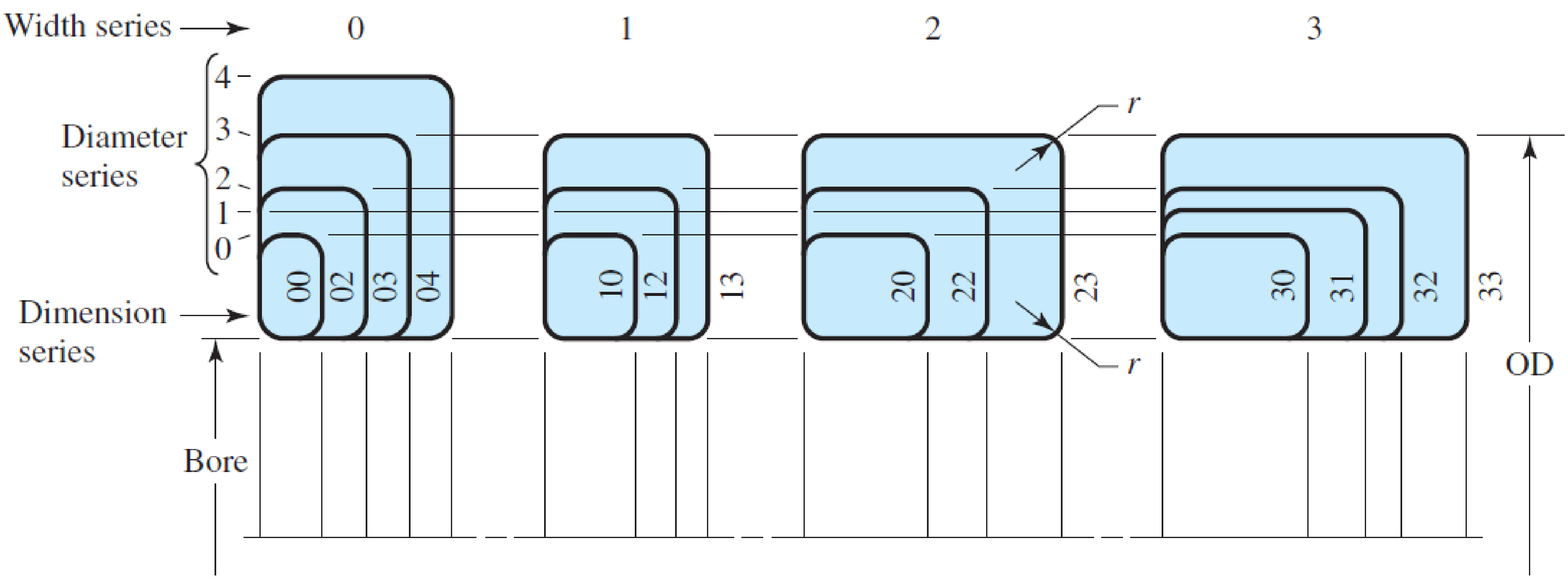




11.6 Combined Radial and Thrust Loading

Figure 11-7: The basic ABMA plan for boundary dimensions.

It shows the variety of bearings that may be obtained with a particular bore



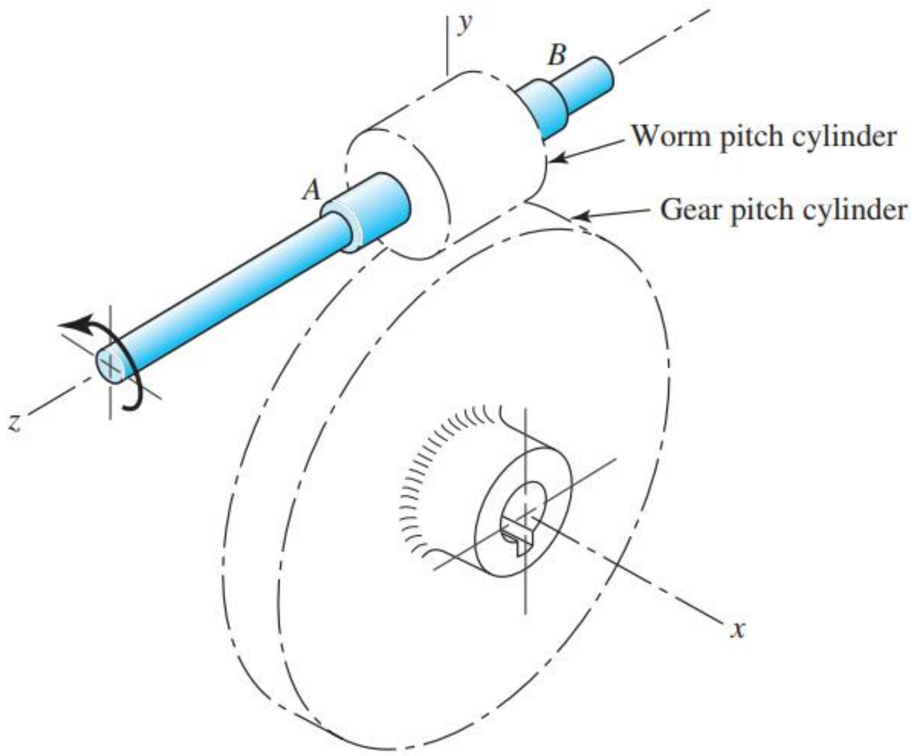
The bearings are identified by a two-digit number called the *dimension-series code*.

- The first number in the code is from the *width series*.
- The second number is from the *diameter series* (outside).

Since the dimension series code does not reveal the dimensions directly, it is necessary to resort to tabulations.

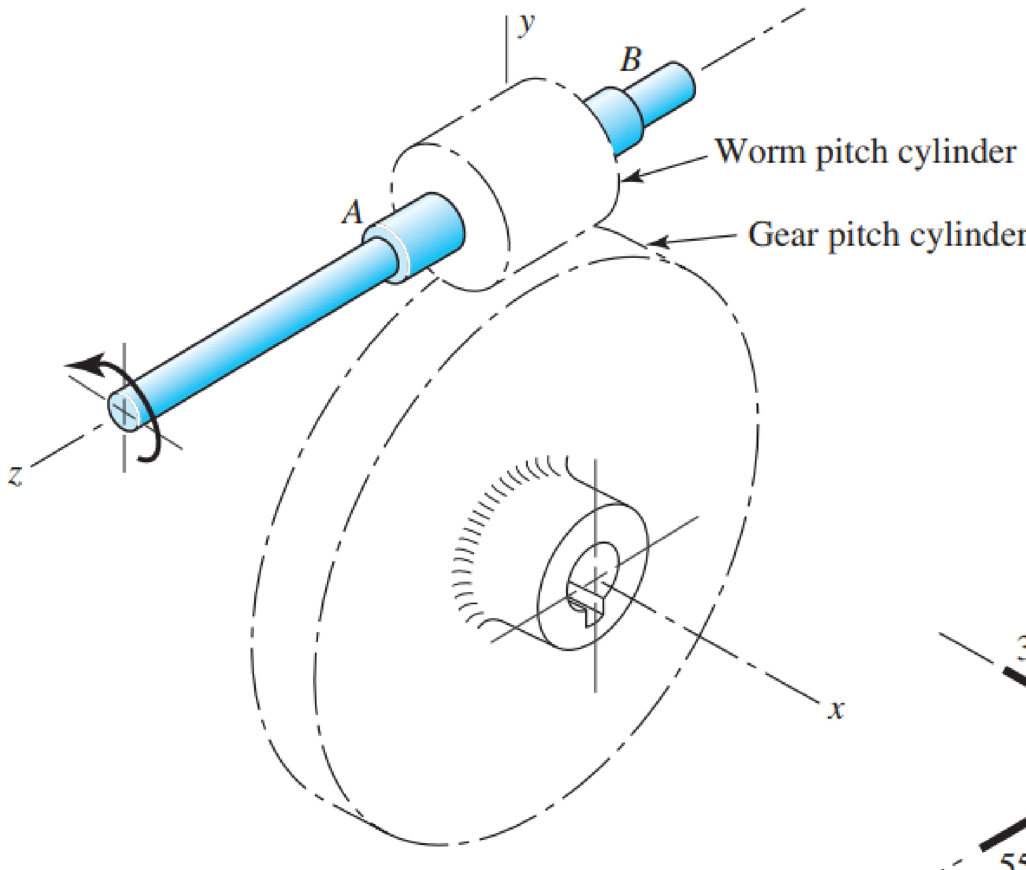
Problem 11-35

The worm shaft shown in part *a* of the figure transmits 1.2 hp at 500 rev/min. A static force analysis gave the results shown in part *b* of the figure. Bearing *A* is to be an angular-contact ball bearing selected from Table 11–2, mounted to take the 555-lbf thrust load. The bearing at *B* is to take only the radial load, so an 02-series cylindrical roller bearing from Table 11–3 will be employed. Use an application factor of 1.2, a desired life of 30 kh, and a combined reliability goal of 0.99, assuming distribution data from manufacturer 2 in Table 11–6. Specify each bearing.



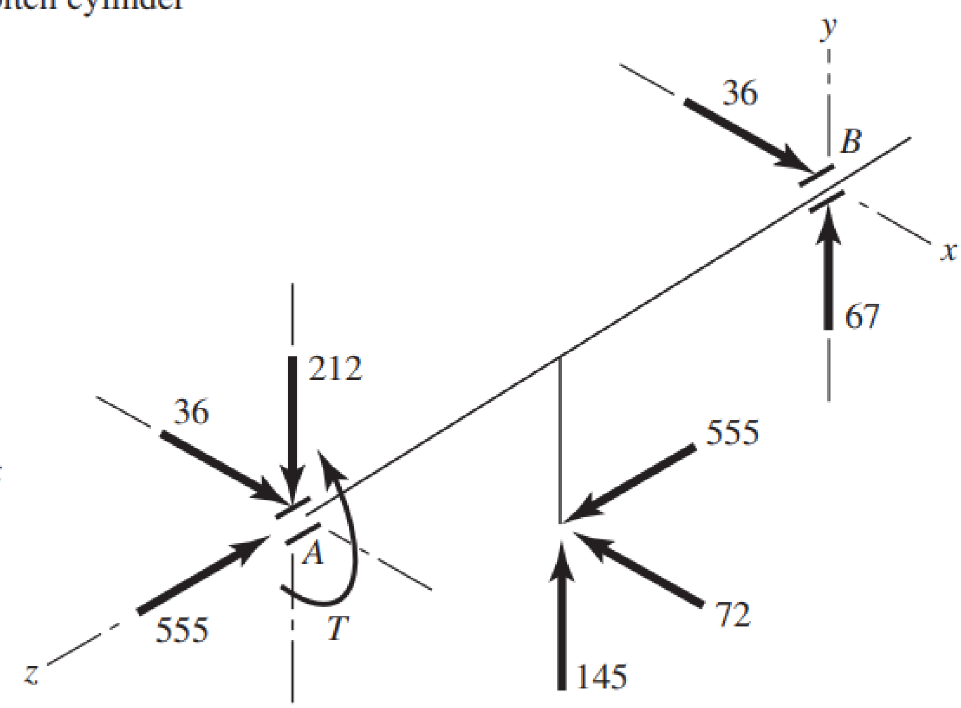
(*a*)

Problem 11-35



(*a*)

(*a*) Worm and worm gear; (*b*) force analysis of worm shaft, forces in pounds.



(*b*)

11.5 Relating Load, Life, and Reliability

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$$C_{10} \approx a_f F_D \left[\frac{x_D}{x_0 + (\theta - x_0)(1 - R_D)^{1/b}} \right]^{1/a} \qquad R \geq 0.90 \qquad (11\text{–}10)$$

Table 11–6

Typical Weibull Parameters for Two Manufacturers

Manufacturer	Rating Life, Revolutions	Weibull Parameters Rating Lives x_0	θ	b
1	$90(10^6)$	0	4.48	1.5
2	$1(10^6)$	0.02	4.459	1.483

11.6 Combined Radial and Thrust Loading

Table 11–3

Dimensions and Basic Load Ratings for Cylindrical Roller Bearings

	02-Series				03-Series			
Bore, mm	OD, mm	Width, mm	Load Rating, kN C_{10}	Load Rating, kN C_0	OD, mm	Width, mm	Load Rating, kN C_{10}	Load Rating, kN C_0
25	52	15	16.8	8.8	62	17	28.6	15.0
30	62	16	22.4	12.0	72	19	36.9	20.0
35	72	17	31.9	17.6	80	21	44.6	27.1
40	80	18	41.8	24.0	90	23	56.1	32.5
45	85	19	44.0	25.5	100	25	72.1	45.4
50	90	20	45.7	27.5	110	27	88.0	52.0
55	100	21	56.1	34.0	120	29	102	67.2
60	110	22	64.4	43.1	130	31	123	76.5
65	120	23	76.5	51.2	140	33	138	85.0
70	125	24	79.2	51.2	150	35	151	102
75	130	25	93.1	63.2	160	37	183	125
80	140	26	106	69.4	170	39	190	125
85	150	28	119	78.3	180	41	212	149
90	160	30	142	100	190	43	242	160
95	170	32	165	112	200	45	264	189
100	180	34	183	125	215	47	303	220

11.6 Combined Radial and Thrust Loading

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Table 11–2

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Bore, mm	OD, mm	Width, mm	Fillet Radius, mm	Shoulder Diameter, mm d_S	d_H	Load Ratings, kN Deep Groove C_{10}	Deep Groove C_0	Angular Contact C_{10}	Angular Contact C_0
25	52	15	1.0	30	47	14.0	6.95	14.8	7.65
30	62	16	1.0	35	55	19.5	10.0	20.3	11.0
35	72	17	1.0	41	65	25.5	13.7	27.0	15.0
40	80	18	1.0	46	72	30.7	16.6	31.9	18.6
45	85	19	1.0	52	77	33.2	18.6	35.8	21.2
50	90	20	1.0	56	82	35.1	19.6	37.7	22.8
55	100	21	1.5	63	90	43.6	25.0	46.2	28.5
60	110	22	1.5	70	99	47.5	28.0	55.9	35.5
65	120	23	1.5	74	109	55.9	34.0	63.7	41.5
70	125	24	1.5	79	114	61.8	37.5	68.9	45.5
75	130	25	1.5	86	119	66.3	40.5	71.5	49.0
80	140	26	2.0	93	127	70.2	45.0	80.6	55.0
85	150	28	2.0	99	136	83.2	53.0	$\boxed{90.4}$	$\boxed{63.0}$
90	160	30	2.0	104	146	95.6	62.0	106	73.5
95	170	32	2.0	110	156	108	69.5	121	85.0

11.6 Combined Radial and Thrust Loading

$$F_e = X_i V F_r + Y_i F_a \qquad (11\text{–}12)$$

Table 11–1

Equivalent Radial Load Factors for Ball Bearings

0.0392 → ? →

		$F_a/(VF_r) \le e$		$F_a/(VF_r) > e$	
F_a/C_0	e	X_1	Y_1	X_2	Y_2
0.014*	0.19	1.00	0	0.56	2.30
0.021	0.21	1.00	0	0.56	2.15
0.028	0.22	1.00	0	0.56	1.99
0.042	0.24	1.00	0	0.56	1.85
0.056	0.26	1.00	0	0.56	1.71
0.070	0.27	1.00	0	0.56	1.63
0.084	0.28	1.00	0	0.56	1.55
0.110	0.30	1.00	0	0.56	1.45
0.17	0.34	1.00	0	0.56	1.31
0.28	0.38	1.00	0	0.56	1.15
0.42	0.42	1.00	0	0.56	1.04
0.56	0.44	1.00	0	0.56	1.00

*Use 0.014 if $F_a/C_0 < 0.014$.

11.7 Variable Loading

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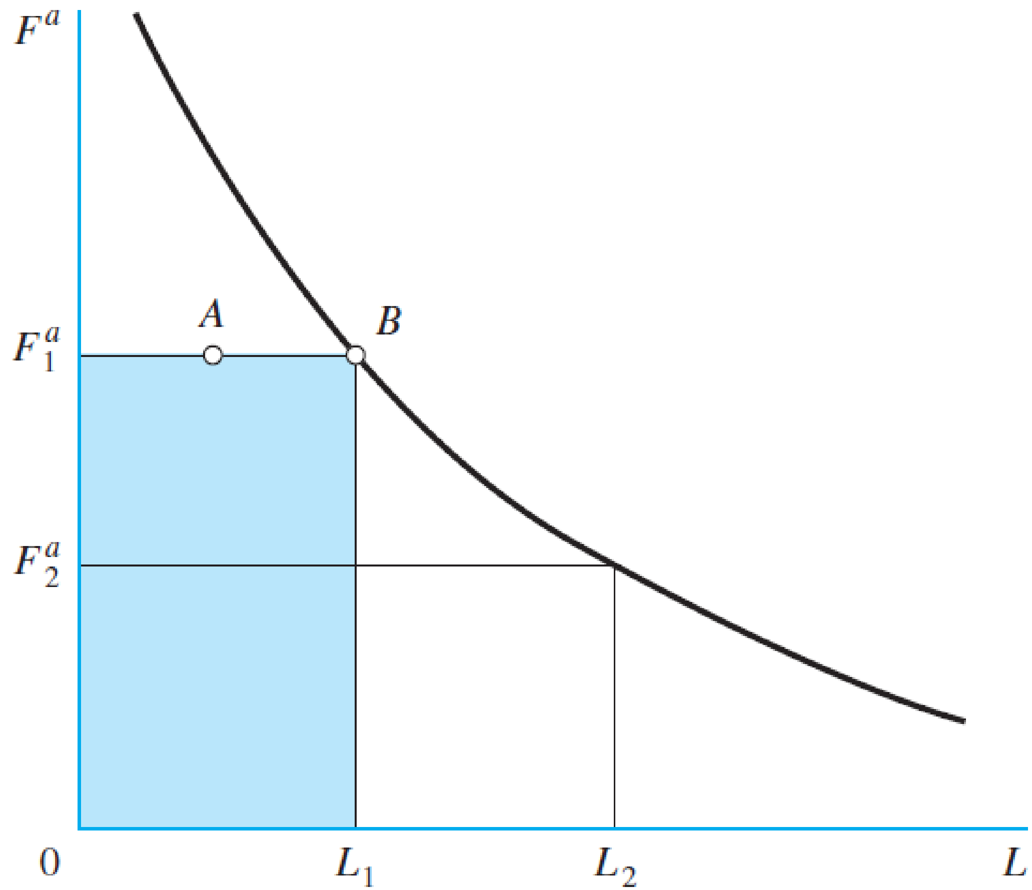
Figure 11–9

Plot of F^a as ordinate and L as abscissa for $F^a L$ = constant. The linear damage hypothesis says that in the case of load F_1, the area under the curve from $L = 0$ to $L = L_A$ is a measure of the damage $D = F_1^a L_A$. The complete damage to failure is measured by $C_{10}^a L_B$.



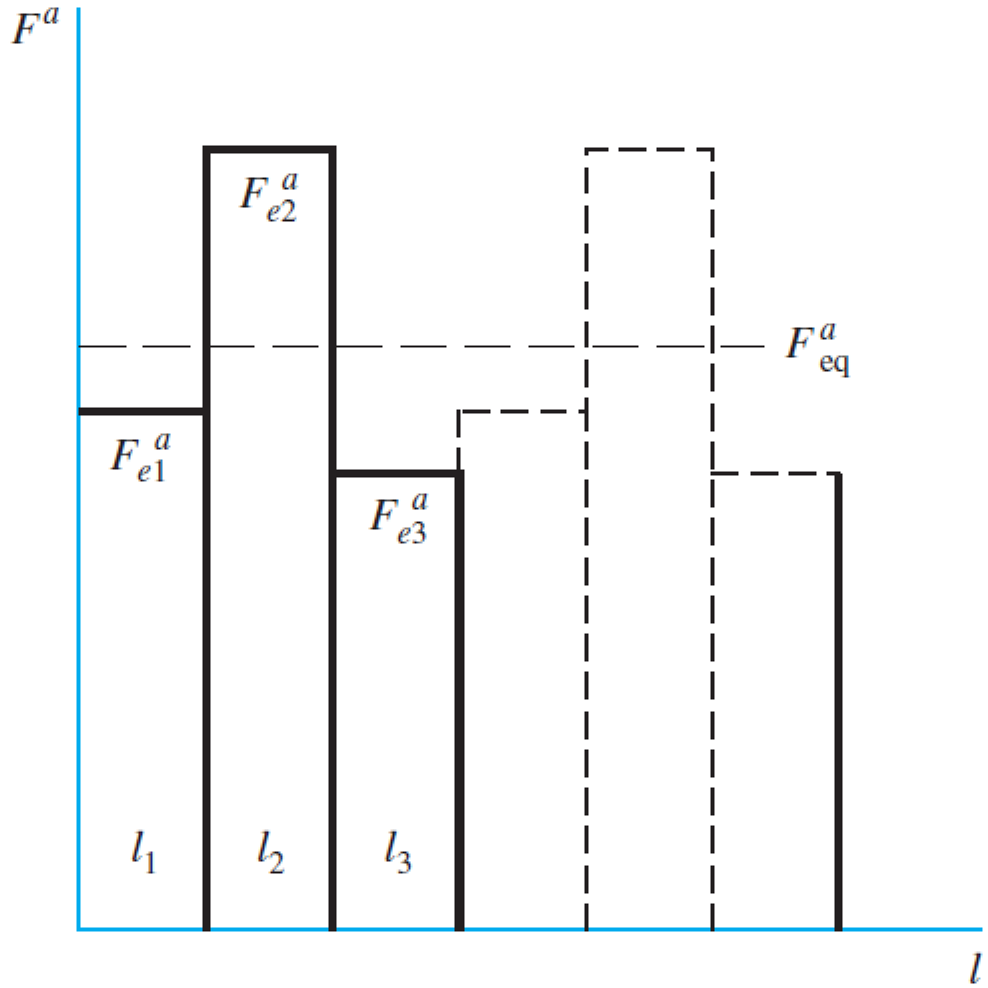
$$F^a L = \text{constant} = K$$

(a)

11.7 Variable Loading

Figure 11–10

A three-part piecewise-continuous periodic loading cycle involving loads F_{e1}, F_{e2}, and F_{e3}. F_{eq} is the equivalent steady load inflicting the same damage when run for $l_1 + l_2 + l_3$ revolutions, doing the same damage D per period.



$$D = F_{e1}^a l_1 + F_{e2}^a l_2 + F_{e3}^a l_3$$

$$D = F_{eq}^a (l_1 + l_2 + l_3)$$

11.7 Variable Loading

Equation 1:

$$D = F_{e1}^{a} l_1 + F_{e2}^{a} l_2 + F_{e3}^{a} l_3$$

Equation 2:

$$D = F_{\mathrm{eq}}^{a}(l_1 + l_2 + l_3)$$

Equating Equation 1 and 2, we get the $\boldsymbol{F_{eq}}$

$$F_{\mathrm{eq}} = \left[\frac{F_{e1}^{a} l_1 + F_{e2}^{a} l_2 + F_{e3}^{a} l_3}{l_1 + l_2 + l_3} \right]^{1/a} = \left[\sum f_i F_{ei}^{a} \right]^{1/a}$$

11.7 Variable Loading

$$F_{eq}^{a} L_{eq} = F_{e1}^{a} l_1 + F_{e2}^{a} l_2 + F_{e3}^{a} l_3$$

and note that

$$K = F_{e1}^{a} L_1 = F_{e2}^{a} L_2 = F_{e3}^{a} L_3$$

and K also equals

$$K = F_{e1}^{a} l_1 + F_{e2}^{a} l_2 + F_{e3}^{a} l_3 = \frac{K}{L_1} l_1 + \frac{K}{L_2} l_2 + \frac{K}{L_3} l_3 = K \sum \frac{l_i}{L_i}$$

From the outer parts of the preceding equation we obtain

$$\sum \frac{l_i}{L_i} = 1$$

Problem 11 - 38

Estimate the remaining life in revolutions of an 02-30 mm angular-contact ball bearing already subjected to 200 000 revolutions with a radial load of 18 kN, if it is now to be subjected to a change in load to 30 kN.

Problem 11 - 38

Table 11–3

Dimensions and Basic Load Ratings for Cylindrical Roller Bearings

	02-Series				03-Series			
Bore, mm	OD, mm	Width, mm	Load Rating, kN C_{10}	C_0	OD, mm	Width, mm	Load Rating, kN C_{10}	C_0
25	52	15	16.8	8.8	62	17	28.6	15.0
30	62	16	22.4	12.0	72	19	36.9	20.0
35	72	17	31.9	17.6	80	21	44.6	27.1
40	80	18	41.8	24.0	90	23	56.1	32.5
45	85	19	44.0	25.5	100	25	72.1	45.4
50	90	20	45.7	27.5	110	27	88.0	52.0
55	100	21	56.1	34.0	120	29	102	67.2
60	110	22	64.4	43.1	130	31	123	76.5
65	120	23	76.5	51.2	140	33	138	85.0
70	125	24	79.2	51.2	150	35	151	102
75	130	25	93.1	63.2	160	37	183	125
80	140	26	106	69.4	170	39	190	125
85	150	28	119	78.3	180	41	212	149
90	160	30	142	100	190	43	242	160
95	170	32	165	112	200	45	264	189
100	180	34	183	125	215	47	303	220

Problem 11 - 38

Table 11–2

Dimensions and Load Ratings for Single-Row 02-Series Deep-Groove and Angular-Contact Ball Bearings

Bore, mm	OD, mm	Width, mm	Fillet Radius, mm	Shoulder Diameter, mm d_S	Shoulder Diameter, mm d_H	Load Ratings, kN Deep Groove C_{10}	Load Ratings, kN Deep Groove C_0	Load Ratings, kN Angular Contact C_{10}	Load Ratings, kN Angular Contact C_0
25	52	15	1.0	30	47	14.0	6.95	14.8	7.65
30	62	16	1.0	35	55	19.5	10.0	20.3	11.0
35	72	17	1.0	41	65	25.5	13.7	27.0	15.0
40	80	18	1.0	46	72	30.7	16.6	31.9	18.6
45	85	19	1.0	52	77	33.2	18.6	35.8	21.2
50	90	20	1.0	56	82	35.1	19.6	37.7	22.8
55	100	21	1.5	63	90	43.6	25.0	46.2	28.5
60	110	22	1.5	70	99	47.5	28.0	55.9	35.5
65	120	23	1.5	74	109	55.9	34.0	63.7	41.5
70	125	24	1.5	79	114	61.8	37.5	68.9	45.5
75	130	25	1.5	86	119	66.3	40.5	71.5	49.0
80	140	26	2.0	93	127	70.2	45.0	80.6	55.0
85	150	28	2.0	99	136	83.2	53.0	90.4	63.0
90	160	30	2.0	104	146	95.6	62.0	106	73.5
95	170	32	2.0	110	156	108	69.5	121	85.0

11.9 Selection of Tapered Roller Bearings

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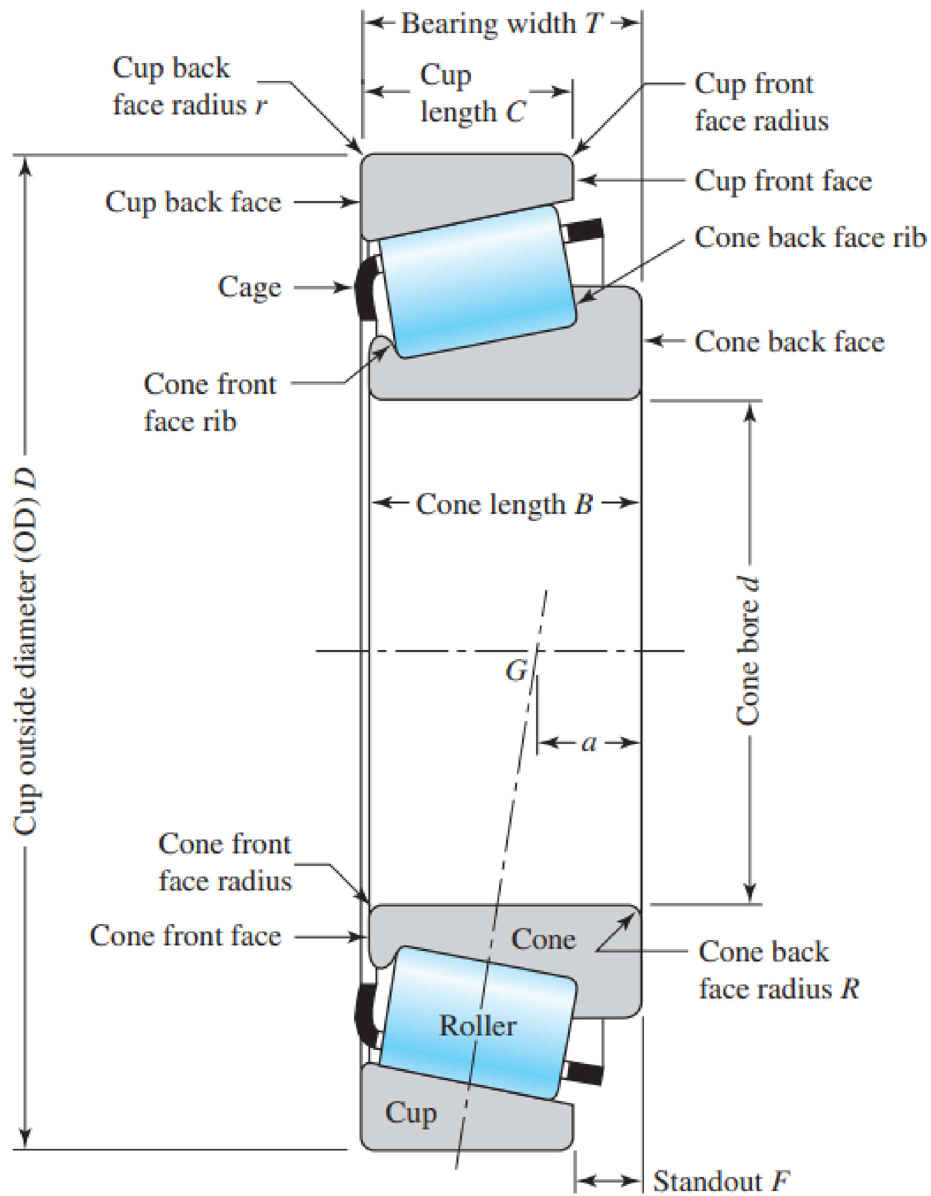
Figure 11–13

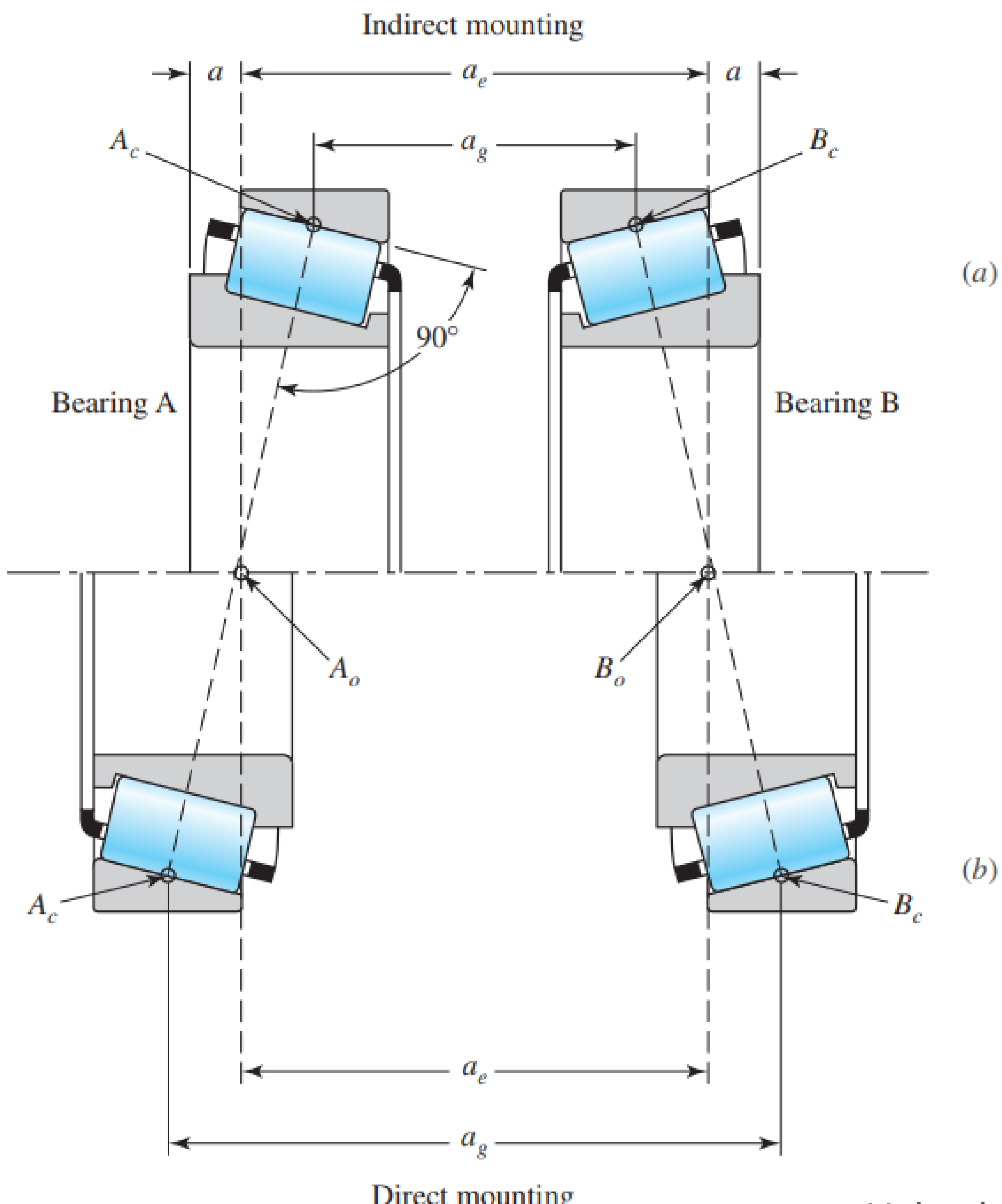
Nomenclature of a tapered roller bearing. Point G is the location of the effective load center; use this point to estimate the radial bearing load. *(Courtesy of The Timken Company.)*



11.9 Selection of Tapered Roller Bearings

Figure 11–14

Comparison of mounting stability between indirect and direct mountings. *(Courtesy of The Timken Company.)*



Cone face facing each other

Cone back facing each other

11.9 Selection of Tapered Roller Bearings

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Using F_i for the induced thrust load from a radial load, Timken provides the equation:

$$F_i = \frac{0.47F_r}{K} \quad (11\text{–}18)$$

$$F_e = X_i V F_r + Y_i F_a \quad (11\text{–}12)$$

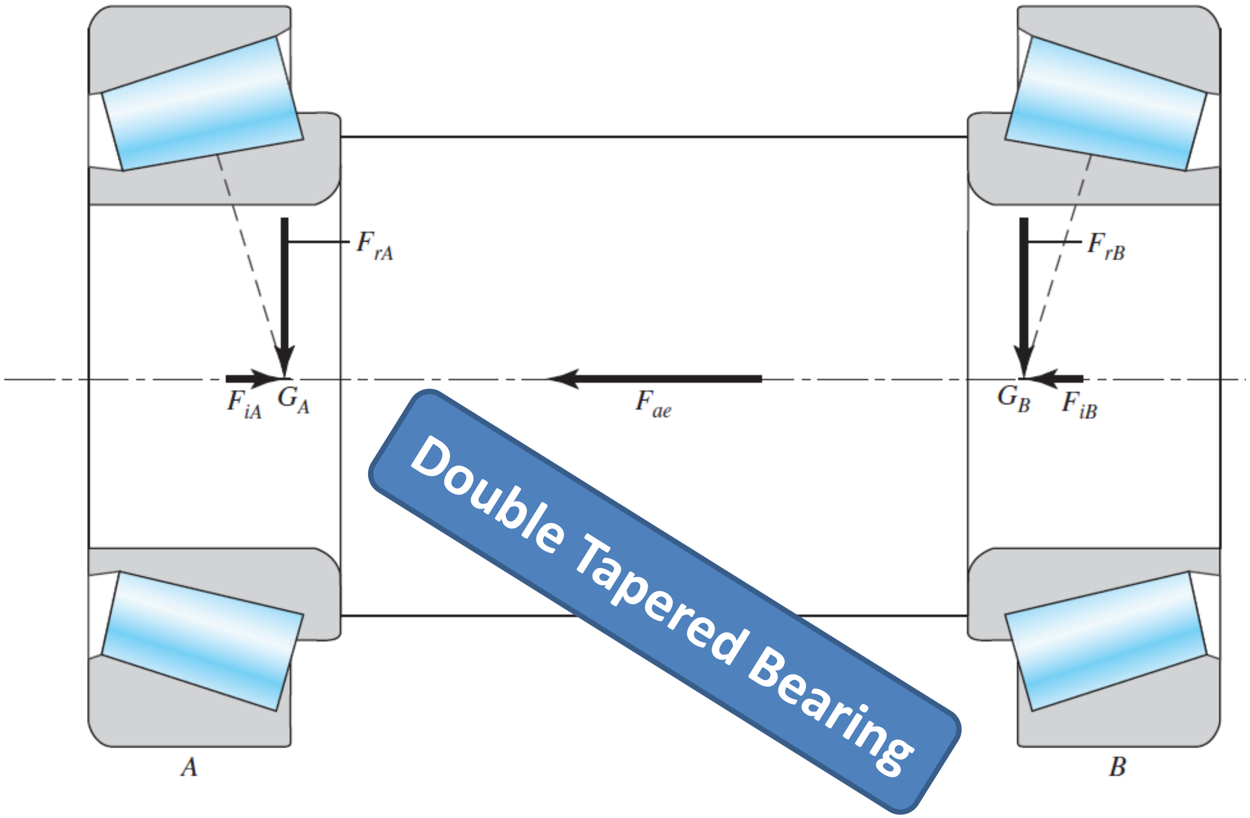
$$F_e = 0.4F_r + KF_a \quad (a)$$

Single Tapered Bearing

11.9 Selection of Tapered Roller Bearings

Figure 11–16

Direct-mounted tapered roller bearings, showing radial, induced thrust, and external thrust loads.



If $\quad F_{iA} \leq (F_{iB} + F_{ae})$

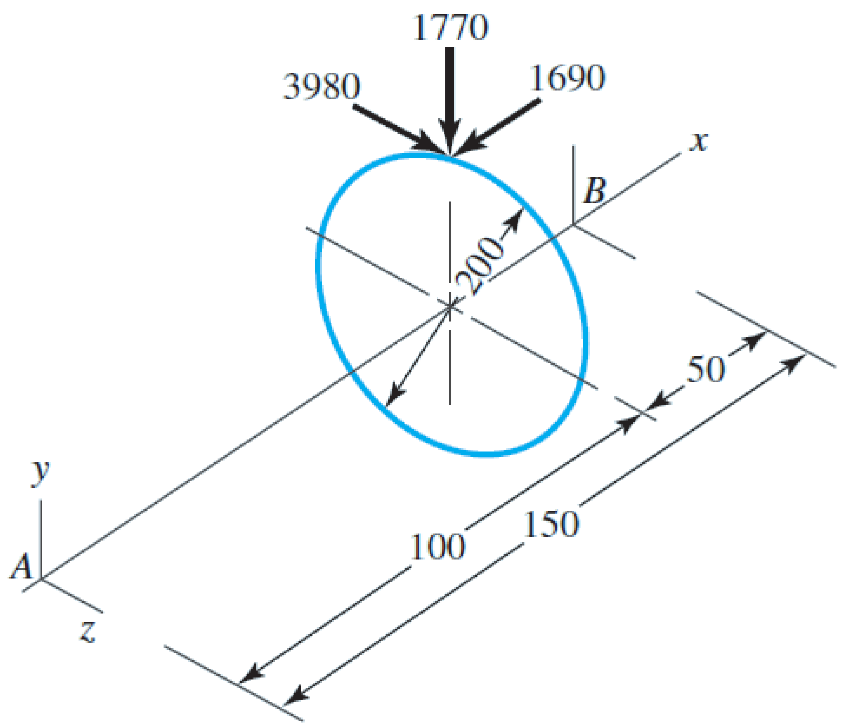
$$\begin{cases} F_{eA} = 0.4F_{rA} + K_A(F_{iB} + F_{ae}) & (11\text{–}19a) \\ F_{eB} = F_{rB} & (11\text{–}19b) \end{cases}$$

If $\quad F_{iA} > (F_{iB} + F_{ae})$

$$\begin{cases} F_{eB} = 0.4F_{rB} + K_B(F_{iA} - F_{ae}) & (11\text{–}20a) \\ F_{eA} = F_{rA} & (11\text{–}20b) \end{cases}$$

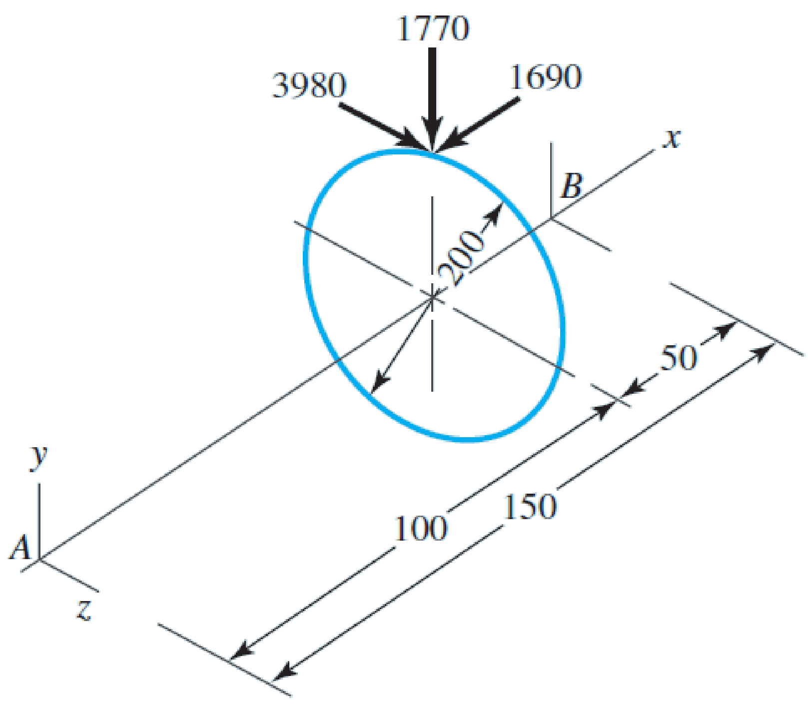
Example 11-8

The shaft depicted in Fig. 11–18*a* carries a helical gear with a tangential force of 3980 N, a radial force of 1770 N, and a thrust force of 1690 N at the pitch cylinder with directions shown. The pitch diameter of the gear is 200 mm. The shaft runs at a speed of 800 rev/min, and the span (effective spread) between the direct-mount bearings is 150 mm. The design life is to be 5000 h and an application factor of 1 is appropriate. If the reliability of the bearing set is to be 0.99, select suitable single-row tapered-roller Timken bearings.

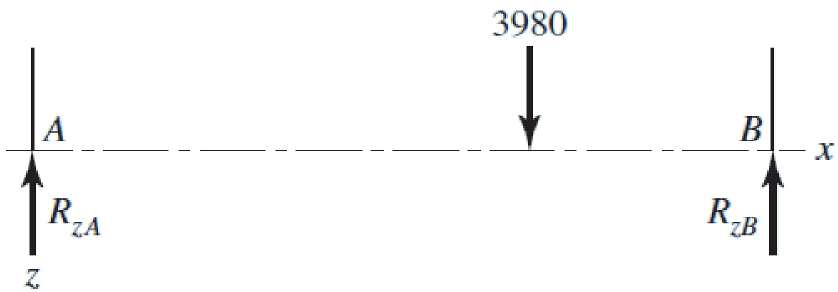


(*a*)

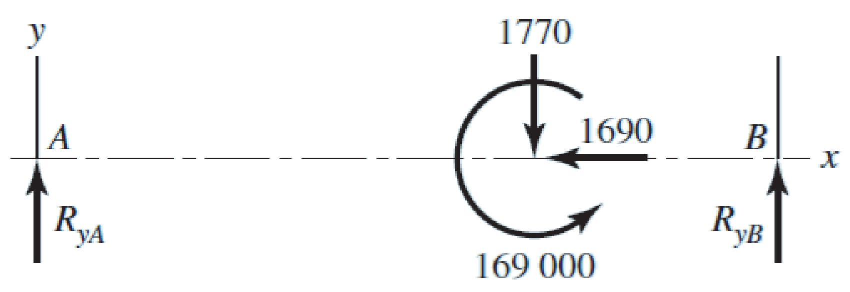
Example 11-8



(a)



(b)



(c)

11.5 Relating Load, Life, and Reliability

$$C_{10} \approx a_f F_D \left[\frac{x_D}{x_0 + (\theta - x_0)(1 - R_D)^{1/b}} \right]^{1/a} \qquad R \geq 0.90 \qquad (11\text{–}10)$$

Table 11–6

Typical Weibull Parameters for Two Manufacturers

Manufacturer	Rating Life, Revolutions	Weibull Parameters Rating Lives x_0	θ	b
1	$90(10^6)$	0	4.48	1.5
2	$1(10^6)$	0.02	4.459	1.483

Example 11-8

Trail 1

$$C_{10} = (1)(4651)\left[\frac{2.67}{(4.48)(1-0.995)^{2/3}}\right]^{3/10} = 11\,486\text{ N}$$

From Fig. 11–15, tentatively select type TS 15100 cone and 15245 cup, which will work: $K_A = 1.67$, $C_{10} = 12\,100$ N.

For bearing B, from Eq. (11–10), the catalog entry C_{10} should equal or exceed

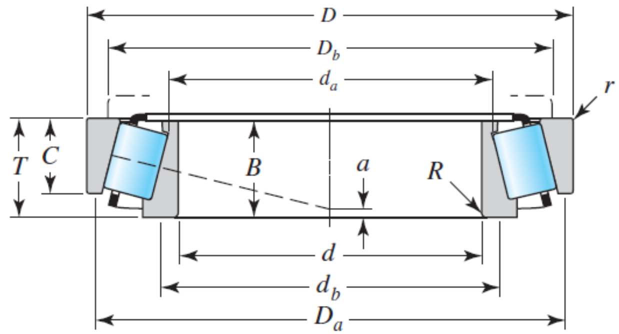
$$C_{10} = (1)2654\left[\frac{2.67}{(4.48)(1-0.995)^{2/3}}\right]^{3/10} = 6554\text{ N}$$

Tentatively select the bearing identical to bearing A, which will work: $K_B = 1.67$, $C_{10} = 12\,100$ N.

Figure 11 - 15

Catalog entry of single-row straight-bore Timken roller bearings

SINGLE-ROW STRAIGHT BORE



bore d	outside diameter D	width T	rating at 500 rpm for 3000 hours L_{10}: one-row radial N lbf	rating at 500 rpm for 3000 hours L_{10}: thrust N lbf	factor K	eff. load center a②	part numbers: cone	part numbers: cup	cone: max shaft fillet radius R①	cone: width B	cone: backing shoulder diameters d_b	cone: backing shoulder diameters d_a	cup: max housing fillet radius r①	cup: width C	cup: backing shoulder diameters D_b	cup: backing shoulder diameters D_a
25.400 1.0000	50.292 1.9800	14.224 0.5600	7210 1620	4620 1040	1.56	−3.3 −0.13	L44642	L44610	3.5 0.14	14.732 0.5800	36.0 1.42	29.5 1.16	1.3 0.05	10.668 0.4200	44.5 1.75	47.0 1.85
25.400 1.0000	50.292 1.9800	14.224 0.5600	7210 1620	4620 1040	1.56	−3.3 −0.13	L44643	L44610	1.3 0.05	14.732 0.5800	31.5 1.24	29.5 1.16	1.3 0.05	10.668 0.4200	44.5 1.75	47.0 1.85
25.400 1.0000	51.994 2.0470	15.011 0.5910	6990 1570	4810 1080	1.45	−2.8 −0.11	07100	07204	1.0 0.04	14.260 0.5614	30.5 1.20	29.5 1.16	1.3 0.05	12.700 0.5000	45.0 1.77	48.0 1.89
25.400 1.0000	56.896 2.2400	19.368 0.7625	10900 2450	5740 1290	1.90	−6.9 −0.27	1780	1729	0.8 0.03	19.837 0.7810	30.5 1.20	30.0 1.18	1.3 0.05	15.875 0.6250	49.0 1.93	51.0 2.01
25.400 1.0000	57.150 2.2500	19.431 0.7650	11700 2620	10900 2450	1.07	−3.0 −0.12	M84548	M84510	1.5 0.06	19.431 0.7650	36.0 1.42	33.0 1.30	1.5 0.06	14.732 0.5800	48.5 1.91	54.0 2.13

Figure 11 - 15

									cone				cup			
bore	outside diameter	width	rating at 500 rpm for 3000 hours L_{10}		factor	eff. load center	part numbers		max shaft fillet radius	width	backing shoulder diameters		max housing fillet radius	width	backing shoulder diameters	
			one-row radial	thrust			cone	cup								
d	D	T	N lbf	N lbf	K	a②			R①	B	d_b	d_a	r①	C	D_b	D_a
25.400 1.0000	50.292 1.9800	14.224 0.5600	7210 1620	4620 1040	1.56	−3.3 −0.13	L44643	L44610	1.3 0.05	14.732 0.5800	31.5 1.24	29.5 1.16	1.3 0.05	10.668 0.4200	44.5 1.75	47.0 1.85
25.400 1.0000	51.994 2.0470	15.011 0.5910	6990 1570	4810 1080	1.45	−2.8 −0.11	07100	07204	1.0 0.04	14.260 0.5614	30.5 1.20	29.5 1.16	1.3 0.05	12.700 0.5000	45.0 1.77	48.0 1.89
25.400 1.0000	56.896 2.2400	19.368 0.7625	10900 2450	5740 1290	1.90	−6.9 −0.27	1780	1729	0.8 0.03	19.837 0.7810	30.5 1.20	30.0 1.18	1.3 0.05	15.875 0.6250	49.0 1.93	51.0 2.01
25.400 1.0000	57.150 2.2500	19.431 0.7650	11700 2620	10900 2450	1.07	−3.0 −0.12	M84548	M84510	1.5 0.06	19.431 0.7650	36.0 1.42	33.0 1.30	1.5 0.06	14.732 0.5800	48.5 1.91	54.0 2.13
25.400 1.0000	58.738 2.3125	19.050 0.7500	11600 2610	6560 1470	1.77	−5.8 −0.23	1986	1932	1.3 0.05	19.355 0.7620	32.5 1.28	30.5 1.20	1.3 0.05	15.080 0.5937	52.0 2.05	54.0 2.13
25.400 1.0000	59.530 2.3437	23.368 0.9200	13900 3140	13000 2930	1.07	−5.1 −0.20	M84249	M84210	0.8 0.03	23.114 0.9100	36.0 1.42	32.5 1.27	1.5 0.06	18.288 0.7200	49.5 1.95	56.0 2.20
25.400 1.0000	60.325 2.3750	19.842 0.7812	11000 2480	6550 1470	1.69	−5.1 −0.20	15578	15523	1.3 0.05	17.462 0.6875	32.5 1.28	30.5 1.20	1.5 0.06	15.875 0.6250	51.0 2.01	54.0 2.13
25.400 1.0000	61.912 2.4375	19.050 0.7500	12100 2730	7280 1640	1.67	−5.8 −0.23	15101	15243	0.8 0.03	20.638 0.8125	32.5 1.28	31.5 1.24	2.0 0.08	14.288 0.5625	54.0 2.13	58.0 2.28
25.400 1.0000	62.000 2.4409	19.050 0.7500	12100 2730	7280 1640	1.67	−5.8 −0.23	15100	15245	3.5 0.14	20.638 0.8125	38.0 1.50	31.5 1.24	1.3 0.05	14.288 0.5625	55.0 2.17	58.0 2.28
25.400 1.0000	62.000 2.4409	19.050 0.7500	12100 2730	7280 1640	1.67	−5.8 −0.23	15101	15245	0.8 0.03	20.638 0.8125	32.5 1.28	31.5 1.24	1.3 0.05	14.288 0.5625	55.0 2.17	58.0 2.28

Example 11-8

Trail 2

For bearing A, from Eq. (11–10) the corrected catalog entry C_{10} should equal or exceed

$$C_{10} = (1)(4938)\left[\frac{2.67}{(4.48)(1 - 0.995)^{2/3}}\right]^{3/10} = 12\,195 \text{ N}$$

Although this catalog entry exceeds slightly the tentative selection for bearing A, we will keep it since the reliability of bearing B exceeds 0.995. In the next section we will quantitatively show that the combined reliability of bearing A and B will exceed the reliability goal of 0.99.

For bearing B, $F_{eB} = F_{rB} = 2654$ N. From Eq. (11–10),

$$C_{10} = (1)2654\left[\frac{2.67}{(4.48)(1 - 0.995)^{2/3}}\right]^{3/10} = 6554 \text{ N}$$