Chapter 11

Rolling-Contact Bearings

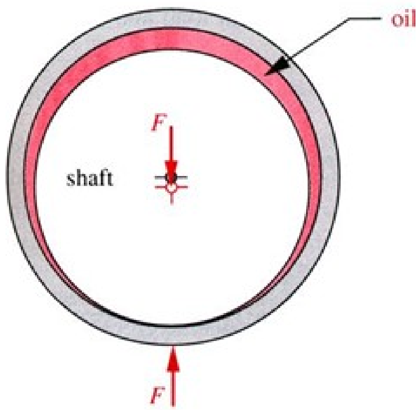
11-1. bearing Types

Function:

- Carry load in one or several directions while allowing frictionless motion in other directions

I. Ball Bearings
II. Roller Bearings

III. Journal Bearing



Rolling Bearing types

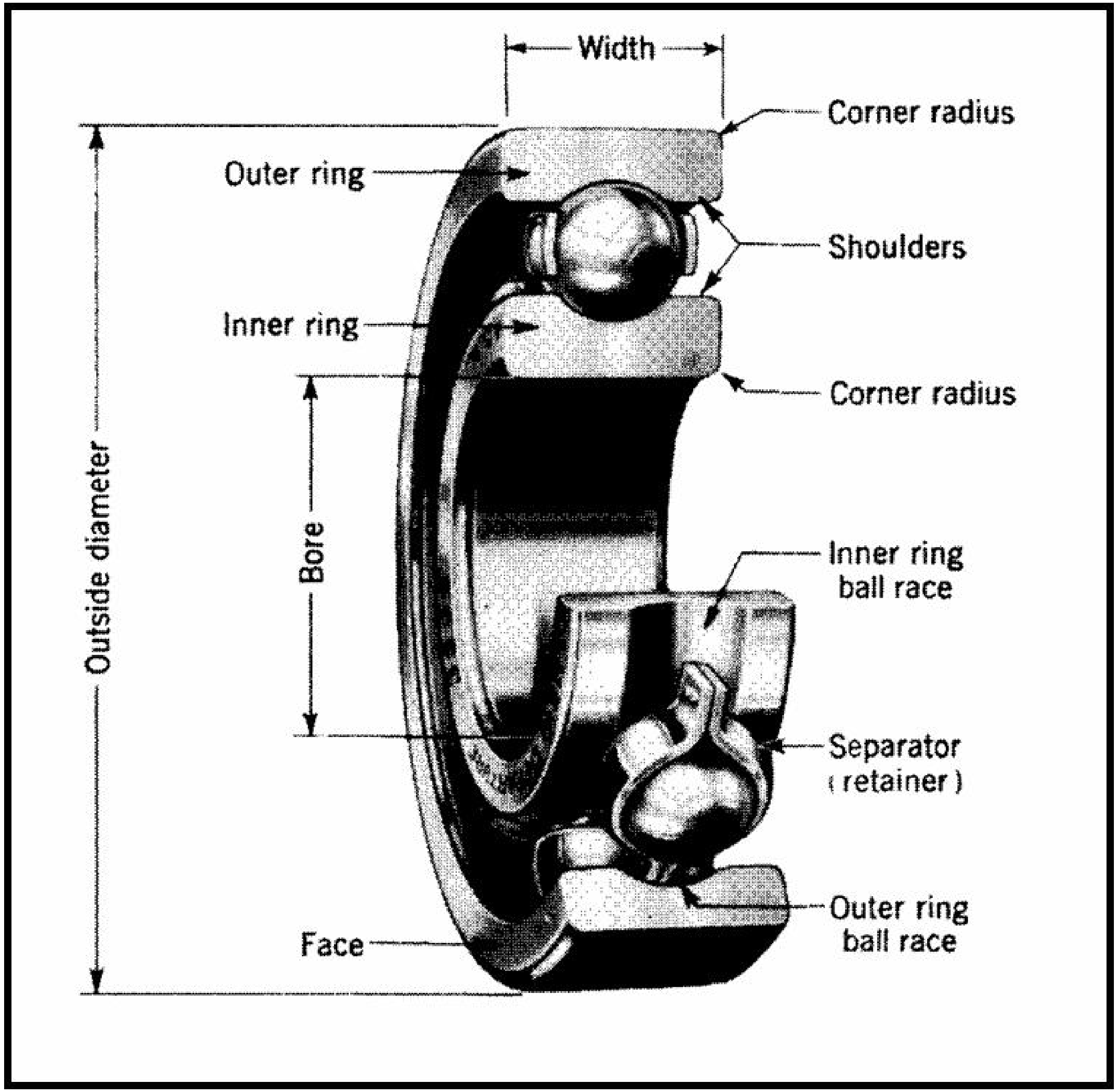
Ball bearing

Thrust bearing

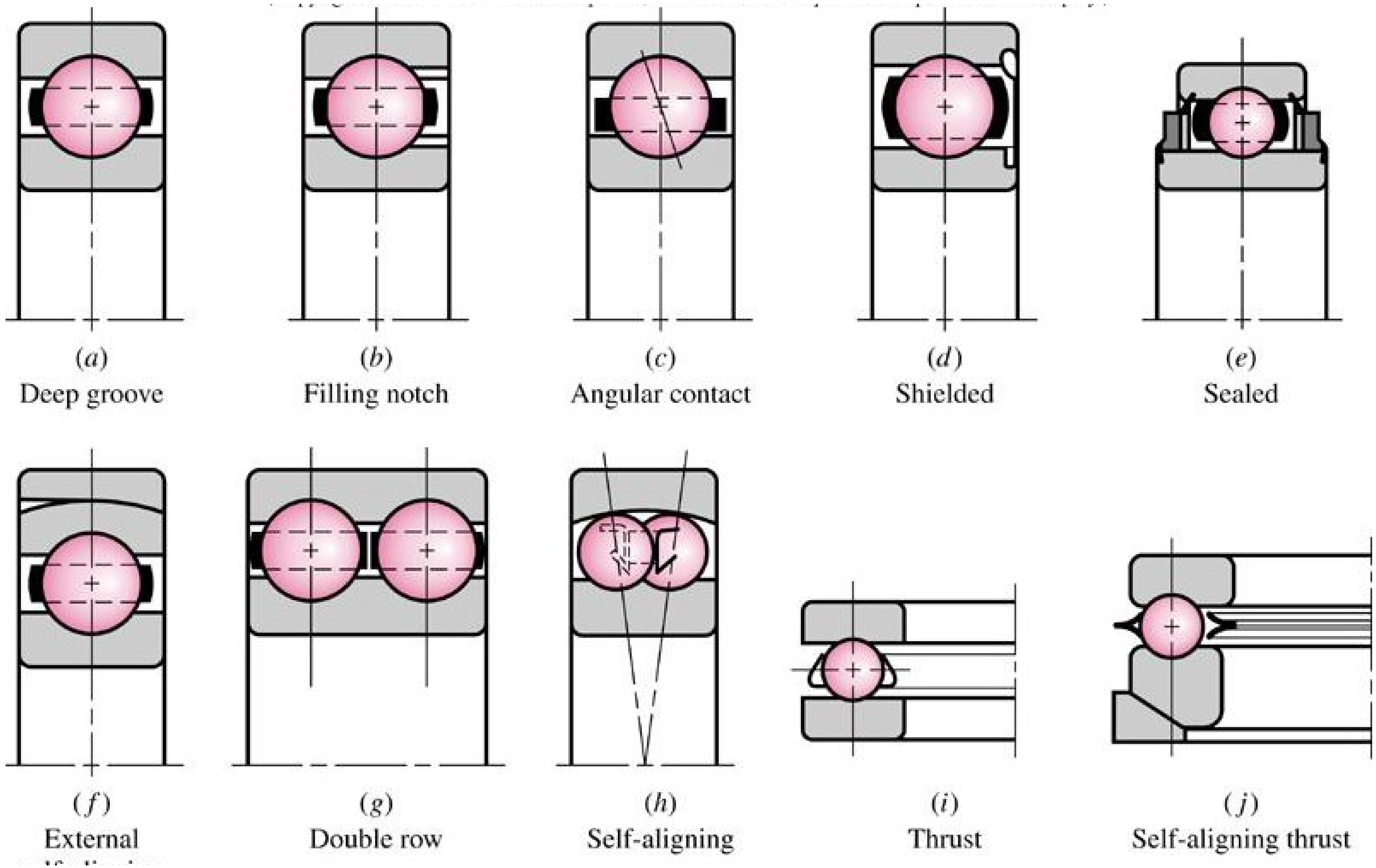
Tapered roller bearing

Needle roller bearing

Load is transferred through elements in rolling contact rather than sliding contact

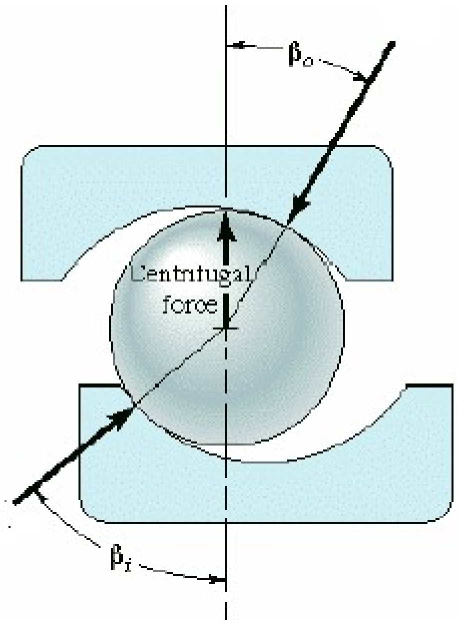


Types of ball bearings



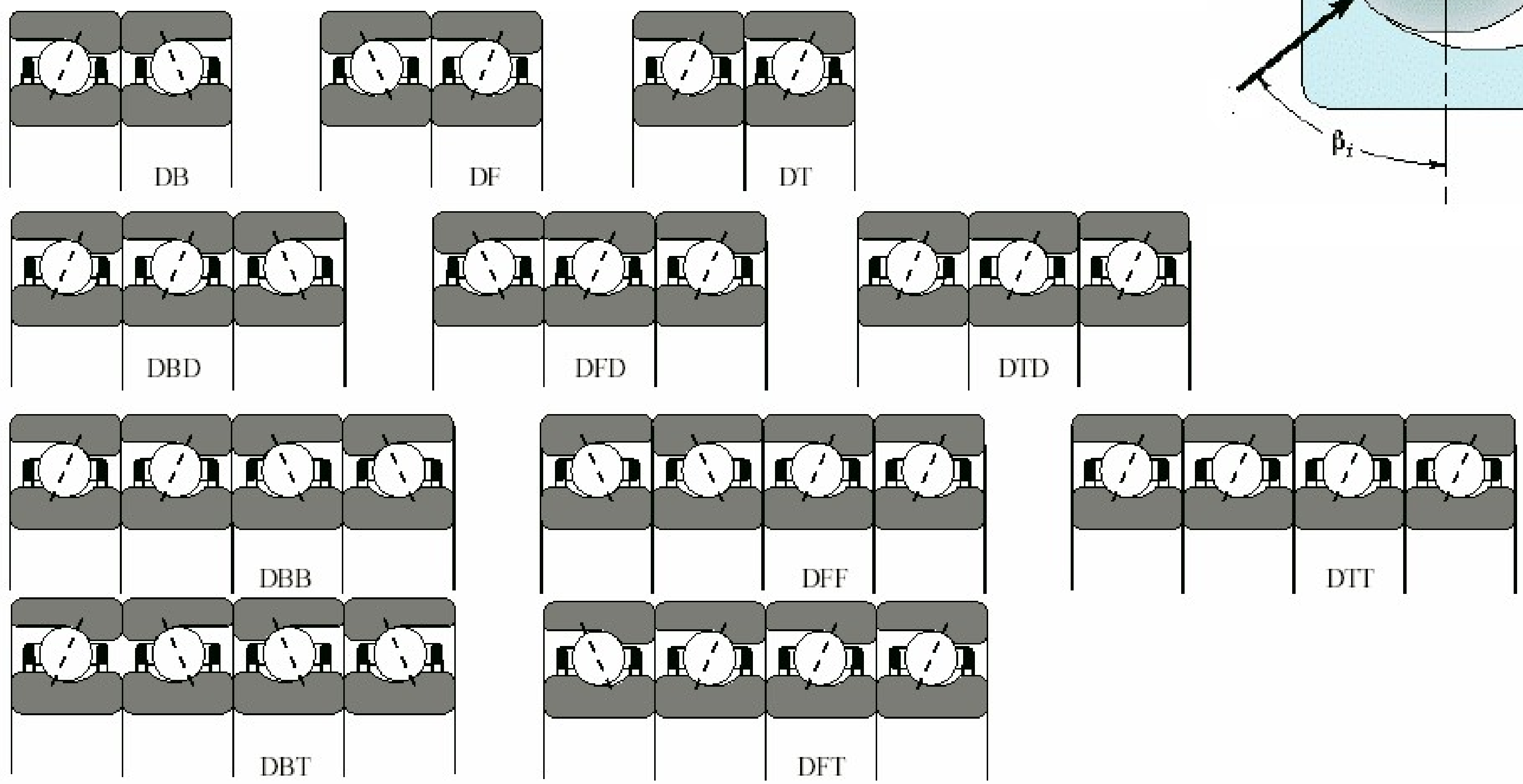
A *deep-groove* radial bearing is one in which the race dimensions are close to the dimensions of the balls that run in it.

Angular Contact Bearings



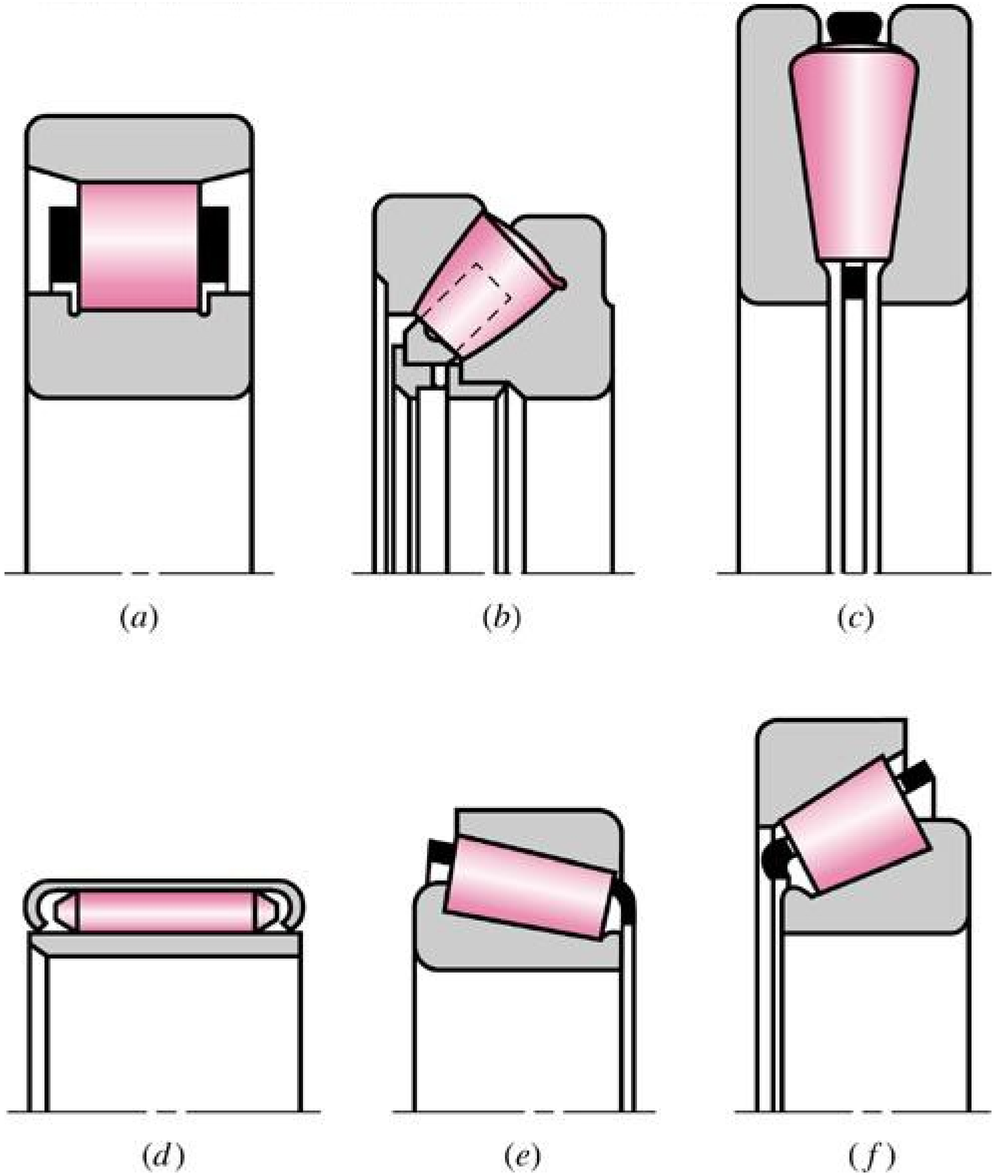
To attain high stiffness and load capacity:

✓ ***Two, three, or four (or more) bearings can be used forming Duplex, Triplex, or Quadruplex sets:***



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



Ball vs. Roller Bearings

• Roller bearings are stiffer and have a higher load capacity that comparably sized ball bearings. This is due to the type of contact, line contact for rollers vs. point contact for balls.

• Ball bearings have a lower friction. This also is a function of contact type.

• Ball bearings can often be operated at higher speeds.

• Most ball bearings can take modest axial load for “free”. **Only tapered rollers can take axial loads.**

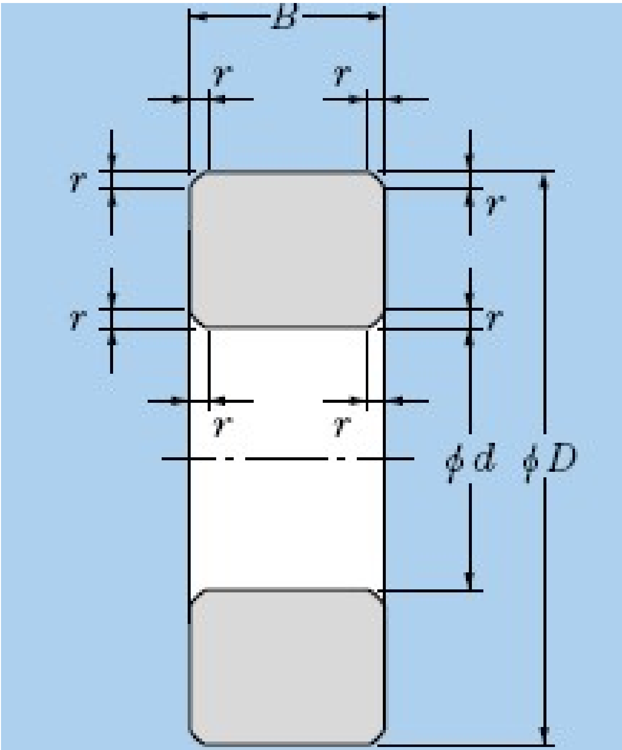
• Ball bearings are less expensive than roller bearings.

•**Straight roller bearings will carry greater radial load due to increased contact area. However, they require nearly perfect raceways and rollers to maintain alignment.**

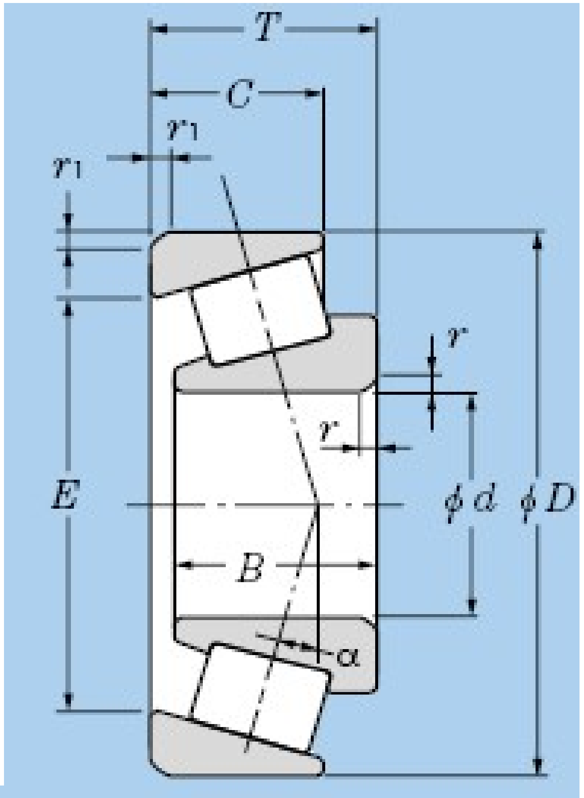
•**Spherical-roller thrust bearings are useful where heavy loads and misalignment occur.**

•Needle bearings very useful when radial space is limited.

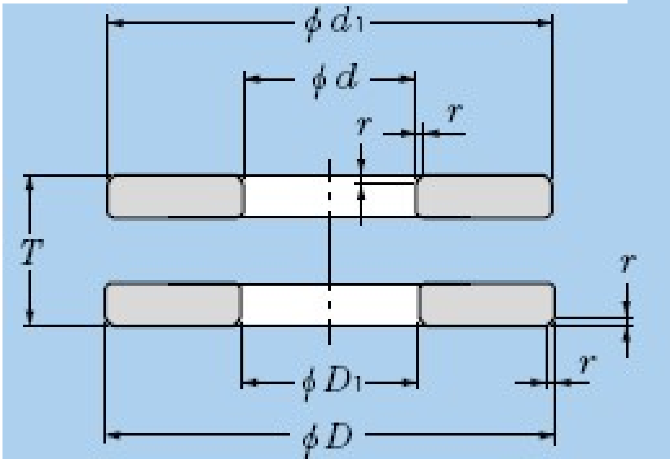
•**Tapered roller bearings combine the advantages of ball and straight roller bearings, since they can take radial and/or thrust load and have high load-carrying capacity.**



Radial bearings



Tapered roller bearings

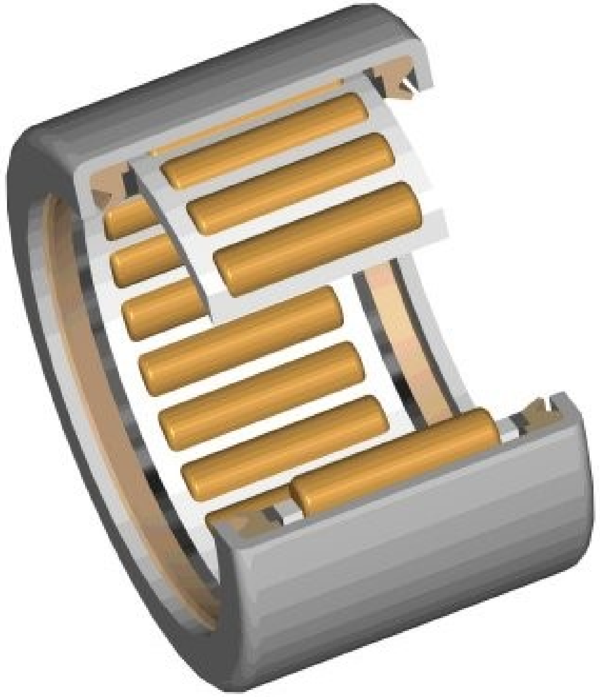


Single direction thrust bearings

Ex:Types of Roller Bearings

Tapered Roller Bearing

Spherical Roller Bearings

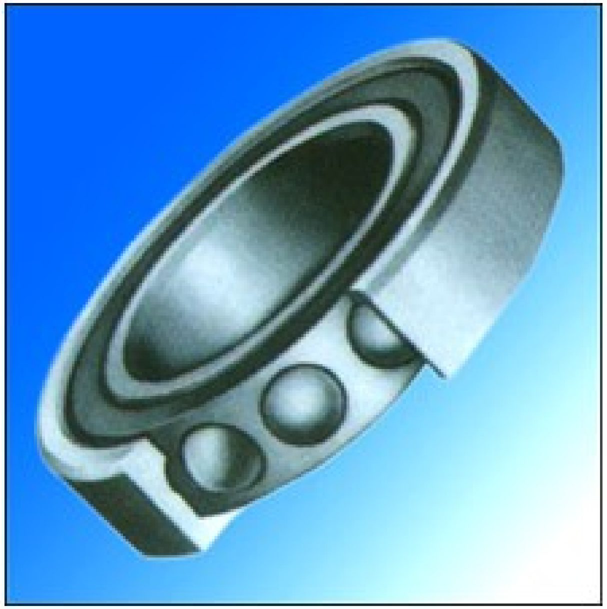


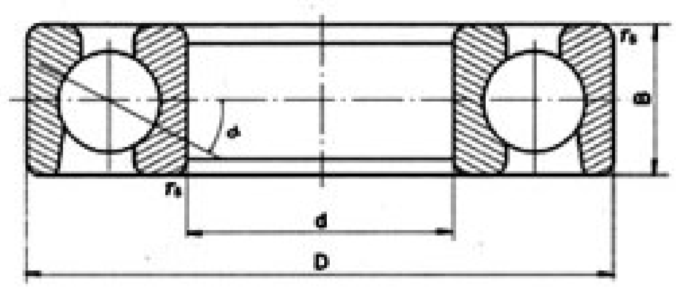
- **Needle Bearings**

Double
Deep
Groove

Thrust Bearings

- Angular contact ball bearing
  - Increased thrust load due to increase in lateral contact area between ball and race





Model 70000C(α =15°)

Model 70000AC(α =25°)

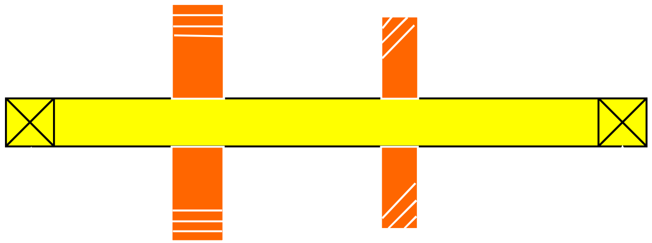
Model 70000B(α =40°)

The ball bearing inner ring is a press fit on the shaft so there is no relative movement between the two while the shaft is rotating.

Design Considerations

Bearings are selected from catalogs, before referring to catalogs you should know the followings:

- Bearing load – radial, thrust (axial) or both



Thrust load

- Bearing life and reliability
- Bearing speed (rpm)
- Space limitation
- Accuracy

11-2 Bearing Life

Common measures of bearing life are:

•No. of revs of inner ring (with outer ring stationery) until first evidence of fatigue.

•No. of hours of use at a standard speed until first evidence of fatigue. The ANTI-Friction Bearing Manufacturer's Association (AFBMA) sanctions the term rating life and defines it as the number of revs (or hours at constant speed) that 90% of a group of bearings will achieve before fatigue failure occurs.-Synonymous with minimum life, L_{10} life and B_{10} life

•Median life is the 50th percentile life of a group of bearings.

Median life = 4 to 5 times L_{10}life

Life – number of revolutions (or hours of operation at design speed) of the inner race that a certain percentage of the bearings will survive at a known load.

- **SKF rates bearings for 1 million revs, so that L10life is :**

$60 L_R n_R = 10^6$ revs. In Catalog

L_R rated life in hours

the $60 L_R n_R$ product produces a familiar number.

- **Timken uses $90(10^6)$ revs.**

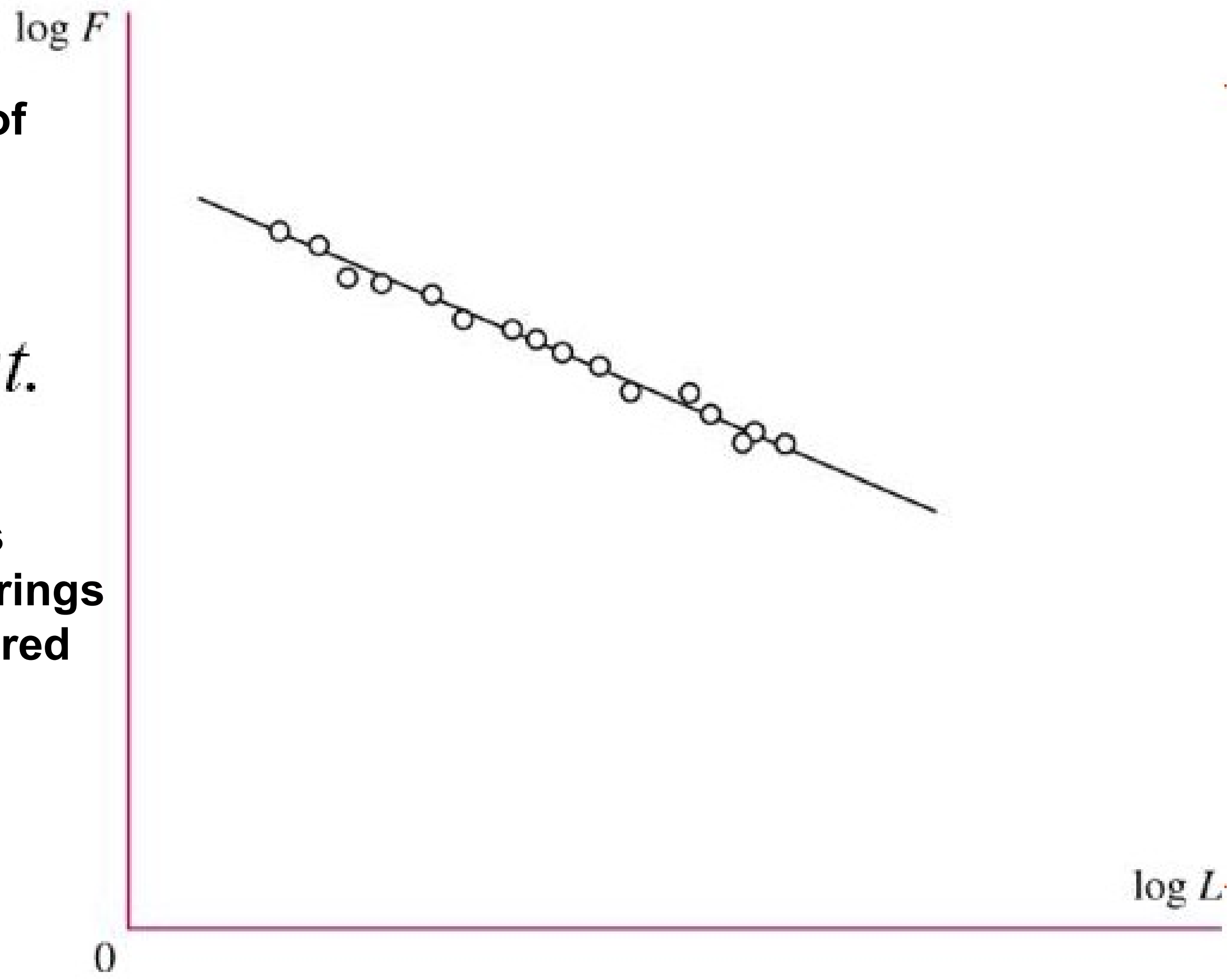
L_{10} Life - 10% of the bearings tested fail before a rated number of revolutions of the inner race at the rated load.

11-3 Bearing Load Life at Rated Reliability(constant reliability)

A regression equation of form

$$FL^{1/a} = const.$$

a= 3 for ball bearings
a = 10/3 for roller rearings (cylindrical and tapered roller)



ReliabilityTypical life-failure criterion at different loads (Reliability = 0.9)

A manufacturer may choose a rated cycle value of 10^6revs asthe rated life corresponding to a basic load rating. This is called the catalog load rating, C_{10}, to correspond to the 10th percentile rating life for the particular bearing. Then

$$F_1 L_1^{1/a} = F_2 L_2^{1/a}$$

OR

units of L are revs

$$C_{10} L_{10}^{1/a} = F\, L^{1/a}$$

C_{10} is the catalog basic dynamic load rating corresponding to L_R hours of life at the speed of n_R rpm.

$$C_{10}\,(L_R n_R 60)^{1/a} = F_D\,(L_D n_D 60)^{1/a}$$

- C_{10}: catalog rating
- L_R: rating life in hours
- n_R: rating speed
- F_D: desired radial load, lb or kN
- L_D: desired life, hours
- n_D: desired speed, r/min

Solving for C_{10} gives

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

$$C_{10} = F_R$$

Ex:Select a deep groove ball bearing for a desired life of 5000 hours at 1725 rpm with 90% reliability. The bearing radial load is 400 lb.

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

$$= 400 \left[\frac{5000(1725)60}{10^6} \right]^{1/3} = 3211 \text{ lb} = 14.3 \text{ kN}$$

			Fillet	Shoulder		Load Ratings, kN			
Bore,	OD,	Width,	Radius,	Diameter, mm		Deep Groove		Angular Contact	
mm	mm	mm	mm	d_S	d_H	C_{10}	C_0	C_{10}	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
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

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

11-4 Bearing Survival: The Reliability-Life Trade-Off

▪ Constant Load and different Reliability than the rated

The distribution of bearing failure can be best approximated by ***two and three parameter Weibull distribution***

life measured is expressed in dimensionless form

$$x = L/L_{10}$$

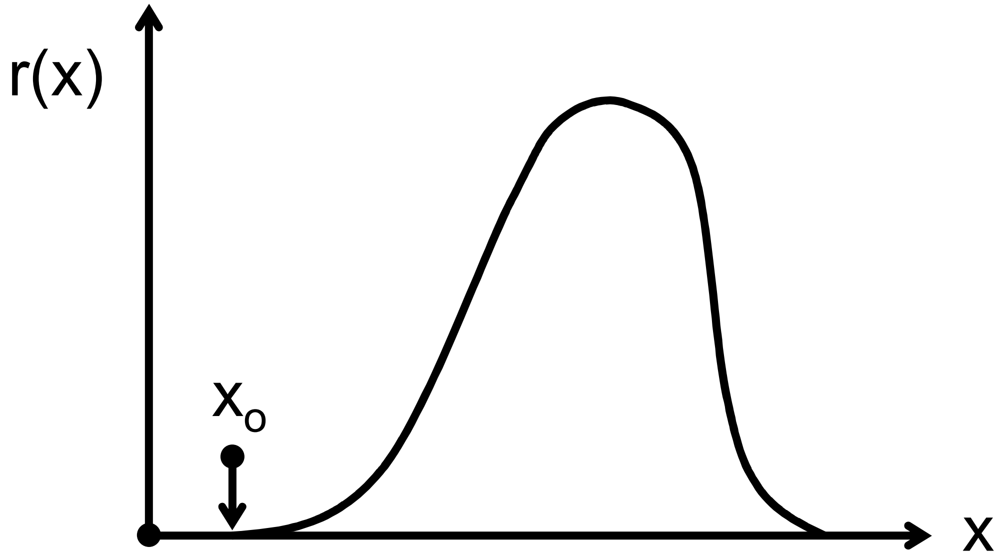
then the reliability, R is

$$R = \exp\left[-\left(\frac{x - x_0}{\theta - x_0}\right)^b\right]$$

where x0is the guaranteed or minimum life, θ is a characteristic parameter corresponding to the 63.2121 percentile, b is a skewness shape parameter

Reliability often well-predicted via Weibull distribution

- x_o = minimum guaranteed value of x
- θ = corresponds to 63.2 percentile of the variate (stochastic variable)
- b = a shape parameter (controls skew, large = right)



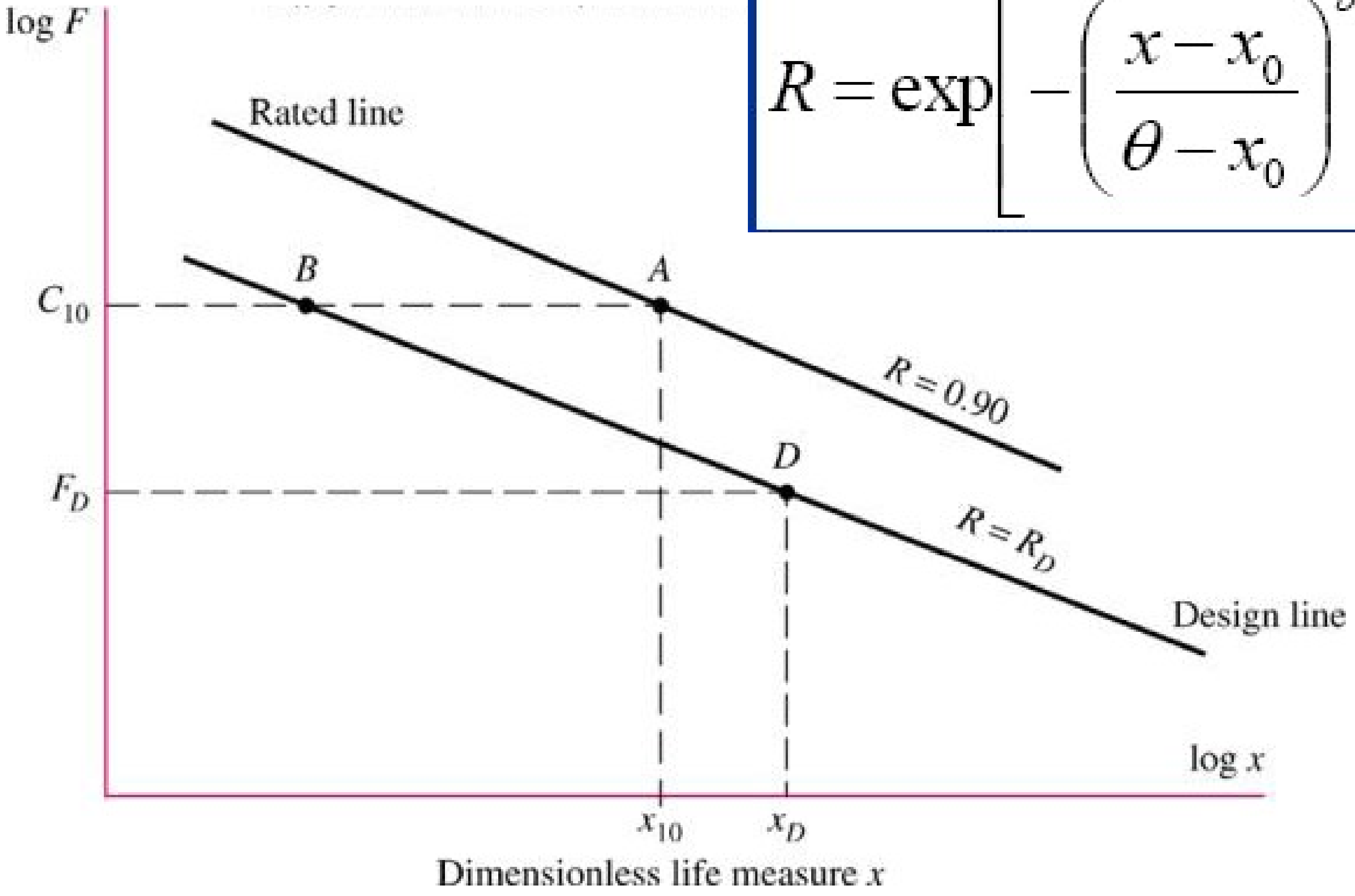
$$x = \frac{L}{L_{10}}$$

$$R(x) = \exp\left[-\left(\frac{x - x_o}{\theta - x_o} \right)^b \right]$$

This is for common load on bearings

Commonly used to fit experimental data; b & θ come from fit

$$R = \exp\left[-\left(\frac{x - x_0}{\theta - x_0}\right)^b\right]$$



At constant load, the life measure distribution is as shown in this graph.Such a distribution is right skewed

11-5 Load-Life-Reliability Trade-Off

$$F_B x_B^{1/a} = F_D x_D^{1/a}$$

$$F_B = F_D \left(\frac{x_D}{x_B} \right)^{1/a}$$

$$R_D = \exp\left[-\left(\frac{x_B - x_0}{\theta - x_0} \right)^b \right]$$

$$x_B = x_0 + (\theta - x_0)\left(\ln \frac{1}{R_D} \right)^{1/b}$$

$$F_B = F_D\left(\frac{x_D}{x_B}\right)^{1/a} = F_D\left[\frac{x_D}{x_0 + (\theta - x_0)(\ln 1/R_D)^{1/b}}\right]^{1/a}$$

$$F_B = C_{10}$$

$$C_{10} = F_D\left[\frac{x_D}{x_0 + (\theta - x_0)(\ln 1/R_D)^{1/b}}\right]^{1/a}$$

- Equation can be written

$$C_{10} = F_D\left[\frac{x_D}{x_0 + (\theta - x_0)(1 - R_D)^{1/b}}\right]^{1/a} \Rightarrow R \geq 0.90$$

$$C_{10} = a_f F_D\left[\frac{x_D}{x_0 + (\theta - x_0)(\ln 1/R_D)^{1/b}}\right]^{1/a} \qquad (11\text{–}6)$$

Ex: Select a deep groove ball bearing for a desired life of 5000 hours at 1725 rpm ***with 99% reliability***. The bearing radial load is 400 lb.

For 90% reliability C_{10} = 14.3 kN

30 mm Bore deep groove bearing. The Weibull parameters are b=1.483, x_0=0.02 and θ-x_0=4.439

Use 99% reliability, R = .99

$$F_R = F_D \left\{ \frac{(L_D n_D / L_R n_R)}{0.02 + 4.439[\ln(1/R)]^{1/1.483}} \right\}^{1/a} = 23.7 \text{ kN}$$

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}	Deep Groove C_0	Angular Contact C	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
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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

Select a 35 mm bearing instead of 30 mm for 90% reliability

❖Shafts generally have two bearings. Often these bearings are different. If the bearing reliability of the shaft with its pair of bearings is to be R, *then* R *is related to the* individual bearing reliabilities R_A *and* R_B *by*

$$R = R_A R_B$$

Ex: If a shaft is assembled with 4 bearings, each having a reliability of 90%, then the reliability of the system is $(0.9)^4$ =0.65 = 65%. This points out the need to select bearings with higher than 90% reliability.

The outer ring is a close push fit in the housing for assembly reasons and also to allow slight axial movement to accommodate manufacturing tolerances and differential thermal expansion between the shaft and housing.

Size tolerance of the shaft and housing should be equal to those of the bearing bore and OD.

Roundness and taper should be held to one-half of size tolerance.

Surface finish should be held as close as possible.