The University of Tennessee at Martin

MARTIN School of Engineering

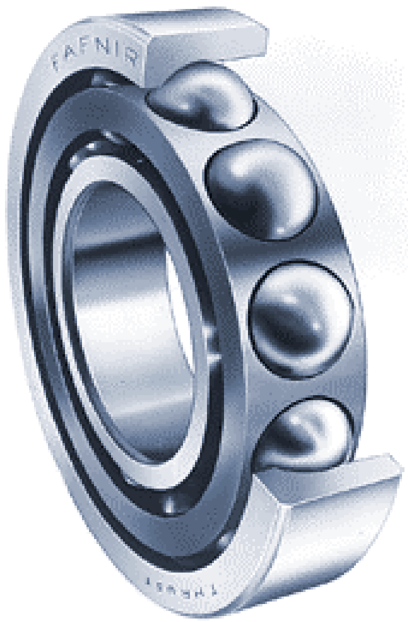
Rolling Contact Bearings

Lecture 23

Engineering 473
Machine Design

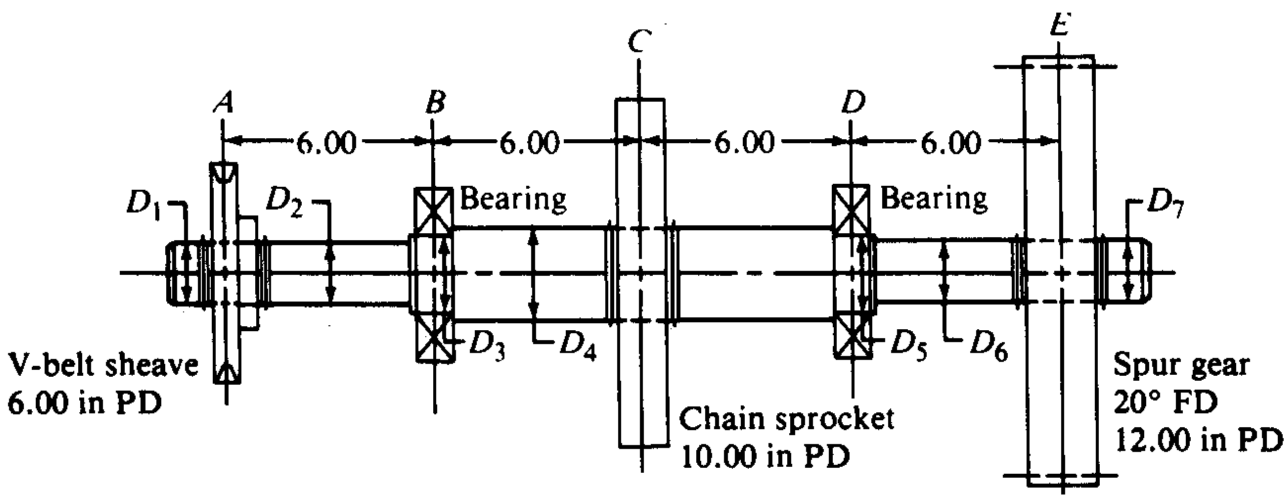
MARTIN

Why Rolling Contact Bearings?

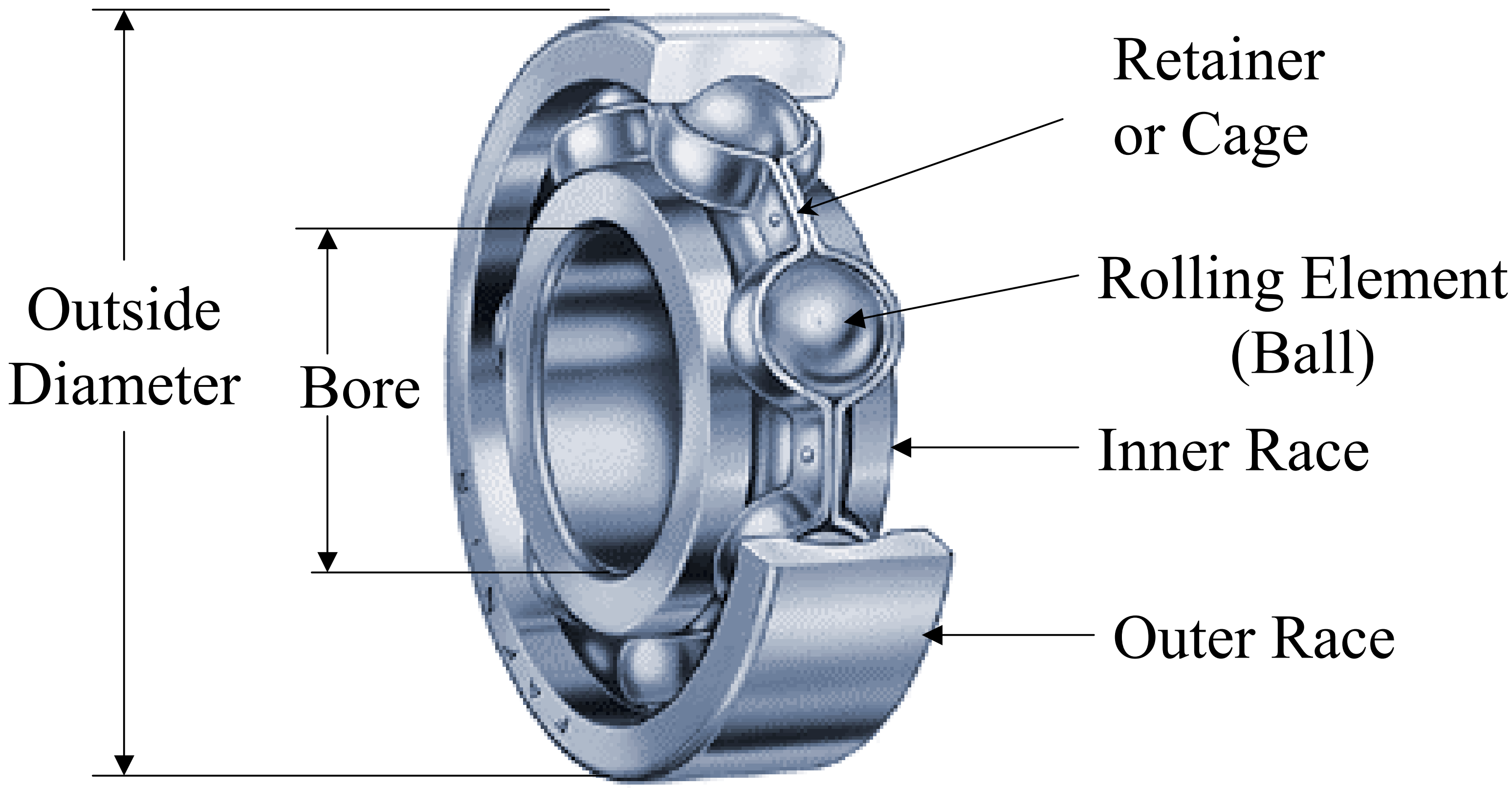


Rolling contact bearings are used to minimize the friction associated with relative motion performed under load.

Typical applications include supporting shafts.

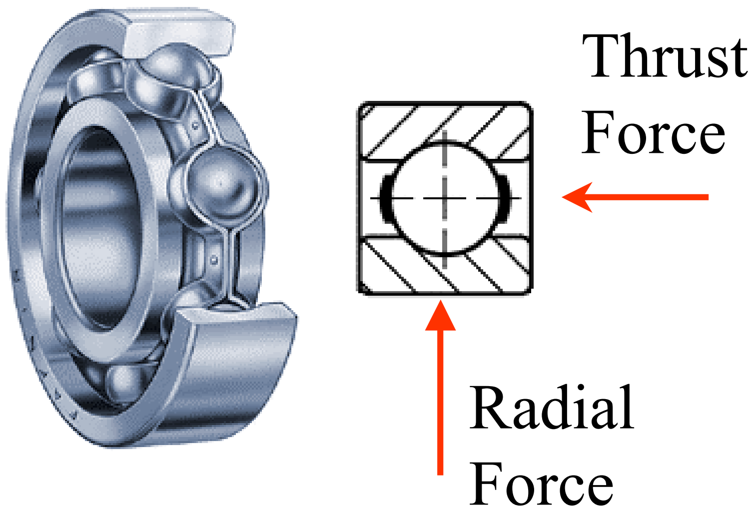


Bearing Nomenclature

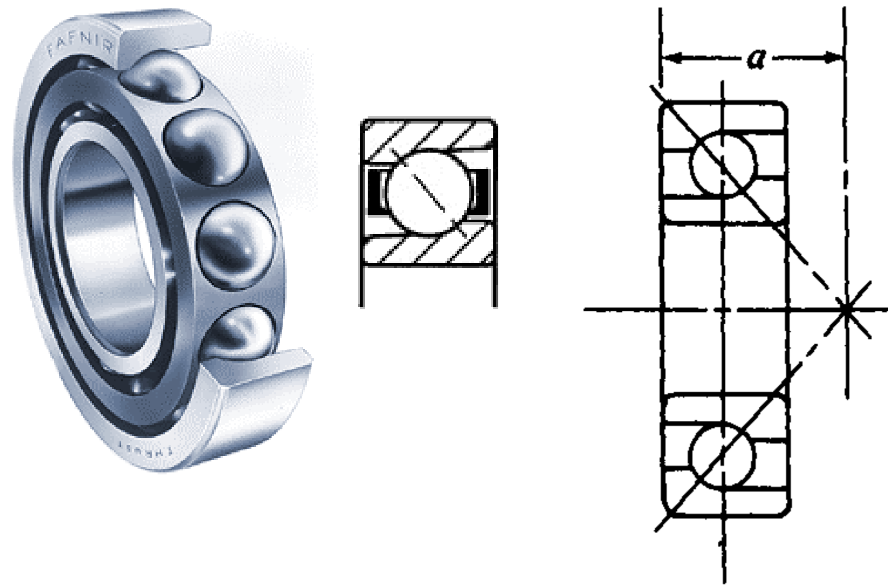


Inner and outer races are typically pressed onto the shaft or hub with a slight interference fit to make them move with the shaft (inner race) or remain stationary (outer race).

Ball Bearings



Radial Ball

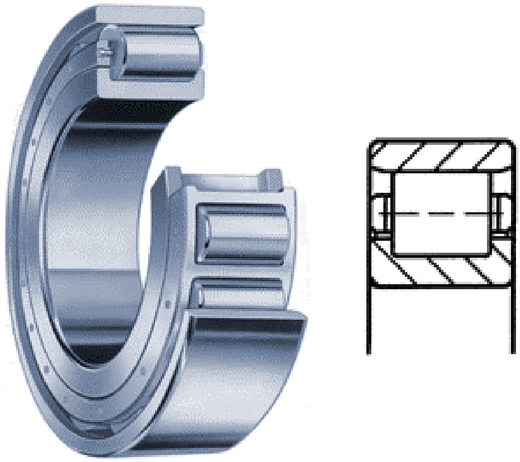


Angular Ball

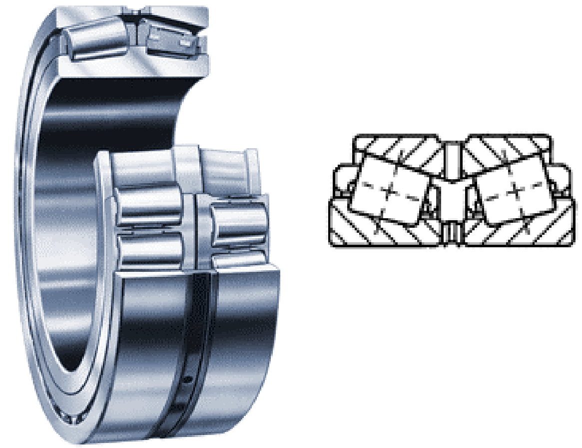
Angular ball bearings have higher thrust load capacity in one direction than due radial ball bearings.

www.torrington.com/products

Roller Bearings



Radial Cylindrical



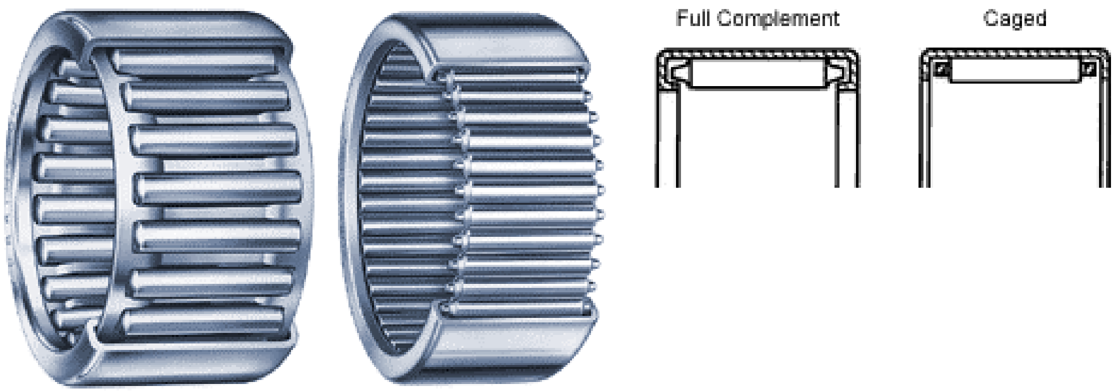
Radial Tapered

Roller bearings have higher load capacity than ball bearings.

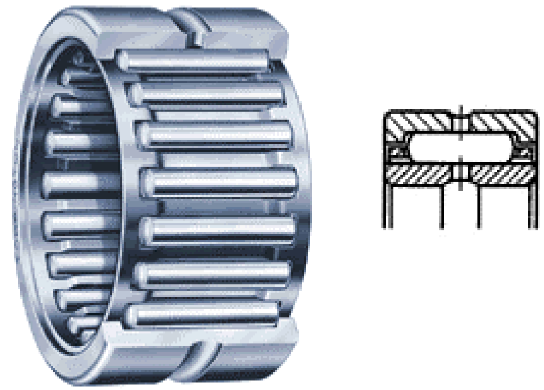
Thrust

www.torrington.com/products

Needle Bearings

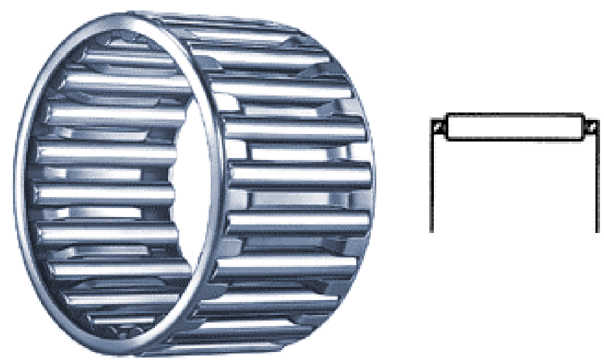


Drawn Cup



Heavy Duty

Thrust



Gage

Needle bearings have very high load ratings and require less space.

www.torrington.com/products

Other Types of Bearings

Sperical

Polymer
Bearings

www.igus.com/iglide/iglide.htm

Bronze Bushings

Rolling Contact Bearing Materials

TABLE 14–2 Comparison of bearing materials

	Material			
	Silicon nitride	52100 steel	440C stainless steel	M50 steel
Room-temperature hardness, HRC	78	62	60	64
Room-temperature elastic modulus	45×10^6 psi 310 GPa	30×10^6 psi 207 GPa	29×10^6 psi 200 GPa	28×10^6 psi 193 GPa
Maximum operating temperature	2 200°F 1 200°C	360°F 180°C	500°F 260°C	600°F 320°C
Density, kg/m^3	3 200	7 800	7 800	7 600

The space shuttle uses silicon nitride balls in the oxygen and hydrogen turbopumps.

Mott, Table 14-2

Static Load Capacity

- The static load rating is the load at which permanent deformation of a race or ball will occur.
- The bearing is not rotating when this measurement is made.
- The static load rating is usually designated at C_0.

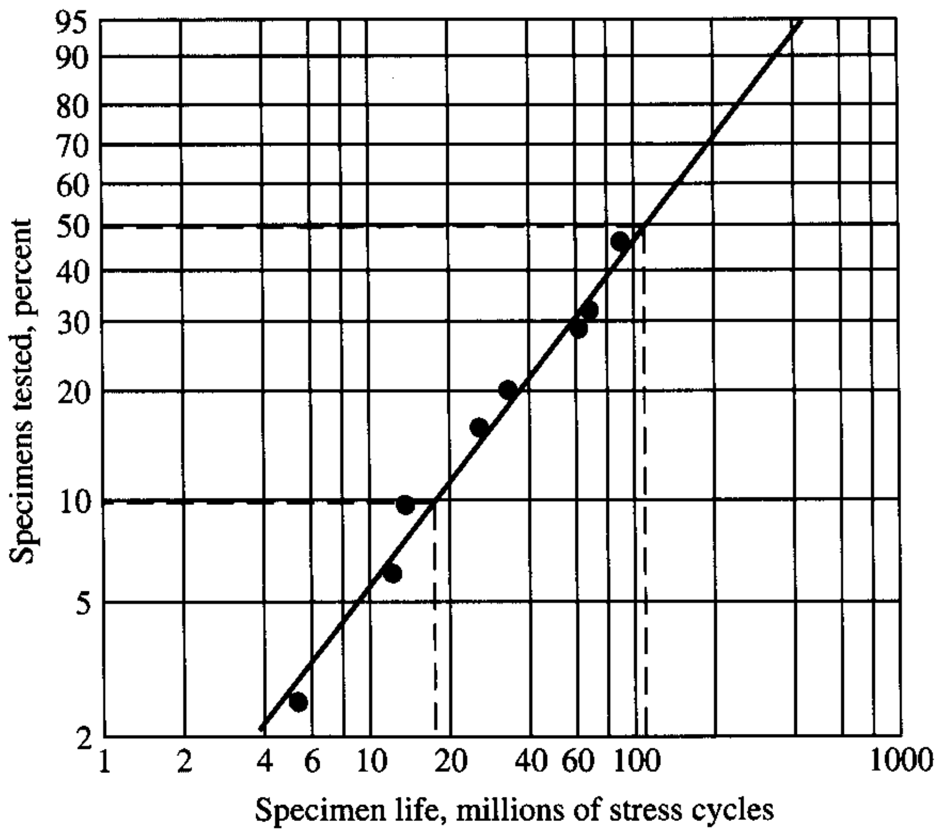
Bearing Life

Bearings of the same type, size, and material will exhibit wide variations in 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.

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

Statistical Nature of Life Estimates



Typical Weibull Plot of Bearing Fatigue Failures

10% of the bearings tested had failed by 18 million cycles.

50% of the bearings tested had failed by 100+ million cycles.

B.J. Hamrock and W.J. Anderson, Rolling-Element Bearings, NASA Reference Publication 1105, 1983.

Load/Life Relationship

$$\frac{L_2}{L_1} = \left(\frac{F_1}{F_2}\right)^k$$

$k = 3$ for ball bearings
$= 3.33$ for roller bearings

Basic Dynamic Load Rating

$$L_1 = 1{,}000{,}000 \text{ revolutions}$$

$$F_1 = C = \text{Basic Dynamic Load Rating}$$

The **Basic Dynamic Load Rating** is that load which will cause 10% of a sample of bearings to fail at or before 1 million revolutions. (i.e. 90% of bearings would achieve at least 1 million revolutions at this load).

Rated Load/Life Relationship

$$\frac{L_2}{L_1} = \left(\frac{F_1}{F_2}\right)^k$$

Bearing manufacturers provide one set of data relating load and life.

$$L_2 = \left(\frac{C}{F_2}\right)^k \times 10^6 \text{ Revolutions}$$

This equation is used to find the life at different loads.

Example Bearing Data

Principal dimensions			Basic load ratings Dynamic	Static	Allowable load limit	Speed ratings Grease	Oil	Mass	Designation
d_b	d_a	b_w	C	C_0	w_{all}				
mm			N		N			kg	
in.			lbf		lbf	rpm		lbm	—
15	**35**	**11**	**12 500**	**10 200**	**1 200**	**18 000**	**22 000**	**0.047**	**NU 202 EC**
0.5906	1.3780	0.4331	2 810	2 290	274			0.10	
	42	**13**	**19 400**	**15 300**	**1 860**	**16 000**	**19 000**	**0.086**	**NU 302 EC**
	1.6535	0.5118	4 360	3 440	418			0.19	
20	**47**	**14**	**25 100**	**22 000**	**2 750**	**13 000**	**16 000**	**0.11**	**NU 204 EC**
0.7874	1.8504	0.5512	5 640	4 950	618			0.24	
	52	**15**	**30 800**	**26 000**	**3 250**	**12 000**	**15 000**	**0.15**	**NU 304 EC**
	2.0472	0.5906	6 920	5 850	731			0.33	
25	**52**	**15**	**28 600**	**27 000**	**3 350**	**11 000**	**14 000**	**0.13**	**NU 205 EC**
0.9843	2.0472	0.5906	6 430	6 070	753			0.29	
	62	**17**	**40 200**	**36 500**	**4 550**	**9 500**	**12 000**	**0.24**	**NU 305 EC**
	2.4409	0.6693	9 040	8 210	1 020			0.53	
30	**62**	**16**	**38 000**	**36 500**	**4 450**	**9 500**	**12 000**	**0.20**	**NU 206 EC**
1.811	2.4409	0.6299	8 540	8 210	1 020			0.44	
	72	**19**	**51 200**	**48 000**	**6 200**	**9 000**	**11 000**	**0.36**	**NU 306 EC**
	2.8346	0.7480	11 500	10 800	1 390			0.79	
35	**72**	**17**	**48 400**	**48 000**	**6 100**	**8 500**	**10 000**	**0.30**	**NU 207 EC**
1.3780	2.8346	0.6693	10 900	10 800	1 370			0.66	
	80	**21**	**64 400**	**63 000**	**8 150**	**8 000**	**9 500**	**0.48**	**NU 307 EC**
	3.1496	0.8268	14 500	14 200	1 830			1.05	
40	**80**	**18**	**53 900**	**53 000**	**6 700**	**7 500**	**9 000**	**0.37**	**NU 208 EC**
1.5748	3.1496	0.7087	12 100	11 900	1 510			0.82	
	90	**23**	**80 900**	**78 000**	**10 200**	**6 700**	**8 000**	**0.65**	**NU 308 EC**
	3.5433	0.9055	18 200	17 500	2 290			1.05	
45	**85**	**19**	**60 500**	**64 000**	**8 150**	**6 700**	**8 000**	**0.43**	**NU 209 EC**
1.7717	3.3465	0.7480	13 600	14 400	1 830			0.95	
	100	**25**	**99 000**	**100 000**	**12 900**	**6 300**	**7 500**	**0.90**	**NU 309 EC**
	3.9370	0.9843	22 300	22 500	2 900			2.00	
50	**90**	**20**	**64 400**	**69 500**	**8 800**	**6 300**	**7 500**	**0.48**	**NU 210 EC**
1.9685	3.5433	0.7874	14 500	15 600	1 980			1.05	
	110	**27**	**110 000**	**112 000**	**15 000**	**5 000**	**6 000**	**1.15**	**NU 310 EC**
	4.3307	1.0630	24 700	25 200	3 370			2.55	

SKF Catalog

Outer Race Rotation

Manufacturer's data is normally based on a rotating inner race and a stationary outer race.

A rotating outer race and a stationary inner race will have a lower life.

The Anti-Friction Bearing Manufacturer's Association (AFBMA) has developed a standard equation for computing an equivalent radial load that takes this into account.

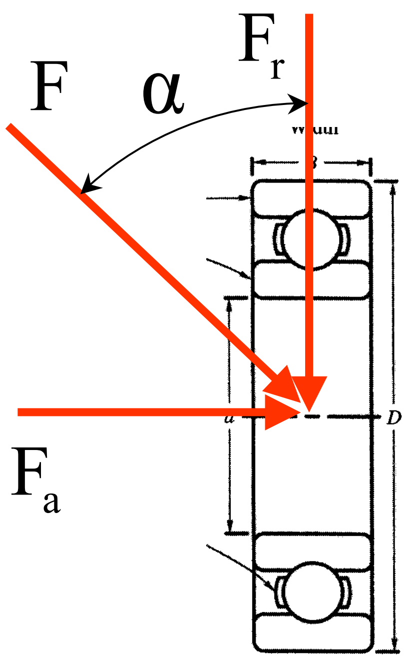
$$F_e = XVF_r$$

$$V = 1.0 \text{ Rotating Inner Race}$$

$$V = 1.2 \text{ Rotating Outer Race}$$

Combined Radial and Thrust Loads

The AFBMA has also developed a standard equation for computing an equivalent radial load.



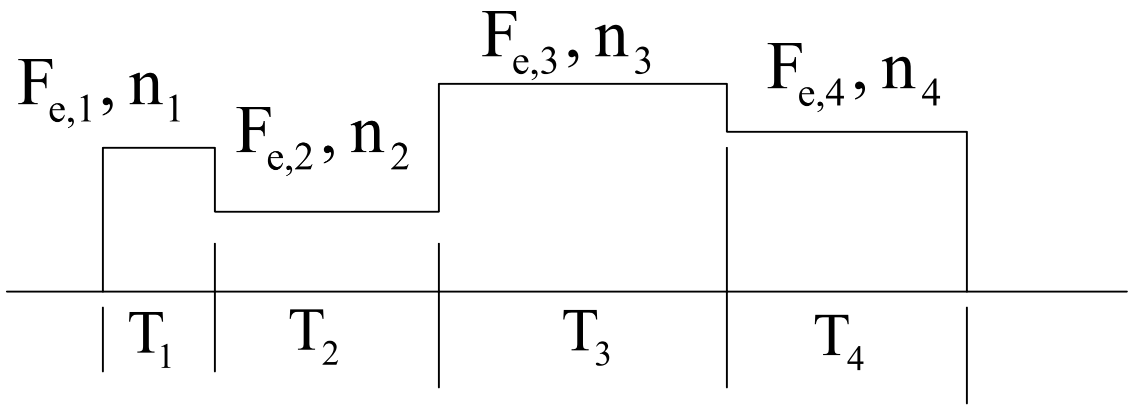
$$F_e = XVF_r + YF_a$$

$V = 1.0$ Rotating Inner Race

$V = 1.2$ Rotating Outer Race

X and Y depend on the bearing geometry and are given in manufacturers data books

Variable Loads



$F_{e,i} \equiv$ Equivalent radial load for ith event

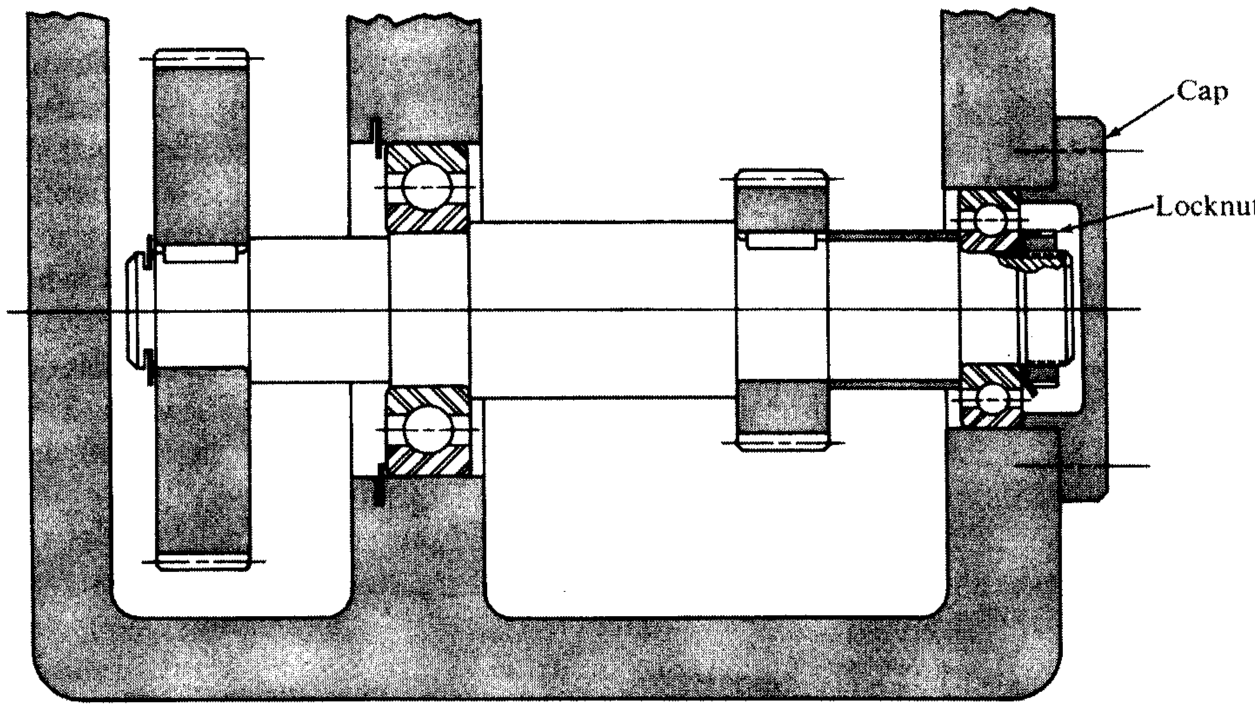
$n_i \equiv$ Speed of the ith event

$T_i \equiv$ Time period of the ith event

$$F_e \equiv \left[\frac{\sum_{i=1}^{j} T_i n_i \left(F_{e,i}\right)^k}{\sum_{i=1}^{j} T_i n_i} \right]^{1/k}$$

Mounting Bearings

Most manufacturer's catalogs specify the limiting dimensions for the shaft and housing bore. These are generally controlled to within a few thousands of an inch.



Mott, Fig. 14-13

Assignment

1. A certain application requires a bearing to last for 1800 h with a reliability of 90 percent. What should be the rated life of the bearing?

2. A ball bearing is to be selected to withstand a radial load of 4 kN and have an L_{10} life of 1200 h at a speed of 600 rev/min. The bearing maker's catalog rating sheets are based on an L_{10} life of 3800 h at 500 rev/min. What load should be used to enter the catalog?

3. Read Shigley, Chapter 11

4. Read www.timken.com/bearings/fundamen/