

Rolling Contact Bearings

Lecture 23

Engineering 473
 Machine Design

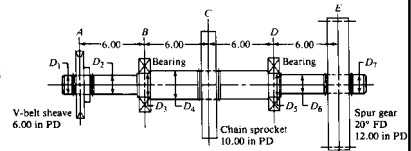


Why Rolling Contact Bearings?

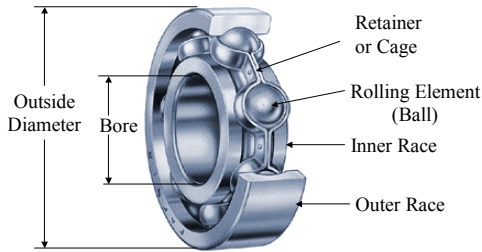


Rolling contact bearings are used to minimize the friction associated with relative motion performed under load.

Typical applications include supporting shafts.

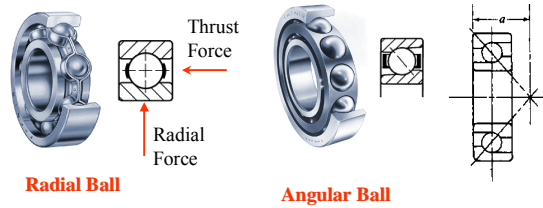


Bearing Nomenclature



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).

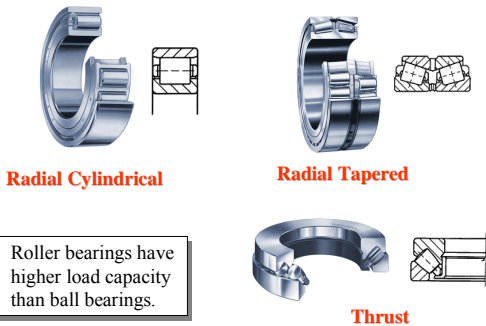
Ball Bearings



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

www.torrington.com/products

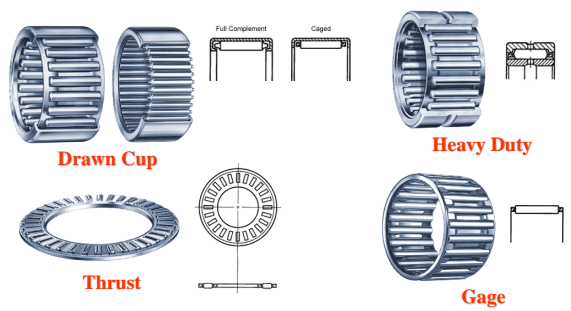
Roller Bearings



Roller bearings have higher load capacity than ball bearings.

www.torrington.com/products

Needle Bearings



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

www.torrington.com/products

Other Types of Bearings



Spherical



Bronze Bushings



Polymer Bearings

www.igus.com/iglide/iglide.htm

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 .

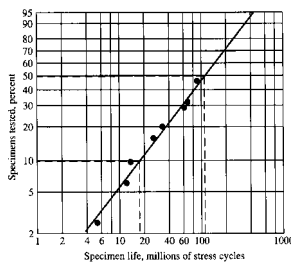
Bearing Life

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



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

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

Typical Weibull Plot of Bearing Fatigue Failures

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

Load/Life Relationship

$$\frac{L_2}{L_1} = \left(\frac{F_1}{F_2} \right)^k \quad \begin{array}{l} k = 3 \text{ for ball bearings} \\ = 3.33 \text{ for roller bearings} \end{array}$$

Basic Dynamic Load Rating

$L_1 = 1,000,000$ 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		Allowable load limit *a	Speed ratings Grease Oil	Mass kg lbm	Designation		
d_i	d_e	C	C_0						
mm in		N lbf		N lbf	rpm				
15	35	11	12 500	10 200	1 200	18 000	21 000	0.047	NU 202 EC
0.5906	1.3780	0.4331	2 810	2 280	274	16 000	19 000	0.101	NU 302 EC
	42	13	19 400	15 300	1 840	16 000	19 000	0.086	NU 204 EC
	1.6535	0.5118	4 360	3 460	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	20 400	17 900	3 950	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	35 500	4 550	9 500	12 000	0.24	NU 305 EC
	2.4409	0.6893	9 040	8 210	1 020			0.53	
30	62	16	30 600	26 500	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
	2.8746	0.7480	11 500	10 900	1 300			0.79	
35	72	17	48 000	48 000	6 100	9 500	10 000	0.30	NU 207 EC
1.3780	2.8346	0.6093	10 900	10 900	1 370			0.66	
	80	21	64 000	63 000	8 150	8 000	9 500	0.48	NU 307 EC
	3.1496	0.8268	14 500	14 300	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	12 140	11 960	1 510			0.82	
	90	23	80 900	78 000	10 240	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	8 160	6 700	8 000	0.43	NU 209 EC
1.7717	3.3465	0.7480	13 640	14 430	1 830			0.95	
	100	25	95 000	100 000	12 900	6 300	7 500	0.90	NU 309 EC
	3.9370	0.9843	21 300	22 500	2 800			2.00	
50	90	20	64 000	69 500	8 900	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	6 000	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.

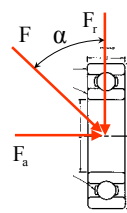
The Anti-Friction Bearing Manufacturer's Association (AFBMA) has developed a standard equation for computing an equivalent radial load that takes this into account.

$$F_e = XV F_r$$

V = 1.0 Rotating Inner Race
V = 1.2 Rotating Outer Race

Combined Radial and Thrust Loads

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

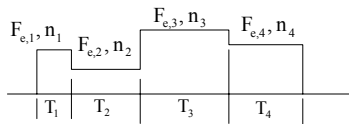


$$F_e = XV F_r + Y F_a$$

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



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

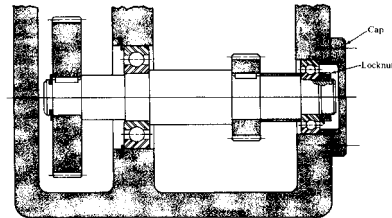
n_i ≡ Speed of the ith event

T_i ≡ Time period of the ith event

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

Mounting Bearings

Most manufacturer's catalogs specify the limiting dimensions for the shaft and housing bore. These are generally controlled to within a few thousandths 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/