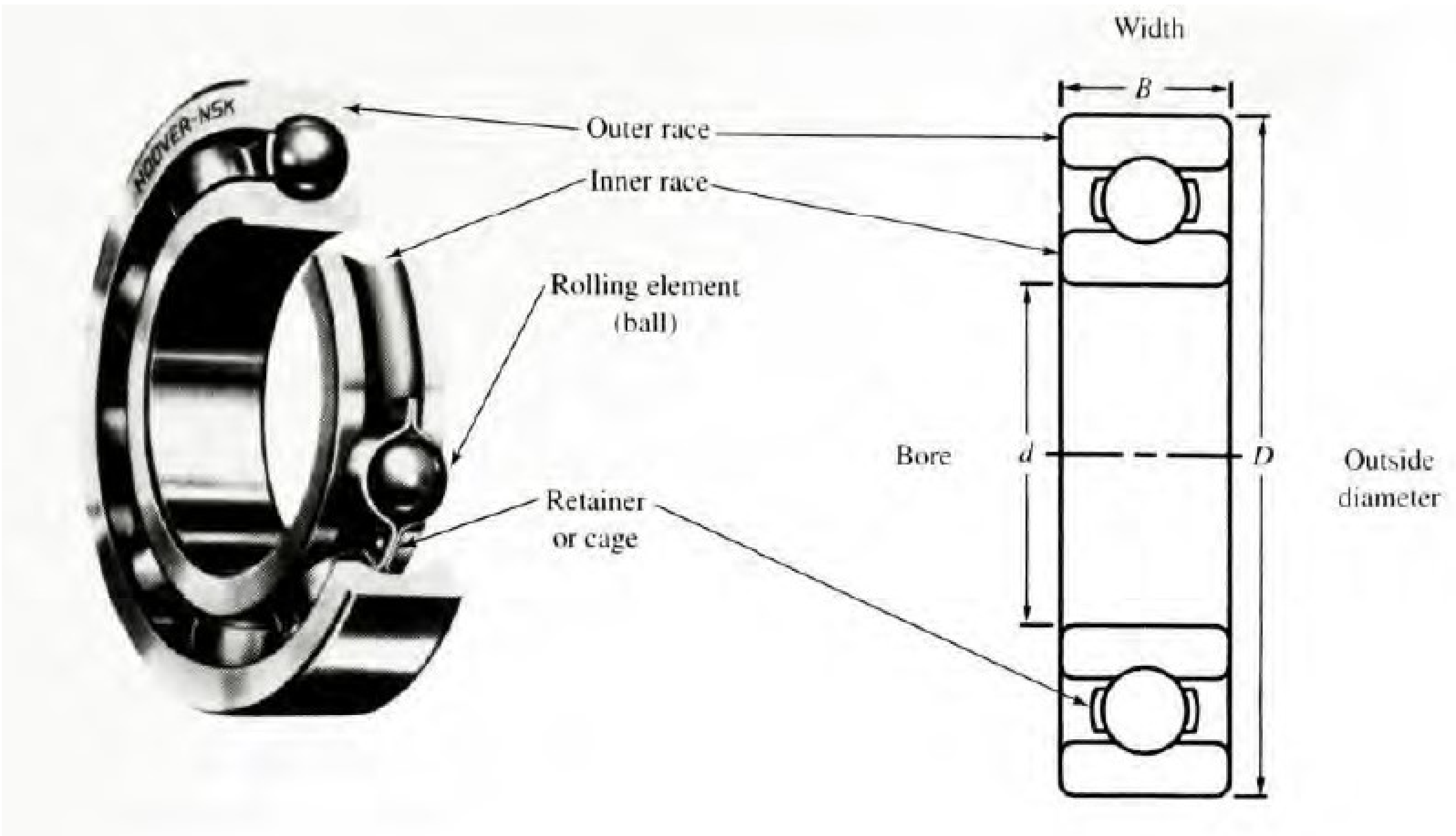
ROLLING ELEMENT BEARINGS

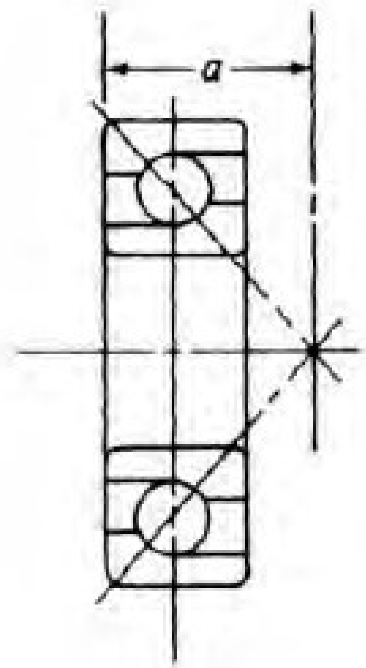
Antifriction Bearings

Single-row, deep-groove ball bearing



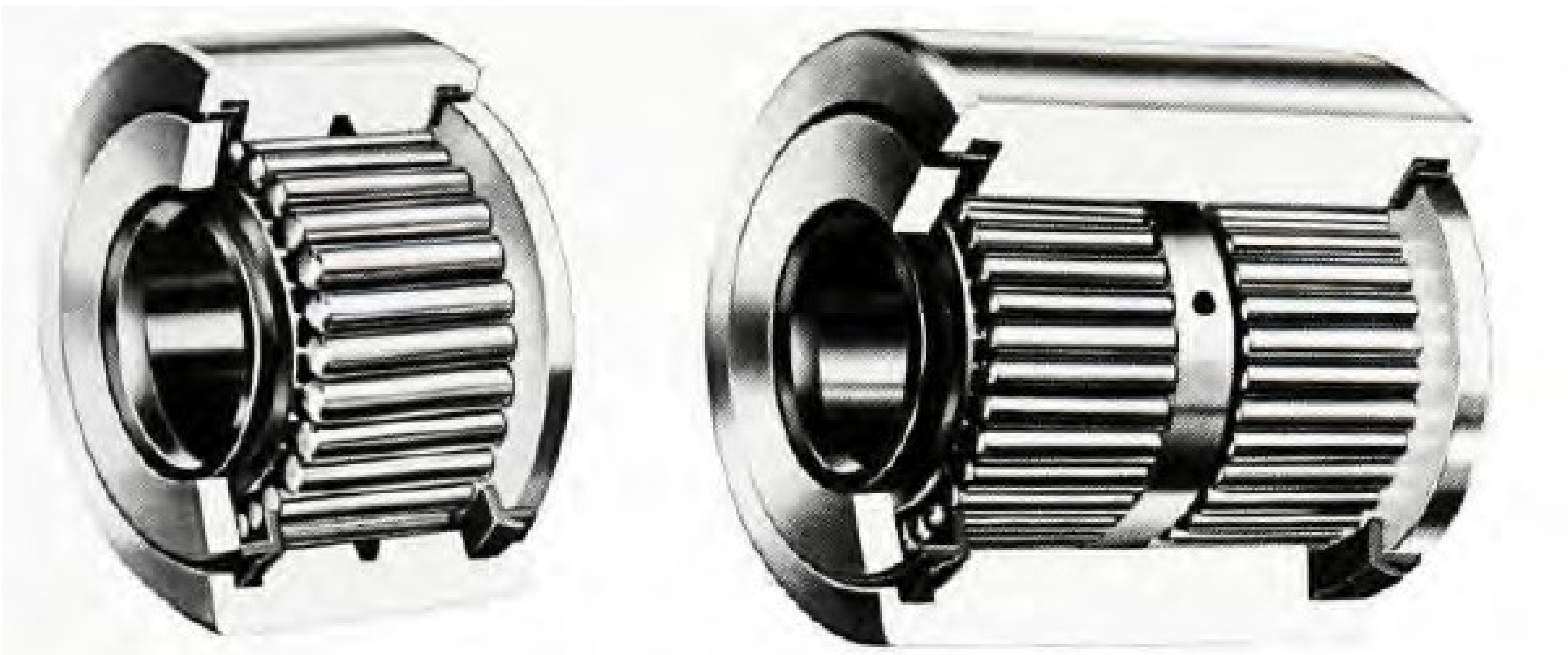
Double-row, deep-groove ball bearing

Angular contact ball bearing



Cylindrical roller bearing

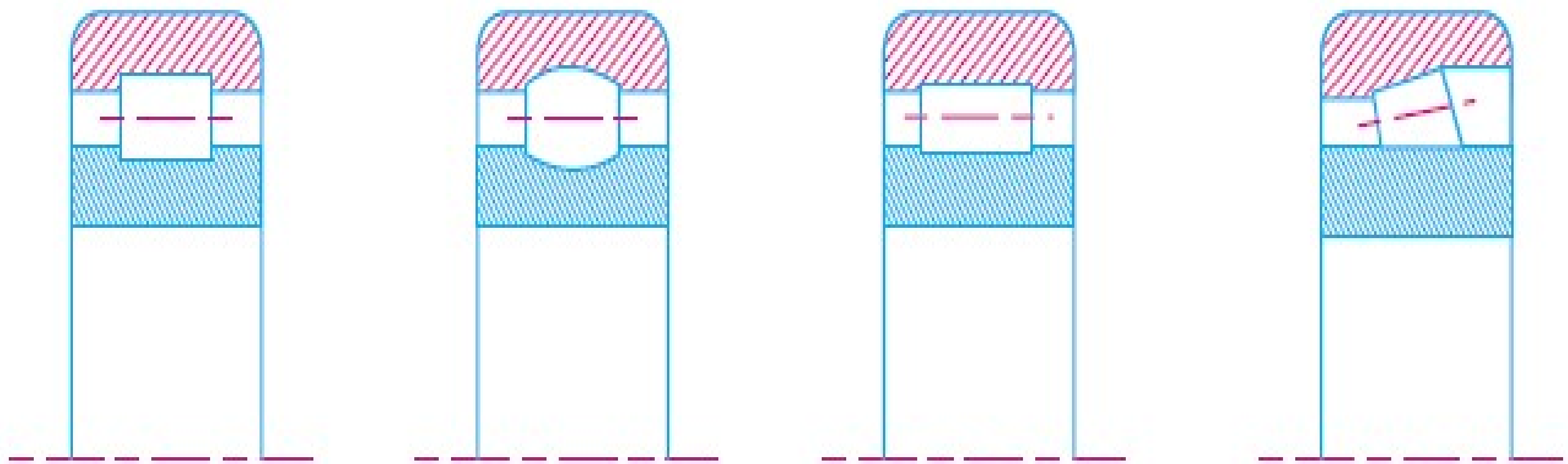
Single- and double-row needle bearings



Spherical roller bearing

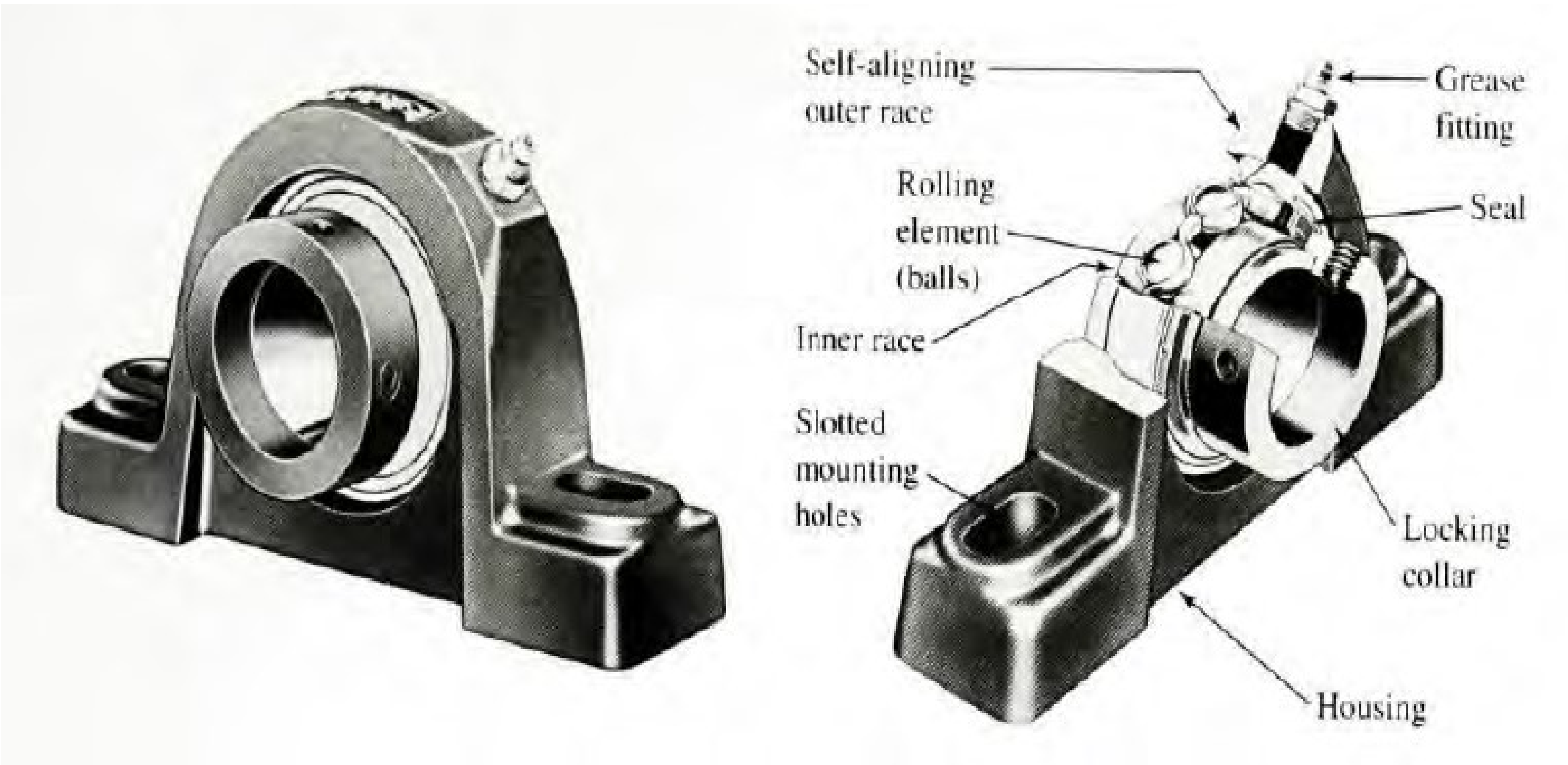
Tapered roller bearing

Sectional views

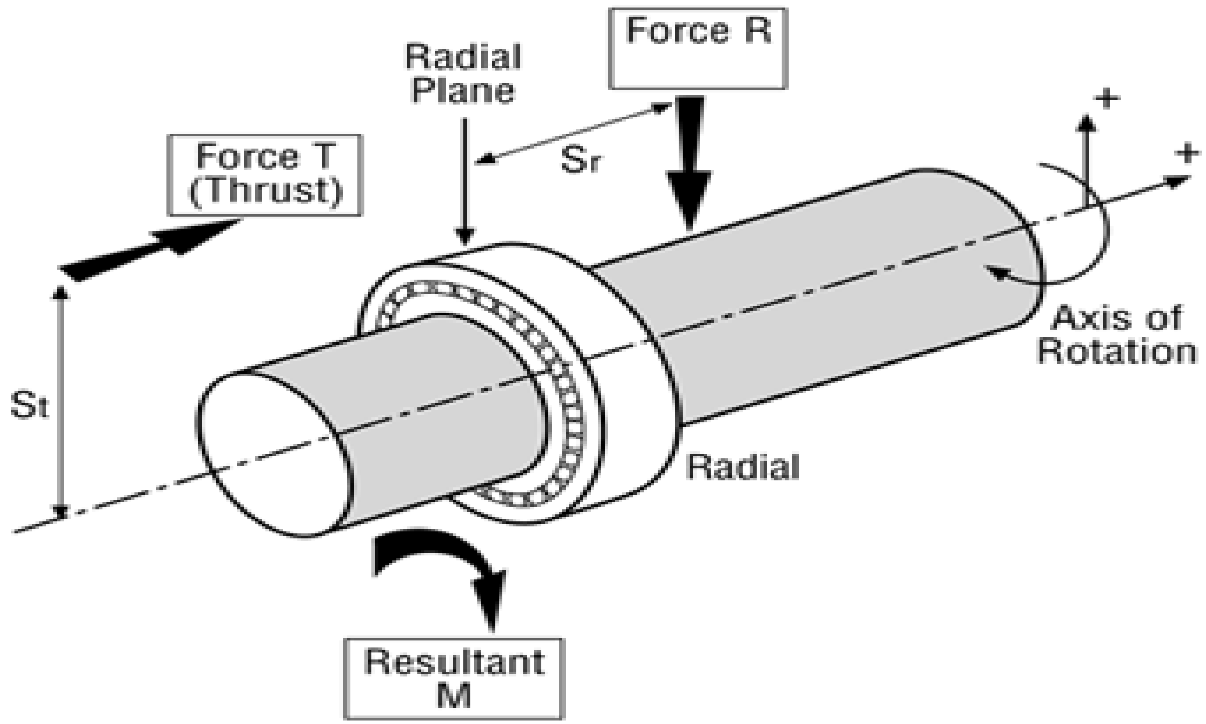


(*a*) Cylindrical roller. (*b*) Spherical roller. (*c*) Needle roller. (*d*) Tapered roller.

Ball
bearing pillow block



Loads on Bearing



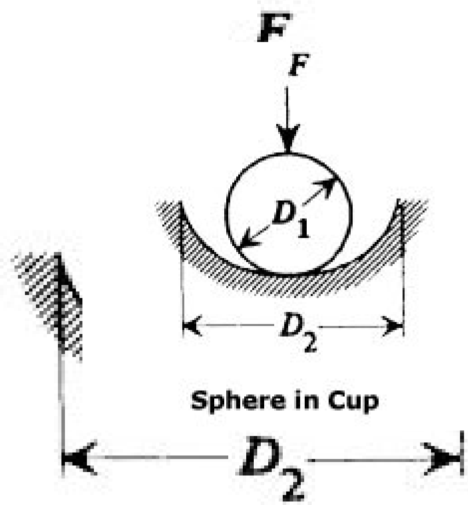
The resultant moment load (M) equation:

$M = (\pm T)(S_t) + (\pm R)(S_r)$

Comparison of Rolling bearing types

Bearing type	Radial load capacity	Thrust load capacity	Misalignment capability
Single-row, deep-groove ball	Good	Fair	Fair
Double-row, deep-groove ball	Excellent	Good	Fair
Angular contact	Good	Excellent	Poor
Cylindrical roller	Excellent	Poor	Fair
Needle	Excellent	Poor	Poor
Spherical roller	Excellent	Fair/good	Excellent
Tapered roller	Excellent	Excellent	Poor

Hertzian contact stress



Sphere in Cup

Consider a solid sphere held in a Cup by a force F such that their point of contact expands into a circular area of radius, a

$$a = K_a \sqrt[3]{F}$$

$$\text{where } K_a = \left[\frac{3}{8} \frac{(1-\nu_1^2)/E_1 + (1-\nu_2^2)/E_2}{(1/d_1)+(1/d_2)} \right]^{1/3}$$

Where,

F= Applied force

V1 & V2= Poisons ratios for the sphere and cup

E1 & E2 = Elastic Modulii for sphere and cup

D1 and D2= diamete ... up

The maximum contact pres ... center point of the contact area

$$p_{max} = \frac{3F}{2\pi a^2}$$

TYPES OF LOADING AND STRESS RATIO

The primary factors to consider when specifying the type of loading to which a machine part is subjected are the manner of variation of the load and the resulting variation of stress with time. Stress variations are characteri

1. Maximum stress, σ_{max}
2. Minimum stress, σ_{min}
3. Mean (average) stress, σ_m
4. Alternating stress, σ_a (*stress amplitude*)

The maximum and minimum stresses are usually computed from known information by stress analysis or finite-element methods, or they are measured using experimental stress analysi

alterna

$$\sigma_m = (\sigma_{max} + \sigma_{min})/2$$

$$\sigma_a = (\sigma_{max} - \sigma_{min})/2$$

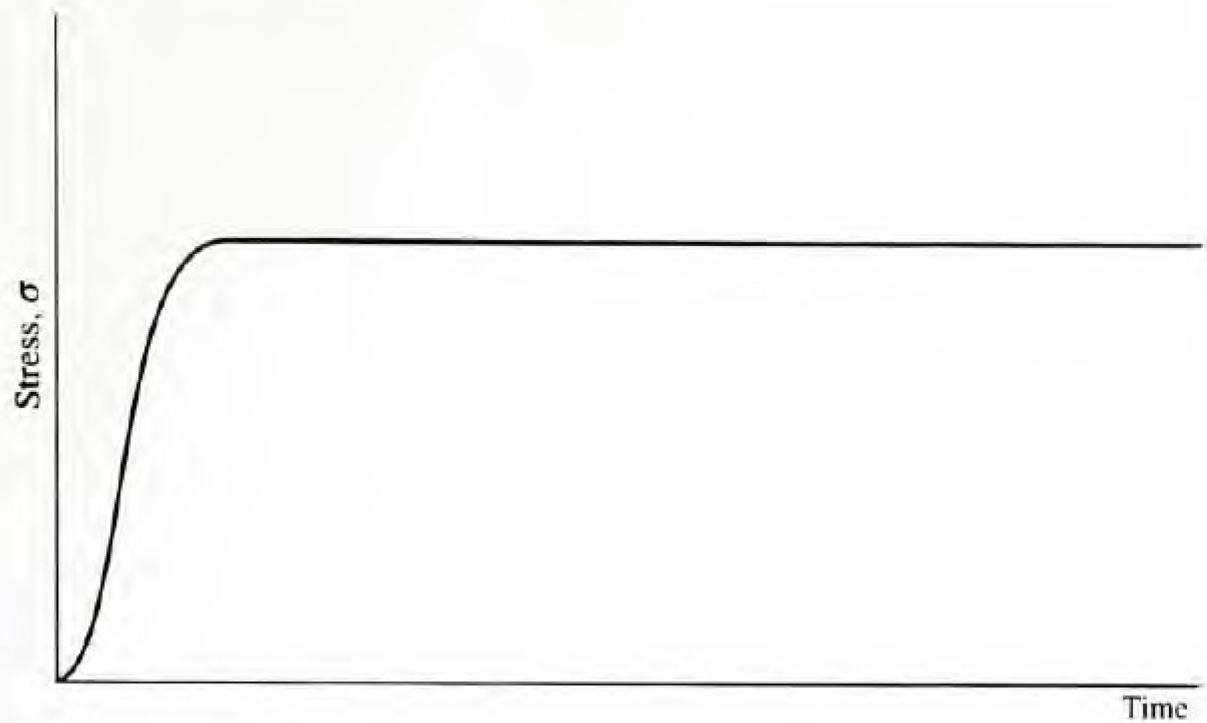
Stress Ratio

The behavior of a material under varying stresses is dependent on the manner of the variation. One method used to characterize the variation is called *stress ratio*. Two types of stress ratio

$$\text{Stress ratio } R = \frac{\text{minimum stress}}{\text{maximum stress}} = \frac{\sigma_{min}}{\sigma_{max}}$$

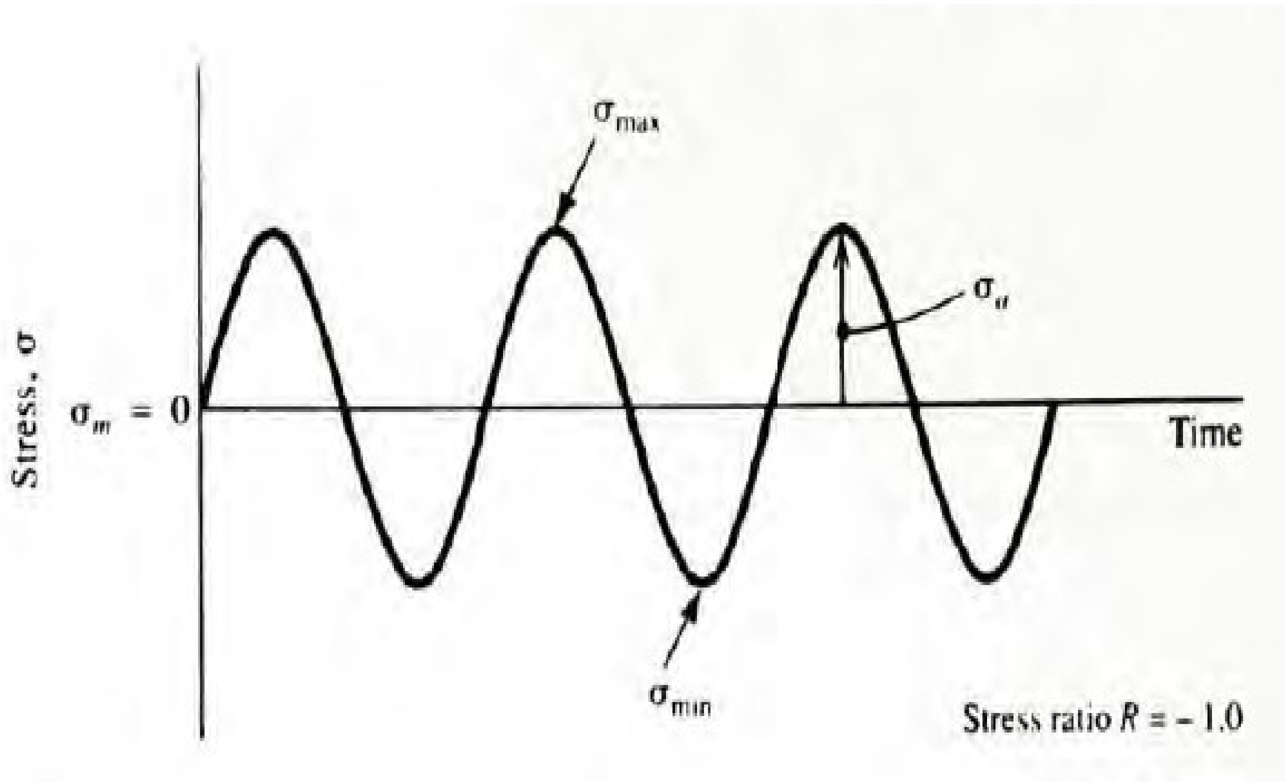
$$\text{Stress ratio } A = \frac{\text{alternating stress}}{\text{mean stress}} = \frac{\sigma_{a}}{\sigma_{m}}$$

Static Stress

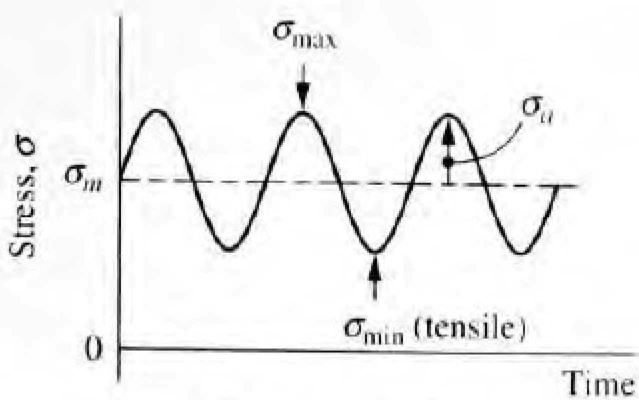


Stress ratio $R = 1.0$

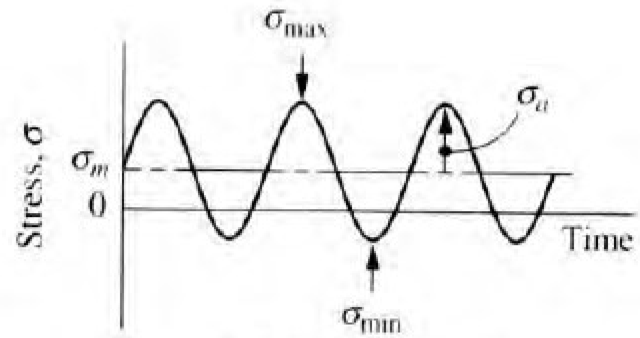
Repeated and Reversed Stress



Fluctuating Stress

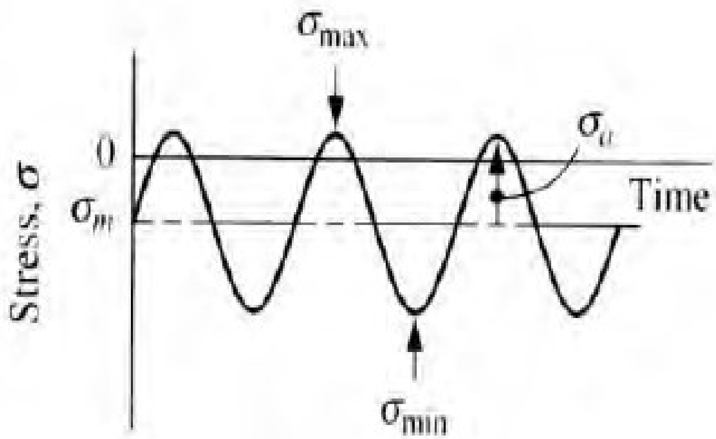


(a) Tensile mean stress —
all stresses tensile
$0 < R < 1.0$

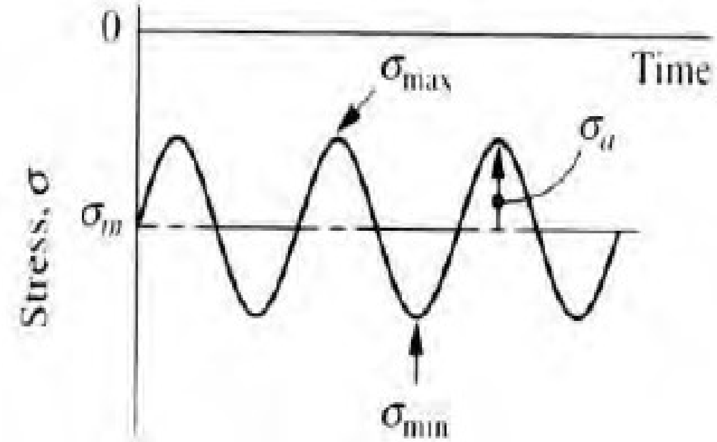


(b) Tensile mean stress —
σ_{max} tensile
σ_{min} compressive
$-1.0 < R < 0$

Fluctuating Stress continued…

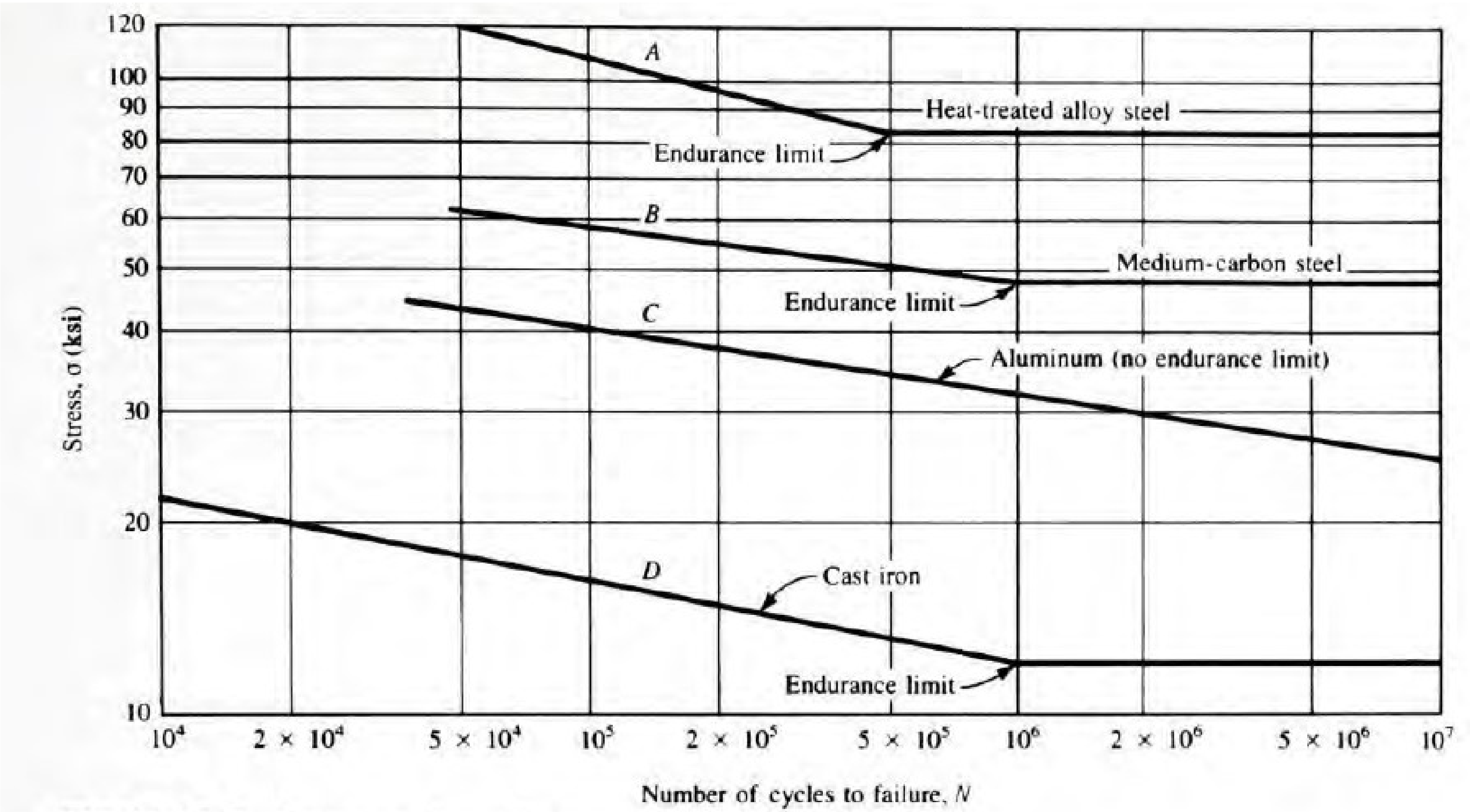


(c) Compressive mean stress —
σ_{max} tensile
σ_{min} compressive
$-\infty < R < -1.0$

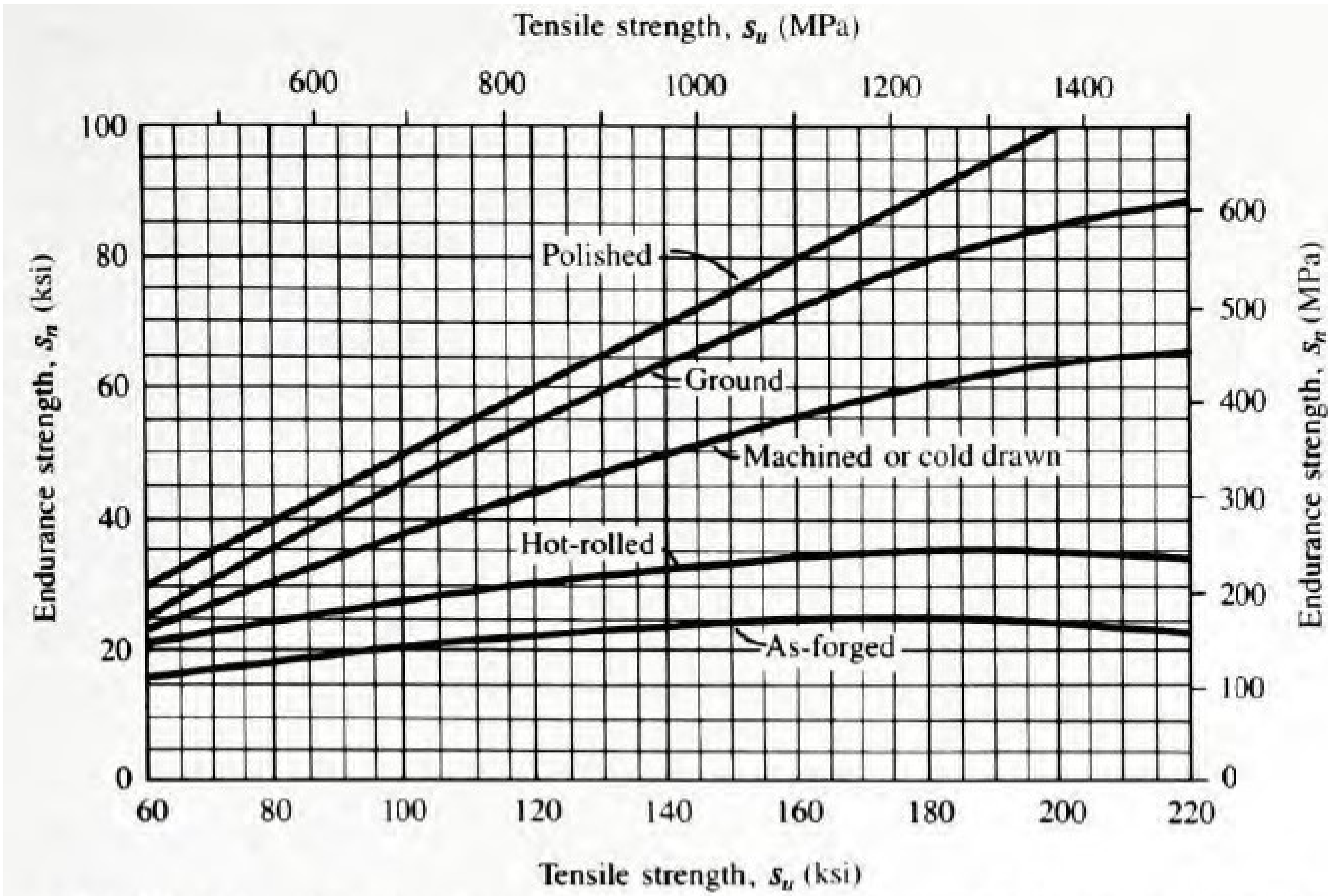


(d) Compressive mean stress —
all stresses compressive
$1.0 < R < \infty$

Endurance Strength



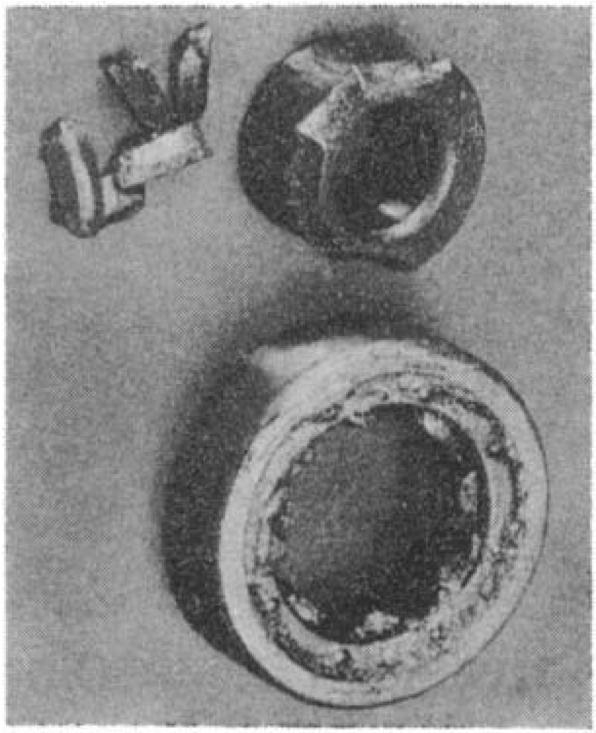
Endurance strength vs. tensile strength for wrought steel for various surface conditions

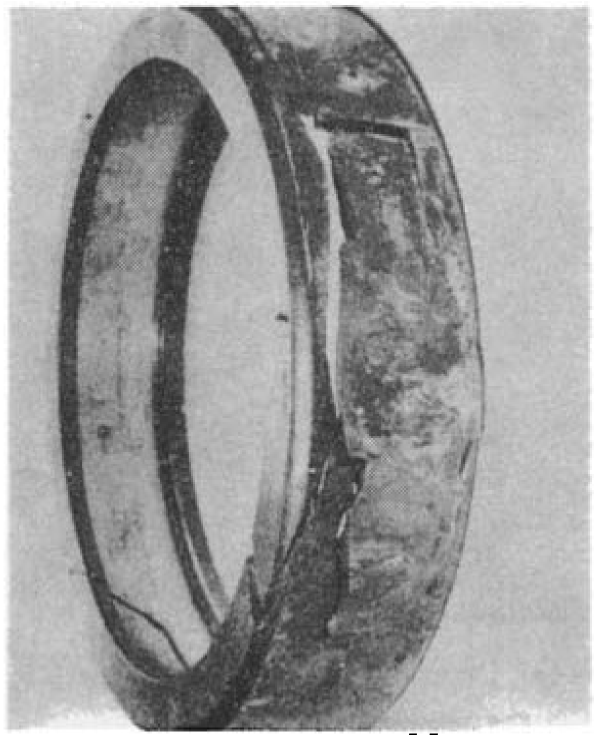


Rolling Bearing Failures

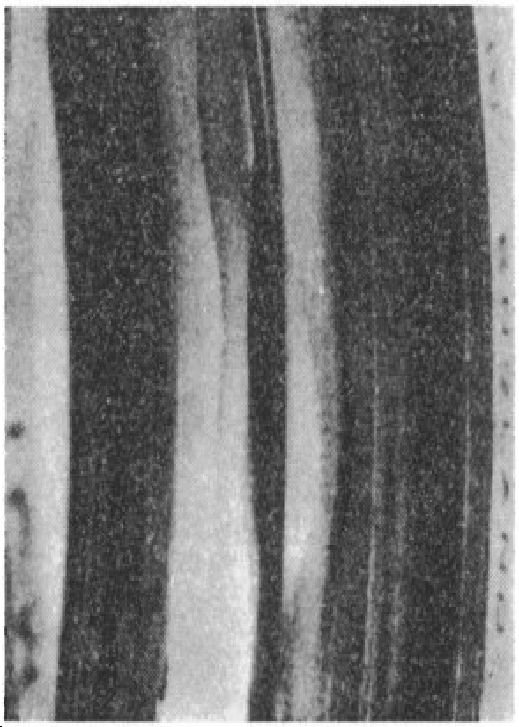
Fatigue failure

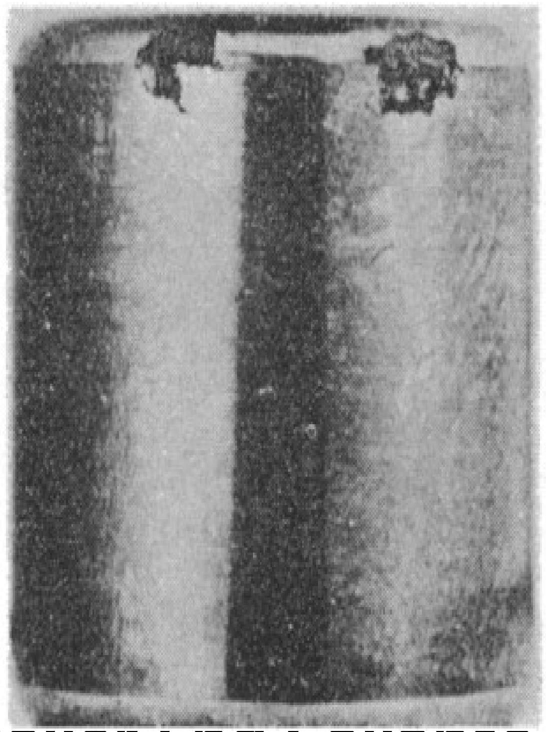
Failures continued….

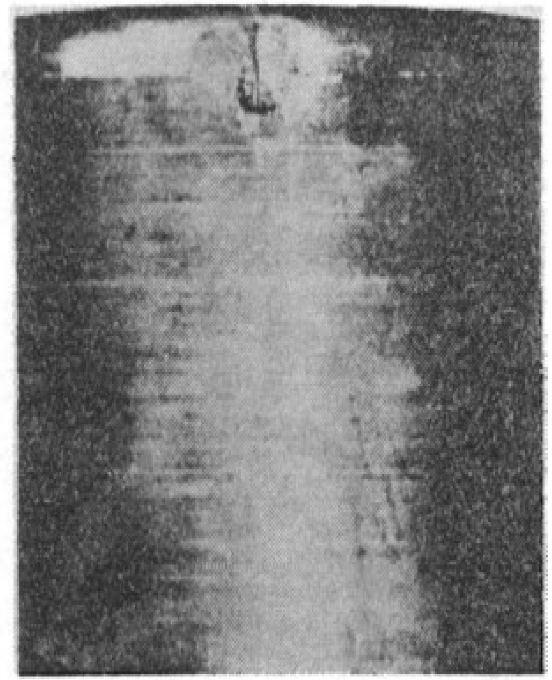




Failures continued….

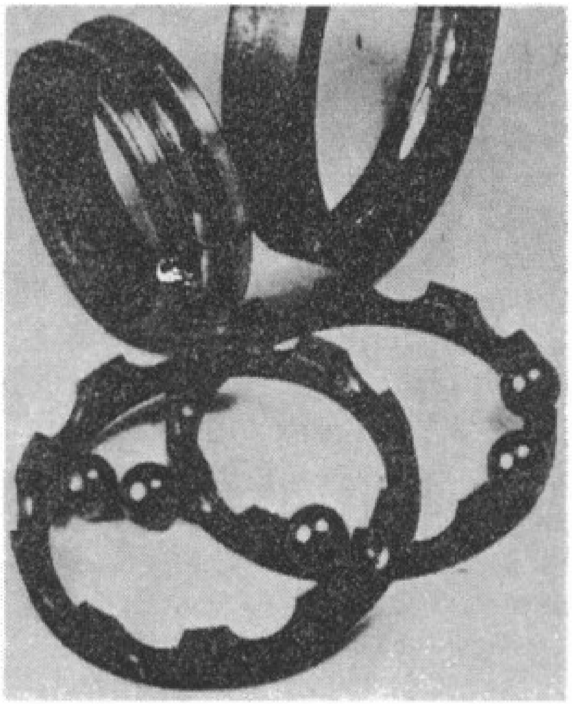




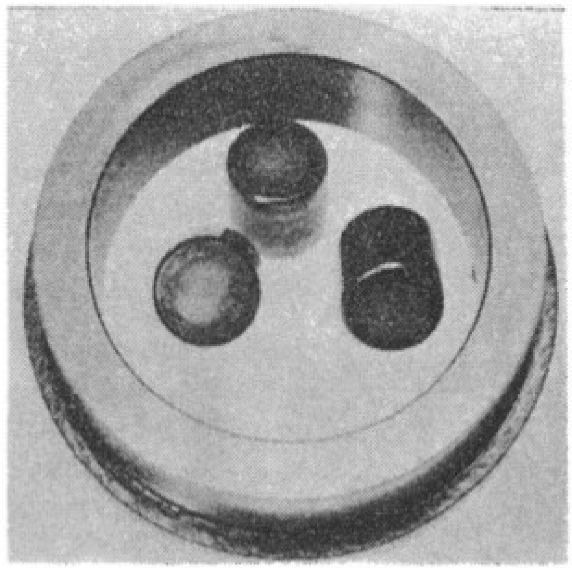


Uneven Wear Marks Roller End Collapse Roller End Chipping

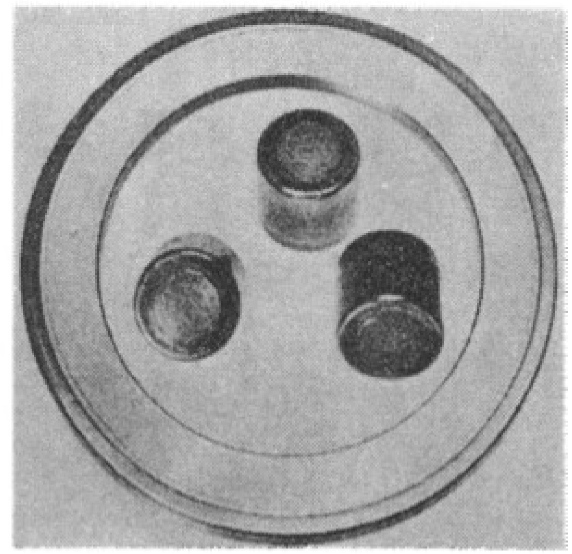
Failures continued….



Overheating

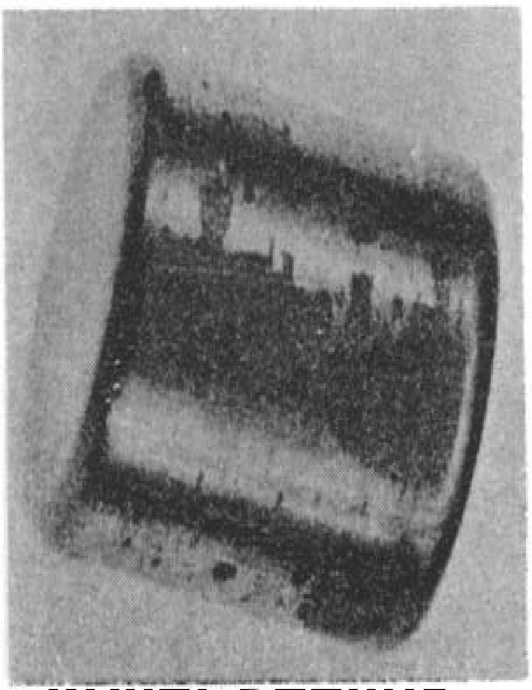


Smearing

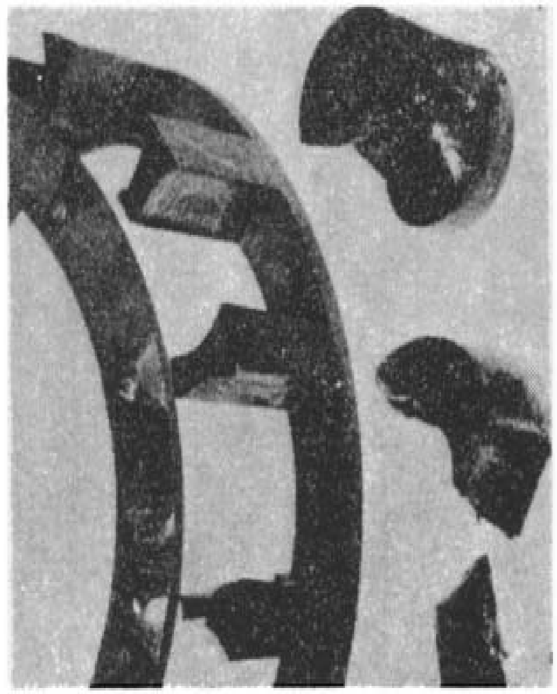


Abrasive Wear

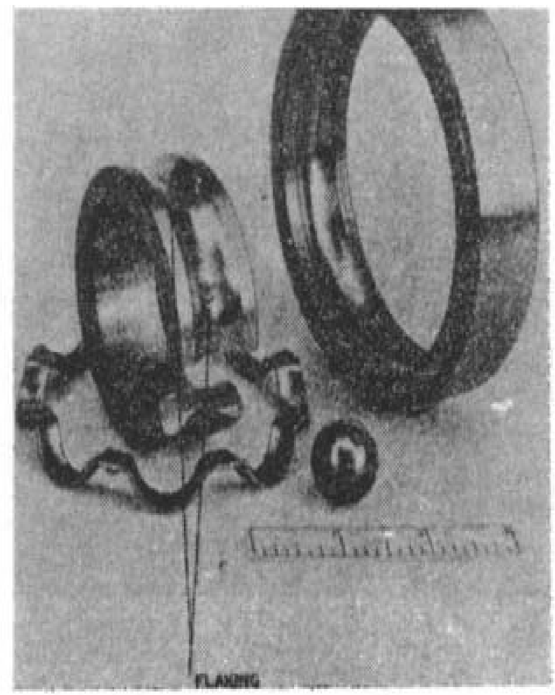
Failures continued….



Roller Peeling



Roller Breakage



Magnetic Damage

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	2200°F 1200°C	360°F 180°C	500°F 260°C	600°F 320°C
Density, kg/m^3	3200	7800	7800	7600

LOAD/LIFE RELATIONSHIP

L2/L1 =(P1/P2)^k,

- **Where k =3.00 for Ball Brgs.**
- **=3.33 fro roller brgs**

Where

P1 & L1 = rated load and life

P2 & L2= Design load and life

Bearing Selection data for single row, deep groove ball bearings

A. *Series 6200*

Bearing number	Nominal bearing dimensions *d*		*D*		*B*		*r*[a]	Preferred shoulder diameter Shaft	Housing	Bearing weight	Basic static load rating, C_o	Basic dynamic load rating, *C*
	mm	in	mm	in	mm	in	in	in	in	lb	lb	lb
6200	10	0.3937	30	1.1811	9	0.3543	0.024	0.500	0.984	0.07	520	885
6201	12	0.4724	32	1.2598	10	0.3937	0.024	0.578	1.063	0.08	675	1180
6202	15	0.5906	35	1.3780	11	0.4331	0.024	0.703	1.181	0.10	790	1320
6203	17	0.6693	40	1.5748	12	0.4724	0.024	0.787	1.380	0.14	1010	1660
6204	20	0.7874	47	1.8504	14	0.5512	0.039	0.969	1.614	0.23	1400	2210
6205	25	0.9843	52	2.0472	15	0.5906	0.039	1.172	1.811	0.29	1610	2430
6206	30	1.1811	62	2.4409	16	0.6299	0.039	1.406	2.205	0.44	2320	3350
6207	35	1.3780	72	2.8346	17	0.6693	0.039	1.614	2.559	0.64	3150	4450
6208	40	1.5748	80	3.1496	18	0.7087	0.039	1.811	2.874	0.82	3650	5050
6209	45	1.7717	85	3.3465	19	0.7480	0.039	2.008	3.071	0.89	4150	5650
6210	50	1.9685	90	3.5433	20	0.7874	0.039	2.205	3.268	1.02	4650	6050
6211	55	2.1654	100	3.9370	21	0.8268	0.059	2.441	3.602	1.36	5850	7500
6212	60	2.3622	110	4.3307	22	0.8661	0.059	2.717	3.996	1.73	7250	9050
6213	65	2.5591	120	4.7244	23	0.9055	0.059	2.913	4.390	2.18	8000	9900
6214	70	2.7559	125	4.9213	24	0.9449	0.059	3.110	4.587	2.31	8800	10 800
6215	75	2.9528	130	5.1181	25	0.9843	0.059	3.307	4.783	2.64	9700	11 400
6216	80	3.1406	140	5.5118	26	1.0236	0.079	3.504	5.118	3.09	10 500	12 600
6217	85	3.3465	150	5.9055	28	1.1024	0.079	3.740	5.512	3.97	12 300	14 600
6218	90	3.5433	160	6.2992	30	1.1811	0.079	3.937	5.906	4.74	14 200	16 600
6219	95	3.7402	170	6.6929	32	1.2598	0.079	4.213	6.220	5.73	16 300	18 800
6220	100	3.9370	180	7.0866	34	1.3386	0.079	4.409	6.614	6.94	18 600	21 100
6221	105	4.1339	190	7.4803	36	1.4173	0.079	4.606	7.008	8.15	20 900	23 000
6222	110	4.3307	200	7.8740	38	1.4961	0.079	4.803	7.402	9.59	23 400	24 900
6224	120	4.7244	215	8.4646	40	1.5748	0.079	5.197	7.992	11.4	26 200	26 900

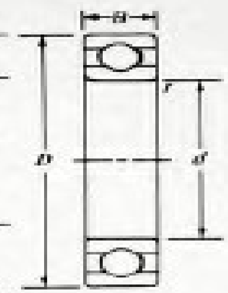


Table continued….

B. Series 6300, continued

Bearing number	Nominal bearing dimensions							Preferred shoulder diameter		Bearing weight	Basic static load rating, C_o	Basic dynamic load rating, C
	d		D		B		r^*	Shaft	Housing			
	mm	in	mm	in	mm	in	in	in	in	lb	lb	lb
6316	80	3.1496	170	6.6929	39	1.5354	0.079	3.622	6.220	7.93	18 300	21 300
6317	85	3.3465	180	7.0866	41	1.6142	0.098	3.898	6.535	9.37	20 400	22 900
6318	90	3.5433	190	7.4803	43	1.6929	0.098	4.094	6.929	10.8	22 500	24 700
6319	95	3.7402	200	7.8740	45	1.7717	0.098	4.291	7.323	12.5	24 900	26 400
6320	100	3.9370	215	8.4646	47	1.8504	0.098	4.488	7.913	15.3	29 800	30 000
6321	105	4.1339	225	8.8583	49	1.9291	0.098	4.685	8.307	17.9	32 500	31 700
6322	110	4.3307	240	9.4488	50	1.9685	0.098	4.882	8.898	21.0	38 000	35 500
6324	120	4.7244	260	10.2362	55	2.1654	0.098	5.276	9.685	27.6	38 500	36 000
6326	130	5.1181	280	11.0236	58	2.2835	0.118	5.827	10.315	40.8	44 500	39 500
6328	140	5.5118	300	11.8110	62	2.4409	0.118	6.220	11.102	48.5	51 000	43 500
6330	150	5.9055	320	12.5984	65	2.5591	0.118	6.614	11.890	57.3	58 000	47 500
6332	160	6.2992	340	13.3858	68	2.6772	0.118	7.008	12.677	58	58 500	48 000
6334	170	6.6929	360	14.1732	72	2.8346	0.118	7.402	13.465	84	73 500	56 500
6336	180	7.0866	380	14.9606	75	2.9528	0.118	7.795	14.252	98	84 000	61 500
6338	190	7.4803	400	15.7480	78	3.0709	0.157	8.346	14.882	112	84 000	61 500
6340	200	7.8740	420	16.5354	80	3.1496	0.157	8.740	15.669	127	91 500	65 500

Rated Life and Basic dynamic load rating

- **The rated life is the standard means of reporting the results of many tests of bearings of a given design. It represents the life that 90% of the bearings would achieve successfully at a rated load.**
- **It also represents the life that 10% of the bearings would not achieve. The rated life is thus typically referred to as the L10 *life* at the rated load.**
- **Now the *basic dynamic load* rating can be defined as that load to which the bearings can be subjected while achieving a rated life (L10) of 1 million revolutions (rev).**

Problem: A catalog lists the basic dynamic load rating for a ball bearing to be 8000 lb for a rated life of 1 million rev. What would be the expected L_{10} life of the bearing if it were subjected to a load of 4000 lb?

Solution:

P1 = 8000 Ib, L1=106

P2 =4000 Ib, k=3

L2= 10^6 (8000/4000)^3 = 8x10^6 rev

This is interpreted as L10 life at Load of 4000 Ib

Procedure for computing the required basic dynamic load rating C for a given design load P_d and a given design life L_d

We have already discussed^

L2/L1 = (P1/P2)^K

L2= Ld= L1 (P1/P2)^K

Ld = (C/Pd)^K (10^6)

If the reported load data in the manufacturer's literature is for 10^6 revolutions the above equation can be written as

The required C for a given design load and life would be

$$C = P_d (L_d / 10^6)^{1/k}$$

Now, for a specified design life in hours, and a known speed of rotation in rpm, the number of design revolutions for the bearing would be

$$L_d = (\text{h})(\text{rpm})(60 \text{ min/h})$$

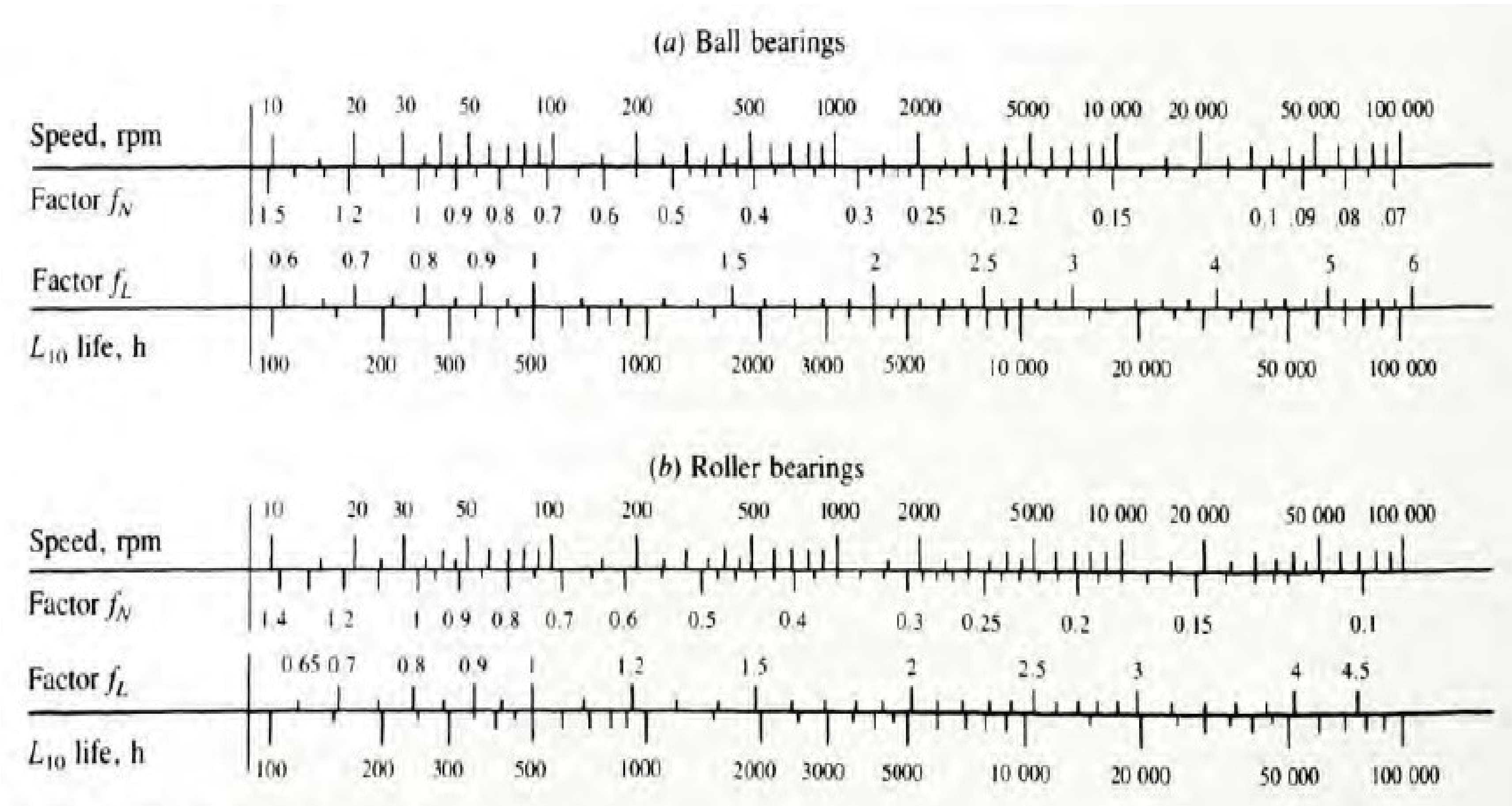
Recommended design life for bearings

Application	Design life L_{10}, h
Domestic appliances	1000–2000
Aircraft engines	1000–4000
Automotive	1500–5000
Agricultural equipment	3000–6000
Elevators, industrial fans, multipurpose gearing	8000–15 000
Electric motors, industrial blowers, general industrial machines	20 000–30 000
Pumps and compressors	40 000–60 000
Critical equipment in continuous, 24-h operation	100 000–200 000

- The rated life of 1 million rev would be achieved by a shaft rotating $33\frac{1}{3}$ rpm for 500 h.
- If the actual speed or desired life is different from these two values, a speed factor f_N and a life factor f_L can be determined from charts shown in the next slide.
- The factors account for the load/life relationship.
- The required basic dynamic load rating, *C,* for a bearing to carry a design load, P_d, would then be

$$C = P_d f_L / f_N$$

Life and speed factors for ball and roller bearings



Problem: Compute the required basic dynamic load rating, C for a ball bearing to carry a radial load of 700 lb from a shaft rotating at 500 rpm that is part of an assembly conveyor in a manufacturing plant.

Solution:

From table, a design life of 30 000 h is desired

Then L_d is

$$L_d = (\text{h})(\text{rpm})(60\ \text{min/h})$$

Ld = (30,000) (500) (60 min/h)=9x10^8 rev

C= Pd(Ld/10^6)^l/k

$$C = P_d\,(L_d/10^6)^{1/k}$$

C =700(9x10^8)/10^6) ^1/k

C= 6743 lb

Also C= Pd (fL/fN)

C= 700 (3.91/.41))= 6670 Ib

Procedure for Selecting a Bearing Radial Load Only

Step 1: Specify the design load on the bearing, usually called *equivalent load.* The method of determining the equivalent load when only a radial load, *R,* is applied takes into account whether the inner or the outer race rotates.

P = VR

where *V* = *rotation factor*

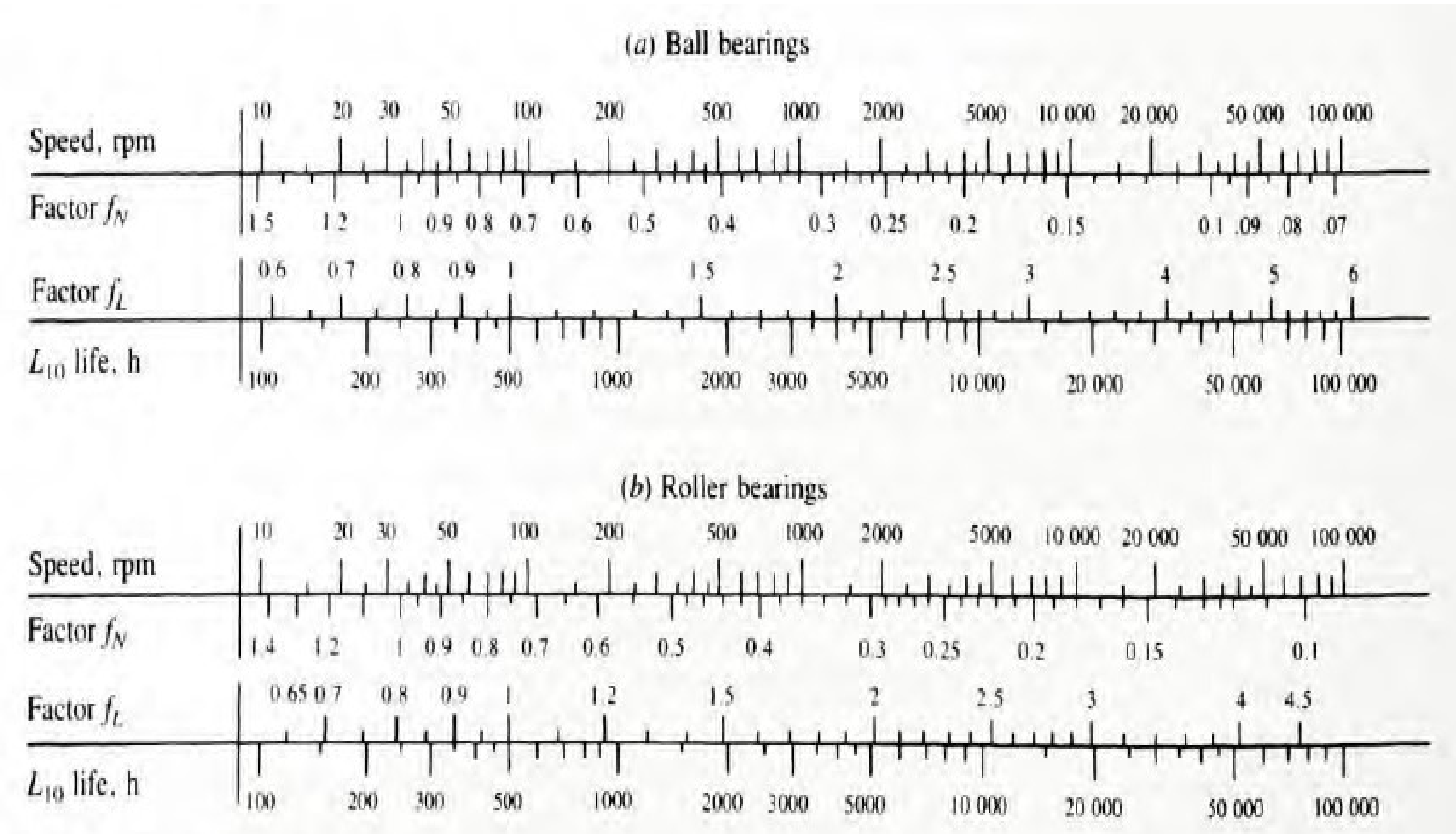
V=1.0 if the inner race of the bearing rotates,

= 1.2 if the outer race rotates

Step 4: Specify the design life of the bearing, using the following table

Application	Design life L_{10}, h
Domestic appliances	1000–2000
Aircraft engines	1000–4000
Automotive	1500–5000
Agricultural equipment	3000–6000
Elevators, industrial fans, multipurpose gearing	8000–15 000
Electric motors, industrial blowers, general industrial machines	20 000–30 000
Pumps and compressors	40 000–60 000
Critical equipment in continuous, 24-h operation	100 000–200 000

Step 5: Determine the speed factor and the life factor if such tables are available for the selected type of bearing.



Step 6: Compute the required basic dynamic load rating C from following equations

$$\frac{L_2}{L_1} = \left(\frac{P_1}{P_2}\right)^k$$

$$C = P_d\,(L_d/10^6)^{1/k}$$

or

$$C = P_d f_L / f_N$$

Step 7: Identify a set of candidate bearings that have the required basic dynamic load rating.

Step 8: Select the bearing having the most convenient geometry, also considering its cost and availability.

Step 9: Determine mounting conditions, such as shaft seat diameter and tolerance, housing bore diameter and tolerance, means of locating the bearing axially, and special needs such as seals or shields.

Problem: Select a single-row, deep-groove ball bearing to carry 650 lb of pure radial load from a shaft that rotates at 600 rpm. The design life is to be 30 000 h. The bearing is to be mounted on a shaft with a minimum acceptable diameter of 1.48 in.

Solution:

- Note that this is a pure radial load and the inner race is to be pressed onto the shaft and rotates with it. Therefore, the rotation factor *V*= 1.0 in
- Therefore From equation

$$P = VR$$

P=R

the design load is equal to the radial load.

We know,

$$L_d = (\text{h})(\text{rpm})(60 \text{ min/h})$$

$$L_d = (30\,000 \text{ h})(600 \text{ rpm})(60 \text{ min/h}) = 1.08 \times 10^9 \text{ rev}$$

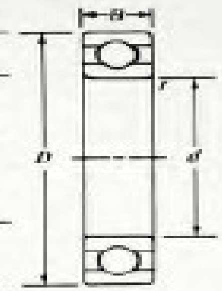
Also, Dynamic loa($C = P_d\,(L_d/10^6)^{1/k}$

$$C = 650(1.08 \times 10^9/10^6)^{1/3} = 6670 \text{ lb}$$

- **Giving design data for two classes of bearings, we find from table that we could use a bearing 6211 or a bearing 6308.**

A. Series 6200

Bearing number	Nominal bearing dimensions: d		D		B		r*	Preferred shoulder diameter: Shaft	Preferred shoulder diameter: Housing	Bearing weight	Basic static load rating, C_o	Basic dynamic load rating, C
	mm	in	mm	in	mm	in	in	in	in	lb	lb	lb
6200	10	0.3937	30	1.1811	9	0.3543	0.024	0.500	0.984	0.07	520	885
6201	12	0.4724	32	1.2598	10	0.3937	0.024	0.578	1.063	0.08	675	1180
6202	15	0.5906	35	1.3780	11	0.4331	0.024	0.703	1.181	0.10	790	1320
6203	17	0.6693	40	1.5748	12	0.4724	0.024	0.787	1.380	0.14	1010	1660
6204	20	0.7874	47	1.8504	14	0.5512	0.039	0.969	1.614	0.23	1400	2210
6205	25	0.9843	52	2.0472	15	0.5906	0.039	1.172	1.811	0.29	1610	2430
6206	30	1.1811	62	2.4409	16	0.6299	0.039	1.406	2.205	0.44	2320	3350
6207	35	1.3780	72	2.8346	17	0.6693	0.039	1.614	2.559	0.64	3150	4450
6208	40	1.5748	80	3.1496	18	0.7087	0.039	1.811	2.874	0.82	3650	5050
6209	45	1.7717	85	3.3465	19	0.7480	0.039	2.008	3.071	0.89	4150	5650
6210	50	1.9685	90	3.5433	20	0.7874	0.039	2.205	3.268	1.02	4650	6050
6211	55	2.1654	100	3.9370	21	0.8268	0.059	2.441	3.602	1.36	5850	7500
6212	60	2.3622	110	4.3307	22	0.8661	0.059	2.717	3.996	1.73	7250	9050
6213	65	2.5591	120	4.7244	23	0.9055	0.059	2.913	4.390	2.18	8000	9900
6214	70	2.7559	125	4.9213	24	0.9449	0.059	3.110	4.587	2.31	8800	10 800
6215	75	2.9528	130	5.1181	25	0.9843	0.059	3.307	4.783	2.64	9700	11 400
6216	80	3.1496	140	5.5118	26	1.0236	0.079	3.504	5.118	3.09	10 500	12 600
6217	85	3.3465	150	5.9055	28	1.1024	0.079	3.740	5.512	3.97	12 300	14 600
6218	90	3.5433	160	6.2992	30	1.1811	0.079	3.937	5.906	4.74	14 200	16 600
6219	95	3.7402	170	6.6929	32	1.2598	0.079	4.213	6.220	5.73	16 300	18 800
6220	100	3.9370	180	7.0866	34	1.3386	0.079	4.409	6.614	6.94	18 600	21 100
6221	105	4.1339	190	7.4803	36	1.4173	0.079	4.606	7.008	8.15	20 900	23 000
6222	110	4.3307	200	7.8740	38	1.4961	0.079	4.803	7.402	9.59	23 400	24 900
6224	120	4.7244	215	8.4646	40	1.5748	0.079	5.197	7.992	11.4	26 200	26 900



A. *Series* 6200, continued

Bearing number	Nominal bearing dimensions: d		D		B		r^*	Preferred shoulder diameter: Shaft	Housing	Bearing weight	Basic static load rating, C_o	Basic dynamic load rating, C
	mm	in	mm	in	mm	in	in	in	in	lb	lb	lb
6226	130	5.1181	230	9.0551	40	1.5748	0.098	5.669	8.504	12.7	29 100	28 700
6228	140	5.5118	250	9.8425	42	1.6535	0.098	6.063	9.291	19.5	29 300	28 700
6230	150	5.9055	270	10.6299	45	1.7717	0.098	6.457	10.079	25.3	32 500	30 000
6232	160	6.2992	290	11.4173	48	1.8898	0.098	6.850	10.886	32.0	35 500	32 000
6234	170	6.6929	310	12.2047	52	2.0472	0.118	7.362	11.535	38.5	43 000	36 500
6236	180	7.0866	320	12.5984	52	2.0472	0.118	7.758	11.929	41.0	46 500	39 000
6238	190	7.4803	340	13.3858	55	2.1654	0.118	8.150	12.717	50.5	54 500	44 000
6240	200	7.8740	360	14.1732	58	2.2835	0.118	8.543	13.504	61.5	60 000	46 500
B. *Series* 6300												
6300	10	0.3937	35	1.3780	11	0.4331	0.024	0.563	1.181	0.12	805	1400
6301	12	0.4724	37	1.4567	12	0.4724	0.039	0.656	1.220	0.13	990	1680
6302	15	0.5906	42	1.6535	13	0.5118	0.039	0.781	1.417	0.18	1200	1980
6303	17	0.6693	47	1.8504	14	0.5512	0.039	0.875	1.614	0.25	1460	2360
6304	20	0.7874	52	2.0472	15	0.5906	0.039	1.016	1.772	0.32	1730	2760
6305	25	0.9843	62	2.4409	17	0.6693	0.039	1.220	2.165	0.52	2370	3550
6306	30	1.1811	72	2.8346	19	0.7480	0.039	1.469	2.559	0.76	3150	4600
6307	35	1.3780	80	3.1496	21	0.8268	0.059	1.688	2.795	1.01	4050	5800
6308	40	1.5748	90	3.5433	23	0.9055	0.059	1.929	3.189	1.40	5050	7050
6309	45	1.7717	100	3.9370	25	0.9843	0.059	2.126	3.583	1.84	6800	9150
6310	50	1.9685	110	4.3307	27	1.0630	0.079	2.362	3.937	2.42	8100	10 700
6311	55	2.1654	120	4.7244	29	1.1417	0.079	2.559	4.331	2.98	9450	12 300
6312	60	2.3622	130	5.1181	31	1.2205	0.079	2.835	4.646	3.75	11 000	14 100
6313	65	2.5591	140	5.5118	33	1.2992	0.079	3.031	5.039	4.63	12 600	16 000
6314	70	2.7559	150	5.9055	35	1.3780	0.079	3.228	5.433	5.51	14 400	18 000
6315	75	2.9528	160	6.2992	37	1.4567	0.079	3.425	5.827	6.61	16 300	19 600

- **Either has a rated C of just over 6670 lb.**
- **But note that the 6211 has a bore of 55 mm (2.1654 in), and the 6308 has a bore of 40 mm (1.5748 in). The 6308 is more nearly in line with the desired shaft size.**

Summary of data for the selected bearing:

Bearing number: 6308, single-row, deep-groove ball bearing

Bore: d = 40 mm (1.5748 in)

Outside diameter: D = 90 mm (3.5433 in)

Width: B = 23 mm (0.9055 in)

Maximum fillet radius: r = 0.059 in

Basic dynamic load rating: C = 7050 lb

BEARING SELECTION: RADIAL AND THRUST LOADS COMBINED

For this case equivalent load is given by

$$P = VXR + YT$$

where P = equivalent load
V = rotation factor (as defined)
R = applied radial load
T = applied thrust load
X = radial factor
Y = thrust factor

- The values of *X* and *Y* vary with the specific design of the bearing and with the magnitude of the thrust load relative to the radial load.

- For relatively small thrust loads, X = 1 and Y = 0, so the equivalent load equation reverts to the form for pure radial loads.

i.e., $P = VR$

- To indicate the limiting thrust load for which this is the case, manufacturers list a factor called *e.*
- If the ratio $T/R > e$ Equation

$$P = VXR + YT$$

must be used to compute *P.*

- If $T/R < e$. Equation

$$P = VR$$

must be used to compute *P.*

Radial and thrust factors for single-row, deep-groove ball bearings

e	T/C_o	Y	e	T/C_o	Y
0.19	0.014	2.30	0.34	0.170	1.31
0.22	0.028	1.99	0.38	0.280	1.15
0.26	0.056	1.71	0.42	0.420	1.04
0.28	0.084	1.55	0.44	0.560	1.00
0.30	0.110	1.45			

Note: $X = 0.56$ for all values of Y.

where C_o is the static load rating of a particular bearing.

Procedure for Selecting a Bearing—Radial and Thrust Load

Step 1: Assume a value of *Y* from Table . The value *Y* =1.50 is reasonable, being at about the middle of the range of possible values.

e	T/C_o	Y	e	T/C_o	Y
0.19	0.014	2.30	0.34	0.170	1.31
0.22	0.028	1.99	0.38	0.280	1.15
0.26	0.056	1.71	0.42	0.420	1.04
0.28	0.084	1.55	0.44	0.560	1.00
0.30	0.110	1.45			

Note: $X = 0.56$ for all values of Y.

Step 2: Compute

$$P = VXR + YT.$$

Step 3: Compute the required basic dynamic load rating C.

Step 4: Select a candidate bearing having a value of C at least equal to the required value.

Step 5: For the selected bearing, determine C_o.

***Step 6:* Compute T/C_o.**

Step 7: From Table determine *e*,

Step 8: If $T/R > e$, then determine *Y* from Table.

Step 9: If the new value of *Y* is different from that assumed in Step 1, repeat the process.

Step 10: If $T/R < e$, use equation $P = VR$ to compute *P*, and proceed as for a pure radial load.

Problem: Select a single-row, deep-groove ball bearing from Table to carry a radial load of 1850 lb and a thrust load of 675 lb. The shaft is to rotate at 1150 rpm, and a design life of 20000 h is desired. The minimum acceptable di

So

Step 1. Assume $Y = 1.50$.

Step 2. $P = VXR + YT = (1.0)(0.56)(1850) + (1.50)(675) = 2049$ lb.

Step 3. From Figure the speed factor $f_N = 0.30$, and the life factor $f_L = 3.41$. Then the required basic dynamic load rating C is

$$C = Pf_L/f_N = 2049(3.41)/(0.30) = 23\ 300 \text{ lb}$$

Step 4. From Table we could use either bearing number 6222 or 6318. The 6318 has a bore of 3.5433 in and is well suited to this application.

Step 5. For bearing number 6318, $C_o = 22\ 500$ lb.

Step 6. $T/C_o = 675/22\ 500 = 0.03$.

Step 7. From Table , $e = 0.22$ (approximately).

Step 8. T/R = 675/1850 = 0.36. Because $T/R > e$, we can find Y = 1.97 from Table by interpolation based on T/C_0 = 0.03.

Step 9. Recompute $P = (1.0)(0.56)(1850) + (1.97)(675) = 2366$ lb:

$$C = 2366(3.41)/(0.30) = 26\,900 \text{ lb}$$

The bearing number 6318 is not satisfactory at this load. Let's choose bearing number 6320 and repeat the process from Step 5.

Step 5. C_0 = 29 800 lb.

Step 6. T/C_0 = 675/29 800 = 0.023.

Step 7. e = 0.20.

Step 8. $T/R > e$. Then $Y = 2.10$ using $T/C_0 = 0.023$.

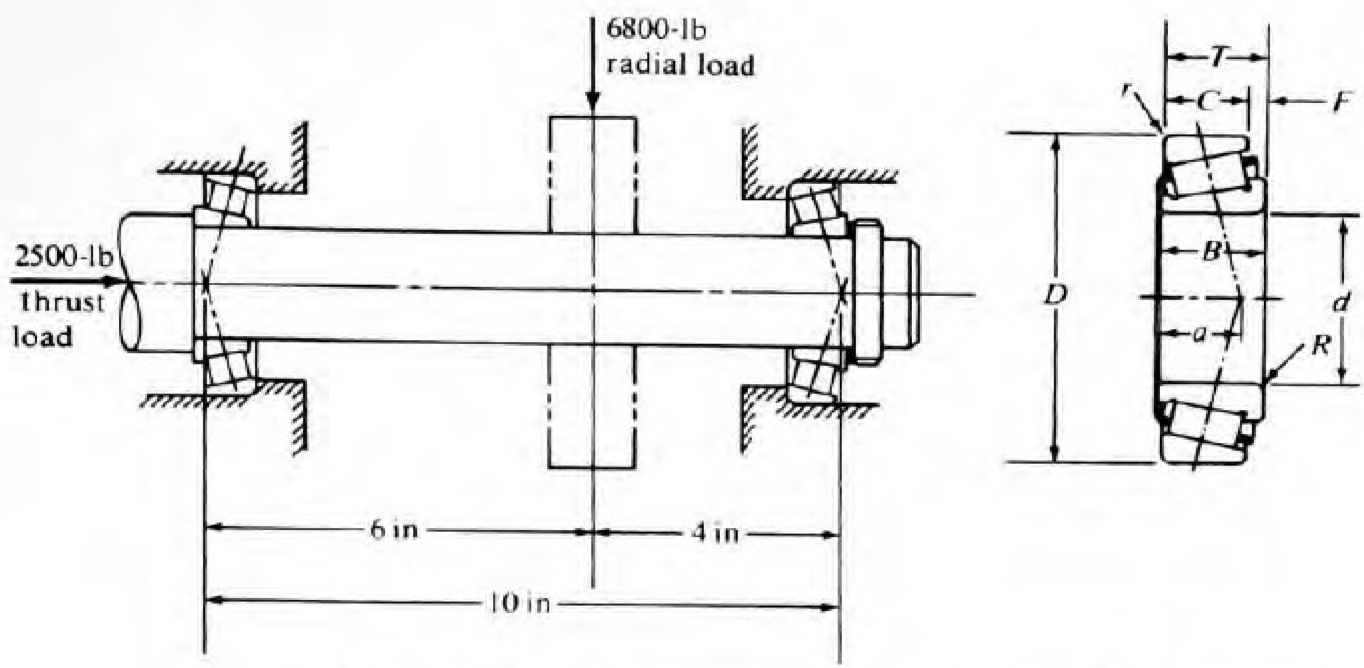
Step 9. $P = (1.0)(0.56)(1850) + (2.10)(675) = 2454$ lb. Thus,

$$C = 2454(3.41)/(0.30) = 27\,900 \text{ lb}$$

Because bearing number 6320 has a value of $C = 30\,000$ lb, it is satisfactory.

Tapered roller bearing

Tapered roller bearing installation



(a) Shaft loading and support

(b) Bearing details

The American Bearings Manufacturers" Association (ABMA) recommends the following approach in computing the equivalent loads on

$$P_A = 0.4F_{rA} + 0.5\frac{Y_A}{Y_B}F_{rB} + Y_A T_A$$

$$P_B = F_{rB}$$

where P_A = equivalent radial load on bearing A
P_B = equivalent radial load on bearing B
F_{rA} = applied radial load on bearing A
F_{rB} = applied radial load on bearing B
T_A = thrust load on bearing A
Y_A = thrust factor for bearing A from tables
Y_B = thrust factor for bearing B from tables

Tapered Roller Bearing data

Bore	Outside diameter	Width	a	Thrust factor, Y	Basic dynamic load rating, C
1.0000	2.5000	0.8125	0.583	1.71	8370
1.5000	3.0000	0.9375	0.690	1.98	12 800
1.7500	4.0000	1.2500	0.970	1.50	21 400
2.0000	4.3750	1.5000	0.975	2.02	26 200
2.5000	5.0000	1.4375	1.100	1.65	29 300
3.0000	6.0000	1.6250	1.320	1.47	39 700
3.5000	6.3750	1.8750	1.430	1.76	47 700

Note: Dimensions are in inches. Load C is in pounds for an L_{10} life of 1 million rev.

Problem: The shaft shown in previous figure carries a transverse load of 6800 lb and a thrust load of 2500 lb. The thrust is resisted by bearing *A.* The shaft rotates at 350 rpm and is to be used in a piece of agricultural equipment. Specify suitable tapered roller bearings for the shaft.

Solutio The radial loads on the bearings are

$$F_{rA} = 6800(4\ \text{in}/10\ \text{in}) = 2720\ \text{lb}$$

$$F_{rB} = 6800(6\ \text{in}/10\ \text{in}) = 4080\ \text{lb}$$

$$T_A = 2500\ \text{lb}$$

we must assume values of Y_A and Y_B.

Let's use $Y_A = Y_B = 1.75$. Then,

$$P_A = 0.40(2720) + 0.5\,\frac{1.75}{1.75}\,4080 + 1.75(2500) = 7503 \text{ lb}$$

$$P_B = F_{rB} = 4080 \text{ lb}$$

- Using Table as a guide, let's select 4000 h as a design life.

$$L_d = (4000\ \text{h})(350\ \text{rpm})(60\ \text{min/h}) = 8.4 \times 10^7\ \text{rev}$$

The required basic dynamic load rating can now be calculated , using *k* = 3.33

$$C_A = P_A(L_d/10^6)^{1/k}$$

$$C_A = 7503(8.4 \times 10^7/10^6)^{0.30} = 28\,400\ \text{lb}$$

Similarly,

$$C_B = 4080(8.4 \times 10^7/10^6)^{0.30} = 15\,400\ \text{lb}$$

From following Table , we can choose the b

Bore	Outside diameter	Width	*a*	Thrust factor, *Y*	Basic dynamic load rating, *C*
1.0000	2.5000	0.8125	0.583	1.71	8370
1.5000	3.0000	0.9375	0.690	1.98	12 800
1.7500	4.0000	1.2500	0.970	1.50	21 400
2.0000	4.3750	1.5000	0.975	2.02	26 200
2.5000	5.0000	1.4375	1.100	1.65	29 300
3.0000	6.0000	1.6250	1.320	1.47	39 700
3.5000	6.3750	1.8750	1.430	1.76	47 700

Note: Dimensions are in inches. Load *C* is in pounds for an L_{10} life of 1 million rev.

Bearing A

$$d = 2.5000 \text{ in} \quad D = 5.0000 \text{ in}$$
$$C = 29\,300 \text{ lb} \quad Y_A = 1.65$$

Bearing B

$$d = 1.7500 \text{ in} \quad D = 4.0000 \text{ in}$$
$$C = 21\,400 \text{ lb} \quad Y_B = 1.50$$

We can now recompute the equivalent loads:

$$P_A = 0.40(2720) + 0.5\,\frac{1.65}{1.50}\,4080 + 1.65(2500) = 7457 \text{ lb}$$
$$P_B = F_{rB} = 4080 \text{ lb}$$

From these, the new values of $C_A = 28\,200$ lb and $C_B = 15\,400$ lb are still satisfactory for the selected bearings.

Alternatively, if the bearing is rotating at a constant speed, and because the number of revolutions is proportional to the time of operation, N_i can be the number of minutes of operation at F_i, and N is the sum of the number of minutes in the total cycle. That is,

$$N = N_1 + N_2 + \cdots + N_i$$

Then the total expected life, in millions of revolutions of the bearing, would be

$$L = \left(\frac{C}{F_m}\right)^p$$

Life of bearing

mean effective load, F_m:

$$F_m = \left(\frac{\sum_i (F_i)^p N_i}{N} \right)^{1/p}$$

where F_i = individual load among a series of i loads

N_i = number of revolutions at which F_i operates

N = total number of revolutions in a complete cycle

p = exponent on the load/life relationship; $p = 3$ for ball bearings, and $p = 10/3$ for rollers

Problem

A single-row, deep-groove ball bearing number 6308 is subjected to the following set of loads for the given times:

Condition	F_i	Time
1	650 lb	30 min
2	750 lb	10 min
3	250 lb	20 min

This cycle of 60 min is repeated continuously throughout the life of the bearing. The shaft carried by the bearing rotates at 600 rpm. Estimate the total life of the bearing.

Solution

$$F_m = \left(\frac{\sum_i (F_i)^p N_i}{N} \right)^{1/p}$$

$$F_m = \left(\frac{30(650)^3 + 10(750)^3 + 20(250)^3}{30 + 10 + 20} \right)^{1/3} = 597 \text{ lb}$$

$$L = \left(\frac{C}{F_m}\right)^p$$

From Table for the 6308 bearing, we find that $C = 7050$ lb. Then

$$L = \left(\frac{7050}{597}\right)^3 = 1647 \text{ million rev}$$

At a rotational speed of 600 rpm, the number of hours of life would be

$$L = \frac{1647 \times 10^6 \text{ rev}}{1} \cdot \frac{\text{min}}{600 \text{ rev}} \cdot \frac{\text{h}}{60 \text{ min}} = 45\,745 \text{ h}$$