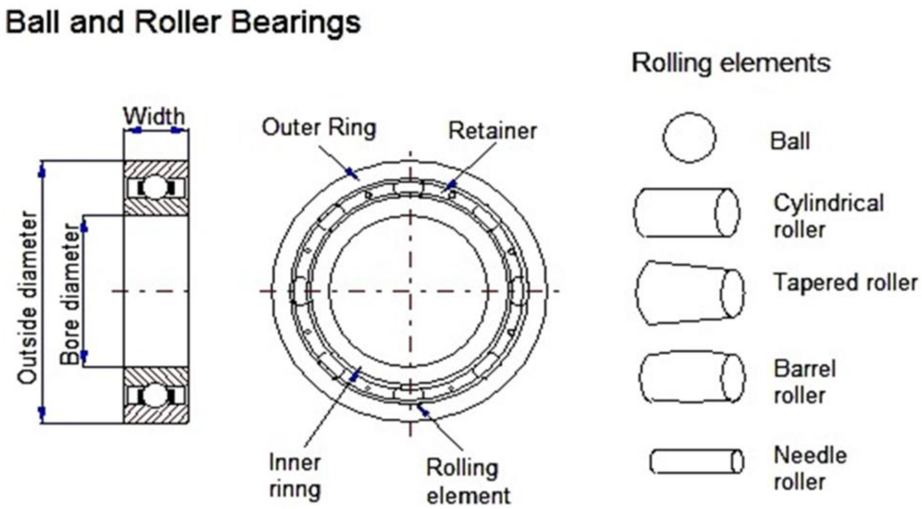
LECTURES FOURTEEN & FIFTEEN

ROLLING CONTACT BEARINGS



<u>Reference</u>: "Machine Elements in Mechanical Design" 4th Edition in SI units, By: Robert L. Mott, Chapter 14.

Introduction:

- See all sections on this chapter i.e.

14-1 Objectives of this chapter (Page 600)
14-2 Types of rolling contact bearings (Page 600 to 604)
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- See also tables and figures on this chapter.
- See the CD for MDesign which give all types of rolling contact bearings, fixation, and calculations.

Summary of design procedure for rolling contact bearings:

1. From analysis of forces on shaft take reaction on bearing and speed.
2. Specify equivalent load (P) as below:

P= VR ………. (14-5) for radial load only (see page 613)

P= VXR + YT ……….. (14-6) for axial & radial load (see page 614)

$$\mathbf{P_A = 0.4F_{rA} + 0.5\left(\frac{Y_A}{Y_B}\right) F_{rB} + Y_A T_A}$$

$$\mathbf{P_B = F_{rB}}$$

(14-8) for tapered rolling bearing (See page 618)

Where:

V: Rotation parameter (V=1 if inner race rotating; V=1.2 if outer race rotating)
R: Radial load; T: Thrust load; X: Radial factor = 0.56;
Y: Thrust factor (see table 14.5)

Note: for small thrust load X=1 & Y=0 as in equation (14-5)

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 table 14.7 page 614)
Y_B: Thrust factor for bearing B (from table 14.7 page 614)

3. Assume recommended life from table 14-4 (page 612) and find suitable capacity & bearing or choose the bearing then find its life.

$$C = P_d \frac{F_L}{F_n} \qquad \text{....... (14-4) page 612}$$

Where:

C: Dynamic load rating

You can also use the following equation for C:

load (P) & life (L) relationship

$$\frac{L_2}{L_1} = \left(\frac{P_1}{P_2}\right)^K \quad \text{.......} \qquad (14\text{-}1)$$

$$C = P_1/(L_d/10^6)^{1/k} \qquad (14\text{-}3)$$

F_L: Life factor……… see figure (14-12)

F_n: Speed factor ……… see figure (14-12)

K: factor (K=3 for ball bearing & K=3.33 for roller bearing)

$L_2 = L_d$ = Design life at design load ($P_2=P_d$)

$L_1=L_{10}$= Life at load C ($L_{10}= 10^6$ revolution at P_1=C)

$L_2=L_d$= (hours) (rpm) (60 min/hr)

Ex: 14-1 (Page 611), Ref. 1:

A catalog lists the basic dynamic load rating for a ball bearing to be (31358 N) 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 15568 N)?

Sol:

P_1 = C = 31358 N ; $P_2 = P_d$ = 15568 N ; $L_1=L_{10}=10^6$ rev. ; K=3

Find: L_2=design life at design load P_2

$L_2=L_d= L_1 (P_1/P_2)^K = 10^6 (31356/15568)^3 = 8.17*10^6$ rev.

$L_2=8.17*10^6$ rev. at P_d= 15568 N

Ex: 14-2 (Page 611), Ref. 1:

Compute the required basic dynamic load rating, C for a ball bearing to carry a radial load of (2891.2 N) from a shaft rotating at 600 rpm that is part of an assembly conveyor in a manufacturing plant.

Sol:

C=? ; P_d= 2891.2 N ; n=600 rpm ; Application: conveyor

From eq.(14-3) $C= P_d (L_d/10^6)^{1/K}$ K=3

L_d= {30000 hr (from table 14-4, page 612)}* 600 rpm * (60 min/hr)

L_d= 1.08 *10^9 rev.

C= 2891.2 $(1.08*10^9/10^6)^{1/3}$ = 29668 N

Or, you can solve this example as follows:

From figure 14-12 page 612:

F_n= 0.381 at 600 rpm (62.82 rad/sec)

F_L= 3.9 at 30000 hr life

C= P_d (F_L/F_n) ….. Equation (14-4)

C = 2891 (3.9/0.381) = 29596 N

Ex: 14-3 (Page 614), Ref.1:

Select a single-row, deep-groove ball bearing to carry (2891 N) 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 40 mm.

Sol:

R= 2891 N ; N=62.82 rad/sec = 600 rpm ; life = 30000 hr ; d= 40 mm

Select a single-row deep groove ball bearing

V= 1 for inner race rotating

Use table 14-3 page 607 to page 609 at d=40 mm; choose:

A-series 6200 ⟶ C=22.46 KN at d=40 mm type 6208

B-series 6300 ⟶ C=31.36 KN at d= 40 mm type 6308

But from Ex: 14-2 (page 611) choose type 6308, C= 31.36 KN

Which is greater than 29.7 KN?

Ex: 14-4 (Page 615), Ref.1:

Select a single-row, deep-groove ball bearing from Table 14-3 to carry a radial load of (8220 N) and a thrust load of (3002 N). The shaft is to rotate at 1150 rpm, and a design life of 20 000 h is desired. The minimum acceptable diameter for the shaft is 78.74 mm.

Sol:

R= 8228 N; T=3002 N; N=120.4 rad/sec; L_d= 20000 hr; d≥ 78.74 mm

Select a single-row deep groove ball bearing?

P= VXR + YT ……… (14-6)

Assume Y= 1.5; V=1 (inner race rotates); X=0.56

P= (1*0.56*8228) + (1.5*3002) = 9113 N

F_n = 0.3 & F_L= 3.41 ⟶ C= P*F_L /F_n = 9113 * 3.41/0.3 =103.64 KN=23300 Ib

From table 14-3 ⟶ choose 6222 or 6318 , so take 6318 with d= 90 mm,

So at this bearing the following information are:

Bearing No.	d	D	B	C_0	C
6318	90 mm	190 mm	43 mm	100.1 KN	109.8 KN

Now we should check the suitable Y and we will make the new calculation:

T/C_0 = 3002/100100 = 0.03 & from table 14-5 (Page 614) ⟶ Y=1.97

P= VXR + YT = (1*0.56*8228) + (1.97*3002) = 10523 N

& C = 10523 (3.41/0.3) = 119651 N = 119.6 KN = 29700 Ib

(from table 14-3), 119.6 KN(29700 Ib) < 133.44 KN (30000 Ib)

This bearing is satisfactory.

Bearing No.	d	D	B	C_0	C
6320	100 mm	215 mm	47 mm	132.6 KN	133.4 KN

Ex: 14-5 (Page 619), Ref.1:

The shaft shown in Figure 14-15 carries a transverse load of (30246 N) and a thrust load of (11120 N). 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.

Sol:

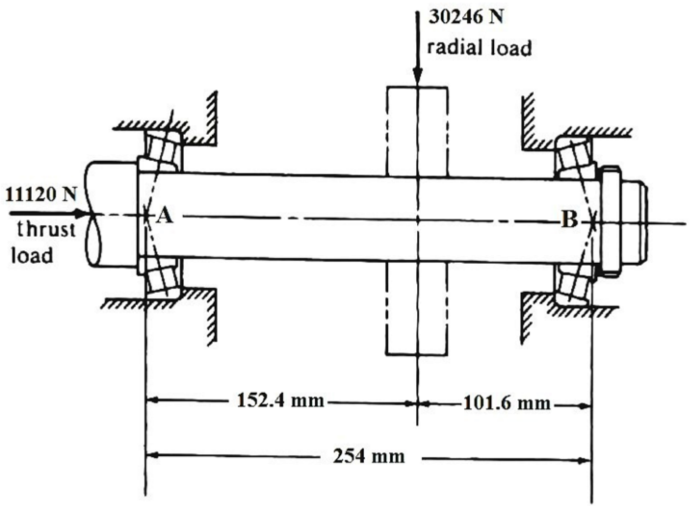
The thrust resisted by bearing A

N= 36.64 rad/sec

Application:

Agricultural Equipment

Select suitable tapered rolling bearing contact for shaft?



F_{rA} = 30246 * (101.6/254) = 1209

F_{rB} = 20246 * (152.4/254) = 18147 N

T_A = 11120 N

Assume $Y_A = Y_B = 1.75$

Now use equation 14-8 ⟶ $P_A = 0.4F_{rA} + 0.5 \frac{Y_A}{Y_B} F_{rB} + Y_A T_A$

P_A = 0.4 (12098) + 0.5(1.75/1.75) (18147) + 1.75 (11120) = 33373 N

$P_B = F_{rB}$ = 18147 N

From table 14-4 ⟶ choose L_d = 4000h * (350 rpm) * 60 min/h

$L_d = 8.4 * 10^7$ rev.

From eq. 14-3 ⟶ $C_A = P_A (L_d/10^6)^{1/K} = 33373 (8.4*10^7/10^6)^{1/3.33}$

C_A = 126323 N=28400 Ib

& $C_B = P_B (L_d/10^6)^{1/K} = 18147 (8.4*10^7/10^6)^{1/3.33}$ = 68499 N=15400 Ib

From table 14-7 (page 619) ⟶ choose the following bearings:

Bearing A ⟶ d= 63.5 mm ; D= 127 mm ; Y_A= 1.65 ; C= 130326 N

Bearing B ⟶ d= 44.45 mm ; D= 106.6 mm ; Y_B = 1.5 ; C = 95187 N

Now we should check our calculation as follows:

P_A= 0.4(12098) + 0.5(1.65/1.5) (18147) + 1.65 (11120) = 33168 N

& $P_B = F_{rB}$ = 18147 N

C_A = 125433 N & C_B = 68499 N

They are still satisfactory for the selected bearings.

Note: if $P_A < F_{rA}$ then let $P_A = F_{rA}$ and compute P_B

$P_B = 0.4 F_{rB} = 0.5 (Y_B/Y_A) (F_{rA}) - (Y_B T_A)$ ………. 14-10 (Page 620)

Note: follow the same procedure for Angular contact ball bearing.

7-3: Life predication under varying loads, (Page 625):

Mean effective load (F_m) = $\left\{\frac{\sum i\ (Fi)^P\ Ni}{N}\right\}^{\frac{1}{P}}$

Where: Fi = individual load among a series of i loads

Ni = No. of revolutions at which Fi operates

N = total No. of revolutions in complete cycle

P = 3 for ball bearings; P = 10/3 for roller bearings

Ni = No. of minutes of operation at Fi

N = the sum of no. of minutes in the total cycle = N1 + N2 + …….. + Ni

Expected life in millions of revolutions is:

L = $(C/F_m)^P$ ……… 14-12

Ex: 14-6 (Page 626), Ref.1:

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

Condition	Fi	Time
1	2891 N	30 min.
2	3336 N	10 min.
3	1112 N	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 (62.82 rad/sec). Estimate the total life of the bearing.

Sol:

$F_m = \left\{\frac{\sum i\ (Fi)^P\ Ni}{N}\right\}^{\frac{1}{P}}$

$= \left\{\frac{30\ (2891)^3 + 10\ (3336)^3 + 20\ (1112)^3}{30+10+20}\right\}^{1/3}$ = 2655 N

L = $(C/F_m)^P$ = {(31358 (tab. 14-3 for No. 6308)) / 2655}^{3} = 1647 million rev.

L = (1647*10^6/1) * (min / 600 rev.) * (h / 60 min.) = 4574 hours