Tutorial 4: Bearing

In-class Activities

1. Choose the bore diameter of a deep groove ball bearing with requirement of a basic dynamic load rating of 4 kN.

2. Select the bore diameter of a 03 series cylindrical roller bearing with minimum design of load rating of 30 kN.

3. Straight cylindrical bearings are commonly used in heavy machinery. Compare the differences in term of outer diameter, width, and load rating between 02-series and 03-series straight cylindrical bearings for a bore diameter of 50 mm.

Theory

1. List two advantages of roller bearing over ball bearing.

2. What is the difference between deep groove ball bearing and angular contact ball bearing?

3. What are the factors that affect the life of a bearing?

4. What is the purpose of lubrication in a bearing?

5. What are the common types of failure in a bearing?

Calculations

Question 1
A 50 mm bore (02 series) deep groove ball bearing carries a combined load of 9kN radially and 6 kN axially at 1200 rpm. Calculate:

(i) The equivalent radial load

(ii) Rating life in hours.

(iii) Median life in hours.

(iv) The loading of a ball bearing if the expected life is increased by 25%.

(v) The expected rating life if probability of failure in decreases to 5%.

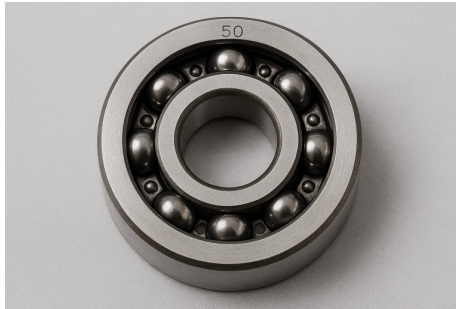Assumptions: The outer ring rotates and loads in moderate shock

Figure Q1

Example Solution

Bore diameter $d = 50mm$
Bearing type: Deep groove ball bearing
Radial load $F_r = 9kN$
Axial load $F_a = 6kN$
Speed $n_{rpm} = 1200rpm$
Outer ring rotates $V = 1.2$
Moderate shock for ball bearing $K_s = 2$

i - The equivalent radial load.

Step 1: Find C and Cs from Table 3.1.
From Table 3.1, for a 50 mm bore deep groove ball bearing, the basic dynamic
load rating C is 35.1 kN and the basic static load rating C_s is 19.6 kN.

Bore Diameter (mm)	C (kN)	Cs (kN)
50	35.1	19.6

Table 3.1

Step 2: Find X and Y using Table 3.3.
First, find $F_a/C_s = 6000/19600 = 0.306$ to use Table 3.3.

F_a/C_s	e
0.28	0.38
0.306	**e**
0.22	0.42

Table 3.3

Interpolate to find e when $F_a/C_s = 0.306$.

$$e = 0.38 + \frac{0.306 - 0.28}{0.42 - 0.38} \times (0.42 - 0.38) = 0.39$$

Find $F_a/VF_r = 6000/1.2(9000) = 0.556$.

F_a/C_s	Y
0.28	1.15
0.306	**Y**
0.42	1.04

Table 3.3

Since $F_a/VF_r > e$ which $0.556 > 0.39$, use the second column of Table 3.3.
From Table 3.3, $X = 0.56$. Y value is between 1.15 and 1.04.
Interpolate to find Y.

$$Y = 1.15 + \frac{0.306 - 0.28}{1.04 - 1.15} \times (0.42 - 0.28) = 1.13$$

Step 3: Find equivalent radial load.
Considering the outer ring rotates and moderate shock.

$$P = K_s(XVF_r + YF_a) \tag{1}$$

Substitute $V = 1.2$ and $K_s = 2$ into (1).

$$\begin{aligned}
P &= 2(0.56(1.2)(9000) + 1.13(6000)) \\
&= 25651N \\
&= 25.651kN
\end{aligned}$$

ii - The rating life in hours.

$$L_{10} = \frac{10^6}{60n_{rpm}} \left(\frac{C}{P}\right)^a \text{ hours} \tag{2}$$

where a=3 for ball bearing.
$n_{rpm} = 1200$ rpm
Substitute C and P into (2).

$$\begin{aligned}
L_{10} &= \frac{10^6}{60(1200)} \left(\frac{35.1}{25.651}\right)^3 \\
&= 36 \text{ hours}
\end{aligned}$$

iii - The median life in hours.
Median life if five times of rating life, $5L_{10}$.

$$\begin{aligned}
5L_{10} &= 5(36) \\
&= 180 \text{ hours}
\end{aligned}$$

iv - The loading of a ball bearing if the expected life is increased by 25%.

$$\frac{L'_{10}}{L"_{10}} = \left(\frac{P_2}{P_1}\right)^a \qquad (3)$$

Current expected life: $L'_{10} = 100\%$
Increase expected life to 25%: $L"_{10} = 125\%$

$$\frac{100}{125} = \left(\frac{P_2}{25651}\right)^3$$
$$P_2 = 23812N$$

v - The expected rating life if probability of failure decreases to 5%.
Current probability of failure is 10% when rating life $L_{10} = 36$ hours.
Probability of failure 10% means 90% reliability.
When probability of failure decreases to 5%, reliability increases to 95%.
From Figure 3.1 Graph of reliability factor, when reliability is 0.95, the life adjustment factor is $K_r = 0.62$.
Use Rating life equation when reliability greater than 90%, L_5.

$$L_5 = K_r \frac{10^6}{60 n_{rpm}} \left(\frac{C}{P}\right)^a \quad \text{hours} \qquad (4)$$

$$L_5 = 0.62 \frac{10^6}{60(1200)} \left(\frac{35.1}{25.651}\right)^3$$
$$= 22 \text{ hours}$$

Question 2

A 60mm bore (02 series) double row angular contact ball bearing shown in Figure 2 has a 15° contact angle. The outer ring rotates, and the bearing carries a combined steady load of 5kN radially and 1.5kN axially at 1000rpm. Calculate the median life in hours.

  (i) The equivalent radial load.

 (ii) Rating life in hours.

(iii) Median life in hours.

Figure Q2

Question 3

A 40mm bore (03 series) straight cylindrical bearings shown in Fig.3 operates at 2400rpm. Radial load is 5kN, with heavy shock and the outer rings rotate.

(i) Find the rating life in hours.

(ii) Next, during assembly, the width of the bearing have limitations to be below than 20mm. Suggest an alternative bearing type that can be used to replace the straight cylindrical bearing.
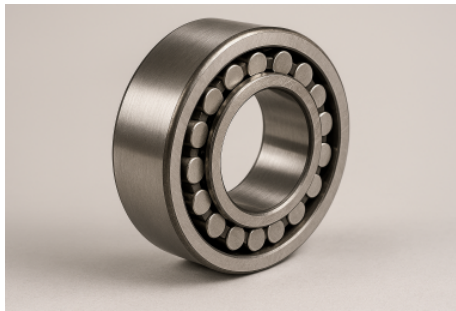
(iii) Estimate decrease of the rating life.

Figure Q3

Question 4

A solid steel shaft carries belt tension at pulley C as shown in Figure 4. Bearing at both ends of the shaft are taken to be identical 02 series deep groove and subjected to light shock loading. The inner ring rotates and operating at a speed of 1800 rpm. The average life of 10 years at 10 hours per day and 300 working day per years. Determine:

  (i) The equivalent radial load on each bearing.

 (ii) The suitable bore diameter of the bearing.

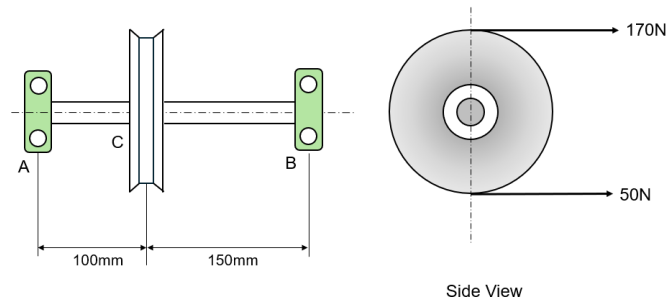(iii) Expected rating life if the probability of failure is reduced to 5% at 1200 rpm.

Figure Q4

Answer

Q2

  (i) The equivalent radial load is 8.08 kN.

 (ii) The rating life is 5519 hours.

(iii) The median life is 27595 hours.

Q3

  (i) The rating life is 2039 hours.

 (ii) Use 02-series straight cylindrical bearing with 40mm bore diameter and 18mm width.

(iii) The decrease of the rating life is 1274 hours.

Q4

  (i) The equivalent radial load on bearing A is 198 N and on bearing B is 132 N.

 (ii) The suitable bore diameter of the bearing is 10 mm.

(iii) The expected rating life if the probability of failure is reduced to 5% at 1200 rpm is 144573 hours.