

C_0 - static capacity
 L_{10} - mr $10,000 mr$
~~act~~ - Dynamic - max. radial load $\rightarrow L_{10} = ?$ $1 mr$

Design of Machines and Mechanical Systems (PC-BTM711)

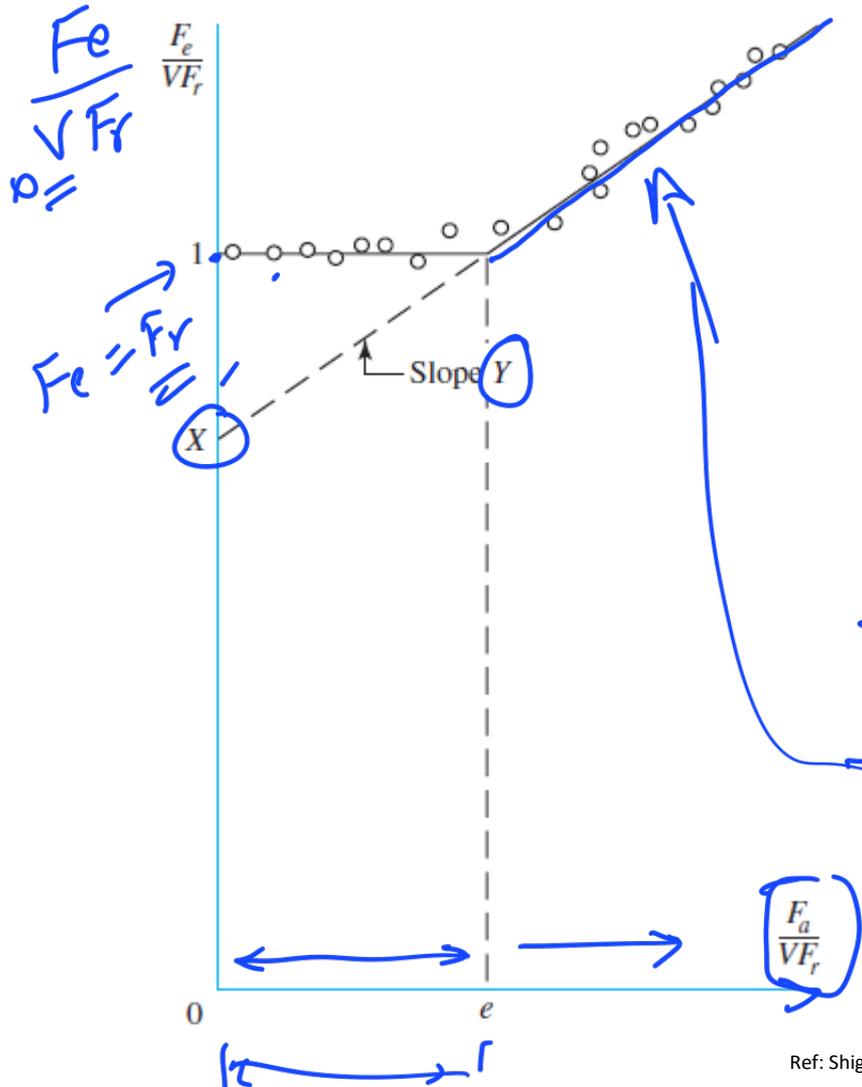
Session 08

Module 2: Rolling Contact Bearing Design

Session Outcomes

- Calculate equivalent load
- Select bearing from manufacturer's catalogue
- Bearing design for combination of loads and speeds
- Calculate reliability of bearings
- Discuss practical aspects of bearing design

Equivalent Dynamic Load



F_e is equivalent radial load that does same damage as F_a and F_r together

V is race factor (1.0 when inner race rotating and 1.2 when outer race rotating)

$$\frac{F_e}{VF_r} = 1$$

when $\frac{F_a}{VF_r} \leq e$

$$\frac{F_e}{VF_r} = X + Y \frac{F_a}{VF_r}$$

when $\frac{F_a}{VF_r} > e$

$$f\left(\frac{F_a}{C_0}\right)$$

static load capacity

- ① $F_e = VF_r$ when $\frac{F_a}{VF_r} \leq e$
- ② $F_e = XVFr + YFa$ when $\frac{F_a}{VF_r} > e$

Ref: Shigley, Joseph E., Charles R. Mischke, and Richard G. Budynas. Mechanical engineering Design. McGraw-Hill, 2014

Equivalent Dynamic Load (P)

$$e = f\left(\frac{F_a}{F_r}\right)$$

- Equivalent of combined radial and axial load acting on the bearing

$$P = XV F_r + Y F_a$$

$$\begin{aligned} Y &= 0 \\ X &= 1 \\ P &= V F_r \end{aligned}$$

where

P : Equivalent dynamic load

X, Y : Radial and thrust factors (DDB T15.9)

V : Race rotation factor (=1 when inner ring is rotating,
=1.2 when outer ring is rotating)

F_r, F_a : Radial and thrust loads acting on bearing

- To be compared against dynamic load capacity (C)

QUIZ

Equivalent Dynamic Load

Which of the following statement is TRUE regarding the equivalent dynamic load for radial bearings?

1. It is a pure radial load ✓
2. It may depend on static capacity of bearing
3. Both of above

X, y

Load Life Relationship

$$L \propto \frac{1}{P}$$

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

in mr

For $P_2 = C$, $L_2 = 1 \text{ mr}$

$$\rightarrow L_{10} = \left(\frac{C}{P}\right)^p$$

where $p = 3$ for ball bearings

$p = \frac{10}{3}$ for roller bearings

$$C = P(L_{10})^{\frac{1}{p}}$$

Dynamic load capacity required to sustain load P for a life of L_{10}

$$C = P(L_{10})^{\frac{1}{p}}$$

Example : Dynamic Load Capacity

A single-row deep groove ball bearing is subjected to a radial force of 8 kN. The shaft rotates at 1450 rpm and the expected life L_{10h} of the bearing is 8,000 hrs.

Compute the required dynamic capacity of the bearing.

$$P = F_r = 8 \text{ kN}$$

~~$F_r = 8 \text{ kN}$~~

$$n = 1450 \text{ rpm}$$

$$L_{10h} = 8000 \text{ hrs}$$

$$C = ?$$

$$C = P (L_{10})^{1/p}$$

Radial load

$p = 3$ for ball bearing

$$L_{10} = ? \text{ in } m_r$$

$$= \frac{(8000 \times 60) \times 1450}{10^6}$$

$$= 696 \text{ } m_r$$

$$C = 8 \times (696)^{1/3} = 70.9 \text{ kN}$$

QUIZ

Load-Life Relation

Given the same radial load P and life L_{10} , which of the bearing type will require higher dynamic capacity?

1. Ball bearing ✓
2. Roller bearing

$$C = P(L_{10})^{\frac{1}{p}}$$

where $p = 3$ for ball bearings
 $p = \frac{10}{3}$ for roller bearings

Miscellaneous Topics in bearing design

- Selection of bearing life (DDB T15.3-5)
- Bearing load factors (DDB T15.6)
- Designation of bearings (DDB T15.8)

Selection of bearing from Manufacturer's catalogue

Force calc.

- Calculate radial and axial forces acting on bearing
- Determine diameter of shaft for fitting bearing

X, Y factors

- Assume series of bearing (DDB T15.10)
- Determine X, Y factors from DDB T15.2

Calculate P

- Calculate equivalent dynamic load $P = XVF_r + YF_a$

Life L_{10}

- Decide expected bearing life L_{10} in mr

Load C

- Calculate dynamic load capacity $C = P(L_{10})^{\frac{1}{p}}$

Check if okay

- Check if assumed series has required dynamic capacity
- If not, select next series and repeat steps starting with determination of X, Y factors

Example 1: Selection of bearing

A single-row deep groove ball bearing is subjected to a radial force of 8 kN and a thrust force of 3 kN.

The shaft rotates at 1200 rpm. The expected life L_{10h} of the bearing is 10,000 hrs. The minimum acceptable diameter of shaft is 70 mm.

Select a suitable bearing for this application.

$$F_r = 8 \text{ kN}$$

$$F_a = 3 \text{ kN}$$

$$n = 1200 \text{ rpm}$$

$$L_{10h} = 10,000 \text{ hrs}$$

$$d_{\min} = 70 \text{ mm}$$

(i) Determine X, Y factors

From DDB T 15.10

Let's assume series 6014 for $d = 70 \text{ mm}$

$$C = 37,700 \text{ N}$$

$$C_0 = 24,500 \text{ N}$$

From DDB T 15.9

$$\frac{F_a}{C_0} = \frac{3000}{24,500} = 0.1225$$

$$\Rightarrow \boxed{0.27 < e < 0.31}$$

$$\frac{F_a}{F_r} = \frac{3000}{8000} = \underline{\underline{0.375}}$$

$$\Rightarrow \frac{F_a}{F_r} > e$$

$$X = 0.56$$

$$Y = \boxed{1.425} \text{ (by interpolation)}$$

(ii) Eqv. Dynamic load

$$P = X V F_r + Y F_a$$

$$V = \text{Race factor} = 1 \text{ (assuming inner race rotating)}$$

$$= 0.56 \times 1 \times 8 + 1.425 \times 3$$

$$= \boxed{8.755 \text{ kN}}$$

(iii) Determine L_{10} life

$$L_{10} = \left(1000 \text{ hr} \times 1200 \text{ rpm} \times 60 \frac{\text{min}}{\text{rpm}} \right) \times 10^{-6}$$

$$L_{10} = \boxed{720 \text{ mr}}$$

(iv) Required dynamic capacity

$$\begin{aligned} C_{\text{req}} &= P (L_{10})^{1/p} \\ &= 8755 \times (720)^{1/3} \\ &= \boxed{78,469.4 \text{ N}} \end{aligned}$$

3 for ball bearings

(v) Check against actual bearing capacity

For series 6014, $C = 37,700 \text{ N}$

Since $C < C_{\text{req}}$.

→ choose another series

Let's choose series 6314

$$C = 104,000 \text{ N}$$

$$C_0 = 63,000 \text{ N}$$

$$\frac{F_a}{C_0} = \frac{3000}{63,000} = 0.0496 \Rightarrow \underline{\underline{0.24 < e < 0.27}}$$

$$\frac{F_a}{F_r} = \underline{\underline{0.375}} \Rightarrow \underline{\underline{\frac{F_a}{F_r} > e}}$$

$$X = 0.56$$

$$Y = 1.749 \quad (\text{by interpolation w.r.t. } \frac{F_a}{C_0})$$

$$P = 0.56 \times 1 \times 8 + 1.749 \times 3 = \underline{\underline{9,727 \text{ kN}}}$$

$$(C_{req}) = 9727 \times (720)^{\frac{1}{3}} = \underline{\underline{87,181 N}}$$

$$\because C_{req} < C = 104,000$$

⇒ Series 6314 is suitable

QUIZ

Selection of Bearing from Catalogue

While selecting bearing from manufacturer's catalogue, which of the following step needs value of static load capacity C_0 ?

1. Calculation of radial and axial load

2. Deciding expected bearing life L_{10}

3. None of the above