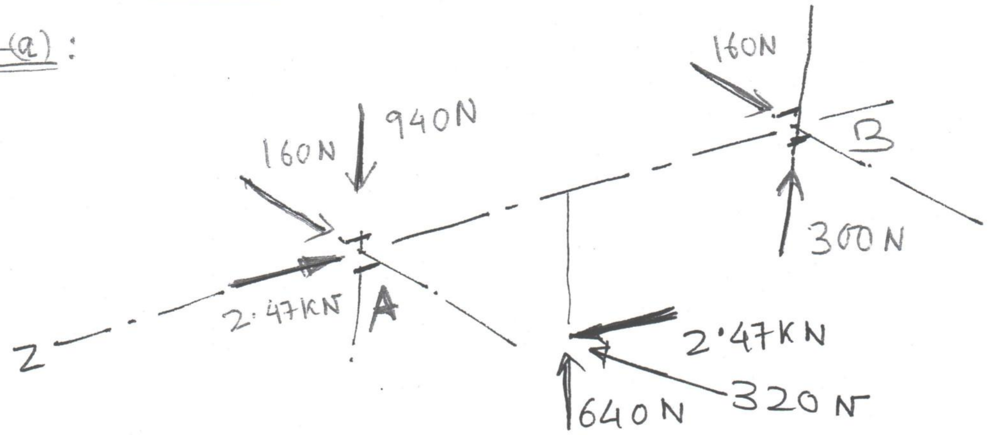
# TUTORIAL-7 Solution

## Part-(a):




- Bearing at A: Angular contact bearing. Takes all the thrust load.
- Bearing at B: Straight roller bearing
- Desired reliability: $R_A = 0.99$, $R_B = 1$

## Selection of bearing at A:

$$F_r = (0.16^2 + 0.94^2)^{1/2} = 0.954 \text{ kN}$$

$$F_a = 2.47 \text{ kN}$$

Trial 1: Refer to table 11-1. Choose a starting $F_a/C_o$ value at the middle of the table.

$$\Rightarrow \frac{F_a}{C_o} \simeq 0.07 \Rightarrow C_o = 35.3 \text{ kN}$$

Refer to 11-2 (table): select 02-60 mm angular contact bearing.

$$\boxed{C_{10} = 55.9 \text{ kN}, \quad C_o = 35.5 \text{ kN}}$$

$$\Rightarrow F_a/C_o = 0.0696 \simeq 0.07$$

Assume inner ring rotation. Rotation factor $\boxed{V = 1.}$

$$\Rightarrow \frac{F_a}{VF_r} = 2.59 > e \quad (e \simeq 0.27 \text{ table 11-1})$$

$$\Rightarrow X_2 = 0.56, \quad Y_2 = 1.632 \quad (\text{Table 11-1})$$

$\Rightarrow$ Equivalent ~~radial~~ load: $F_e = X_2(VF_r) + Y_2 \cdot F_a$

$$\Rightarrow \boxed{F_e = 4.57 \text{ kN}} = (0.56(0.954) + 1.632 \times 2.47) \text{ kN}$$

Application factor $a_f = 1.3$. Desired load $F_D = F_e$

Life: $\mathcal{L}_D = 25\,kh$ (Desired) . $L_{10} = 10^6$ cycles

$$\Rightarrow \boxed{x_D = \frac{25 \times 10^3 \times 600 \times 60}{10^6} = 900}$$

$$\Rightarrow C_{10} = a_f \cdot F_D \cdot \left[ \frac{x_D}{x_0 + (\theta - x_0)\{\ln \frac{1}{R_D}\}^{1/b}} \right]^{1/a}.$$

$a = 3$ (for ball bearing)

$x_0 = 0.02$, $\theta - x_0 = 4.439$, $b = 1.483$.

$$\Rightarrow C_{10} = 1.3 \times 4.57 \left[ \frac{900}{0.02 + 4.439\{\ln(\frac{1}{0.99})\}^{1/1.483}} \right]^{1/3}$$

$$= 1.3 \times 4.57 \times [16.003]$$

$$\Rightarrow \boxed{C_{10} = 95.1\,kN > 55.9\,kN}$$

This will not work.

Trial-2: Select 02-90 mm bearing

$\Rightarrow \boxed{C_{10} = 106\,kN,\ C_0 = 73.5\,kN}$ (Table 11-2)

$\Rightarrow F_a/C_0 = 0.034$, $X_2 = 0.56$, $Y_2 = 1.93$ (Table 11-1)

$\Rightarrow \boxed{F_D = F_e = 5.3\,kN}$

$\Rightarrow C_{10} = 110.2\,kN > 106\,kN$

Again, will not work.

Trial-3: Select 02-95 mm bearing.

$\Rightarrow \boxed{C_{10} = 121\,kN,\ C_0 = 85\,kN}$ (Table 11-2)

$\Rightarrow F_a/C_0 = 0.029$, $X_2 = 0.56$, $Y_2 = 1.98$ (Table 11-1)

$\Rightarrow F_D = F_e = 5.425\,kN$

$\Rightarrow \boxed{C_{10} = 112.8\,kN < 121\,kN}$

Thus we select 02-series 95 mm angular contact bearing for A.

**Bearing at B:** (straight roller)

$R_D = 1, \quad F_r = F_D = (0.16^2 + 0.3^2)^{1/2} = 0.34\ kN$

$\Rightarrow \quad C_{10} = a_f \cdot F_D \cdot \left[\frac{900}{0.02}\right]^{1/a} \quad (a = 10/3 \text{ for roller bearing})$

$= 11\ kN$

Refer to table 11-3: Even the smallest bore size straight roller bearing has $C_{10} = 16.8\ kN > 11\ kN$.

$\Rightarrow$ Any bearing can be chosen.

- Choose bearing with same bore size.

$\Rightarrow$ For B: 02-series 95 mm roller bearing.

$\boxed{C_{10} = 165\ kN, \quad C_0 = 112\ kN}$

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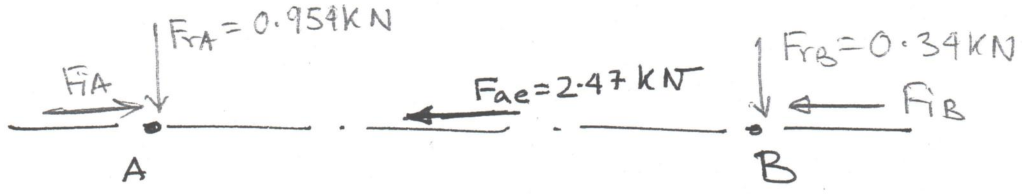
**Part-b:** The modified FBD looks like the following




- Consider direct mounting.
- $F_{ae}$ is positive as per convention (i.e. towards A)
- Induced thrust $F_i = \frac{0.47 F_r}{K}$. Starting guess for $K = 1.5$.

$\Rightarrow \quad \boxed{F_{iA} = 0.30\ kN, \quad F_{iB} = 0.107\ kN}$

Since $F_{iA} < (F_{iB} + F_{ae}) = 2.577\ kN$, bearing A takes thrust load.

$\Rightarrow$ Equivalent loads are:

$F_{eA} = 0.4 F_{rA} + K_A (F_{iB} + F_{ae}) = 4.25\ kN$

$F_{eB} = F_{rB} = 0.34\ kN$

(Eq 11-16)

**Reliability:** $R_A = R_B = \sqrt{0.9} = 0.949$

**Rated life:** $L_{10} = 3000 \times 500 \times 60 = 90 \times 10^6$ revs.

$$\Rightarrow \boxed{x_D = \frac{900 \times 10^6}{90 \times 10^6} = 10}$$

$$C_{10} = a_f F_D \cdot \left[ \frac{x_D}{x_0 + (\theta - x_0)\{\ln(\frac{1}{R_D})\}^{1/b}} \right]^{1/a} \quad \left( a = \frac{10}{3} \text{ for roller bearings} \right)$$

$x_0 = 0, \quad \theta = 4.48, \quad b = 1.5$

$$\Rightarrow C_{10} = 1.3 \times 4.25 \left[ \frac{10}{4.48 \times \{\ln(\frac{1}{0.949})\}^{2/3}} \right]^{3/10}$$

$$= 1.3 \times 4.25 \times [2.295]$$

$$\Rightarrow \boxed{C_{10} = 12.68 \text{ kN}}$$

**Refer to Fig 11-15:**

Select 33205 Cone, 33205 Cup. $\Rightarrow$ $C_{10} = 13.2$ kN (radial), $C_{10} = 7.96$ kN (axial)

$\boxed{K = 1.66}$

**Note:** 30305 Cup and Cone had lower $C_{10}$ (13 kN), However this was chosen because K value is closer to initial guess.

**Trial-2:** $F_{iA} = \dfrac{0.47 \times F_{rA}}{1.66} = 0.27$ kN

**Bearing at B:** $C_{10} = 1.01$ kN.

$\Rightarrow$ Select. 30205 Cup and 30205 Cone

(has lowest $C_{10}$ rating and same bore size as bearing A,

$\Rightarrow \boxed{K = 1.56}$

$\Rightarrow F_{iB} = \dfrac{0.47 F_{rB}}{1.56} = 0.102$ kN

Again: $F_{iA} < (F_{iB} + F_{ae}) = 2.572$ kN

$$\Rightarrow \boxed{F_{eA} = 4.65 \text{ kN}, \quad F_{eB} = 0.34 \text{ kN}}$$

$\Rightarrow C_{10} = 13.88$ kN (Bearing A) — will not work.

$C_{10} = 1.01$ kN (Bearing B) — will work.

Trial-3: Select Cone — 32305 } Bearing A
Cup — 32305,

$\Rightarrow C_{10} = 17.4\ kN$ (radial)

$K = 1.95$

Bearing B : no change.

$\Rightarrow F_{iA} = 0.23\ kN < (F_{iB} + F_{ae}) = 2.572\ kN$

$\Rightarrow \boxed{F_{eA} = 5.397\ kN,\ F_{eB} = 0.34\ kN}$

$\Rightarrow C_{10} = 16.1\ kN$ (Bearing A) $< 17.4\ kN$

This will work. Hence the selected bearings are.

| | | | |
|---|---|---|---|
| For A : | Cone — 32305 | Cup — 32305 | $C_{10} = 17.4\ kN$ (radial), $K = 1.95$ |
| For B : | Cone — 30205 | Cup — 30205 | $C_{10} = 8.19\ kN$ (radial), $K = 1.56$ |