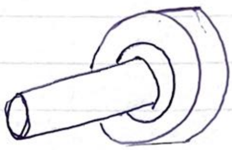
Rolling Contact Bearing

Rolling contact Bearing (Anti-friction Bearing)

Substitute sliding friction by rolling

Shaft is fixed in the ring



- **Rolling contact bearing Parts**

1- inner and outer rings (races)
2- Rolling elements
3- Retainer or separator (to prevent friction)

- **Types of rolling contact bearing**

1- Ball
2- Roller

See figure 11-2, 11-3

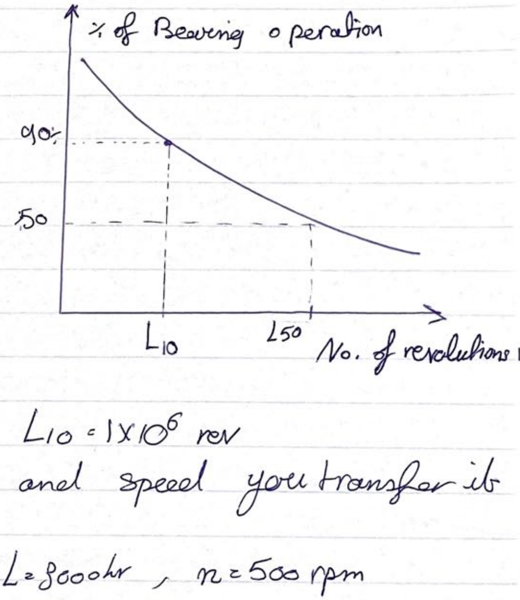
Bearing and design selection

① Bearing life
②. Rating capacity

1. Defenition: Number of revolutions or hours at constant speed that 90% of group of bearings complete before failure

2. Definition: load that causes failure of 10% of group of bearings after rating life

→ 90% of Bearings are working at L_{10}



L_{10}: rating life for $R = 90\%$

L_{50}: " " $R = 50\%$

- Most of manufacturer use $L_{10} = 1 \times 10^6$ rev
- If life is given with hours and speed you transfor it to rev.

Such as Timken uses life $L = 3000\,hr$, $n = 500\,rpm$

Relation between ① and ②:

load ~ $F^a L =$ constant

$a = \begin{cases} 3, & \text{ball bearing} \\ \frac{10}{3}, & \text{roller "} \end{cases}$

C = rating capacity
L_{10} = rating life

load at L_{10} → $C^a L_{10}$ = constant

If different load is used it becomes

$$C^a L_{10} = F_r^a L \longrightarrow C = F_r \left(\frac{L}{L_{10}}\right)^{1/a}$$

from

If I want to find life:-

$$L = L_{10}\left(\frac{C}{F_r}\right)^a$$

Bearing Selection

Find rating capacity of bearing that meets the design requirements

Design values:-

1- Radial load F_r
2- Design life L_D = hr
3- " speed n_D = rpm

} assumed or given

Catalog values

1- C = rating capacity
2- Catalog life L_R = hrs
3- " speed n_R = rpm

To find Life

$L_{rev} = L_{hrs} (n = rpm) \, 60$

$$C = F_D \left[\frac{L_D \, n_D}{L_R \, n_R} \right]^{1/a}$$ ← In hours

L_D (hrs), F_D, n_D ← Design

L_R, n_R ← Catalog

In rev:

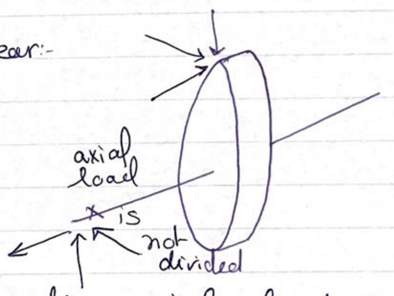
$$C = F_D \left[\frac{60 \, L_D \, n_D}{1 \times 10^6} \right]^{1/a}$$

find c then choose larger from table

F_r, F_t abs

- IF a Bearing is in axial and Radial load

Example: helical gear:-



→ Bearing Catalog gives rating capacity based on applied radial load

Some Bearings can't handle axial load such as straight roller bearing because of side sliding friction

- Ball Bearing can handle it.

- Fe : equivalent load of radial Fr and axial load Fa

$$F_e = \max \begin{cases} V F_r \\ V X F_r + Y F_a \end{cases}$$

V: rotation correction factor = 1 for inner ring rotating / tapered and self aligning bearing (اللي جوا بدور والـ outer ثابت)

= 1.2 outer ring rotation (اللي جوا ثابت والـ outer بدور)

Table 11-1

C_o → from table 11-2

Then $\frac{F_a}{C_o}$ → get (e)

Then $\frac{F_a}{F_r}$ → compare with e

$e \geq \frac{F_a}{F_r}$ → X_1, Y_1

$\frac{F_a}{F_r} \geq e$ → X_2, Y_2

الرمز اللي بدي اياها

C_{10} rating

C_o static rating

F equivalent is obtained → get C

$$C = F_e \left[\frac{L}{L_{10}}\right]^{1/a}$$

go to table of C_o and compare C_o with C obtained.

Table 11-2

Bore: inner diameter

Get C_o

Do as said here and if C is not good with C_o

→ $C_{calculated} < C_{table}$ → choose another C

- Bearing code:

For bore we can have different width and outside diameter:- X X

width ← (first X): 0, 1, 2 ... 6

outside diameter → (second X): O.D: 8, 9, 1, 0, 4, 2, 3

- Series
  Bore is constant
  Width, OD changes
  (Different series)

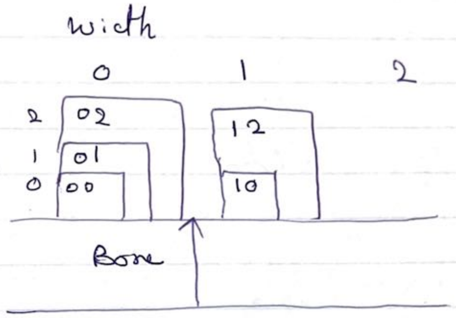


Figure 11-7

Figure 11-8, d_s, d_H

Note: Bore < shaft Diameter

Bore < d_s (always)

Table 11-4 (life for different machines)

- Load factor (K_a) → Table 11-5
  we use it for C

$$C_{10} = K_a F_e \left(\frac{L}{L_{10}}\right)^{1/a}$$

C_0 ~ static rating capacity

- Reliability factor (K_r) (To increase R ↑) $R \neq 90\%$

اللي بدنا ياها

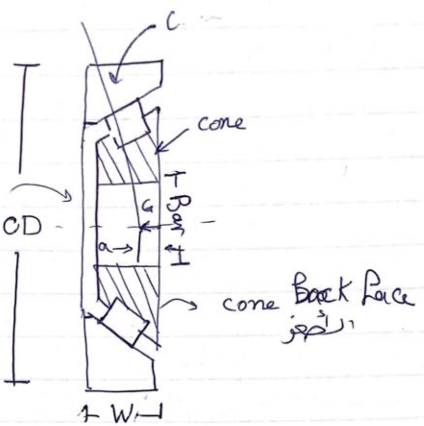
$$K_r = X_0 + (\theta - X_0)(1 - R)^{1/b}$$

$X_0 = 0.02$
$\theta = 4.459$
$b = 1.483$
} $L_{10} = 1 \times 10^6$ rev

$$C_{10} = K_a F_e \left(\frac{L}{K_r L_{10}}\right)^{1/a}$$

Tapered bearing

G: effective load center
It is used to
calculate reactions



- To prevent cup and cone separation
→ Two bearings are used on same shaft

Direct mounting = back faces facing eachother
InDirect " = front " " "

Load on Bearing

Induced Axial load (caused by radial load)

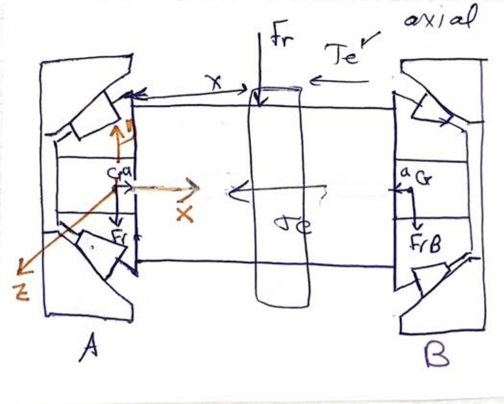
For timken :- $F_a = \frac{0.4 F_r}{K}$ (Remember $L_{10} = 3000$ hr, $n = 500$ rpm)

offset Distance (a)

$\sum M_z = (F_r)(x) - (F_{rB})(2x)$

If T_e exists →

$\sum M = -F_r x - F_{rB}(2x) + T_e\left(\frac{d}{2}\right)$



$F_e = X F_r + Y F_a$ ($V = 1$) always

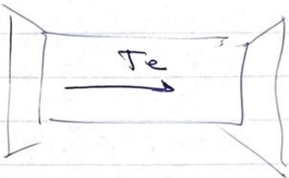
- for Temken   لانه بزيد Axial force على A

$$F_{eA} = 0.4\, F_{rA} + K_A \left(\frac{0.47\, F_{rB}}{K_B} + T_e \right)$$

تقلل بزيدها تسبب بال axial lad

$$F_{eB} = 0.4\, F_{rB} + K_B \left(\frac{0.47\, F_{rA}}{K_A} - T_e \right)$$

- If Te is in opposite direction



$$F_{eA} = 0.4\, F_{rA} + K_A \left(\frac{0.47\, F_{rB}}{K_B} - T_e \right)$$

$$F_{eB} = 0.4\, F_{rB} + K_B \left(\frac{0.47\, F_{rA}}{K_A} + T_e \right)$$

- To find F_A → $F_{AD} = \max \begin{cases} F_{rA} \\ F_{eA} \end{cases}$

$$F_{BD} = \max \begin{cases} F_{rB} \\ F_{eB} \end{cases}$$

shaft ع → n_D ; $3/10$ ← roller bearing

- $$C = K_a F_D \left[\frac{L_D\, n_D}{L_{10}\, n_{10}} \right]^{3/10}$$

$L_{10}\, n_{10}$: for temken $= 3000 \times 500$

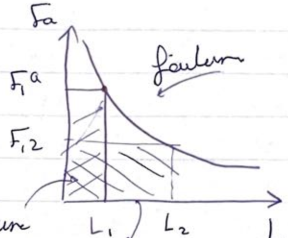
$$C = K_a F_e \left(\frac{L_D\, n_D}{f_e\, f_v\, k_r\, L_R\, n_R} \right)^{3/10}$$

k_r (for temken) $= 4.48\,(1-R)^{2/3}$

Variable loading

for example: $F_1 = 15\,kN \rightarrow l = 1\times10^3$ rev
$F_2 = 20\,kN \rightarrow l = 2\times10^3$ rev
$F_3 = 30\,kN \rightarrow l \Rightarrow \alpha$

linear damage hypothesis



failure caused by F_1 for L_1

failure caused by F_2 for L_2

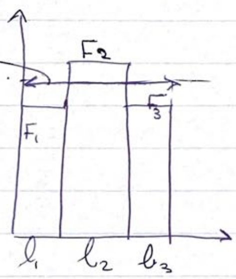
$F^a L = \text{constant}$

$F_1^a l_1 + F_2^a l_2 + F_3^a l_3 = \text{constant}$

So :-

$(F_{eq})^a (l_1 + l_2 + l_3) = \text{constant}$

Fequivalent for total life = F_e



$F_{eq} = F_1^a \frac{l_1}{\Sigma l} + F_2^a \frac{l_2}{\Sigma l} + F_3^a \frac{l_3}{\Sigma l}$ $\quad \Sigma l = l_1 + l_2 + l_3$

taking $\frac{l_i}{\Sigma l} = f_i$

$$F_e = \left(\Sigma f_i F_i^a\right)^{1/a}$$

if $l_i = n_i t_i$

$$F_{eq} = \left(\frac{n_i t_i}{\Sigma n_i t_i} F_i^a\right)^{1/a}$$

- l_i : Part of rating life
- L_i : rating life

عمر ال Bearing اذا حملت هذا ال load

To obtain L_1

$F_1^a L_1 = C^a L_{10} \rightarrow L_1$ is calculated

($C^a L_{10} = C^a \times 10^6$; C from Table) to Find l_3:-

$$F_1^a l_1 + F_2^a l_2 + F_3^a l_3 = K = F_1^a L_1 = F_2^a L_2$$
$$= F_3^a L_3 = K = \underbrace{C^a L_{10}}_{\text{Known}}$$

Example:

$F_1 = 10$ KN $\quad l_1 = 2\times10^3$ rev

$F_2 = 20$ KN $\quad l_2 = 15\times10^3$ rev

$F_3 = 15$ KN $\quad l_3 = ?$

In another way:-

$$\frac{l_1}{L_1} + \frac{l_2}{L_2} + \frac{l_3}{L_3} = 1$$ ← Palmgren - Mi_r rule

Bearing is finished