Unit-V:

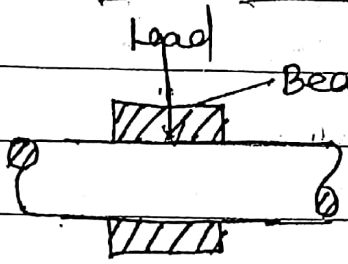
Design of Bearings and Miscellaneous Elements:

Design of sliding contact bearing:

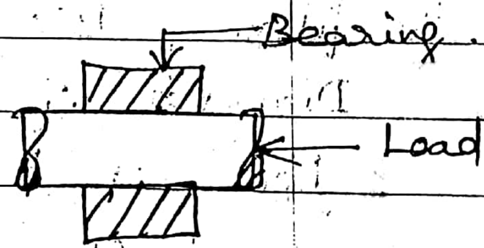
Sliding contact bearing:

Sliding is taking place along the surfaces of contact between the moving element and fixed element. It is also known as "plain bearing"

Radial and thrust bearings: (Depends on direction of load

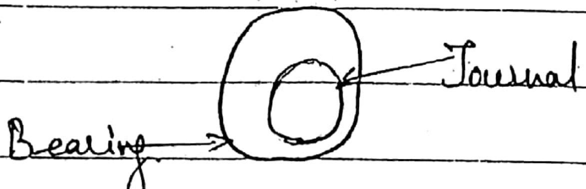


Radial bearing

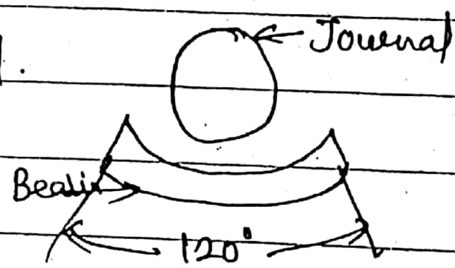


Thrust bearing.

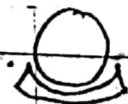
Journal Bearing (or) Sleeve bearing.



Full Journal (360°)



partial Journal (120°)



Fitted Journal.

ϕ of Bearing = ϕ of Journal

Hydrodynamic Lubricated bearing:

The lubricant is used between the Journal and bearing to avoid friction b/w the two elements.

Assumptions in Hydrodynamic lubricated bearings:

Lubricant obeys Newton's law of viscous flow.

pressure assumed to be constant.

The liquid is assumed to be incompressible.

Viscosity is assumed to be constant.

The flow of lubricat is one dimensional (leakage is neglect)

Problem on Journal bearing:

1. Design a journal bearing for a centrifugal pump with the following data:

Diameter of the journal = 150mm.

Load on bearing = 40kN.

Speed on Journal = 900rpm.

Given data:

Diameter of journal D = 150mm.

Load on bearing W = 40 kN = 40×10^3 N.

Speed N = 900rpm.

① To find Length of Journal:

From PSG.D.B 7.31,

For centrifugal pumps: the L/D ratio is 1 to 2.

Let us take, $\frac{L}{D} = 1.5$.

∴ Length of Journal $L = 1.5 \times D$.

$L = 1.5 \times 150$

$L = 225$ mm.

(2) To find the pressure developed in journal;

$$p = \frac{W}{L \times D} = \frac{40 \times 10^3}{225 \times 150}$$

Pressure developed $p = 1.185 \, N/mm^2$

$p = 11.85 \, kgf/cm^2$ $\because 1 \, kgf/cm^2 = 10 \, N/mm^2$.

From PSG D.B 7.31;

Bearing allowable pressure $p = 7$ to $14 \, kgf/cm^2$, so the pressure is within the safe limit.

(3) Selection of lubricating oil:

From PSG DB 7.31;

$\frac{Zn}{p} = 2844.5$

$Z_{min} = 28$

The min. value of $\frac{Zn}{p} = 2844.5$

$$\therefore \left(\frac{Zn'}{p}\right)_{min} = 2844.5 \quad \text{where } Z = \text{Viscosity of oil.}$$

$$Z_{min} = \frac{2844.5 \times 11.85}{900}$$

$Z_{min} = 37.45$ centipoise $\approx$ 40 Cp.

From PSG DB: 7.41; Graph - II.

at 40 Cp and 60°, [As operating Temp. is 60° - 75°C]

SAE 40 oil is Selected

(4) Calculation of Co-efficient of friction:

From PSGDB 7.34;

From Mckee's equation,

$$\mu = \frac{33.25}{10^{10}}\left(\frac{Zn}{P}\right)\left(\frac{D}{C}\right)+K.$$

where C = Diameteral clearance b/w Journal & Bearing.

K = Correction factor for end leakage.

From PSGDB 7-32.

Assume $C = 150 \text{microns} = 150\times10^{-3}$ mm.

$$\therefore \frac{D}{C} = \frac{150}{150\times10^{-3}} = 1000.$$

from graph

$K = 0.002$ for $0.75 < \frac{L}{D} < 2.8$ (PSG 7.34).

$$\therefore \mu = \frac{33.25}{10^{10}}\left(\frac{40\times900}{11.85}\right)\times1000 + 0.002.$$

$\mu = 0.0121.$

$\therefore$ Co.efficient of friction $\mu = 0.0121$

(5) Heating Calculation:

Heat generated $H_g = \mu . W . V$ (PSG . 7.34).

$V \Rightarrow$ Rubbing velocity $= \frac{\pi DN}{60}$

$$V = \frac{\pi \times 0.15 \times 900}{60}$$

$$\boxed{V = 7.0686 \text{ m/s}}$$

Heat generated $H_g = 0.0121 \times 40 \times 10^3 \times 7.0686$

$$\boxed{H_g = 3.421 \times 10^3 \text{ W}}$$

Heat Dissipated,

$$H_d = \frac{(\Delta t + 18)^2 \times LD}{K} \quad \text{(PSG. 7.34)}$$

where K = Heat dissipation Constant.

Take K = 0.273 for Heavy construction

K = 0.484 for light & medium Construction.

$\Delta t = \frac{1}{2}(t_o - t_a)$ where t_o = oil Temprature (usually $60^\circ - 75^\circ c$)

$t_a \Rightarrow$ Ambient Temp. ($28^\circ c$)

$$\therefore \Delta t = \frac{1}{2}(60^\circ - 28^\circ)$$

$$\boxed{\Delta t = 16^\circ c.}$$

$$H_d = \frac{(16+18)^2 \times 0.225 \times 0.15}{0.484}$$

$$\boxed{H_d = 80.6 \text{ W}}$$

The heat generated Hg is greater than Heat dissipated

i.e $H_g > H_d$.

Hence, the artificial cooling arrangement is to be provided. either by cooling fans (or) circulated water.

(6) Diameter of bearing (D_b):

$D_b = D + C$ where $C \Rightarrow$ diameteral clearance in mm.

$= 150 + 0.15$ (From PSG. 7.32) $\Rightarrow$ (C = 150 microns)

$\therefore D_b = 150.15$ mm

(7) Material Selection for bearing:

From PSG DB 7.30;

For pumps (as centrifugal pump given),

The Material is **Rubber (or) Modulated plastic laminate.**

Full Journal

2. The following data is given for a 360° hydrodynamic bearing. Journal diameter D = 100mm, radial clearance = 0.12 mm, Radial load = 50kN. Bearing length = 100mm, Journal Speed = 1440rpm and viscosity of lubricant = 16 cp. calculate
i) Minimum film thickness.
ii) Co-efficient of friction.
iii) power lost due to friction.

Given: $\beta = 360°$

Diameter of Journal	D	$= 100\,mm$.
Diameteral clearance	c	$=$ Radial clearance $c/2 = 0.12\,mm$.
Radial Load	W	$= 50\,kN = 50\times10^3\,N$. $c = 0.24\,mm$.
Bearing length	L	$= 100\,mm$.
Journal speed	n	$= 1440\,rpm$.
Viscosity of lubricant	Z	$= 16\,cp$.

① To find minimum film thickness:

Minimum film thickness ~~ho is found~~ may be found from. Minimum film thickness variable.

i.e $\frac{2h_o}{c}$; (From PSG D.B. 7.40).

We have to find Sommerfield number;

$$S = \frac{Z'n'}{p}\left(\frac{D}{c}\right)^2$$ (From PSG. 7.34).

$Z' \Rightarrow$ Absolute viscosity (kgf sec/cm²)

~~W~~ p = Bearing pressure.

~~S = 16 x 10⁻³ x (1440/...)~~

Bearing pressure $p = \frac{W}{L \times D}$

$= \frac{50 \times 10^3}{100 \times 100}$

$p = 5\ N/mm^2$

$\therefore$ Sommerfield Number $S = \frac{Z'n'}{p}\left(\frac{D}{c}\right)^2$

$= \frac{16 \times 10^{-3} \times \left(\frac{1440}{60}\right)}{5 \times 10^6\ (N/m^2)} \left(\frac{100}{0.24}\right)^2$

$S = 0.0133$

From PSG DB 7.40: (Graph - 1)

For $\beta = 360^0$, $S' = 0.0133$ and corresponding to $L/D =$

The minimum film thickness variable $\frac{2h_o}{c} = 0.071$

$\therefore$ Minimum film thickness $h_o = \frac{0.071 \times c}{2}$

$= \frac{0.071 \times 0.24}{2}$

Minimum film thickness $h_o = 0.00852\,mm$

To find co-efficient of friction:

From PSG D.B. 7.40, (Graph - II).

For $\beta = 360°$, and $S = 0.0133$ Corresponding $L/D = 1$.

$$\mu \frac{D}{C} = 1.$$

$$\mu = \frac{1 \times C}{D}$$

$$= 1 \times \frac{0.24}{100}.$$

Co-efficient of friction: $\boxed{\mu = 2.4 \times 10^{-3}}$

power lost due to friction:

We know,

power lost due to friction is nothing but Heat generated in Bearing.

i.e $H_g = \mu \cdot W \cdot v$.

Rubbing velocity $v = \frac{\pi D n}{60}$.

$$= \frac{\pi \times 100 \times 10^{-3} \times 1440}{60}.$$

$\boxed{v = 7.54 \ m/s.}$

∴ Heat generated = $\mu \cdot W \cdot v$.

$= 2.4 \times 10^{-3} \times 50 \times 10^{3} \times 7.54$.

$H_g = 904.8$ W.

∴ The power lost due to friction = 904.8 W.

3. Design a (sleeve) Journal bearing for a centrifugal pump running at 1440 rpm. Diameter of the Journal is 10 cm and Load on each bearing is 2000 kg. The factor (ZN/p) may be taken as 2800. For centrifugal pump bearings.

Assume Atmospheric Temperature = $30^\circ c$.

Operating Temperature = $75^\circ c$.

Energy dissipation co-efficient = 0.00125

C/R ratio = 0.001

$\frac{L}{D}$ ratio = 1.5.

Gn:

Speed $n = 1440$ rpm.

Dia of Journal $D = 10$ cm $= 100$ mm.

Load on bearing $W = 2000$ kg $= 20,000$

The factor, $\frac{Zn}{P} = 2800$.

Atmospheric Temperature $T_a = 30°c$.

Operating Temperature $T_o = 75°c$.

Energy dissipation co.efficient $= 0.00125$

C/R ratio $= 0.001$, & L/D ratio $= 1.5$

Assume $L/D = 1.5$.

$\therefore L = 1.5 \times D = 1.5 \times 100$

Length of Journal $\boxed{L = 150\ mm}$.

Given:

Ratio of radial clearance to radius of Journal

$C/R = 0.001$.

$\therefore$ Radial Clearance $C_1 = R \times 0.001$ ($R \Rightarrow$ Radius of Journ

$= 50 \times 0.001$

Radial clearance $= \boxed{C_1 = 0.05\ mm}$.

Diameteral clearance C = Radial clearance × 2.

$= 0.05 \times 2.$

$\boxed{C = 0.1\,mm}$

$\therefore \boxed{\frac{D}{C} = \frac{100}{0.1} = 1000}$

Bearing pressure $p = \frac{W}{L \cdot D} = \frac{20000}{150 \times 100}.$

$p = 1.333\ N/mm^2$

$\therefore$ Bearing pressure is $\boxed{p = 13.33\ kgf/cm^2}$

For centrifugal pump $p = 7$ to $14\ kgf/cm^2$ (safe).
(PSG. 7.31)

To find viscosity of lubricant:

We know,

$$\frac{Zn}{P} = 2800.$$

$$Z = \frac{2800 \times 13.33}{1440}.$$

$$Z = 25.9 \simeq 26\ Cp = 26 \times 10^{-3}\ N.s/m^2$$

From PSG DB 7.41: for operating temp of 75°C and 26 cp, the next standard oil SAE 50 is Selected.

To find Co-efficient of friction:

From Mckee's equation, (PSG 7.34).

$$\mu = \frac{33.25}{10^{10}}\left(\frac{Zn}{P}\right)\left(\frac{D}{C}\right)+k.$$

$k = 0.002$ for $L/D = 1.5$. (PSG 7.34 graph)

$$\therefore \mu = \frac{33.25}{10^{10}}\left(2800\right)\left(1000\right)+0.002.$$

$\boxed{\mu = 0.0113}$

Heat equations:

Heat generated in the bearing:

$$H_g = \mu . W . v .$$

Sliding (or) Velocity } $V = \frac{\pi D n}{60} = \frac{\pi \times 0.1 \times 1440}{60}$

Rubbing velocity }

$$V = 7.54 \text{ m/s.}$$

$$H_g = 0.0113 \times 20 \times 10^3 \times 7.54 .$$

Heat generated $H_g = 1705.5 \text{ W}$

Heat dissipated by lub oil:

As the energy dissipation co.efficient 'Q' is given,

$H_d = Q \cdot A \,(T_o - T_a)$. where Q = Energy dissipation co eff
A = Area of radiating surface
= L×D in cm².

$H_d = 0.00125 \times 10 \times 15 \times (75 - 30)$.

$H_d = 8.4375$ K.cal/min

Note: 4.186 cal = 1J

∴ $H_d = 8.4375 \times 4.186 = 35.32$ kJ/min.

$H_d = 588.66$ J/sec.

Note: J/s = W

$H_d = 588.66$ W.

Hg is greater, so artificial cooling needed.

Material Selection:

From PSGDB 7:30, for pump,

Material is Rubber or modulated plastic laminate.

4. Design a full Journal bearing for the following specifications:

Diameter of Journal = 75mm.

Load on Journal = 3500N.

Length of Journal = 75mm.

Speed n = 400 rpm

Minimum film thickness = 0.02mm.

Soln Given:

Diameter of Journal $D = 75$ mm.

Load on Journal $W = 3500$ N.

Length of Journal $L = 75$ mm

Speed $n = 400$ rpm

Minimum film thickness $h_o = 0.02$ mm.

~~Soln~~ Given:

Diameter of Journal $D = 75\,mm$

Load on Journal $W = 3500\,N$.

Length of Journal $L = 75\,mm$

Speed $n = 400\,rpm$

Minimum film thickness $h_o = 0.02\,mm$.

~~Power~~ developed:
Pressure

$$P = \frac{W}{L \times D} = \frac{3500}{75 \times 75}$$

$$P = 0.622\ N/mm^2$$

$$\boxed{P = 6.22\ kgf/cm^2}$$

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Calculation of Co-efficient of friction:

From PSGDB. 7.32,

For general machine practice upto 90mm shaft dia, diameteral clearance C may be taken as 150 microns.

∴ $C = 150$ microns $= 0.15$ mm.

The minimum film thickness variable $= \frac{2h_o}{c}$.

$= \frac{2 \times 0.02}{0.15}$.

The min. film thickness variable $= 0.267$.

By given,

Full Journal bearing $\beta = 360^\circ$ and $\frac{2h_o}{c}$.

Sommerfeld Number $S = 0.065$ (7.40 Graph 1).

From 7.40 Graph-2 :

Coefficient of friction variable $\mu \frac{D}{C} = 2$.

$\therefore \mu = 2 \times \frac{C}{D}$.

$= \frac{2 \times 0.15}{75}$

$\boxed{\mu = 4 \times 10^{-3}} = \boxed{\mu = 0.004}$.

Heating Calculation:

Heat generated on the bearing $H_g = \mu . W \times V$.

Rubbing velocity $V = \frac{\pi D n}{60} = \frac{\pi \times 0.075 \times 400}{60}$.

$V = 1.57 \ m/s$.

$H_g = 4 \times 10^{-3} \times 3500 \times 1.57$

$H_g = 21.98 \ W$.

Heat dissipated:

$$H_d = \frac{(\Delta t + 18)^2 \cdot L \cdot D}{K}$$

Δt = Temp. rise of bearing surface from ambiant temp. in °c.

$\therefore \Delta t = \frac{1}{2}(T_o - T_a) = \frac{1}{2}[60 - 16] = 22°c$

$$\therefore H_d = \frac{(22+18)^2 \times 0.075 \times 0.075}{0.484}$$ (for medium construction).

$\boxed{H_d = 18.6\ W.}$

$H_d > H_g$ hence artificial cooling is needed.

Diameter of bearing:

Diameter of bearing $D_b = D + C$

$D_b = 75 + 0.15$

$D_b = 75.15 \text{ mm}$

Selection of material:

For general applications, the material is.
Light liner on steel or bronze backing. (PSG. 7.3

5. A Journal bearing 80mm diameter and 120mm long runs at 600 rpm. It uses oil having viscosity of 60 Cp. Radial clearance provided is 0.15mm. Determine the safe load that bearing can withstand. Assume Sommerfield number $S = 1.43 \times 10^9$.

Given:

Diameter of Journal $D = 80mm$.

Length of Journal $L = 120mm$.

Speed $n = 600 rpm$.

Viscosity $Z = 60 \text{ cp}$.

Radial clearance $\frac{C}{2} = 0.15 = C = 0.3mm$.

Sommerfield Number $S = 1.43 \times 10^9$.

From Sommer field number: (PSG. D.B 7.34).

$$S = \frac{Z' n'}{P} \left(\frac{D}{C}\right)^2$$

$$1.43 \times 10^{9} = \frac{60 \times 10^{-3} \times \left(\frac{600}{60}\right)}{P} \left(\frac{80}{0.3}\right)^2$$

$$\boxed{P = 2.98 \times 10^{-5} \ N/m^2}$$

We know, Bearing pressure $P = \frac{W}{L \cdot D}$

$$2.98 \times 10^{-5} = \frac{W}{0.08 \times 0.12}$$

$$\boxed{\therefore \ \text{Safeload} = 2.86 \times 10^{-7} \ N.}$$

6. Design a Journal bearing for centrifugal pump from the following data:

Load on Journal = 20kN.

Speed of the Journal = 900rpm.

Type of oil SAE 10 for absolute viscosity at $55^{\circ}c$ = 17 cp

Ambient Temperature of oil = $15.5^{\circ}c$.

Max. bearing pressure for the pump = $1.5\ N/mm^2$

Calculate also the mass of the lubricating oil required for artificial cooling to rise in temperature of oil is limited to $10^{\circ}c$.

Given:

Load on journal $W = 20kN = 20 \times 10^3 N$.

Speed of journal $n = 900$ rpm.

Type of oil = SAE 10.

Viscosity of oil $Z = 17$ cp.

Operating Temperature $T_o = 55°c$.

Ambient Temperature $T_a = 15.5°c$.

Max. bearing pressure for pump, $p = 1.5 N/mm^2 = 15 kgf/cm^2$

Rise in Temperature, $\Delta t = 10°c$.

pressure developed: (To find Diameter of Journal).

$$P = \frac{W}{L.D.}$$

$$1.5 = \frac{20\times10^3}{L\times D.}$$

$$L\times D = \frac{20\times10^3}{1.5}$$

① ∴ $L\times D = 13333.33 mm^2.$ ≃ $A = 13333.33$

For Centrifugal pump;

$\frac{L}{D}$ ratio is b/w 1 to 2. (PSG DB 7.31).

∴ $\frac{L}{D} = 1.5$ (Assume)

∴ $L = 1.5D.$

Sub in ① ⇒ $1.5D\times D = 13333.33$

$1.5D^2 = 13333.33$

$D = 94.28 mm \simeq 100 mm.$

$\therefore$ Diameter of journal $D = 100 mm.$

$\therefore$ Length of Journal $L = 1.5D = 150 mm.$

To calculate Co-efficient of friction: (μ).

We know,
$$\mu = \frac{33.25}{10^{10}} \left(\frac{Zn}{P}\right)\left(\frac{D}{C}\right) + k.$$

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Diameteral clearance C may be assumed as 150 microns from PSG 7.32.

$\therefore \frac{D}{C} = \frac{100}{150 \times 10^{-3}}$

$D/C = 666.66$

For $\frac{L}{D} = 1.5$, $k = 0.002$ (PSG 7.34).

$\therefore \mu = \frac{33.25}{10^{10}} \left(\frac{17 \times 900}{15} \right) \times 666.67 + 0.002$

$\mu = 0.00426$

$\therefore$ Co.eff. of friction $\mu = 0.00426$

Heat Calculations:

Heat generated:

$$H_g = \mu \cdot W \cdot V.$$

Rubbing velocity $V = \frac{\pi D N}{60} = \frac{\pi \times 0.1 \times 900}{60}$

$V = 4.71\ m/s$

$$H_g = 0.00426 \times 20 \times 10^3 \times 4.71.$$

$H_g = 401.5\ W.$

Heat Dissipated:

$$H_d = \frac{(\Delta t + 18)^2 \times L \times D}{K} \quad [K = 0.484 \text{ for medium Construction.}]$$

$$\Delta t = \frac{1}{2}[T_o - T_a] = \frac{1}{2}[55 - 15.5]$$

$$\boxed{\Delta t = 19.75^\circ}$$

$$\therefore H_d = \frac{(19.75 + 18)^2 \times 0.1 \times 0.15}{0.484}$$

$$\boxed{H_d = 21.3\,W} \quad \boxed{H_d = 44.16\,W.}$$

$H_d > H_g$, $\therefore$ artificial cooling is provided either by cooling fans or by circulated water.

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case: ii)

Mass of lubricating oil required:

For artificial cooling to rise the temperature of oil limited to $10^\circ c$ (given).

To find Mass of lub. oil,

H_g = m × sp. heat of oil × Temperature rise.

$401.5 = m \times 1.9 \times 10^3 \times 10$

Take,
[sp. ht. of oil = 1.9 kJ/kg°c]

∴ m = 0.0211 kg/s.

∴ The mass of lub oil to cool the ~~the rela temp~~

m = ~~0.02~~ 0.0211 kg/s