26/04/22
Tuesday

MODULE : 01

LUBRICATION AND ANTIFRICTION BEARINGS

Lubrication :- It is a science of reducing the friction between two Rubbing surfaces of a body having relation motion by the application of a suitable substance called lubricant.

A lubrication is any substant when applied between relatively moving part will reduced the friction, wear, and carry away the heat that is generated.

Lubricant :- Any substance which is appleid between the 2 Number (ex :- Synthetic oil, animal oil, Greece, wax)

Purpose of Lubrication :-

* Reduce the friction
* Carry away the heat Generatar
* To remove the dirt away the Surface

Types of Lubricant :-

a. **Liquid Lubricant :-** Commonly used liquid lubricant are mineral oil, animal oil there are generally preffered when they have to be retain
(ex :- Synthesis oil, vegetable oil etc)

b. **Semi liquid lubricant :-** A Greece is a Semi liquid lubricant having higher viscosity than oils. the Greece are Employee wher slow speed and heavy pressure exist (ex :- Greece).

c. <u>Solid lubricant</u> :- These are preffered in reducing the friction where Oil films cannot be maintain because of pressure & Temp^e (ex :- Graphite, wax, Soap stonoam etc)

<u>Properties :- of lubrication</u> :-

<u>Viscosity</u> :- It is defined as Internal frictional resistance Offered by a fluid to change in its shape (or) relative motion of its Parts. viscosity is Important since the load bearing capacity is perpendicular to viscosity.

<u>Flash point</u> :- the lowest temperature at which an oil gives of Sufficien vapour to Support a momentary flash upon Introduction of flames. A Good lubricant should have flash point above that of operating temperature.

<u>Fire point</u> :- It is the lowest temperature at which an oil gives of Sufficient vapour to burn it Continuously when it ignited

<u>Oilness</u> :- It is the measure of ability of maintaining unbroken oil film layer between mating Surfaces.

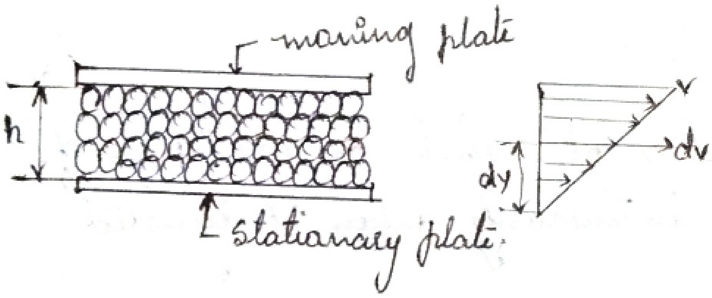
<u>Pour point</u> :- It is the temperature @ which and oil will ceased to flow when Cool. A good lubricant should have low PP

<u>Cloud point</u> :- The temp^r @ which oil became cloudly when Coole is Called cloud point.

Requirements of good lubricants :-

* It must have high flash and fire point
* It has to be free from corrosion
* It should be non volatile.
* It must have high sufficient viscosity.
* Resistance to Emulsion.

Viscosity :- The fundamentals of viscosity can be understood by considering a flat plate moving with velocity 'V' under a force 'F' parallel to stationary plate. The two plates are separated by a thin film of fluid lubricant having thickness h as shown in figure.



The molecular of oil are visualized as small balls oil will stick to both the surfaces. There fore the layer of molecule in contact with stationary plate will have '0' velocity and layer of molecule in contact with moving plate will have maximum velocity.

The in Between will move with velocity which are ~~perpend~~ proportional to distance from stationary plate.

$$\frac{V}{h} \propto \frac{dv}{dy}$$

The tangential for per unit are is shear stress.

$$\tau = \frac{F}{A}$$

and the ratio of $\frac{V}{h}$ is the rate of shear.

According to newton's law of viscosity the shear stress is directly proportional to the rate of shear at any point in the fluid.

i.e. shear stress ∝ rate of shear

$$\tau \propto \frac{V}{h}$$

$$\boxed{\tau = Z.\frac{V}{h}} \longrightarrow \text{General Express.}$$

$$\boxed{\tau = Z.\frac{dv}{dy}} \longrightarrow \text{at any point.}$$

where Z = absolute viscosity

$\frac{dv}{dy}$ = rate of shear / velocity Gradient.

The unit of Absolute viscosity is pascalseconds (or) Ns/m^2.

Kinematic viscosity :-

It is the ratio of absolute viscosity to the mass density of fluid

i.e. $\boxed{Z_K = \frac{Z}{\rho}}$ SI unit is = m^2/s.

Bearing :- Bearing is a machine element that Permits relative motion between 2 parts

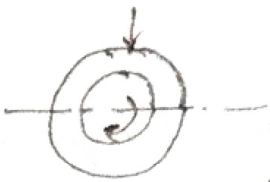
Function of Bearing are :-

1. To support the shaft (or) axial to hold in correct position
2. To take up the force that act on the shaft and transmit them to frame or fondation
3. To ensure free rotation of shaft with minimum friction

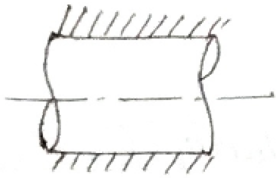
Classification of lubrication :-

1. Depending upon the direction of load supported

a. Radial Bearing :- In this bearing the load will act ⊥r to the direction of moving element



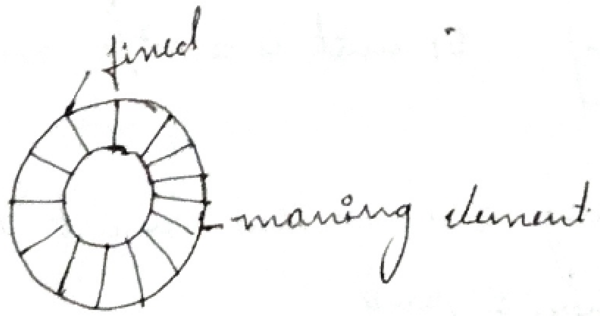
b. Thrust Bearing :- In thrust bearing load acts along the axis of rotation.



2. Depending upon the nature of contact.

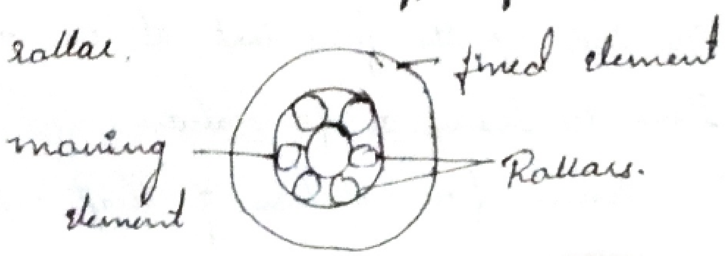
a. Sliding Contact Bearing / plain / general / sleeve Bearing

Sliding takes place along surface of contact b/w moving element and fixed element.



b. Rolling Contact bearing

The steel balls or rollers are interposed b/w moving element and stationary element. The roller offers R friction at two point for each ball or roller.



Modes of lubrication :-

1. <u>Thick film lubrication</u> :- It describes a Condition of lubrication when two surface of bearing in relative motion are Completely separated by a film (or) fluid.

<u>Thick film lubrication is divided into two types</u> :-

a. <u>hydrodynamic lubrication</u> :-

It defined as a system of lubrication in which load supporting fluid film is created by the shape and relative motion of the sliding surfaces.

b. <u>hydrostatic lubrication</u> :-

It is defined as a system of lubrication in which load supporting fluid film is created by the an external space like a pump supply sufficient fluid under pressure these are also called as externally pressurized bearing. Since lubricant is supplied under pressure.

2. <u>Thin film lubrication / Boundary</u> :- It is defined as Condition of lubrication. where the layer of lubrication is relatively. thin and there is partial metal to metal Contact.

3. <u>Elastohydrodynamic lubrication</u> :- when fluid film pressure is high and the surface should be separated are not rigid sufficiently there is elastic deformation of Contacting surfaces. this elastic deformation is useful in formation of fluid film in Certain cases. Since hydrodynamic film is developed due to elastic deformation of part. This mode of lubrication is Called Elastohydrodynamic lubrication.

Principle of hydrodynamic lubrication / mechanism. / hydrodynamic Theory of lubrication :-

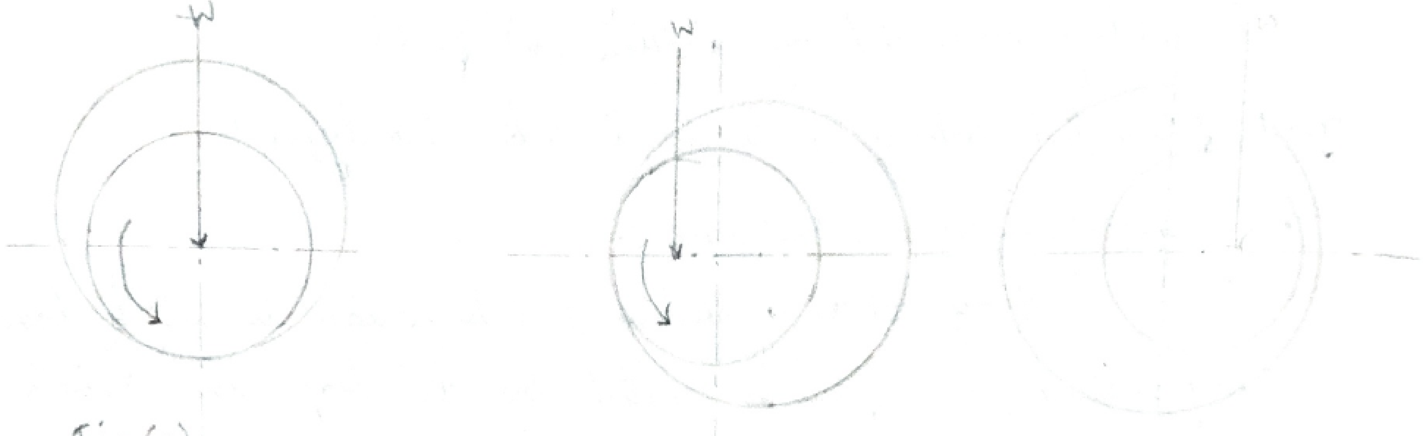


Fig (a) Fig (b) Fig (c)

The action of lubricant in a plain general bearing according to hydrodynamic theory is briefly explain as below.

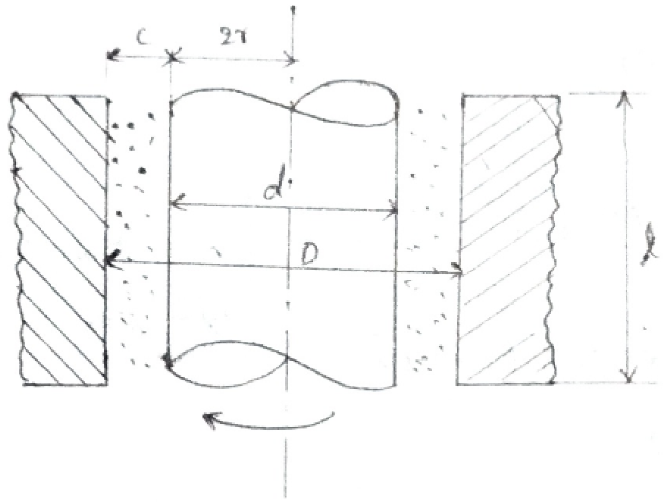
* Initially the shaft is @ rest (fig a) and sinks to bottom of the cleara Theorance space under the action of load 'W'. The surfaces of gernal and bearing touches during the rest.

* As gernal starts rotating it shifts to the leftside of the bearing and a thin film of lubricant wedge - - - is form b/w the contact surfaces (fig b)

* Since more and more fluid is force into wedge shape due to increase in speed of gernal pressure is generated within the system. the internal pressure developed lift the gernal upward and to the right, an Equillibrium state is ~~made~~ reached as shown in (fig c)

* Since the pressure is created within the system due to rotation of the shaft this type of bearing is known as self acting bearing

Petroff's Equation :- → Co-efficient of friction in gernal bearing.



A Petroff Equation gives an expression for Co-Eff of friction in gernal bearing.

The following Assumption are made.

* shaft is Concentric with the bearing.
* The bearing is subjected to light load.
* The clearance is Completely filled with the oil.
* There is no end leakage.
* The gernal rotates at high speeds.
*

Let d = diameter of gernal / shaft.

D = Diameter of Bearing.

l = length of Bearing.

c = clearance.

WKT.

$\tau = Z . \frac{V}{h}$ → ① (Based on Newton's Law's of viscosity)

where, $\tau = \frac{F}{A}$

$V = \pi \times d \times n$. (velocity)

$h = c$.

Substituting the above in the equation (1)

$$\tau = Z \cdot \frac{V}{h}$$

$$\frac{F}{A} = Z \times \frac{\pi d n}{C}$$

$$F = \frac{Z \times \pi (2r) \times n}{C} \times A \longrightarrow$$

| $A = \pi \times d \times l.$
| $d = 2r.$

$$F = \frac{Z \times \pi (2r) \times n \times \pi (2r) \times l}{C}$$

$$F = \frac{4\pi^2 r^2 Z \times n \times l}{C}$$

$$F = \frac{4\pi^2 r^2 \times Z \times n \times l}{C} \times 10^{-6}$$

WKT, $T = \text{Force} \times \text{radius}$

$$T = \frac{4\pi^2 \times r^2 \times n \times l \times Z}{C} \times 10^{-6} \times (r)$$

$$T = \frac{4\pi^2 \times r^3 \times Z \times n \times l}{C} \longrightarrow (2)$$

Frictional force,

$$T = f \times W \times r.$$

$$\text{Pressure } p = \frac{\text{load}}{\text{Projected area}}$$

$$P = \frac{W}{(l \times d)}$$

$$\boxed{W = P \times l \times d}$$

$\therefore$ Frictional force $\boxed{T = f \times P \times l \times d \times r} \longrightarrow (3)$

On Comparing Equa^n (2) and (3)

$$\frac{4\pi^2 r^3 z n l}{c} \times 10^{-6} = f \times p \times l \times d \times r \quad \Big| d = 2r$$

$$\frac{2\pi^2 r z n d}{c} \times 10^{-6} = f \times p \times d \times r$$

$$\boxed{f = (2\pi^2 \times 10^{-6}) \left(\frac{zn}{p}\right)\left(\frac{r}{c}\right)}$$

Surface Velocity of shaft.

* $U = \pi d n'$ ⟶ (eq 23-18)
* Bearing Pressure $p = \frac{W}{l \times d}$.
* Diametric clearance ratio (ψ) ⟶ $\psi = \frac{c}{d}$.
* Speed $n' = \frac{N}{60}$

Co-efficient of friction

* Petroffs Equation :- $\mu = 2\pi^2 \left(\frac{\eta n'}{p}\right)\left(\frac{1}{\psi}\right)$ ⟶ (eq 23-21)
* Mckees Equation :-

$$\mu = K_a \left(\frac{\eta n'}{p}\right)\left(\frac{1}{\psi}\right) 10^{-10} + \Delta\mu \longrightarrow \text{(eq 23-22)}$$

where, $K_a = 5.4 \times 10^8 \beta = 1.95 \times 10^{11}$

$\beta = 360^\circ$

$\Delta\mu$ = factor to correct for end leakage = 0.002.

* Frictional force $f_\mu = \frac{2\pi^2 \eta n' l d}{\psi}$ ⟶ (eq. 23-45).

* Frictional Torque :- $M_t = \mu (Ld)$ (or) $p\frac{d}{2} = \frac{\pi^2 d^2 L \eta n'}{\psi}$ (23-20)

* Power loss due to friction (P) :- $P = \frac{F_\mu U}{1000}$ → eq (23-49c)

where P in KW.

F_μ in Kgf (or) N

$U = \pi d n'$ (m/s)

d = m.

n' = rps.

29/04/22
Friday

Problems:-

1. A lightly loaded bearing has the following specification. Diameter of the jernal (d) = 50mm, Bearing length = 80mm, radial load = 750N, Diameter clearance ratio = 0.002, viscosity of the lubricant = 10CP, Speed = 4000rpm.

Determine,
1. Friction force (F).
2. Friction torque (M_t)
3. Co-eff of friction (μ)
4. Power loss due to friction (P).

η' = viscosity

Solution :-

Diameter of jernal $d = 50mm = 50\times10^{-3}$ m.

Bearing length $L = 80mm = 80\times10^{-3}$ m.

radial load = 750N

Diameter of clearance ratio $\psi = 0.002$.

viscosity $\eta = 10CP \Rightarrow \eta = 10\times10^{-3}$ Pa ——→ (23-2(a))

Speed N = 4000rpm (or) $n' = 4000$rpm.

$n' = \frac{4000}{60} \Rightarrow n' = 66.67$rps.

Bearing pressure (P) = ?

$$P = \frac{W}{l \times d} = \frac{750}{(80\times10^{-3})(50\times10^{-3})} \Rightarrow \boxed{P = 0.187\times10^{6}\,Pa}$$

① Frictional force (F_μ) = ?

$$F_\mu = \frac{2\pi^2 \eta n' l d}{\psi}.$$

$$F_\mu = \frac{2\pi^2 \times (10\times10^{-3})(66.67)(80\times10^{-3})(50\times10^{-3})}{0.002}$$

$$\boxed{F_\mu = 26.32\,N}$$

② Frictional torque (M_t) = ?

$$M_t = \frac{\pi^2 d^2 l \eta n'}{\psi}$$

$$M_t = \frac{\pi^2 \times (50\times10^{-3})^2 (80\times10^{-3})^2 (10\times10^{-3})(66.67)}{0.002}$$

$$\boxed{M_t = 0.658\,Nm}$$

③. Co-efficient of friction (μ) = ?

(from Petroff's Equation)

$$\mu = 2\pi^2 \left(\frac{\eta n'}{P}\right)\left(\frac{1}{\psi}\right)$$

$$\mu = 2\pi^2 \left(\frac{10\times10^{+3}\times 66.67}{0.187\times10^{6}}\right)\left(\frac{1}{0.002}\right)$$

$$\boxed{\mu = 0.035}$$

④ Power loss due to friction (P) = ?

$$P = \frac{F_\mu \times U}{1000}$$

$$P = \frac{F_\mu \times \pi \times d \times n}{1000}$$

$$P = \frac{26.32 \times \pi \times (50\times10^{-3}) \times 66.67}{1000}$$

$$\boxed{P = 0.275\,KW}$$

2. A lightly loaded vane has the following specification diameter of the journal = 50MM, bearing length = 80MM, radial load = 1KN. Diameter clearance ratio = 0.0015, viscosity of the lubricant = 8×10^{-3} PS. Speed = 3000rpm.

determine,
1. Frictional force (F)
2. Frictional Torque (Mt)
3. Co-Eff of friction (μ)
4. Power loss due to friction (P).

Solution :-

Given data

$d = 50mm = 50\times10^{-3}m$

$l = 80mm = 80\times10^{-3}m$

$W = 1KN = 1\times10^{3}N.$

$\psi = 0.0015$

$\eta = 8\times10^{-3}$ ps

$N = 3000rpm$

$$n' = \frac{3000}{60}$$

$$\boxed{n' = 50rps}$$

$$P = \frac{W}{l\times d} = \frac{1\times10^{3}}{(80\times10^{-3})(50\times10^{-3})} \Rightarrow \boxed{P = 0.25\times10^{+6}\,Pa}$$

① $F_\mu = ?$

$$F_\mu = \frac{2\pi^2 \eta n' l d}{\psi}$$

$$= \frac{2\pi^2 \times (8\times10^{-3}) \times (50) \times (80\times10^{-3})(50\times10^{-3})}{0.0015}$$

$$\boxed{F_\mu = 21.05N}$$

$F = ?$
$m_t = ?$
$\mu = ?$
$P = ?$

② $M_t = ?$

$$m_t = \frac{\pi^2 d^2 l \eta n'}{\psi}$$

$$= \frac{\pi^2 \times (50\times10^{-3})^2 \times (80\times10^{-3}) \times (8\times10^{-3}) \times 50}{0.0015}$$

$$\boxed{m_t = 0.52\,N\text{-}m}$$

③ Co-efficient of friction $(\mu) = ?$

(from Petroffs equation)

$$\mu = 2\pi^2 \left(\frac{\eta n'}{P}\right)\left(\frac{1}{\psi}\right)$$

$$= 2\pi^2 \left(\frac{8\times10^{-3}\times 50}{0.25\times10^{-6}}\right)\left(\frac{1}{0.0015}\right)$$

$$\boxed{\mu = 0.021}$$

④ $P = ?$

$$P = \frac{F_u \times \pi \times d \times n}{1000}$$

$$= \frac{21.05 \times \pi \times (50\times10^{-3}) \times (50)}{1000}$$

$$\boxed{P = 0.165\,kW}$$

3. A lightly loaded bearing has the following Assumption, Shaft diameter 60mm, $l = 80mm$, $W = 1KN$, Radial clearance $= 0.05mm$ oil used in SAE 60, at a temperature of 65°C. The Co-efficient of friction of this bearing under the condition is found to be 0.0042. Determine

① Speed of the journal.

2. Power loss.

Given data :-

$d = 60mm = 60 \times 10^{-3} m.$

$l = 80mm = 80 \times 10^{-3} m.$

$W = 1KN = 1 \times 10^{3} N$

Radial diameter $C_r = 0.05mm$

Oil used SAE 60.

$\mu = 0.0042.$

C_r = Radial diameter

C = diameter clearance

ψ = Diameter clearance ratio

Diameter clearance $C = 2C_r \Rightarrow 2 \times 0.05 \Rightarrow \boxed{C = 0.1mm}$

Diameter clearance ratio $\psi = \frac{C}{d} = \frac{0.1}{60} \Rightarrow \boxed{\psi = 1.67 \times 10^{-3}}$

Solution :-

$$P = \frac{W}{l \times d} = \frac{1000}{(80 \times 10^{-3})(60 \times 10^{-3})} \Rightarrow \boxed{P = 0.208 \times 10^{+6} Pa}$$

To find viscosity (η) :-

(from fig 23-26, pg 23.7)

To SAE 60 at $t_o = 65°C$

Absolute viscosity $\eta = 50 mPas.$

$$\boxed{\eta = 50 \times 10^{-3} Pas.}$$

To find speed $N = ?$

WKT. Co-efficient of friction.

(from petroffs equations)

$$\mu = 2\pi^2 \left(\frac{\eta n'}{P}\right)\left(\frac{1}{\psi}\right)$$

$$0.0042 = 2\pi^2 \left(\frac{50 \times 10^{-3} \times n'}{0.208 \times 10^{+6}}\right) \times \left(\frac{1}{1.67 \times 10^{-3}}\right)$$

Speed $n' = 1.478 rps$.

$\therefore$ Speed $N = 1.478 \times 60 \Rightarrow$ $N = 88.65 rpm$

To find Frictional force (F_u) = ?

$$F_u = \frac{2\pi^2 \eta n' l d}{\psi}$$

$$= \frac{2\pi^2 \times 50\times10^{-3} \times 88.65 \times (80\times10^{-3}) \times (60\times10^{-3})}{1.67\times10^{-3}}$$

$F_u = 4.19 N$

To find power loss P = ?

$$P = \frac{F_u \times U}{1000}$$

$$P = \frac{F_u \times \pi \times d \times n}{1000}$$

$$P = \frac{4.19 \times \pi \times (60\times10^{-3}) \times 1.478}{1000}$$

$P = 1.16 kW$

4. A full journal Bearing of the Air Compressor has the following specification, Shaft diameter = 60mm, bearing length 50mm. radial load = 900N. radial clearance = 0.05mm. viscosity = 2.9×10^{-2} Ps. The Co-eff of friction of this bearing under the Condition was found to be 0.042.

Determine,

1. Speed of the journal.
2. power loss at this speed.

Given data :-

$d = 60mm = 60 \times 10^{-3} m$

$l = 50mm = 50 \times 10^{-3} m$

$W = 900N$

$C_r = 0.05mm$

$\eta = 2.9 \times 10^{-2} Ps.$

$\mu = 0.042.$

$N = ?$

$P = ?$

$C = 2C_r \Rightarrow 2 \times 0.05 \Rightarrow \boxed{C = 0.1mm}$

$\psi = \frac{c}{d} \Rightarrow \frac{0.1}{60} \Rightarrow \boxed{\psi = 1.67 \times 10^{-3}}$

P = ?

$P = \frac{W}{l \times d} = \frac{900}{(50 \times 60)} \Rightarrow \boxed{P = 0.3 \times 10^{+6} Pa}$

To find speed N = ?

(from Petraffs Equation)

$$\mu = 2\pi^2 \left(\frac{\eta n'}{P}\right)\left(\frac{1}{\psi}\right)$$

$$0.042 = 2\pi^2 \left(\frac{2.9 \times 10^{-2} \times n'}{0.3 \times 10^{+6}}\right) \times \left(\frac{1}{1.67 \times 10^{-3}}\right)$$

$n' = 3.675 rps.$

$N = 3.675 \times 60 \Rightarrow \boxed{N = 220.5 rpm}$

Frictional force $(F_\mu) = ?$

$$F_\mu = \frac{2\pi^2 \eta n' l d}{\psi}$$

$$= \frac{2\pi^2 \times 2.9 \times 10^{-2} \times 3.675 \times (50 \times 10^{-3}) \times (60 \times 10^{-3})}{1.67 \times 10^{-3}}$$

$\boxed{F_\mu = 3.77N}$

Power loss at this Speed.

$$P = \frac{F_u \times U}{1000}$$

$$P = \frac{F_u \times \pi \times d \times n}{1000}$$

$$P = \frac{3.77 \times \pi \times (60 \times 10^{-3}) \times 3.675}{1000}$$

$$\boxed{P = 2.61 KW}$$

5. A lightly loaded journal bearing has the following specification journal diameter = 70MM, bearing length = 55MM, diameter clearance = 0.01MM, speed of the journal = 22000rpm, radial load = 1KN, power loss in the bearing is found to be 3.5KW. Determine,

1. viscosity of the oil (η).
2. Co-eff of friction at operating conditions (μ).

Given data

$d = 70MM = 70 \times 10^{-3} m.$

$l = 55MM = 55 \times 10^{-3} m.$

$C = 0.01$

$N = 22000 rpm.$

$W = 1KN \Rightarrow 1 \times 10^{3} N$

$P = 3.5 KW$

$\eta = ?$

$\mu = ?$

$$n' = \frac{22000}{60}$$

$$\boxed{n' = 366.66 rps}$$

$$\psi = \frac{c}{d} \Rightarrow \frac{0.01}{70} \Rightarrow \boxed{\psi = 1.42 \times 10^{-4}}$$

$P = ?$

$$P = \frac{W}{l \times d} \Rightarrow \frac{1000}{(55 \times 70)} \Rightarrow \boxed{P = 0.25 \times 10^{+6} Pa}$$

$F_u = ?$

$$P = \frac{F_u \times U}{1000}$$

$$3.5 = \frac{F_u \times \pi \times (70 \times 10^{-3}) \times 366.66}{1000}$$

$$\boxed{F_u = 43.40 N}$$

$$F_\mu = \frac{2\pi^2 \eta n' l d}{\psi}$$

$$43.40 = \frac{2\pi^2 \times \eta \times 366.66 \times (55\times10^{-3})(70\times10^{-3})}{1.42\times10^{-4}}$$

$$\boxed{\eta = 2.22\times10^{-4}\ Ps}$$

Co-eff of friction (μ) = ?

(from petroffs equation)

$$\mu = 2\pi^2\left(\frac{\eta n'}{p}\right)\left(\frac{1}{\psi}\right)$$

$$\mu = 2\pi^2\left(\frac{2.22\times10^{-4}\times 366.66}{0.25\times10^{+6}}\right)\left(\frac{1}{1.4\times10^{-4}}\right)$$

$$\boxed{\mu = 0.0043}$$

6. A 75mm long full journal bearing of diameter 75mm. Supports a radial load of 12KN. at a shaft speed of 1800rpm. Assume ratio of diameter to diametrie clearance has 1000. The viscosity = 0.01Ps. at the operating temperature Determine the following,

1. Sommerfeld Number.
2. Co-Eff friction based on McKees equation
3. Amount of heat generator.

Given data :-

$l = 75mm = 75 \times 10^{-3} m$

$d = 75mm = 75 \times 10^{-3} m$

$W = 12KN = 12 \times 10^{3} N$

$N = 1800 rpm$

$= n' = \frac{1800}{60}$

$n' = 30 rps$

$\frac{d}{c} = 1000$

Diameter clearance ratio

$\psi = \frac{c}{d}$

$\psi = \frac{1}{1000}$

$\psi = 0.001$

$\eta = 0.01 PS$

$S = ?$

$\mu = ?$

$Hg = ?$

Solution :-

$$P = \frac{W}{l \times d} = \frac{12000}{(75 \times 75 \times 10^{-6})} \Rightarrow P = 2.13 \times 10^{6} Pa$$

① **Sommerfeld number (S) = ?**

$$S = \frac{\eta n'}{P} \times \left(\frac{1}{\psi^2}\right) \longrightarrow \text{(eq 23-39 Pg (23.24)}.$$

$$= \frac{0.01 \times 30}{2.13 \times 10^6} \times \frac{1}{(0.001)^2}$$

$$S = 0.1406$$

② **Co-Eff of friction based on mckee Equation.**

$$\mu = Ka \left(\frac{\eta n'}{P}\right)\left(\frac{1}{\psi}\right) 10^{-10} + \Delta\mu.$$

(eq 23-22c, Pg. 23.13)

where, $Ka = 1.95 \times 10^{11}$

$\Delta\mu = 0.002$

(for $\beta = 360°$ for full journal Bearing)

$$\mu = 1.95 \times 10^{11} \left(\frac{0.01 \times 30}{2.13 \times 10^6}\right)\left(\frac{1}{0.001}\right) \times 10^{-10} + 0.002.$$

$$\mu = 4.746 \times 10^{-3}$$

③ **Heat generation (Hg) = ?**

$$Hg = \mu (PLd) v \longrightarrow \text{(eq 23-72a, Pg 23.49)}.$$

$$= 4.746 \times 10^{-3} (2.13 \times 10^6 \times 75 \times 10^{-3} \times 75 \times 10^{-3}) \times \pi \times 75 \times 10^{-3} \times 30$$

$$Hg = 401.31 J/s \text{ (or) watts}$$

7. A full journal bearing of 50mm diameter and 75mm long supports a radial load of 1000N, the speed of the shaft is 600rpm. The surface temperature of bearing (t_b) is limitted to 60°C and the room temperature is 30°C. Determine, The viscosity of the oil. If the bearing is well ventilated and no artificial cooling to be used the ratio of journal diameter to diameter clearance is 1000.

Given data :-

$d = 50mm = 50\times10^{-3}m$

$l = 75mm = 75\times10^{-3}m.$

$W = 1000N$

$N = \frac{600}{60} \Rightarrow \boxed{n' = 10rps}$

$t_b = 60°C$

$t_a = 30°C$ – (If they not given, Assume 27 – 30°C).

$\eta = ?$

$\frac{d}{c} = 1000 \Rightarrow \frac{c}{d} = 0.001.$

artificial cooling

$H_G = H_d$

extra artificial cooling

$H_G > H_d.$

Solution :-

$P = \frac{W}{l\times d} \Rightarrow \frac{1000}{(75\times50\times10^{-6})} \Rightarrow \boxed{P = 0.26\times10^{6} Pa}$

For well ventilated (along Mckees Equation) bearing and no artificial cooling is required (i.e. $H_g = H_d$) where, d = decipated.

$$\mu = K_a \left[\frac{\eta n'}{P}\right]\left[\frac{1}{4}\right)10^{-10} + \Delta\mu.$$

$$= 1.95\times10^{11}\left(\frac{\eta\times10}{0.26\times10^{6}}\right)\left(\frac{1}{0.001}\right)\times10^{-10} + 0.002.$$

$\mu = 0.78\eta + 0.002$

$\eta = ?$

$H_g = H_d$.

$1178.09\eta + 3.14 = 31.64$

$\eta = 0.024 \, Pa\,s$

$H_g = \mu (pLd) U$

$= 0.78\eta + 0.002 [1000] \times \pi \times 50 \times 10^{-3} \times 10$

$H_g = 1178.09\eta + 3.14$

$H_d \Rightarrow$ heat dissipated

According to Pedersan's Equation

$$H_d = \frac{[\Delta T + 18]^2}{K} [Ld] \longrightarrow [\text{eq } 23\text{-}80a, \text{Pg } 23\text{-}53]$$

$$= \frac{[30 + 18]^2}{0.273} \times (75 \times 10^{-3} \times 50 \times 10^{-3})$$

For ventilated bearing

$K = 0.273$.

$H_d = 31.64$ watts

8. A lightly loaded jurnal bearing has a load of 1KN, the Oil used is SAE 60. and the mean effective temperature of operati-on is 40°C. The jurnal has diameter of 50mm. and the bearing has diameter 50.5mm. The speed of the jurnal is 15000rpm. The $\frac{L}{d}$ ratio 1.2. Determine.

1. Co-eff of friction
2. power loss due to friction.

Given data :-

$W = 1KN = 1000N$

$d = 50mm$

$D = 50.5mm$

$N = 15000rpm$

$\frac{15000}{60}$

$n' = 250 rps$

$\frac{L}{d} = 1.2$

$\mu = ?$

$P = ?$

Solution :-

$C = D - d = 50.5 - 50 \Rightarrow \boxed{C = 0.5mm}$

$\psi = \frac{c}{d} = \frac{0.5}{50} \Rightarrow \boxed{\psi = 0.01}$

$l = ?$

$\frac{L}{d} = 1.2. \Rightarrow l = 1.2d \Rightarrow 1.2 \times 50 \Rightarrow \boxed{l = 60mm}$

$P = ?$

$P = \frac{W}{l \times d} \Rightarrow \frac{1000}{(60 \times 50 \times 10^{-6})} \Rightarrow \boxed{P = 0.33 \times 10^{6} Pa}$

i. Co-efficient of friction :-

$\mu = Ka \left[\frac{\eta n'}{P}\right] \cdot \left[\frac{1}{\psi}\right] 10^{-10} + \Delta\mu.$

SAE 60 @ 40°C oil type

$\eta = 290 mPa$

$\boxed{\eta = 290 \times 10^{-3} Ps}$

$\mu = 1.95 \times 10^{11} \left[\frac{290 \times 10^{-3} \times 250}{0.33 \times 10^{6}}\right] \times \left[\frac{1}{0.01}\right] \times 10^{-10} + 0.002$

$\boxed{\mu = 0.4252}$

ii. Power loss due to friction.

$P = \frac{F\mu \times U}{1000}$

$= \frac{429.32 \times \pi \times 50 \times 10^{-3} \times 250}{1000}$

$\boxed{P = 16.85 KW}$

Frictional force $F\mu = ?$

$F\mu = \frac{2\pi^2 \eta n' l d}{\psi}$

$= \frac{2\pi^2 \times 290 \times 10^{-3} \times 250 \times 50 \times 60 \times 10^{-6}}{0.01}$

$\boxed{F\mu = 429.32 N}$

4/05/22
wednesday

9. A full journal bearing 50mm in diameter and 50mm long operates at 1000rpm and carries a load of 5KN. The radial clearance is 0.025m. The bearing is lubricated with SAE 40 Oil. and the operating temperature of the oil is 80°C.

Determine,
1. Bearing pressure.
2. Sommerfeld number.
3. attitude and minimum film thickness.
4. heat generated
5. heat decipated

if the ambient temperature is 20°C. The amount of artificial cooling is necessary use mckees Equation and pedarsan Equation.

Given data :-

$d = 50mm = 50\times10^{-3}m$

$l = 50mm = 50\times10^{-3}m$

$W = 5KN = 5000N$

$N = 1000rpm$

$N = \frac{1000}{60}$

$n' = 16.66 rps$

$C_r = 0.025m$

Bearing lubricated SAE 40 Oil.

$t_o = 80°C$

$P = ?$

$S = ?$

$Hg = ?$

$Hd = ?$

$t_a = 20°C$

minimum film thickness = ?

Solution

$C = 2C_r = 2\times0.025 \Rightarrow C = 0.05mm$

$\psi = \frac{c}{d} = \frac{0.05}{50} \Rightarrow \psi = 0.001$

$\eta = ?$

(from fig 23-2b pg 23.7)

$\eta = 16mPa\,s$

$\eta = 16\times10^{-3} Pa\,s$

$P = ?$

$P = \frac{W}{l\times d} = \frac{5000}{(50\times50\times10^{-6})}$

$P = 2\times10^{6} Pa$

ii $S = ?$

$$S = \frac{\eta n'}{P} \times \frac{1}{(\psi^2)} \longrightarrow \text{(eq 23-29 Pg (23.24))}$$

$$= \frac{16\times10^{-3} \times 16.66}{2\times10^{6}} \times \frac{1}{(0.001)^2}$$

$$\boxed{S = 0.133}$$

iii. Attitude and min film thickness.

To find min film thickness

(from fig 23.15 Pg 23.25)

$$\frac{l}{d} = \frac{50}{50} = 1$$

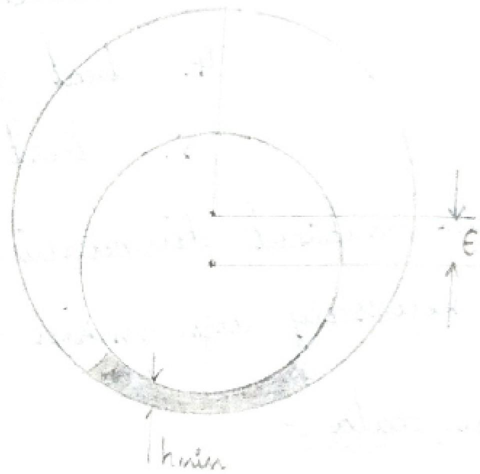
$$\boxed{\delta = 0.42}$$

To find Attitude (ϵ)

(from fig 23.15 Pg 23.25)

$$\frac{l}{d} = 1, \quad S = 0.1333.$$

$$\boxed{\epsilon = 0.58}$$



WKT,

$$\delta = \frac{2 \times h_{min}}{c}$$

$$0.42 = \frac{2\times h_{min}}{0.05\times10^{-3}}$$

$$\boxed{h_{min} = 1.05\times10^{-5}}$$

$$\mu = K_a \left(\frac{\eta n'}{P}\right)\left(\frac{1}{\psi}\right)10^{-10} + \Delta\mu.$$

$$= 1.95\times10^{11}\left(\frac{16\times10^{-3}\times16.66}{2\times10^{6}}\right)\left(\frac{1}{0.001}\right)\times10^{-10} + 0.002.$$

$$\boxed{\mu = 4.59\times10^{-3}}$$

iv $Hg = ?$

$$Hg = \mu [PLd] v$$

$$= 4.59 \times 10^{-3} [5000] \times \pi \times 50 \times 10^{-3} \times 16.66$$

$$\boxed{Hg = 60.09 \ J/s}$$

v $Hd = ?$

For light construction and still air for K:

(from pg. 23.55) $K = 0.475$

$$Hd = \frac{[\Delta T + 18]^2}{K} [Ld]$$

$$= \frac{[30+18]^2}{0.475} \cdot [50 \times 10^{-3} \times 50 \times 10^{-3}]$$

$$\boxed{Hd = 12.12 \ \text{watts}}$$

ΔT for ambient

$t_b - t_a$

ΔT for operating temp^r

$$\frac{t_o - t_a}{2}$$

$$\frac{80-20}{2}$$

$$\boxed{\Delta T = 30}$$

$\therefore$ amount of artificial cooling

$$HG - Hd$$

$$60.09 - 12.12$$

$$\boxed{47.97 \ \text{watts}}$$

10. A hydrodynamic vane of radius 19mm, length = 38mm has a radial clearance of 0.038mm. The viscosity of the oil is 0.02756 Pa. The load on the bearing is 2210N and a speed of the journal is 30rps. Determine,

1. min film thickness and its angular position
2. Eccentricity. (or) attitude.
3. Co-eff friction.
4. Torque to overcome friction (frictional torque).
5. Power loss due to friction.
6. Total volumetric flow.
7. Side flow.

Given data :-

$l = 38mm = 38 \times 10^{-3} m$

$C_r = 0.038mm$

$\eta = 0.02756$ Ps.

$W = 2210N$

$n' = 30rps.$

$h_{min} = ?$

$\epsilon = ?$

$\mu = ?$

$M_t = ?$

$P = ?$

Solution :-

$d = 2r = 2 \times 19 \Rightarrow d = 38mm \Rightarrow \boxed{d = 38 \times 10^{-3} m}$

$C = 2C_r = 2 \times 0.038 \Rightarrow \boxed{C = 0.076mm}$

$\psi = \frac{C}{d} = \frac{0.076}{38} \Rightarrow \boxed{\psi = 0.002}$

P = ?

$$P = \frac{W}{l \times d} = \frac{2210}{(38 \times 38 \times 10^{-6})} \Rightarrow \boxed{P = 1.53 \times 10^{6} Pa}$$

S = ?

$$S = \frac{\eta n'}{P} \left(\frac{1}{\psi^2}\right)$$

$$= \frac{0.002756 \times 30}{1.53 \times 10^{6}} \times \frac{1}{(0.002)^2}$$

$$\boxed{S = 0.1350}$$

1 To find min film thickness

(from fig 23.15 Pg 23.25)

$\frac{L}{d} = \frac{38}{38} = 1$

$\boxed{\delta = 0.43}$

W.K.T,

$\delta = \frac{2 \times h_{min}}{c}$

$0.43 = \frac{2 \times h_{min}}{0.076 \times 10^{-3}}$

$\boxed{h_{min} = 1.634 \times 10^{-5} m}$

2. Eccentricity (e) = ?

(from fig 23.15 Pg 23.25)

$\frac{L}{d} = \frac{38}{38} = 1$

$\boxed{\epsilon = 0.57}$

WKT,

$\epsilon = \frac{2e}{c}$

$0.57 = \frac{2 \times e}{0.076 \times 10^{-3}}$

$\boxed{e = 2.166 \times 10^{-5} m}$

3. Co-efficient of friction (μ) = ?

$\mu = K_a \left[\frac{\eta n'}{p}\right]\left[\frac{1}{\psi}\right] \times 10^{-10} + \Delta\mu \longrightarrow$ (eq 23-22c, Pg 23.13)

$= 1.95 \times 10^{11} \left[\frac{0.02756 \times 30}{1.53 \times 10^{6}}\right]\left[\frac{1}{0.002}\right] 10^{-10} + 0.002.$

$\boxed{\mu = 7.268 \times 10^{-3}}$

4. Frictional torque (M_t) = ?

$M_t = \frac{\pi^2 d^2 L \eta n'}{\psi}$

$= \frac{\pi^2 \times (38 \times 10^{-3})^2 \times 38 \times 10^{-3} \times 0.02756 \times 30}{0.002.}$

$\boxed{M_t = 0.2238 N\text{-}m}$

5. Power loss due to friction (P) = ?

$$P = \frac{F_u \times U}{1000}$$

$$P = \frac{11.78 \times \pi \times 38 \times 10^{-3} \times 30}{1000}$$

P = 0.0421 KW

$$F_u = \frac{2\pi^2 \eta n' L d}{\psi}$$

$$= \frac{2\pi^2 \times 0.02756 \times 30 \times 38 \times 38 \times 10^{-6}}{0.002}$$

Fu = 11.78 N

(or)

$$P = \frac{\mu W U}{1000} \Rightarrow \frac{7.268 \times 10^{-3} \times 2210 \times \pi \times 38 \times 10^{-3} \times 30}{1000}$$

P = 55.40 W

Co-efficient of friction (method 2)

(from fig 23-24, pg 23-37)

$$\lambda_\mu = 3.6$$

$$\lambda_\mu = \frac{\mu}{\psi}$$

$$3.6 = \frac{\mu}{0.002}$$

$\mu = 7.2 \times 10^{-3}$

6. Total volumetric flow (Q) = ?

(from pg 23-49 fig 23-41)

$$\lambda_Q' = 4.3$$

$$\lambda_Q' = \frac{4Q\psi}{c^2 \times n' \times L}$$

$$4.3 = \frac{4 \times Q \times 0.002}{(0.076)^2 \times 30 \times 38 \times 10^{-3}}$$

$$Q = 3.53 \times 10^{-6} \ m^3/s.$$

$$\boxed{Q = 3539 \ mm^3/s}$$

7. side flow $(Q_s) = ?$

(from fig 23-43 Pg 23-50)

$$\frac{Q_s}{Q} = 0.65$$

$$Q_s = 0.65 Q$$

$$= 0.65 \times 3539$$

$$\boxed{Q_s = 2335 \ mm^3/s}$$

5/05/22
Thursday.

11. A 50mm diameter full journal bearing supports a load of 2500N. The bearing length is 50mm. and shaft operates at 300rpm. The radial clearance is 0.05mm. The bearing is lubricated with SAE 110 oil and operating temp is 80°C. Determine,

1. Sommerfeld number.
2. Co-eff of friction
3. min film thickness
4. Eccentricity
5. Heat generated
6. flow of lubricant into bearing.
7. Amount of end leakage using Raimondi - boyd chart.

Given data :-

$d = 50mm = 50\times10^{-3} m.$

$W = 2500N$

$l = 50mm = 50\times10^{-3} m.$

$N = 3000 rpm$

$\frac{300}{60}$

$n' = 5 rps$

$C_r = 0.05mm$

Type of oil SAE 70 @ 80°C

$\eta = 41\times10^{-3} Ps$

(from fig 23-26. Pg 23.7)

Solution :-

$C = 2C_r = 2\times0.05 \Rightarrow C = 0.1mm$

$\psi = \frac{c}{d} = \frac{0.1}{50} \Rightarrow \psi = 0.002$

P = ?

$P = \frac{W}{l\times d} = \frac{2500}{(50\times50\times10^{-6})} \Rightarrow P = 1\times10^{6} Pa$

S = ?

$S = \frac{\eta n'}{P} \times \frac{1}{(\psi^2)}$

$= \frac{41\times10^{-3}\times5}{1\times10^{6}} \times \frac{1}{(0.002)^2}$

$S = 0.051$

2. Co-efficient of friction (μ) = ?

$\lambda_\mu = 1.6$

$\lambda_\mu = \frac{\mu}{\psi}$

$1.6 = \frac{\mu}{0.002}$

$\mu = 3.2\times10^{-3}$

3. min film thickness (h_{min})

$\frac{L}{d} = \frac{50}{50} = 1$

$S = 0.23$

WKT, $S = \frac{2\times h_{min}}{C}$

$0.23 = \frac{2\times h_{min}}{0.1\times10^{-3}}$

$h_{min} = 1.15\times10^{-5} m$

4. eccentricity (ϵ) = ?

$\epsilon = 0.78$ → (from fig 23.15 Pg 23.25)

5. Heat generated (H_g) = ?

$H_g = \mu [PLd] U \longrightarrow$ (from eq 23-72a, pg 23.49)

$= 3.2 \times 10^{-3} (2500) \times \pi \times 50 \times 10^{-3} \times 5$

$$\boxed{H_g = 6.283 \ J/s}$$

6. Flow of lubricant into bearing (oil flow rate).

(Pg (23-49) fig 23-41).

$$\boxed{\lambda' Q = 4.3}$$

$$\lambda Q' = \frac{4 Q \psi}{C^2 \times n' \times l}$$

$$4.3 = \frac{4 \times Q \times 0.002}{(0.1)^2 \times 5 \times 50}$$

$Q = 1343.75 \ mm^3/s$

$$\boxed{Q = 1.34375 \times 10^{-3} m^3/s}$$

7. Amount of end leakage (Q_s) = ? (or) side leakage.

(from fig 23-43, pg 23-50)

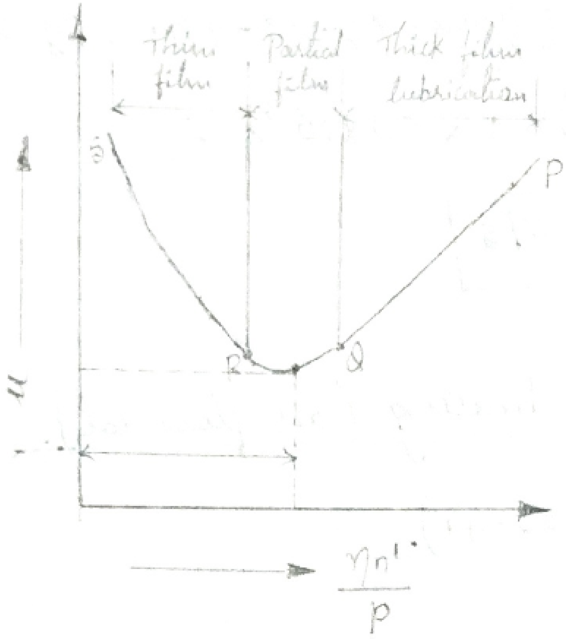
$$\frac{Q_s}{Q} = 0.82$$

$$\frac{Q_s}{1.34375 \times 10^{-3}} = 0.82$$

$$\boxed{Q_s = 1.1018 \times 10^{-3} \ m^3/s}$$

Bearing characteristics numbers and bearing modulus.

5/05/22
Friday



Bearing modulus (S'')

$$3S'' > \frac{\eta n'}{p}$$

★ Bearing characteristics is a dimensionless parameter given. $\frac{\eta n'}{p}$.

★ The minimum amount of friction occurs at point A and at this particular point the corresponding value of $\frac{\eta n'}{p}$ is known as Bearing modulus (S'').

★ The Bearing modulus $3S'' > \frac{\eta n'}{p}$

(TYPE 2 PROBLEMS).

12. Determine the dimensions of the Bearing and jurnal to support a load of 7.5KN (w). at 1000rpm. The Journal is made of hardened steel and the bearing is made of Babbit material abandens of oil is supplied by oil rings. The oil viscosity is 300 Saybolt seconds at 40°C and specific gravity is 0.915 at 15.5°C. The oil operating temperature is 75°C allows a clearance of 0.001mm/mm diameter. Also find min film thickness. and oil flow rate.

Given Data :-

$W = 7.5\,KN = 7500N.$

$N = 1000\,rpm$

$= \frac{1000}{60}$

$\boxed{n' = 16.67\,rps}$

$C = \frac{0.001mm}{1m}$

$\psi = \frac{C}{d} = \frac{0.001}{1}$

$\boxed{\psi = 0.001}$

material :- Journal (hardned steel)
Bearing (Babbit material)

viscosity 300 saybolt second at 40°C

Specific gravity $\gamma_{15.5} = 0.915$

$t_0 = 75°C$

To find,

1. Dimensional of Journal and Bearing = ?
2. min film thickness = ?
3. Flow rate. = ?

Solution :-

1 To find absolute viscosity η = ? (method - 1)

For 300 saybolt seconds at $t = 40°C$

(from fig 23-3, pg 23.9)

Type of oil is 'E'

(from fig 23-2a Pg 23.6)

Type of oil is 'E' at oil 75°C

η = 13.5 Centipoise

$\boxed{\text{Absolute viscosity } \eta = 13.5 \times 10^{-3} Ps}$

2. To find Absolute viscosity $\eta = ?$ (method 2).

Specific gravity $= 0.915$ at $15.5^\circ C$

Specific gravity at operating temp^r $\gamma_t = ?$

(from Pg 23.10 Eq^n 23-10)

$$\gamma_t = \gamma_{15.5} - 0.000637 (t - 15.5)$$

$$\gamma_t = 0.915 - 0.000637 (75 - 15.5)$$

$$\boxed{\gamma_t = 0.877}$$

Saybolt to centipoise,

$$\eta = \gamma_t \left(0.22t - \frac{180}{t}\right)$$ → (from Eq^n 23.7 pg 23.8).

For 300 saybolt seconds at $40^\circ C$

Type of oil is 'E'

From same fig for E type of oil at $75^\circ C$

$$\boxed{\text{Saybolt sec } t = 80^\circ C}$$

$$\eta = \gamma_t \left(0.22t - \frac{180}{t}\right)$$

$$= 0.877 \left(0.22 \times 80 - \frac{180}{80}\right)$$

$\eta = 13.46195 \simeq 13.5$ Centipoise

$$\boxed{\eta = 13.5 \times 10^{-3} \text{ ps}}$$

$3S'' > \frac{\eta n'}{p}$ → (Bearing modulus should be always ≥ or = to Bearing characteristics number)

i. To determine dimensions

(from table 23.7 Pg 23.19)

For hardened steel and babbit material, Bearing modulus

$$S'' = 48.5 \times 10^{-9}$$

For hydrodynamic Bearing,

i.e. $$\frac{\eta n'}{P} > 3S''$$

$$\frac{13.5 \times 10^{-3} \times 16.67}{P} \geq 3 \times 48.5 \times 10^{-9}$$

$$\frac{13.5 \times 10^{-3} \times 16.67}{(3 \times 48.5 \times 10^{-9})} \geq P$$

$$1.5464 \times 10^{6} \geq P$$

$$1.5464 \times 10^{6} \geq \frac{7500}{d^2}$$

| assume $L = d$

$$d \geq 0.0696\text{m} \simeq 0.07\text{m}$$

ii. minimum film thickness (h_{min}):

(from fig 23.15 Pg 23.25)

$\frac{L}{d} = 1$ $S = 0.147$ $\delta = 0.45$

$$\delta = \frac{2 h_{min}}{c}$$

$$0.45 = \frac{2 \times h_{min}}{0.091 \times 10^{-3}}$$

$$h_{min} = 15.75 \times 10^{-3}\text{mm}$$

$$P = \frac{N}{L \times d} = \frac{7500}{0.07 \times 0.07}$$

$$P = 1.5306 \times 10^{6}\,\text{Pa}$$

$$S = \frac{\eta n'}{P} \times \frac{1}{(\psi)^2}$$

$$= \frac{13.5 \times 10^{-3} \times 16.67}{1.5306 \times 10^{6}} \times \frac{1}{(0.001)^2}$$

$$S = 0.147$$

iii. Oil flow rate (Q) = ?

(from fig 23-41 Pg 23-49)

$\lambda'_Q = 4.25$

$$\lambda'_Q = \frac{4Q\psi}{c^2 n' L}$$

$$4.25 = \frac{4 \times Q \times 0.001}{(0.001 \times 10^{-3})^2 \times 16.67 \times 0.07}$$

$Q = 6.074 \times 10^{-6} m^3/s$

$Q = 6074 \; mm^3/s.$

(Type 3 problem).

9/05/22
Monday.

Design procedure for hydrodynamic Journal Bearing :-

STEP : 1 :- selection of design value for the given type of Bearing and machine (or) machinary from table (23-2 Pg 23-15)

i.e. Maximum pressure (P).
Diametral clearance ratio (ψ)
$\frac{L}{d}$ ratio.
viscosity in Pa s.
Bearing modulus (S'').

STEP : 2 :- Design to find $L \times d$ of the Bearing using Bearing Pressure.

STEP : 3 :- selection of oil (from fig 23-26 Pg 23-7);
Based on the Absolute viscosity value (η) and operating temp^r find the type of the oil.
(Assume to b/w 60-70°C if it is not given)

STEP 4 :- check for the oil. Bearing modulus S''calculated.

$$S'' = \frac{\eta n'}{P}$$

if Bearing modulus,

$$\boxed{S''_{cal} > S''_{recamended}}$$

Then thick film lubrication is possible the selected oil is suitable. otherwise select the next higher oil and check again.

STEP : 5 :- Heat generation (H_g).

STEP : 6 :- Heat dissipated (H_d),

STEP : 7 :- minimum film thickness (h_{min}),

STEP : 8 :- Flow rate (Q).

STEP : 9 :- Power loss due to friction. (P);

13. Design a Journal Bearing for centrifugal pump running at 1200rpm. the diameter of the Journal is 100MM, and load on the Bearing is 15KN. take $\frac{L}{d} = 1.5$, Bearing temperature is 50°C and ambient temp^r is 30°C. find whether the artificial cooling is required.

Given data :-

(machine is centrifugal pump)

$N = 1200 rpm$

$\frac{1200}{60}$

$n' = 20 rps$

$d = 100 MM = 0.1 M$

$W = 15 KN = 15000 N$

$\frac{L}{d} = 1.5$

$(L = 1.5 \times 0.1)$

$L = 0.15 m$

Bearing temp^r $t_b = 50°C$

ambient temp^r $t_a = 30°C$

STEP : 1 :- selection of Design value machine is centrifugal pump

(from table 23-2 pg. 23-15)

(from table 23-2 take Bearing value always main)

Bearing pressure $p = 0.69 - 1.37 MPa$

Diameter clearance ratio $\varphi = 0.0013$

Bearing modulus $S'' = 483.5 \times 10^{-9}$

Absolute viscosity $\eta = 25 \times 10^{-3} PaS$

STEP : 2 :- Design.

(from table 23-2 Pg 23-15)

Bearing pressure is 0.69 - 1.37

Take Bearing pressure $P = 1 MPa$

STEP : 3 :- Selection of oil :-

(from figure 23-26 Pg 23.7)

Type of oil is SAE 40

WKT,

$$t_b - t_a = \frac{(t_o - t_a)}{2}$$

$$50 - 30 = \frac{(t_o - 30)}{2}$$

$$t_o = 70^\circ C$$

(If it is not given the operating temp^r. Assume t_o value will be always $70^\circ C$)

STEP : 4 :- To check for oil :-

$$S''_{cal} = \frac{\eta n'}{P}$$

$$= \frac{25 \times 10^{-3} \times 20}{1 \times 10^6}$$

$$S''_{cal} = 500 \times 10^{-9}$$

Since $S''_{cal} > S''_{rec}$, thick film exists.

If $S''_{rec} > S''_{cal}$ change SAE and reset the number as 50.

STEP : 5 :- Heat generator

$$H_g = \mu (PLd) v$$

$$= 9.5 \times 10^{-3} [15000] \times \pi \times 0.1 \times 20$$

$$H_g = 895.35 \text{ watts}$$

To find 'μ' use McKee's Equation.

$$\mu = K_a \left(\frac{\eta n'}{P}\right)\left(\frac{1}{\psi}\right) \times 10^{-10} + \Delta\mu$$

$$= 1.95 \times 10^{11} \left[\frac{25 \times 10^{-3} \times 20}{1 \times 10^6}\right]\left[\frac{1}{0.0013}\right] \times 10^{-10} + 0.002$$

$$\mu = 9.5 \times 10^{-3}$$

STEP : 6 :- Heat decipated (Hd)

$$Hd = \frac{(\Delta T + 18)^2}{K} [Ld] \longrightarrow \text{(eq 23-80a pg 23-53)}$$

$$= \frac{[20+18]^2}{0.273} \times [0.15 \times 0.1]$$

$$Hd = 79.34 \text{ watts}$$

If they not mention 'K' value, choose well ventilated Bearing

amount of artificial cooling

$Hg - Hd$

$895.35 - 79.34$

816.01 watts

STEP : 7 : minimum film thickness (h_{min}).

(from fig 23-15 pg 23-25)

$$\delta = 0.72$$

so. $\delta = \frac{2 \times h_{min}}{C.}$

$$0.72 = \frac{2 \times h_{min}}{1.3 \times 10^{-4}}$$

$$h_{min} = 4.68 \times 10^{-5} m$$

$$S = \frac{\eta n'}{P} \times \frac{1}{(\psi)^2} \longrightarrow \text{(eq 23-29)}$$

$$= \frac{25 \times 10^{-3} \times 20}{1 \times 10^6} \times \frac{1}{(0.0013)^2}$$

$$S = 0.29$$

$$\psi = \frac{C}{d}$$

$$0.0013 = \frac{C}{0.1}$$

$$C = 1.3 \times 10^{-4}$$

STEP : 8 :- Flow rate (Q).

(from fig 23-41 pg 23-49)

$$\lambda' Q = 3.5$$

$$\lambda' Q = \frac{4 Q \psi}{c^2 n' L}$$

$$3.5 = \frac{4 \times Q \times 0.0013}{(1.3 \times 10^{-4})^2 \times 20 \times 0.15}$$

$$Q = 3.41 \times 10^{-5} \ m^3/sec$$

Step : 9 :- Power loss due to friction (P).

(from fig 23.53, eq 23.80a)

$$P = \frac{\mu \times W \times v}{1000}$$

$$= \frac{9.5 \times 10^{-3} \times 15 \times 10^3 \times \pi \times 0.1 \times 20}{1000}$$

$$P = 0.89 KW$$

14M/20M

14. Design the main bearing of four stroke diesel engine to substain a load of 6KN. Operating speed of the shaft is 1000rp

Given data

(machine is four stroke diesel engine).

$W = 6KN = 6 \times 10^3 N$

$N = 1000 rpm$

$$\frac{1000}{60}$$

$$n' = 16.67 rps$$

STEP : 1 : Selection of Design value

(from table 23-2 Pg 23.15)

Bearing pressure $p = 4.85 - 8.35\,MPa$

Diameter clearance ratio $\psi = 0.001$

Bearing modulus $S'' = 48.4 \times 10^{-9}$

Absolute viscosity $\eta = 20 \times 10^{-3}\,Ps$

$\frac{L}{d}$ ratio, $\frac{L}{d} = 0.62 - 2$

STEP ; 2 ; Design

(Take bearing pressure $p = 6\,MPa$)

WKT,

$$p = \frac{W}{l \times d}$$

$$d^2 = \frac{6000}{6 \times 10^6}$$

$d = 0.0316\,m \simeq 0.032\,m$

$l = 0.0316 \simeq 0.032\,m$

$\frac{L}{d} = 1$

$L = 1d$

$L = d.$

STEP ; 3 ; selections of the oil

$t_a = 70°C$ and $\eta = 20 \times 10^{-3}$

Type of oil SAE = 40

STEP ; 4 : To check for oil

$$S''_{cal} = \frac{\eta n'}{p} \Rightarrow \frac{20 \times 10^{-3} \times 16.67}{6 \times 10^6} \Rightarrow S''_{cal} = 5.55 \times 10^{-8}$$

Since the $S''_{cal} > S''_{rec}$. Thick film lubrication is established

STEP : 5 :- heat generated (Hg).

$$Hg = \mu [PLd] v$$

$$= 3.08 \times 10^{-3} [6 \times 10^{3}] \times \pi \times 0.032 \times 16.67$$

$$\boxed{Hg = 30.96 \text{ watts}}$$

$$\mu = Ka \left(\frac{\eta n'}{P}\right) \left(\frac{1}{\psi}\right) \times 10^{-10} + \Delta\mu$$

$$= 1.95 \times 10^{11} \left[\frac{20 \times 10^{-3} \times 16.67}{6 \times 10^{6}}\right] \left[\frac{1}{0.001}\right] \times 10^{-10} + 0.002.$$

$$\boxed{\mu = 3.08 \times 10^{-3}}$$

STEP : 6 :- heat decipated (Hd)

$$Hd = \frac{[\Delta T + 18]^2}{K} [Ld]$$

$$= \frac{[20 + 18]^2}{0.273} \cdot [0.032]^2$$

$$\boxed{Hd = 5.41 \text{ watts}}$$

(If it is not mention ta. Assume ta is always 30°c)

$$tb - ta = \frac{to - ta}{2}$$

$$tb - 30 = \frac{70 - 30}{2}$$

$$\boxed{tb = 50}$$

$$\Delta T = (tb - ta) \Rightarrow 50 - 30$$

$$\boxed{\Delta T = 20}$$

amount of artificial cooling

$$Hg - Hd$$

$$30.96 - 5.41$$

$$\boxed{25.55 \text{ watts}}$$

STEP 7 :- minimum film thickness (h_{min}).

(from fig 23-15 Pg 23-25)

$$\delta = 0.23$$

so $\delta = \frac{2 \times h_{min}}{c}$

$$0.23 = \frac{2 \times h_{min}}{3.2 \times 10^{-5}}$$

$$h_{min} = 3.68 \times 10^{-6} m$$

$$S = \frac{\eta n'}{P} \times \frac{1}{(\psi)^2}$$

$$= \frac{20 \times 10^{-3} \times 16.67}{6 \times 10^{6}} \times \frac{1}{(0.001)^2}$$

$$S = 0.05$$

$$\psi = \frac{c}{d}$$

$$0.001 = \frac{c}{0.032}$$

$$C = 3.2 \times 10^{-5}$$

STEP: 8 :- Flow rate (Q).

(from fig 23-41 pg 23-49)

$$\lambda' Q = 5$$

$$\lambda' Q = \frac{4Q\psi}{c^2 n' L}$$

$$5 = \frac{4 \times Q \times 0.001}{(3.2 \times 10^{-5})^2 \times 16.67 \times 0.032}$$

$$Q =$$

STEP: 9 :- Power loss due to friction (P)

(from fig 23-53 Pg 23.80a)

$$P = \frac{W \times \mu \times v}{1000.}$$

$$P = \frac{3.08 \times 10^{-3} \times 6000 \times \pi \times 0.032 \times 16.67}{1000}$$

$$\boxed{P = 0.030 \, KW}$$

Internal

15. Design the main bearing of the steam turbine and runs at 1300rpm. The load on the bearing is estimated To 2500N.

Given Data :-

(machine steam turbine)

$W = 2500N$

$N = 1300rpm$

$$\frac{1300}{60}$$

$$\boxed{n' = 21.67 \, rps}$$

STEP:1 : select of Design value.

(from table 23-2 pg 23.15)

Bearing pressure $\boxed{P = 0.69 - 1.87 \, MPa}$

Diameter clearance ratio $\boxed{\psi = 0.001}$

Bearing modulus $\boxed{S'' = 241.8 \times 10^{-9}}$

Absolute viscosity $\boxed{\eta = 10 \times 10^{-3} \, Ps}$

$\frac{L}{d}$ ratio, $\boxed{\frac{L}{d} = 1.0 - 2.0}$

STEP:2: Design

(Take bearing pressure $P = \cdot 1 MPa$) | $L = d$

$$P = \frac{W}{l \times d}$$

$$d^2 = \frac{2500}{1 \times 10^6}$$

$$\boxed{d = 0.05 m}$$

$$\boxed{l = 0.05 m}$$

STEP: 3 :- selection of the oil.

$t_a = 70°C \quad \eta = 10 \times 10^{-3}$

Type of the oil SAE =

STEP: 4 :- To check for oil.

$$S''_{cal} = \frac{\eta n'}{P}$$

$$= \frac{10 \times 10^{-3} \times 21.67}{1 \times 10^6}$$

$$\boxed{S''_{cal} = 2.167 \times 10^{-7}}$$

since

STEP: 5 :- Heat generation (Hg),

$$Hg = \mu [PLd] v$$

$$= 6.22 \times 10^{-3} [2500] \times \pi \times 0.05 \times 21.67$$

$$\boxed{Hg = 52.93 \text{ watts}}$$

$$\mu = Ka \left[\frac{\eta n'}{P}\right] \left[\frac{1}{\psi}\right] \times 10^{-10} + \Delta\mu$$

$$= 1.95 \times 10^{11} \left[\frac{10 \times 10^{-3} \times 21.67}{1 \times 10^6}\right] \left[\frac{1}{0.001}\right] \times 10^{-10} + 0.0$$

$$\boxed{\mu = 6.22 \times 10^{-3}}$$

STEP: 6: Heat dissipated (Hd);

$$Hd = \frac{[\Delta T + 18]^2}{K} [Ld]$$

$$= \frac{[20 + 18]^2}{0.273} [0.05]^2$$

$$\boxed{Hd = 13.22 \text{ watts}}$$

$$t_b - t_a = \frac{t_o - t_a}{2}$$

$$t_b - 30 = \frac{70 - 30}{2}$$

$$\boxed{t_b = 50}$$

$$\Delta T = [t_b - t_a]$$

$$= 50 - 30 \Rightarrow \boxed{\Delta T = 20}$$

amount of artificial cooling.

Hg - Hd

52.93 - 13.22

39.71 watts

STEP : 7 :- minimum film thickness (h_{min}),

(from fig 23-15 Pg 23-25)

$S = 0.54$

$S = \frac{2 \times h_{min}}{C}$

$0.54 = \frac{2 \times h_{min}}{5 \times 10^{-5}}$

$h_{min} = 1.35 \times 10^{-5} m$

$S = \frac{\eta n'}{P} \times \frac{1}{\psi^2}$

$= \frac{10 \times 10^{-3} \times 21.67}{1 \times 10^6} \times \frac{1}{(0.001)^2}$

$S = 0.21$

$\psi = \frac{c}{d}$

$0.001 = \frac{c}{0.05}$

$C = 5 \times 10^{-5}$

STEP : 8 :- Flow rate (Q);

(from fig 23-41 Pg 23-49)

$\lambda' Q =$

$\lambda' Q = \frac{4 Q \psi}{c^2 n' L}$

$= \frac{4 \times Q \times 0.001}{(5 \times 10^{-5})^2 \times 21.67 \times 0.05}$

$Q =$

STEP : 9 :- power loss due to friction

(from fig 23-53 Pg 23.80a)

$$P = \frac{W \times \mu \times v}{1000}$$

$$P = \frac{6.22 \times 10^{-3} \times 2500 \times \pi \times 0.05 \times 21.67}{1000}$$

$$\boxed{P = 0.052 KW}$$

Thrust Bearing :-

10/05/22
Tuesday

A foot step bearing [flat pivot bearing] support a shaft of 180mm of diameter which is counter boared at end with a hole of diameter 80mm. If the bearing pressure is limitted to 1MPa and speed is 120rpm, find

1. The load to be supported.
2. Power loss in friction
3. Heat generator (H_g)

$Pa = N/m^2$

$N/mm^2 = 1MPa$

Take Co-eff of friction $\mu = 0.03$.

Given data :-

$d_1 = 180mm$

$d_2 = 80mm$

$P = 1MPa = 1N/mm^2$

$N = 120rpm.$

(Assume uniform pressure theory)

1. Load to be supported.

$$W = P\pi \left(\frac{d_1^2 - d_2^2}{4}\right)$$

$$1 \times \pi \left(\frac{180^2 - 80^2}{4}\right)$$

$$\boxed{W = 20.42 KN}$$

2. Power loss in friction

$P = \frac{M_t \times N}{9550}$

$P = \frac{41.78 \times 120}{9550}$

$P = 0.524 KW$

$M_t = \frac{1}{3} \mu W \left[\frac{d_1^3 - d_2^3}{d_1^2 - d_2^2}\right]$

$= \frac{1}{3} \times 0.03 \times 20.42 \left[\frac{180^3 - 80^3}{180^2 - 80^2}\right]$

$M_t = 41.78 N\text{-}m$

3. heat generation (Hg) = ?

$Hg = \mu [PLd] v$

$= 0.03 [20.42 \times 10^3] \times 0.857$

$Hg = 524.99$ watts | J/s

$d_m = \frac{2}{3} \left(\frac{d_1^3 - d_2^3}{d_1^2 - d_2^2}\right)$

$= \frac{2}{3} \left(\frac{180^3 - 80^3}{180^2 - 80^2}\right)$

$d_m = 136.41 mm$

$v = \frac{\pi \times 136.41 \times 120}{60,000}$

$V = 0.857 m/sec$

2. A Conical pivot bearing has a cone angle of 144°. The Inside and Outside diameter of the Conical pivot are 90mm and 160mm The shaft rotates at 270rpm. Co-eff of friction $\mu = 0.025$, find power loss due to friction. The thrust load on shaft 7.5KN

Given data :-

$\alpha = 144° = \frac{1}{2} = 72°$

$d_1 = 160mm$

$d_2 = 90mm$

$N = 270 rpm$

$\mu = 0.025$

$W = 7.5 KN = 7500N$

$P = ?$

$M_t = \frac{1}{3} \frac{\mu W}{\sin \alpha} \left(\frac{d_1^3 - d_2^3}{d_1^2 - d_2^2}\right)$

$= \frac{1}{3} \times \frac{0.025 \times 7500}{\sin(72)} \times \left(\frac{160^3 - 90^3}{160^2 - 90^2}\right)$

$M_t = 12.64 \times 10^3 N mm$ (or) $12.64 N\text{-}m$

$$P = \frac{M_t \times N}{9550} = \frac{12.64 \times 270}{9550} \Rightarrow \boxed{P = 0.357\,KW}$$

3. A foot step bearing supports a shaft of 150mm diameter which is counter board at the end with a hole of diameter 50mm. If the bearing pressure is limitted to 0.8MPa and the speed is 100rpm. find.

1. load to be supported.
2. The power loss in the friction
3. Heat generatae at the bearing

Assume $\mu = 0.0158$; Consider both uniform pressure and uniform wear Condition.

Given Data :-

$d_1 = 150mm$

$d_2 = 50mm$

Bearing pressure $p = 0.8MPa$

$N = 100rpm$

$\mu = 0.0158$.

(For uniform pressure theory)

1. $$W = p\pi\left(\frac{d_1^2 - d_2^2}{4}\right)$$

$$0.8 \times \pi\left(\frac{150^2 - 50^2}{4}\right)$$

$$\boxed{W = 12.56\,KN}$$

(2). Power loss in friction.

$$M_t = \frac{1}{3}\mu W\left[\frac{d_1^3 - d_2^3}{d_1^2 - d_2^2}\right]$$

$$= \frac{1}{3} \times 0.0158 \times 12.56 \cdot \left(\frac{150^3 - 50^3}{150^2 - 50^2}\right)$$

$$\boxed{M_t = 10.74\,N\text{-}m}$$

$$P = \frac{M_t \times N}{9550}$$

$$= \frac{10.74 \times 100}{9550}$$

$$\boxed{P = 0.11\,KW}$$

3. Heat generated (Hg) = ?

$H_g = \mu [W] \times v$

$= 0.0158 [12.56 \times 10^3] \times 0.56$

$H_g = 111.13$ watts

$d_m = \frac{2}{3} \left(\frac{d_1^3 - d_2^3}{d_1^2 - d_2^2} \right)$

$d_m = 108.33 mm$

$v = \frac{\pi \times d \times N}{60{,}000}$

$= \frac{\pi \times 108.33 \times 100}{60{,}000}$

$v = 0.56 m/s$

(For uniform wear theory) :-

1. Load to be supported (W) = ?

$W = \frac{1}{2} p \pi d_2 (d_1 - d_2)$

$= \frac{1}{2} \times 0.8 \times \pi \times 50 (150 - 50)$

$W = 6.28 KW$

2. Power loss friction (P) = ?

$P = \frac{M_t \times N}{9550}$

$= \frac{4.96 \times 100}{9550}$

$P = 0.05 KW$

$M_t = \mu W \left(\frac{d_1 + d_2}{4} \right)$

$= 0.0158 \times 6.28 \left(\frac{150 + 50}{2} \right)$

$M_f = 4.96 N-m$

3. heat generated (Hg) = ?

$H_g = \mu (W) v$

$= 0.0158 (6.28 \times 10^3) \times 0.52$

$H_g = 51.59$ watts

$d_m = \frac{d_1 + d_2}{2}$

$d_m = 100 mm$

$v = 0.52 m/s$

4. The thrust of a shaft is taken by a Collar bearing of diameter 150mm and 100mm. The shaft rotates at 300rpm. The Thrust load is found to be 5000N. find, power loss in friction Assuming uniform pressure Condition.

Given data :-

(machine, Collar bearing).

$d_1 = 150mm$

$d_2 = 100mm$

$N = 300 rpm$

$W = 5000 N$

$P = ?$

velocity $v = ?$

$$V = \frac{\pi d_m N}{60,000}$$

$$= \frac{\pi \times 126.66 \times 300}{60,000}$$

$$\boxed{v = 1.989 m/s}$$

Co-eff of friction ($\mu = ?$)

$$\mu = 83.8 \cdot \frac{V^{0.5}}{P^{0.67}}$$

$$= 83.8 \cdot \frac{(1.989)^{0.5}}{(0.51)^{0.67}_{\times 10^6}}$$

$$\boxed{\mu = 0.017}$$

mean diameter $d_m = ?$

$$d_m = \frac{2}{3}\left(\frac{d_1^3 - d_2^3}{d_1^2 - d_2^2}\right)$$

$$= \frac{2}{3}\left(\frac{150^3 - 100^3}{150^2 - 100^2}\right)$$

$$\boxed{d_m = 126.66mm}$$

Bearing pressure $P = ?$

$$P = \frac{W}{0.784\,(d_1^2 - d_2^2)\,i} \qquad \boxed{i = 1}$$

$$= \frac{5000}{0.784\,(150^2 - 100^2) \times 1}$$

$$\boxed{P = 0.51\ N/mm^2 \text{ (or) } 0.51 \times 10^6\ Pa}$$

$$M_f = \frac{1}{3}\mu W\left(\frac{d_1^3 - d_2^3}{d_1^2 - d_2^2}\right)$$

$$= \frac{1}{3} \times 0.017 \times 5000\left(\frac{150^3 - 100^3}{150^2 - 100^2}\right)$$

$$M_t = 5.383 \times 10^3 N\text{-}mm$$

$$\boxed{M_t = 5.38 N\text{-}m}$$

Power loss in friction (P=?).

$$P = \frac{M_t N}{9550} = \frac{5.38 \times 300}{9550} \Rightarrow \boxed{P = 0.169 KW}$$

5. The thrust of an propellar shaft in ship engine is taken by number of collars integral with the shaft which is 300mm diameter. The thrust on the bearing shaft is 200KN. and the speed is 75 rpm. bearing pressure is 0.3 MN/m². find number of collars required. if outside diameter is 500mm, power loss in friction. Assuming uniform wear theory of heat generated in the bearing.

Given data:-

(machine collar bearing).

$d_1 = 500mm$

$d_2 = 300mm$

$W = 200KN = 200 \times 10^3 N$

$N = 75 rpm$

$P = 0.3 \times 10^6 N/m^2$

$\boxed{P = 0.3 N/mm^2}$

$i = ?$

$P = ?$

$Hg = ?$

$$V = \frac{\pi d_m N}{60000}.$$

$\boxed{V = 1.57 m/s}$

$$d_m = \frac{d_1 + d_2}{2} \quad \boxed{d_m = 400mm}$$

i. Number of collars (i) = ?

$$W = \frac{1}{2} p \pi d_2 (d_1 - d_2) i$$

$$200 \times 10^3 = \frac{1}{2} \times 0.3 \times \pi \times 300 (500 - 300) i$$

$\boxed{i = 7.07 \simeq 8}$

ii. power loss in friction (P= ?)

$$\mu = 83.8 \times \frac{V^{0.5}}{p^{0.67}}$$

$$= 83.8 \times \frac{(1.57)^{0.5}}{(0.3 \times 10^6)^{0.67}}$$

$\boxed{\mu = 0.022}$

$$M_t = \mu W \left(\frac{d_1 + d_2}{4}\right)$$

$$= 0.022 \times 200 \times 10^3 \left(\frac{500 + 300}{4}\right)$$

$$M_t = 880 \times 10^3 \text{ N-mm}$$

$$\boxed{M_t = 880 \text{ N-m}}$$

$$P = \frac{M_t N}{9550}$$

$$= \frac{880 \times 75}{9550}$$

$$\boxed{P = 6.91 \text{ kW}}$$

Bearing pressure for $(i = 8)$:-

$$W = \frac{1}{2} p \pi d_2 (d_1 - d_2);$$

$$200 \times 10^3 = \frac{1}{2} \times p \times \pi \times 300 (500 - 300) 8$$

$$p = 0.26 \text{ N/mm}^2$$

$$\boxed{p = 0.26 \times 10^6 \text{ N/m}^2}$$

Power loss in friction $(P = ?)$

$$P = \frac{900 \times 75}{9550}$$

$$P = \frac{M_t N}{9550}$$

$$\boxed{P = 7.539 \text{ kW}}$$

Co-eff of friction $\mu = ?$

$$\mu = 83.8 \frac{V^{0.5}}{p^{0.67}}$$

$$= \frac{83.8 \times (1.57)^{0.5}}{(0.26 \times 10^6)^{0.67}}$$

$$\boxed{\mu = 0.024}$$

Frictional Torque $M_t = ?$

$$M_t = \mu W \left(\frac{d_1 + d_2}{4}\right)$$

$$= 0.024 \times 200 \times 10^3 \left(\frac{500 + 300}{2}\right)$$

$$M_t = 960 \times 10^3 \text{ N-mm}$$

$$\boxed{M_t = 960 \text{ N-m}}$$

3. heat generator ($Hg = ?$)

$Hg = \mu (w) v$

$0.024 \times 200 \times 10^3 \times 1.57$

$Hg = 7536$ watts.

$Hg = 7.53\,kW$