B. Bharathan/AP/Mech

UNIT - V

Design of Bearing and Miscellaneous elements

2 Marks :-

1) classify the bearing depending upon type of rolling element.

Based on the type of rolling element bearing may be classified as follows.

(a) Ball bearing, and

(b) Roller bearing.

2) what is a journal bearing? List any two applications.

A journal bearing is a sliding contact bearing which gives a lateral support to be rotating shaft

Applications: Turbine shafts of Most jet engines used on commercial airplanes, Crank shaft bearing of automobile engines, mining machines. etc.

3) what is known as self-acting bearing?

The bearing in which the pressure is created within the system due to the rotational of shaft is known as self-acting bearing.

4) Classify the sliding contact bearing according to the thickness of the lubricant between the bearing and the journal?

(a) Thick film type

(b) Thin film type

(c) Hydrostatic bearings

(d) Hydrodynamic bearing

5) what is meant by static load carrying capacity of a bearing?

Basic static load rating is defined as the load which will produce a total permanent deformation of the rolling element and raceway on the most heavily stressed rolling element / raceway contact of 0.0001 of the rolling element diameter.

6) what is the application of thrust bearing?

Thrust bearing are used to support high axial loads and can also support shafts that are out of alignment. They are used in higher speed applications that require oil lubrication, such as in the automotive and aerospace industries.

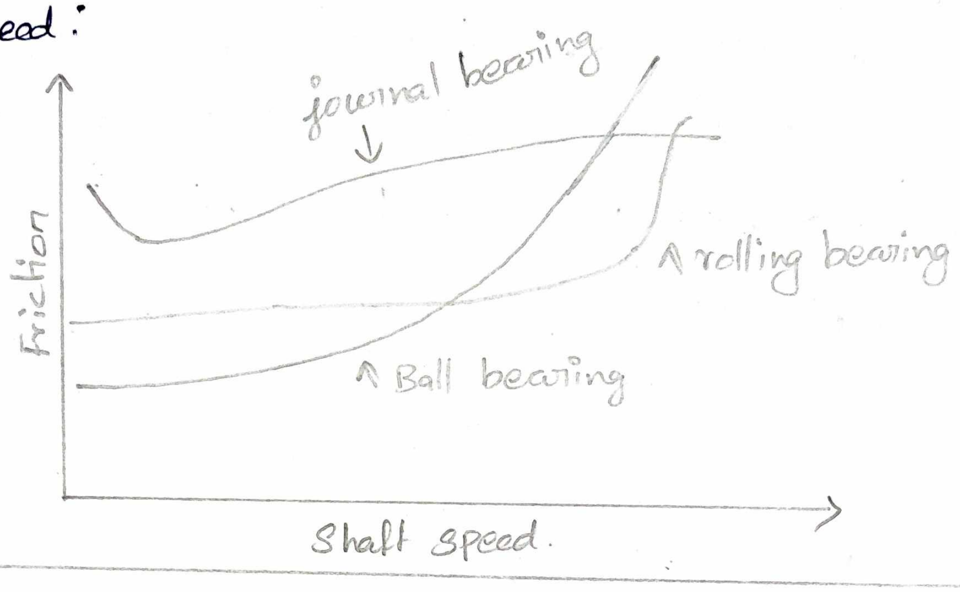
7) what type of bearing can take axial load?

Both thrust ball bearing and four-point contact ball bearings are used to take purely axial load but deep groove ball bearing and tapered roller bearing are used to carry both axial and radial loads.

8) what are the modes of failure of rolling contact bearing?

(i) Flaking or surface fatigue
(ii) peeling
(iii) scoring
(iv) Fretting
(v) Creep.

9) plot the friction induced in various based on shaft speed:



10) what are the advantages of rolling contact bearing over sliding contact bearing?

(i) starting friction is low

(ii) It requires less axial space and more diametral space

(iii) They produce low starting and running friction except at very high speed.

(iv) Accuracy of shaft alignment is high.

(v) They provide good reliability of service.

11) what is bearing modulus?

Bearing modulus is a modulus used in journal bearing design. The combination of term (Zn/p) is called bearing characteristic number or bearing Modulus. It is a dimensionless number

where Z - Absolute viscosity in centipoises

P - Bearing pressure in kgf/cm²

n - speed of journal in rpm

PART-B

1) A 100 mm long and 60 mm diameter journal bearing supports a load of 2500N at 600 rpm. If the room temperature is 20°C, what should be the viscosity of oil to limit the bearing surface temperature to 60°c ? The diameteral clearance is 0.06 mm and energy dissipation coefficient based on projected area of bearing is 210W/m²/°c.

Given data ;

$D = 60mm = 6cm = 0.06m$

$L = 100mm = 10cm = 0.1m$

$W = 2500 N = 250 kgf$

$n = 600 rpm$

$t_a = 20°C$

$t_o = 60°C$

$c = 0.06mm$

$q = 210 W/m^2/°c$

Solu:-

Area of radiating surface, $A = L \times D = 0.06 \times 0.1 = 0.006m^2$

Heat dissipated $H_d = q A (t_o - t_a)$

$= 210 \times 0.006 \times (60-20) = 50.4W$

Using Mckee's equation, $\mu = \frac{33.25}{10^{10}} \left(\frac{Zn}{P}\right)\left(\frac{D}{c}\right) + k$

$k = 0.002 \frac{L}{D} = 1.67$

$P = \frac{W}{LD} = \frac{2500}{100 \times 60}$

$= 0.4167 N/mm^2$

$$\mu = \frac{33.25}{10^{10}} \times \left(\frac{Z \times 600}{0.4167}\right) \times \left(\frac{60}{0.06}\right) + 0.002$$

$$= 4.788 \times 10^{-3} Z + 0.002$$

Speed of journal:

$$V = \frac{\pi D n}{60} = \frac{\pi \times 0.06 \times 600}{60}$$

$$= 1.885 \text{ m/s}$$

Heat generated:

$$H_g = \mu W V$$

$$= (4.788 \times 10^{-3} Z + 0.002) \times 2500 \times 1.885$$

$$= 22.56 Z + 9.425$$

we know that the heat generate is equal to the heat dissipated.

$$H_g = H_d$$

$$22.56 Z + 9.425 = 50.4$$

$$Z = 1.816 \text{ N-s/m}^2$$

$$= 18.16 \text{ CP}$$

2) A single-row deep groove ball bearing is subjected to a radial force of 8 kN and thrust force of 3 kN. The values of X and Y factors are 0.56 and 1.5 respectively. The shaft rotates at 1200 rpm. The diameter of the shaft is 75 mm and bearing no 6315 (dynamic load carrying capacity, C = 112 000 N) is selected for the application.

(i) Estimate the life of this bearing with 90% reliability.

(ii) Estimate the reliability for 20,000 hr life.

Given Data:

Radial load, $F_r = 8\,kN = 8000\,N$

Axial load, $F_a = 3\,kN = 3000\,N$

Factors $X = 0.56$ and $Y = 1.5$

Speed, $n = 1200\,rpm$

Diameter of the shaft, $d = 75\,mm$

Dynamic load carrying capacity, $C = 112000\,N$

Expected Life $L_h = 20000\,hrs$

Solu:-

(i) Estimate the life of this bearing with 90% reliability

Equivalent load, $P = (XF_r + YF_a)\,S$

$= (0.56 \times 8000 + 1.5 \times 3000) 1$

$= 8980$ N [Assume $S = 1$]

Rate life of Bearing :

$$L = \left(\frac{C}{P}\right)^b = \left(\frac{112000}{8980}\right)^3 \quad (\because b = 3 \text{ for ball bearing})$$

$= 1940.1$ million revolutions

From the relationship between life in million revolutions and life in working hours

$$L_h = \frac{16666}{n} \times L = 1940.1$$

$= 26944.8$ hrs

(ii) Estimate the reliability for 20,000 hr life

$$\frac{L}{L'_{10}} = \left[\frac{\ln\left(\frac{1}{P}\right)}{\ln\left(\frac{1}{P_{10}}\right)}\right]^{1/b}$$

[$\because b = 1.17$ for a median life $= 5L_{10}$]

$$\left(\frac{L}{L'_{10}}\right)^{1.17} = \left[\frac{\ln\left(\frac{1}{P}\right)}{\ln\left(\frac{1}{P_{10}}\right)}\right]$$

$$\left(\frac{20000}{26944.8}\right)^{1.17} = \left[\frac{\ln\left(\frac{1}{P}\right)}{\ln\left(\frac{1}{0.9}\right)}\right]$$

$$P = 0.9283$$

$$= 92.83\%$$

3) Discuss about lubrication of ball/roller bearing.

- Lubrication is absolutely nessessary to the proper operation of ball and roller bearings.

- A proper lubricant reduces friction between the internal sliding surfaces of the bearings components and prevents metal-to-metal contact of the rolling elements with their raceways.

- Lithium based greases are popular as bearing greas. due to their water resistance and performance characteristics in both high and low temperatures.

- It comprises of synthetic lubricanting fluids performing well in extreme low and high temperature ranges.

- There are two types of bearing lubricants readily available

(i) oil

(ii) grease.

- Mainly grease is the lubricant of choice for 80% to 90% of bearing.

Advantages of oil:

- It is easy to distribute
- lubes other components
- less drag
- easier to drain out and change.
- It is better for high temperature bearing applications.

Dis advantages of oil:

- It may leak because it is harmfull to the environment.

Advantages of grease:

- It remains in place
- It does not leak out easily.

- It improves sealing, and
- It does not require monitoring.

Disadvantages of grease:

- It may leak because it is harmful to the environment.

4) A 360° journal bearing of length 45 mm and L/D = 1 has been scored due to dirty oil. The surface roughness of the bearing increases due to dirty oil and causes to increase the viscosity of the oil by 10% due to the working environment. decide whether the bearing is to be replaced based on the criterion that 5% increase in power loss justifies the replacement. Consider the radial load 900 N, speed = 3000 rpm. radial clearance = 0.02 mm. SAE 10 oil is to be used and the inlet temperature is limited to 60°C.

Given data:

Bearing Length $L = 45\ mm = 4.5\ cm$

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

Load on bearing $w = 900\ N = 90\ kgf$

Speed, $n = 3000\ rpm$

Radial clearance. $\frac{c}{2} = 0.02\ mm \Rightarrow c = 0.04\ mm = 0.004\ cm$

Inlet temperature, $t_{in} = 60°c$

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Solu:

Diameter of journal. $D = 1 \times L = 1 \times 45 = 4mm = 4.5cm$

Bearing pressure, $P = \frac{W}{LD} = \frac{90}{4.5 \times 4.5} = 4.44\ kgf/cm^2$

Let the temperature rise $\Delta t = 20°c$

Average temperature $t_{ave} = t_{in} + \frac{\Delta t}{2} = 60 + 10 = 70°c$

corresponding to SAE 10 and 70°c, $Z = 10\ cP$

$$Z' = \frac{Z}{9.81 \times 10^7} = \frac{10}{9.81 \times 10^7} = 1.02 \times 10^{-7}\ kgf\text{-}sec/cm^2$$

speed of journal $n' = \frac{3000}{60} = 50\ rps$

Sommerfeld number $S = \frac{Z'n'}{P}\left(\frac{D}{c}\right)^2 = \frac{1.02 \times 10^{-7} \times 50}{4.44}\left(\frac{4.5}{0.004}\right)^2$

$= 1.467$

$\beta = 360°$ (i.e for full journal bearing). corresponding to $\frac{L}{D} = 1$ and $S = 1.467$ (we can take 1.33 as it is the maximum value of S), The value of $\frac{Pc'\Delta t_o}{P} = 106$

$$\Delta t_o = \frac{P \times 106}{Pc'} = \frac{4.44 \times 106}{14.2} = 33.14°c$$

In the first iteration, The average temperater is

$$t_{ave} = t_{in} + \frac{\Delta t_o}{2} = 60 + \frac{33.14}{2} = 76.57°c \text{ say } 77°c$$

PSGDB corresponding to SAE 10 and 77°c, $Z = 8\ cP$

$$Z' = \frac{Z}{9.81\times10^7} = \frac{8}{9.81\times10^7} = 8.15\times10^{-8}\ kgf\text{-}sec/cm^2$$

Sommerfeld number, $S = \frac{Z'n'}{P}\left(\frac{D}{c}\right)^2 = \frac{8.15\times10^{-8}\times50}{4.44}\left(\frac{4.5}{0.004}\right)^2$

5.40

$= 1.16.$

corresponding to $\frac{L}{D} = 1$ and $S = 1.16$, The value of

$\frac{P c' \Delta t_o}{P} = 92.8$ (by linear interpolation)

$$\Delta t_o = \frac{P\times92.8}{Pc'} = \frac{4.44\times92.8}{14.2} = 29°C$$

In the second iteration, the average temperater is

$$t_{ave} = t_{in} + \frac{\Delta t_o}{2} = 60 + \frac{29}{2} = 74.5°C \text{ say } 75°C$$

From PSGDB, corresponding to SAE 10 and 75°C

$Z = 8.5\,CP.$

$$Z' = \frac{Z}{9.81\times10^7} = \frac{8.5}{9.81\times10^7} = 8.66\times10^{-8}\ kgf\text{-}sec/cm^2$$

Sommerfeld number, $S = \frac{Z'n'}{P}\left(\frac{D}{c}\right)^2 = \frac{8.66\times10^{-8}\times50}{4.44}\left(\frac{4.5}{0.004}\right)^2 = 1.23$

$\frac{L}{D} = 1$ and $S = 1.23$, The value of $\frac{Pc'\Delta t_o}{P} = 98.3$

$$\Delta t_o = \frac{P\times98.3}{Pc'} = \frac{4.44\times98.3}{14.2} = 30.70°C$$

In third Iteration, The average temperature is

$$t_{ave} = t_{in} + \frac{\Delta t_o}{2} = 60 + \frac{30.7}{2} = 75.35°C \text{ say } 76°C$$

This average temperature is close to the earlier iteration

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SAE 10 and 76°c, $Z = 8.2$ cP

coefficient of friction, $\mu = \frac{33.25}{10^{10}}\left(\frac{Zn}{P}\right)\left(\frac{D}{c}\right) + k$

$k = 0.002$

$\mu = \frac{33.25}{10^{10}}\left(\frac{8.2 \times 3000}{4.44}\right) \times \left(\frac{4.5}{0.004}\right) + 0.002$

$= 0.023$

Power lost = Heat generated, $H_g = \mu W v$

$v = \frac{\pi D n}{60} = \frac{\pi \times 0.045 \times 3000}{60} = 7.07$ m/s

$H_g = 0.023 \times 900 \times 7.07 = 146.35$ W

If viscosity of the oil increase by 10%.

$\mu' = 1.1 \times \mu = 1.1 \times 0.023 = 0.0253$

Power lost due to increase in viscosity

$H_g' = \mu' W v = 0.0253 \times 900 \times 7.07 = 160.98$ W

Percentage change in power lost $= \frac{160.98 - 146.35}{160.98} = 0.091 = 9.1\%$

This percentage change in power lost is greater than the specified range of 5%. Therefore, the bearing must be replaced.

5) A full journal bearing of 50mm diameter and 100mm long has a bearing pressure of 1.4 N/mm². The speed of the journal is 900 rpm and the ratio of journal diameter to the diametral clearance is 1000. The bearing is lubricated with oil whose absolute viscosity of the operating temperature of 75 °C may be taken as 0.011 kg/m-s. The room temperature is 35°c. Find the

(i) amount of artificial cooling required and

(ii) mass of lubricating oil required if the difference between the outlet and intel temperature of oil is 10°c. Take specific heat of oil as 1850 J/kg/°c.

Given data:

$D = 50\,mm = 5\,cm$

$L = 10\,mm = 10\,cm$

$P = 1.4\,N/mm^2 = 14\,kgf/cm^2$

$n = 900\,rpm$

$D/c = 1000$

$Z = 0.011\,kg/m\text{-}s = 11$ centipoise

$t_o = 75°c$

$t_a = 35°c$

Temperature rise $= 10°c$

Specific heat of oil $= 1850\,J/kg/°c$

Solu:-

using Mckee's equation, $\mu = \frac{33.25}{10^{10}} \left(\frac{Zn}{P}\right)\left(\frac{D}{c}\right) + k$

(From PSGDB 7.34)

where $k = 0.0027$ from graph in PSGDB 7.34,

for $\frac{L}{D} = \frac{10}{5} = 2$

$$\mu = \frac{83.25}{10^{10}}\left(\frac{11 \times 900}{14}\right) \times 1000 + 0.0027 = 0.0051$$

Heat generated $H_g = \mu W v$

where

$W = p\,DL = 14 \times 5 \times 10 = 700$ kgf

$v = \pi D n = \pi \times 0.05 \times 900 = 141.4$ m/min

$H_g = 0.0051 \times 700 \times 141.4 = 503.73$ kgf-m/min

$= 5037.3$ N-m/min $= 83.96$ N-m/s $= 83.96$ W

Heat dissipated $H_d = \frac{(\Delta t + 18)^2 LD}{k}$ (from PSGDB 7.34)

where

$\Delta t = (t_o - t_a)/2 = (75 - 35)/2 = 20^\circ C$

$K = 775$ for light construction (From PSGDB 7.35)

$$H_d = \frac{(20+18)^2 \times 10 \times 5}{775} = 93.16 \text{ kgf-m/min}$$

$= 931.6$ N-m/min $= 15.53$ N-m/s $= 15.53$ W

Heat generation is more than the heat dissipated. So artificial cooling by oil is needed to carry away the excess heat.

Amount of artificial cooling required:

$Q = H_g - H_d = 83.96 - 15.53 = 68.43$ W

Mass of lubricating oil required:

~~Q = H~~. Since the heat generated at the bearing is taken away by the lubricating oil, Therefore equating.

$H_g = m \times$ Specific heat of oil $\times$ Temperature rise

$83.96 = m \times 1850 \times 10$

$\therefore$ Mass of oil required $m = 0.00454$ kg/s

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6) Find the rated load of a deep groove ball bearing for the following load cycle.

S no	Radial load (N)	Axial load (N)	% of time
1	3000	1000	15
2	3500	1000	20
3	3500	100	30
4	500	2000	35

Also find the 90% life of ball bearing if bearing is used for 6207 hrs with dynamic capacity 19620 N.

Given data:

Radial load 1, $F_r = 3000$ N, Axial load 1, $F_a = 1000$ N $t_1 = 15\%$

Radial load 2, $F_r = 3500$ N, Axial load 1, $F_a = 1000$ N $t_2 = 20\%$

Radial load 3, $F_r = 3500$ N, Axial load 1, $F_a = 100$ N $t_3 = 30\%$

Radial load 4, $F_r = 500$ N, Axial load 1, $F_a = 2000$ N $t_4 = 35\%$

Dynamic load, $C = 19620$ N.

Soln:

Assume the factors $X = 0.56$, $Y = 1.2$ and $S = 1.5$

Equivalent load 1, $F_1 = (XF_r + YF_a)S = (0.56 \times 3000 + 1.2 \times 1000)1.5$

$= 4320\ N$

Equivalent load 2, $F_2 = (XF_r + YF_a)S = (0.56 \times 3500 + 1.2 \times 1000)1.5$

$= 4740\ N$

Equivalent load 3, $F_3 = (XF_r + YF_a)S = (1 \times 3500 + 0 \times 100)1.5$

$= 5250\ N$

Equivalent load 4, $F_4 = (XF_r + YF_a)S = (0.56 \times 500 + 1.2 \times 2000)1.5$

$= 4020\ N$

cubic mean load, $F_m = \left[\dfrac{F_1^3 t_1 + F_2^3 t_2 + F_3^3 t_3 + F_4^3 t_4}{\Sigma t}\right]^{1/2}$

- from PSGDB 4.2

~~Fm = 4634.5N~~

$$F_m = \left[\frac{4320^3 \times 0.15 + 4740^3 \times 0.2 + 5250^3 \times 0.3 + 4020^3 \times 0.35}{0.15 + 0.2 + 0.3 + 0.35}\right]^{1/3}$$

$F_m = 4634.5\ N$

Equivalent load, $P = F_m = 4634.5\ N$

Rate life of bearing, $L = \left(\dfrac{C}{P}\right)^b = \left(\dfrac{19620}{4634.5}\right)^3$ ($\because b = 3$ for ball bearing)

$= 75.87$ million revolutions.

Loading ratio $\dfrac{C}{P} = \dfrac{19620}{4634.5} = 4.23$

From graph in figure 5.18 or PSG DB 4.6, Corresponding

to $\dfrac{C}{P} = 4.23$ and 6207 hrs of life Speed

$n = 200$ rpm

From the relationship between life in million revolutions and life in working hours.

$$L_h = \frac{16666}{n} \times L = \frac{16666}{200} \times 75.87 = 6322 \text{ hrs.}$$

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7) Suggest suitable materials for the following parts stating the special property which makes it more suitable use in manufacturing ball bearing.

Bearing Materials:

Bearing material should have the following properties:

(a) High compressive strength

(b) Low coefficient of friction

(c) High thermal conductivity

(d) High resistance to corrosion

(e) Sufficient fatigue strength

(f) Low modulus of elasticity i.e soft materials

(g) not to get weld easily to the journal materials

The following materials are commonly used as bearing materials.

1. Babbitt alloys:

Babbitt alloys are used as bearing materials. the Babbitt materials are recommended where the maximum bearing pressures are not over 7 N/mm^2 to 14 N/mm^2. when applied in automobiles, the Babbitt is generally used as a thin layer with 0.05 mm to 0.15 mm thick, bonded to an insert or steel shell. There are two types of Babbitt metals as follow.

(i) Lead alloys based Babbitt:

It contains Lead - 74%. Antimony - 15%, Tin - 1%, Arsenic - 0.5% And copper - 0.25%. It has excellent resistance to seizure and has good corrosion resistance. Its compressive strength and hardness decrease rapidly with an increase in temperature. Therefore; it should not be used above 115°c. It is used for split bushings made from strip or gravity cast bearings.

(ii) Tin based Babbitt:

It contains Tin - 89%, Antimony - 7.5%. and copper 3.25%. It is slightly harder than lead based babbitt at room temperature. It has excellent anti-Series deformability and acid-resisting properties. It is also used for split bushings.

2. Leaded bronze:

The compositions and use of leaded bronze are as follows.

copper - 80%, Tin - 10%. and Lead - 10%. - used for split bushings made from strip or gravity cast bearing. They are having excellent fatigue life and

and capable of carrying heavy loads at high temperatures.

copper-72%, Tin-3% and Lead-25% - used for split bushing and half bearing made from strip or gravity cast bearings.

3. copper lead alloy:

The compositions and used of copped lead alloy are as follows.

copper-65% and lead-35% - used for split bushing and half bearing made from strip or gravity cast bearings.

Copper-71%, Lead-28% and Silver-1% - used for gravity cast bearings.

They are having excellent fatigue life and capable of carrying heavy loads at high temperatures. But they have poor corrosion resistance when compared to Babbitt.

4. Gun metal:

Its compositions is : copper-88%, Tin-10% and zinc-2%.

It is used for high-grade bearing subjected to high pressure and high speed.

5. phosphor bronze:

Composition is copper-80%, Tin-10%, Lead-9% and phosphor-1%. It is used for bearing subjected to very high pressure and speed.

6. Cast Iron:

It is used with steel journals. It should be provided with adequate lubricant. It is used for low pressure and low speed bearings.

7. Aluminium alloy:

It composition is Aluminium - 92%. copper - 1%, Tin - 6% and nickel - 1%. It is used for cast or forged solid construction. It has better fatigue resistance but poor surface behaviour.

8. Silver:

The usual form of construction is electro-plated bearing used with lead - tin or lead - indium overlay. It has excellent corrosion resistance and superior fatigue resistance.

9. Non-metallic bearing materials:

(i) plastics
(ii) carbon graphite bearings
(iii) soft rubber bearings.
(iv) wood bearings.

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