POSTAL BOOK PACKAGE 2025

MECHANICAL ENGINEERING

CONVENTIONAL Practice Sets

CONTENTS

MACHINE DESIGN

Bearings

Practice Questions : Level-I

Q.1 The dynamic load capacity of 6306 bearing is 22 kN. Calculate the maximum radial load it can sustain to operate at 600 rev/min, for 2000 hours.

Solution:

$$L = 600 \times 60 \times 2000 = 72 \times 10^6 \text{ rev}$$

$$L = \left(\frac{C}{P}\right)^3 \times 10^6 \text{rev} = 72 \times 10^6 = \left(\frac{22}{P}\right)^3 \times 10^6$$

$$P = \textbf{5.29 kN}$$

Q.2 A lightly loaded full journal bearing has journal diameter of 50 mm, bush bore of 50.05 mm and bush length of 20 mm. If rotational speed of journal is 1200 rpm and average viscosity of liquid lubricant is 0.03 Pa s, what will be the power loss.

Solution:

Tangential velocity of shaft, $u = \dfrac{\pi DN}{60} = \dfrac{\pi \times 50 \times 10^{-3} \times 1200}{60} = 3.14 \text{ m/s}$

Clearance, $y = \dfrac{50.05 - 50}{2} = 0.025 \text{ mm}$

By $\tau = \mu \cdot \dfrac{du}{dy}$ shear stress on shaft

$$\tau = 0.03 \times \frac{3.14}{0.025 \times 10^{-3}} = 3768 \text{ N/m}^2$$

Shear force on shaft, $F = \tau \times \text{Area} = 3768 \times \pi D \times L = 3768 \times \pi \times 50 \times 10^{-3} \times 20 \times 10^{-3} = 11.83 \text{ N}$

Torque: $T = F \times \dfrac{D}{2} = 11.83 \times \dfrac{50 \times 10^{-3}}{2} = 0.2953 \text{ Nm}$

$$\text{Power loss} = \frac{2\pi NT}{60} = \frac{2\pi \times 1200 \times 0.2953}{60} = \textbf{37.1 W}$$

Q.3 A hydrodynamic journal bearing is subjected to 2000 N load at a rotational speed of 2000 rpm. Both bearing bore diameter and length are 40 mm. If radial clearance is 20 μm and bearing is lubricated with an oil having viscosity 0.03 Pa.s, determine the Sommerfeld number of the bearing.

Solution:

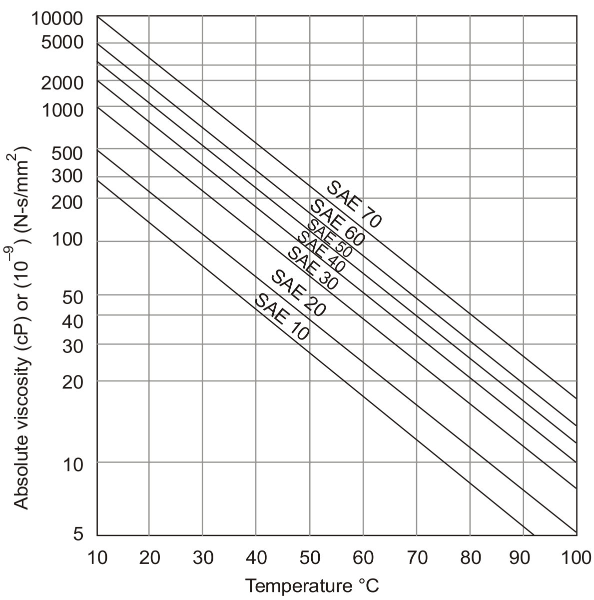
$r = 20$ mm; $N = 2000$ rpm; $c = 20 \times 10^{-3}$ mm; $\mu = 0.03 \text{ Ns/m}^2$

$$p = \frac{2000}{1600} \text{ N/mm}^2 \qquad \left(p = \frac{W}{A}\right)$$

$$= 1.25 \text{ MPa}, \ S = ?$$

$$S = \frac{ZN}{60p}\left(\frac{r}{c}\right)^2 = \frac{0.03 \times 2000}{60 \times 1.25 \times 10^6}\left(\frac{20}{20 \times 10^{-3}}\right)^2 = \textbf{0.8}$$

Q.18 A full hydrodynamic journal bearing with following specification for machine tool application:
Journal diameter = 75 mm, $l/d = 1$, radial load = 15 kN, Journal speed = 1440 rpm, inlet temperature of oil = 41°C, clearance, $c = 0.001 \times r$, density of lubricating oil is 860 kg/m³, specific heat of lubricating oil is 1.76 kJ/kg°C.
The value of surface roughness (C.L.A) of the journal and bearing are 2 and 1 micron respectively. The minimum oil thickness should be five times the sum of surface roughness. Find the flow rate of lubricant and select the suitable oil for this application.



Viscosity temperature relationship

$\left(\frac{l}{d}\right)$	$\left(\frac{h_o}{c}\right)$	S	$CFV = \left(\frac{r}{c}\right)f$	$FV = \left(\frac{Q}{rcn_s l}\right)$
1	0.6	0.264	5.79	3.99
	0.4	0.121	3.22	4.33
	0.2	0.0446	1.70	4.62

l = length of bearing (mm); r = radius of journal (mm); S = Sommerfeld number
CFV = coefficient of friction variable; FV = flow variable; f = coefficient of friction
n_s = Journal speed (rev/s); h_o = minimum film thickness; Q = flow of lubricant (mm³/s)

Solution:

$$l = d = 75 \text{ mm}$$

$$P = \frac{W}{ld} = \frac{15 \times 1000}{75 \times 75} = 2.667 \text{ N/mm}^2$$

$$c = 0.001\, r = 0.001 \times \frac{75}{2} = 0.0375 \text{ mm}$$

$$h_o = 5(2 + 1) = 15 \text{ microns} = 0.015 \text{ mm}$$

So,
$$\frac{l}{d} = 1$$

$$\frac{h_o}{c} = \frac{0.015}{0.0375} = 0.4$$

From table,

$$S = 0.121, \quad \frac{Q}{rcn_s l} = 4.33 = FV$$

$$\left(\frac{r}{c}\right)f = 3.22 = CFV$$

$$n_s = \frac{1440}{60} = 24 \text{ rev/s}$$

$$\frac{r}{c} = \frac{1}{0.001} = 1000$$

$$f = \frac{3.22}{\left(\frac{r}{c}\right)} = 3.22 \times 10^{-3}$$

$$S = \left(\frac{r}{c}\right)^2 \times \frac{\mu \times n_s}{P}$$

$$0.121 = (1000)^2 \times \mu \times \frac{24}{2.667}$$

$$\mu = 1.344 \times 10^{-8}$$

$$\mu = 13.44 \text{ N sec/mm}^2$$

$$\mu = 13.44 \text{ cP} \quad \text{..(i)}$$

[1 poise = 0.1 Pa.s; 1 centipoise = 0.001 N.s/m^2]

$$Q = 4.33 \times n_s crl$$

$$= 4.33 \times 24 \times 0.0375 \times \frac{75}{2} \times 75$$

$$Q = 10960.3125 \text{ mm}^3/\text{s}$$

We know that,

$$\Delta t = \frac{8.3P(CFV)}{FV} = \frac{8.3 \times 2.667 \times 3.22}{4.33} = 16.461°\text{C}$$

OR

$$\text{Heat dissipated by friction} = \text{Heat gained by lubricating oil}$$

$$Hg = mc\Delta T$$

$$f \times W \times V = \rho \times Q \times C\Delta T$$

$$3.22 \times 10^{-3} \times 15 \times 10^3 \times \frac{\pi \times 0.075 \times 1440}{60} = 860 \times 10960.3125 \times 10^{-9} \times 1.76 \times 10^3 \times \Delta T$$

$$273.13 = 16.5895 \times \Delta T$$

$$\Delta T = 16.46°\text{C}$$

So,

$$T_{avg} = T_i + \frac{\Delta t}{2} = 41 + \frac{16.461}{2} = 49.2307°\text{C} \quad \text{...(ii)}$$

From eq. (i) and (ii) it is observed that lubricating oil should have minimum viscosity of 13.44 cP at 49.2307°C. Suitable lubricating oil can be SAE 10 which will satisfy the above condition.

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8 CHAPTER Flywheel

Practice Questions

Q.1 A single cylinder double acting steam engine develops 150 kW at a mean speed of 100 rpm. The coefficient of fluctuation of energy is 0.1 and the fluctuation of speed is ± 2.5% of mean speed. If the mean diameter of the flywheel rim is 2 meter and the hub and spokes provides 5% of the rotational inertia of the wheel, find the mass of the flywheel and cross section of the rim. Assume the density of the flywheel material (which is cast iron) as 7200 kg/m^3.

Solution:

Given data: $P = 150$ kW; $N = 100$ rpm; $C_E = 0.1$; $D = 2$ m; $R = 1$ m

$\rho = 7200$ kg/m^3, $\omega_1 - \omega_1 = \pm 2.5\%\omega$

$$c_s = \frac{\omega_1 - \omega_2}{\omega} = \pm\, 2.5\% \text{ or } 0.05$$

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 100}{60} = 10.47 \text{ rad/s}$$

$$\text{Work done by flywheel per stroke} = \frac{P \times 60}{N \times 2} \qquad [\because \text{for double acting}]$$

$$= \frac{150 \times 10^3 \times 60}{100 \times 2} = 45000 \text{ Nm}$$

$$\text{Coefficient of fluctuation of energy, } C_E = \frac{\text{Maximum fluctuation of energy}(\Delta E)}{\text{Workdone/cycle}}$$

$$\Delta E = C_E \times \text{Workdone/cycle} = 0.1 \times 45000 = 4500 \text{ Nm}$$

Since 5% of the rotational inertia is provided by hub and spokes, therefore the maximum fluctuation of energy of the flywheel rim will be 95% of the flywheel.

$$(\Delta E)_{rim} = 0.95 \times 4500 = 4275 \text{ Nm}$$

$$(\Delta E)_{rim} = mR^2\omega_{avg}^{\ 2}\, C_s$$

$$m = \frac{4275}{1^2 \times (10.47)^2 \times 0.05} \simeq 779.96 \text{ kg}$$ **Ans.**

$$\text{mass} = \text{cross section area} \times \text{perimeter} \times \text{density}$$

$$A = \frac{779.96}{2\pi R \times 7200} = \frac{779.96}{2\pi \times 7200} = 0.01724 \text{ m}^2$$ **Ans.**