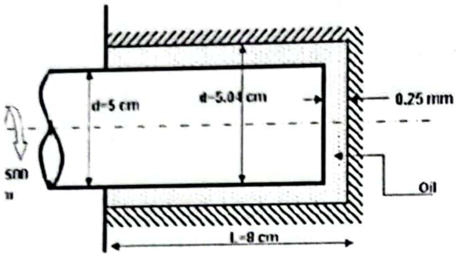
MEP212 Project

Design of Journal Bearing



Schematic of the project
Guide dimensions

In this project you are required to design a journal bearing and equip it with all measuring devices in order to determine the maximum temperature in oil and shaft rotating speed and estimate the viscosity of oil based on readings of T and N.

You should do the following:

1. Read carefully the attached solved example.

2. Select suitable dimensions for your journal bearing.

3. Select suitable oil gap to perform lubrication.

4. Submit full detailed drawing of your project complete with dimensions.

5. Perform all the calculations required to estimate the maximum temperature.

6. You are required to reduce Tmax by 20% based on the appropriate variables.

7. You are required to increase Tmax by 20%, in this case the system should give alarm when temperature is 10% higher than design temp and stop completely when the temp is 20% higher than design temperature.

8. Be able to match your design with your calculations.

9. You should provide very neat wiring and electrical connections.

	Submission Date Two weeks after announcement

Temperature rise of oil in a journal bearing

The flow of oil in a journal bearing can be approximated as parallel flow between two large plates with one plate moving and the other stationary. Such flows are known as Coutte flows. Consider two large isothermal plates separated by 2mm thick oil film. The upper plates moves at a constant velocity of 1.2 m/s while the lower plate is stationary. Both plates are maintained at 20°C. (a) Obtain relations for the velocity and temperature distributions in the oil. (b) Determine the maximum temperature in the oil and the heat flux from the oil to each plate.

Solution:

Parallel flow of oil between two plates is considered. The velocity and the temperature distributions, the maximum temperature and the total heat transfer rate to be determined.

Assumptions:

1. Steady operating conditions exist.2. Oil is an incompressible substance with constant properties. 3. Body forces such as gravity are negligible. 4. The plates are large so that there is no variation in the z-direction.

Properties:

The properties of oil at 20°C are: k = 0.145 W/m.K and μ = 0.837 Pa.s.

Analysis:

(a) We take the x-axis to be the flow direction and y to be the normal direction. This is a parallel flow between two plates and thus v = 0. Then the continuity equation reduces to:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \quad \rightarrow \quad \frac{\partial u}{\partial y}=0$$

$$\therefore u = u(y)$$

Therefore the x-component of velocity does not change in the flow direction (i.e. the velocity profile remains unchanged). Noting that u = u(y), v = 0 and ∂P/∂x = 0 (flow is maintained by the motion of upper plate rather than the x – momentum equation reduces to:

$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}\right)=\mu\frac{\partial^2 u}{\partial y^2}-\frac{\partial P}{\partial x}$$

$$\therefore \frac{\partial^2 u}{\partial y^2}=0$$

This is a second order ordinary differential equation, by integrating twice gives:

u(y) = C1y + C2

the fluid velocities at the plate surfaces must be equal to velocities of the plates because of the no slip condition. Therefore the boundary conditions are u(0) = 0 and u(L) = V and when applied gives the velocity distribution to be:

$$u(y)=\frac{y}{L}V$$

Frictional heating due to viscous dissipation in this case is significant because of the high viscosity of oil and the large plate velocity. The plates are isothermal and there is no charge in the flow direction and thus the temperature depends on y only T = T(y). Also u u(y) and v = 0. Then the energy equation with dissipation reduce to:

$$\rho C_p\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right)=k\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)+\mu\varphi$$

$$\varphi=2\left[\left(\frac{\partial u}{\partial x}\right)^2+\left(\frac{\partial v}{\partial y}\right)^2\right]+\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)^2$$

$$\therefore 0=k\frac{\partial^2 T}{\partial y^2}+\mu\left(\frac{\partial u}{\partial y}\right)^2$$

$$\therefore k\frac{\partial^2 T}{\partial y^2}=\mu\left(\frac{V}{L}\right)^2$$

$$\because \frac{\partial u}{\partial y}=\frac{V}{L}$$

Dividing both sides by k and integrating twice give:

$$T(y)=\frac{\mu}{2k}\left(\frac{y}{L}V\right)+C_3y+C_4$$

Applying the boundary conditions:

T(0) = T0 and T(L) = T0 to give the temperature distribution:

$$T(y)=T_0+\frac{\mu V^2}{2k}\left(\frac{y}{L}-\frac{y^2}{L^2}\right)$$

b. The temperature gradient determined by differentiating T(y) with respect to y;

$$\frac{dT}{dy}=\frac{\mu V^2}{2kL}\left(1-2\frac{y}{L}\right)$$

The location of maximum temperature is determined by setting dT/dy = 0 and solving for y:

$$\frac{dT}{dy}=\frac{\mu V^2}{2kL}\left(1-2\frac{y}{L}\right)=0$$

$$\therefore y=\frac{L}{2}$$

Therefore maximum temperature at mid plane which is not surprising since both plates are maintained at the same temperatures the maximum temperature is given by;

$$T_{max}=T\left(\frac{L}{2}\right)=T_0+\mu V^2\left(\frac{L/2}{L}-\frac{(L/2)^2}{L^2}\right)$$

$$T_{max}=T_0+\frac{\mu V^2}{8k}$$

$$T_{max} = 20 + \frac{(0.8374 \times 12^2)}{8 \times 0.145}$$

Tmax = 124°C

Heat flux at the plates is determined from the definition of heat flux.

$$\dot{q}_0 = -k\frac{dT}{dy}\bigg|_{y=\infty} = -k\frac{\mu V^2}{2kL}(1-0) = -\frac{\mu V^2}{2L}$$

$$\dot{q}_0 = \frac{0.8374 \times 12^2}{2 \times 0.002} = 30.1kW/m^2$$