Heat Transfer Assignment 5 — Couette Flow

Instructions

ξ is a parameter related to your student ID, with ξ_1 corresponding to the last digit, ξ_2 to the last two digits, ξ_3 to the last three digits, etc. For instance, if your ID is 199225962, then $\xi_1 = 2$, $\xi_2 = 62$, $\xi_3 = 962$, $\xi_4 = 5962$, etc. Keep a copy of the assignment — the assignment will not be handed back to you. You must be capable of remembering the solutions you hand in.

Question #1

Consider two large (infinite) parallel plates, 5 mm apart. One plate is stationary, while the other plate is moving at a speed of 200 m/s. Both plates are maintained at 27° C. Consider two cases, one for which the plates are separated by water and the other for which the plates are separated by air.

(a) For each of the two fluids, what is the force per unit surface area required to maintain the above condition? What is the corresponding power requirement?

(b) What is the viscous dissipation associated with each of the two fluids?

(c) What is the maximum temperature in each of the two fluids?

Question #2

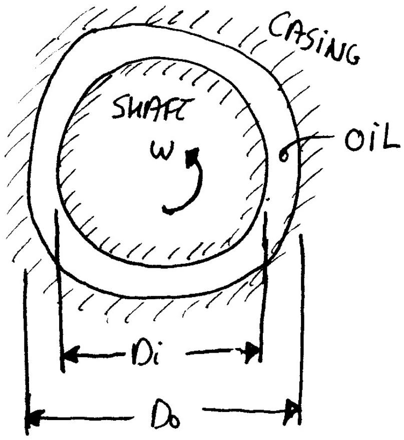
Consider a lightly loaded journal bearing using oil having the constant properties $\rho = 800$ kg/m^3, $\mu/\rho = 10^{-5}$ m^2/s, and $k = 0.13$ W/m·K. The journal diameter is 75 mm; the clearance (i.e. gap width) is 0.25 mm, and the bearing operates at 3600 rpm.

(a) Determine the temperature distribution in the oil film assuming that there is no heat transfer into the journal and that the bearing surface is maintained at 75°C.

(b) What is the rate of heat transfer from the bearing, and how much power is needed to rotate the journal?

Question #3

Consider a journal bearing with a shaft diameter D_i and a casing diameter D_o as follows:



The shaft rotates at a speed ω (in rad/s), and the oil has a density ρ (in kg/m^3), a viscosity μ (in kg/ms), and a thermal conductivity k in (W/mK). Knowing that there is heat generation *inside the shaft* of S (in W/m^3) and that the temperature of the casing is of T_o (in °C), do the following:

(a) From the momentum equation, derive the velocity distribution within the oil as a function of D_i, D_o, ω and the distance from the casing, y.

(b) From the energy equation, derive the temperature distribution within the oil as a function of D_i, D_o, ω, y, T_o, S, μ, and k.

Answers

1. 0.74 N/m^2, 34.4 N/m^2, 148 W/m^2, 6880 W/m^2, 29.6 kW/m^3, 1.376 MW/m^3, 30.5 °C, 34.0°C.

2. $T = -97.7 \times 10^6[°\text{C/m}^2] \times y^2 + 48946[°\text{C/m}] \times y + 75°\text{C}$, 1499 W/m, 1499 W/m.

3. $$T = T_0 + \frac{SD_i}{4}\frac{y}{k} + \frac{\mu}{k}\left(\frac{\omega D_i}{D_o - D_i}\right)^2\left(\frac{(D_o - D_i)y}{2} - \frac{y^2}{2}\right).$$

Due on Wednesday May 1st at 9:00. Do Questions #1, #2, and #3.

Due again on Wednesday May 8th at 9:00. Do Questions #1, #2, and #3. If you got 2 points or more in the Quiz on May 1st, you don't need to do the assignment again. Only those who got 1.5 point or less must submit the assignment again.