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Problems

Hydrodynamic Considerations

8.1 Fully developed conditions are known to exist for water flowing through a 25-mm-diameter tube at 0.01 kg/s and 27°C. What is the maximum velocity of the water in the tube? What is the pressure gradient associated with the flow?

8.2 What is the pressure drop associated with water at 27°C flowing with a mean velocity of 0.2 m/s through a 600-m-long cast iron pipe of 0.15-m inside diameter?

8.3 Water at 27°C flows with a mean velocity of 1 m/s through a 1-km-long pipe of 0.25-m inside diameter.

(a) Determine the pressure drop over the pipe length and the corresponding pump power requirement, if the pipe surface is smooth.

(b) If the pipe is made of cast iron and its surface is clean, determine the pressure drop and pump power requirement.

(c) For the smooth pipe condition, generate a plot of pressure drop and pump power requirement for mean velocities in the range from 0.05 to 1.5 m/s.

8.4 An engine oil cooler consists of a bundle of 25 smooth tubes, each of length $L = 2.5$ m and diameter $D = 10$ mm.

(a) If oil at 300 K and a total flow rate of 24 kg/s is in fully developed flow through the tubes, what is the pressure drop and the pump power requirement?

(b) Compute and plot the pressure drop and pump power requirement as a function of flow rate for $10 \le \dot{m} \le 30$ kg/s.

8.5 For fully developed laminar flow through a parallel-plate channel, the x-momentum equation has the form

$$\mu\left(\frac{d^2u}{dy^2}\right) = \frac{dp}{dx} = \text{constant}$$

The purpose of this problem is to develop expressions for the velocity distribution and pressure gradient analogous to those for the circular tube in Section 8.1.

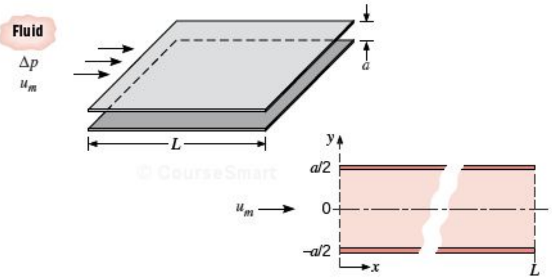
(a) Show that the velocity profile, $u(y)$, is parabolic and of the form

$$u(y) = \frac{3}{2}u_m\left[1 - \frac{y^2}{(a/2)^2}\right]$$

where u_m is the mean velocity

$$u_m = -\frac{a^2}{12\mu}\left(\frac{dp}{dx}\right)$$

and $-dp/dx = \Delta p/L$, where Δp is the pressure drop across the channel of length L.



(b) Write an expression defining the friction factor, f, using the hydraulic diameter D_h as the characteristic length. What is the hydraulic diameter for the parallel-plate channel?

(c) The friction factor is estimated from the expression $f = C/Re_{D_h}$, where C depends upon the flow cross section, as shown in Table 8.1. What is the coefficient C for the parallel-plate channel?

(d) Air flow in a parallel-plate channel with a separation of 5 mm and a length of 200 mm experiences a pressure drop of $\Delta p = 3.75$ N/m^2. Calculate the mean velocity and the Reynolds number for air at atmospheric pressure and 300 K. Is the assumption of fully developed flow reasonable for this application? If not, what is the effect on the estimate for u_m?

Thermal Entry Length and Energy Balance Considerations

8.6 Consider pressurized water, engine oil (unused), and NaK (22%/78%) flowing in a 20-mm-diameter tube.

(a) Determine the mean velocity, the hydrodynamic entry length, and the thermal entry length for each of the fluids when the fluid temperature is 366 K and the flow rate is 0.01 kg/s.