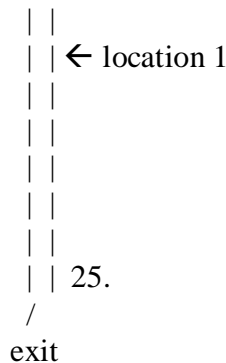


## Homework 8 Solutions

1. A production process for the manufacture of fine fiber was described in class which involved the use of high velocity jets. A typical jet is produced by air exiting a parallel-walled channel as shown in the diagram. When a flow takes place in a non-circular duct, it is standard to replace  $L/D$  and  $L_{max}/D$  by  $L/DH$  and  $L_{max}/DH$ , where  $DH$  is the hydraulic diameter of the non-circular duct. Also, the Reynolds number is evaluated as  $Re = (\rho)V(DH)/(\mu)$ .



The parallel-walled channel shown in the diagram has a hydraulic diameter  $DH = 0.060$  inches, and a length  $L$  given by  $L/DH = 25$ . At location 1, the pressure is  $25 \text{ lbf/in}^2$ , and the temperature is  $1000\text{R}$ . At the channel exit, the pressure is  $14.5 \text{ lbf/in}^2$ . The flow in the channel can be regarded as adiabatic, but friction must be taken into account.

- (1) What is the velocity of the air at the location 1?
- (2) What is the velocity of the air at the exit of the channel?
- (3) What is the Mach number at the channel exit?

### Solution Procedure

- (a) Guess  $p^{**} = 13.058 \text{ lbf/in}^2$ .
- (b)  $p/p^{**} = 1.91454$  at location 1.
- (c) Table B4  $\rightarrow M = 0.5553$ ,  $4f(L_{max})/(DH) = 0.69891$ ,  $T/T^{**} = 1.1303$  at location 1.
- (d) Calculate  $V = 49.02M(T)^{**0.5} = \mathbf{860.9 \text{ ft/s at location 1}}$ .
- (e) Calculate  $(\rho) = p/RT = 0.06748 \text{ lbm/ft}^3$  at location 1.
- (f) Calculate  $(\mu) = (1.09608 + 0.00187 * T - 0.00000075 * T^2) * 10^{-5} = 1.8875e-5 \text{ lbm/ft-sec}$
- (g) Calculate the Reynolds number  $Re = (\rho)V(DH)/(\mu) = 15,388$  at location 1.
- (10) Get  $4f = 1/(1.8 * \text{LOG}_{10}(Re/6.9))^2 = 0.02791$ .
- (11)  $4fL/(DH) = 0.6882$ .
- (12)  $4f(L_{max})/(DH)|_{\text{exit}} = [4f(L_{max})/(DH)]_1 - 4fL/(DH) = 0.01067$ .
- (13) Table B4  $\rightarrow p/p^{**}|_{\text{exit}} = 1.1105$ ;  $M|_{\text{exit}} = 0.9132$ ;  $T/T^{**}|_{\text{exit}} = 1.0285$
- (14)  $p^{**} = 13.057 \text{ lbf/in}^2$ .
- (15)  $T|_{\text{exit}} = T_1 * (T/T^{**}|_{\text{exit}} / T/T^{**}|_1) = 909.9\text{R}$
- (16)  $V|_{\text{exit}} = 49.02 * M|_{\text{exit}} * T|_{\text{exit}}^{0.5} = \mathbf{1350.3 \text{ ft/s}}$
- (17)  $M|_{\text{exit}} = \mathbf{0.9132}$

2. At a certain cross section 1 in a round pipe, the velocity, pressure, and temperature were measured as  $V = 350$  ft/sec,  $p = 21$  lbf/in<sup>2</sup>, and  $T = 95$ F. The pipe diameter is 2 inches.

Find the pressure and temperature at a location that is 8 feet downstream of the cross section 1.

$$L = 8 \text{ ft}, D = 2 \text{ in} \rightarrow L/D = 48$$

$$[4fL_{\max}/DH]M1 - [4fL_{\max}/DH]M2 = 4fL/DH$$

$$Re = \rho VD/(\mu).$$

$$\mu = (1.09608 + 0.00187 * T - 0.00000075 * T^2) * 10^{-5}$$

$$4f = 1/(1.8 * \text{LOG}(Re/6.9))^2$$

At Location 1:

$$M1 = V1/(49.02 * T1^{.5}) = 0.3032 \rightarrow B4 \rightarrow [4fL_{\max}/DH]M1 = 5.1573;$$

$$P1/P^{**} = 3.5815, P^{**} = 5.8635 \text{ lbf/in}^2; T1/T^{**} = 1.17833$$

$$\rho = P/RT = 21(12^2)/(53.35 * 554.67) = 0.1022 \text{ lbf/ft}^3$$

$$\mu = 1.2670e-5 \text{ lbf/ft-sec}$$

$$Re = 0.1022 * 350 * 2(1/12) / 1.2670e-5 = 470,507$$

$$4f = 0.01321$$

$$4fL/DH = 0.6341$$

$$[4fL_{\max}/DH]M2 = [4fL_{\max}/DH]M1 - 4fL/DH = 5.1573 - 0.6341 = 4.5233$$

$$\rightarrow B4 \rightarrow M2 = 0.3181; P2/P^{**} = 3.4099$$

$$\rightarrow T2/T^{**} = 1.17619$$

$$P2 = P1 (P2/P^{**})/(P1/P^{**}) = 21 (3.4099/3.5815) = \mathbf{19.99 \text{ lbf/in}^2}$$

$$T2 = T1 (T2/T^{**})/(T1/T^{**}) = 95 (1.17619/1.17833) = \mathbf{94.83 \text{ F}}$$