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 Lmax/D by L/DH and Lmax/DH, where DH is the hydraulic diameter of the non-circular duct. Also, the Reynolds number is evaluated as Re = (rho)V(DH)/(mu).

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 | | ← location 1
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 | |
 | | 25.
 /
exit
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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 l, the pressure is 25 lbf/in**2, and the temperature is 1000R. At the channel exit, the pressure is 14.5 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 lbf/in^2..
(b) p/p** = 1.91454 at location 1.
(c) Table B4 → M = 0.5553, 4f(Lmax)/(DH) = 0.69891, T/T**= 1.1303 at location 1.
(d) Calculate V = 49.02M(T)**0.5 = **860.9 ft/s at location 1.**
(e) Calculate (rho) = p/RT = 0.06748 lbm/ft^3 at location 1.
(f) Calculate (mu) =(1.09608+0.00187*T-0.00000075*T^2)*10^-5 = 1.8875e-5 lbm/ft-sec
(g) Calculate the Reynolds number Re = (rho)V(DH)/(mu) = 15,388 at location 1.
(10) Get 4f =1/(1.8*LOG10(Re/6.9))^2 = 0.02791.
(11) 4fL/(DH) = 0.6882.
(12) 4f(Lmax)/(DH)]exit = [4f(Lmax)/(DH)]1 - 4fL/(DH) = 0.01067.
(13) Table B4 → p/p**|exit = 1.1105; M|exit = 0.9132; T/T**|exit = 1.0285
(14) p** = 13.057 lbf/in^2.
(15) T|exit = T1 * (T/T**|exit / T/T**|1) = 909.9R
(16) V|exit = 49.02*M|exit*T|exit^0.5 = **1350.3 ft/s**
(17) **M|exit = 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**2, and T = 95F. 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 ft, D = 2in -> L/D = 48

[4fLmax/DH]M1 – [4fLmax/DH]M2 = 4fL/DH

Re = ρVD/(mu).

Mu = (1.09608+0.00187*T - 0.00000075*T^2)*10^-5

4f = 1/(1.8*LOG(Re/6.9))^2

At Location 1:
M1 = V1/(49.02*T1^.5) = 0.3032 → B4 → [4fLmax/DH]M1 = 5.1573;
P1/P** = 3.5815, P** = 5.8635 lbf/in^2; T1/T** = 1.17833

ρ = P/RT = 21(12^2)/(53.35*554.67) = 0.1022 lbm/ft^3
μ = 1.2670e-5 lbm/ft-sec
Re = 0.1022*350*2(1/12) / 1.2670e-5 = 470,507
4f = 0.01321
4fL/DH = 0.6341

[4fLmax/DH]M2 = [4fLmax/DH]M1 – 4fL/DH = 5.1573-0.6341 = 4.5233
→ B4 → M2 = 0.3181; P2/P** = 3.4099
→ T2/T** = 1.17619

P2 = P1 (P2/P**)/(P1/P**) = 21 (3.4099/3.5815) = **19.99 lbf/in^2**

T2 = T1 (T2/T**)/(T1/T**) = 95 (1.17619/1.17833) = **94.83 F**