Compressible Aerodynamics (AE-311 A) (2019-20 – I Semester)

Assignment 3

(Rayleigh and Fanno Flow)

Problem 1: Consider air entering a heated duct at p_1 = 1 atm and T_1 = 288 K. Ignore the frictional effects. Calculate the amount of heat added per unit mass necessary to choke the flow at the exit of the duct, as well as pressure and temperature at the duct exit, for an inlet Mach number of (a) M_1 = 2.0 (b) M_1 = 0.2.

Problem 2: Air is flowing through a pipe of 0.02 m inside diameter and 40 m length. The conditions at the exit of the pipe are M_2 = 0.5, p_2 = 1 atm, and T_2 = 170 K. Assuming 1-D, adiabatic flow, with a local friction coefficient of 0.005, calculate M_1, p_1, and T_1 at the entrance to the pipe.

Problem 3: Consider a Mach 2.5 flow of air entering a constant area duct. Heat is added to this flow in the duct; the amount of heat added is equal to 30% of the total enthalpy at the entrance to the duct. Calculate the Mach number at the exit of the duct.

Problem 4: Derive in closed form an equation

$$\frac{1}{a^2}\frac{dp}{d\rho} = fnc(M^2;\gamma)$$

for the flow of a perfect gas in a Fanno process. What is the significance of your result for M = 1?

Problem 5: Consider the flow of a perfect gas along a Fanno line. Show that the pressure at the maximum entropy point (the reference state) is given by the relation

$$p^* = \frac{\dot{m}}{A}\left[\frac{2RT_t}{\gamma(\gamma+1)}\right]^{1/2}$$

$\dot{m}$ is the mass flow rate, A is the tube cross sectional area, and T_t is the total temperature.

Problem 6: Air enters a circular duct with a Mach number of 3.0. The friction factor is 0.01.

a) How long a duct (measured in diameters) is required to reduce the Mach number to 2.0
b) What is the percentage change in pressure, temperature, and density?
c) Determine the entropy increase of the air.
d) Assume the same length of duct as computed in part (a), but the initial Mach number is 0.5. Compute the percentage change in temperature, pressure, density, and the entropy increase for this case. Compare the changes in the same length duct for subsonic and supersonic flow.