Gasdynamics task 3

2020/2021

Chapter 11: Fanno flow

11.1.
11.2.
11.3.
11.4.

Chapter 2: Rayleigh flow

12.1.
12.2.
12.3.
12.4.

Chapter 11: Fanno flow

Problem 11.1

Air is expanded from a large reservoir, in which the pressure and temperature are 250 kPa and 30°C respectively, through a convergent nozzle which gives an exit Mach number of 0.3. The air from the nozzle flows down a pipe having a diameter of 5 cm. The Mach number at the end of this pipe is 0.95. Find the length of the pipe and the pressure at the end of the pipe. If the actual pipe length was only 0.75 of this length, find the Mach number and the pressure that would exist at the end of the pipe. The flow in the nozzle can be assumed to be isentropic and the friction factor in the pipe can be assumed to be 0.005.

Problem 11.2

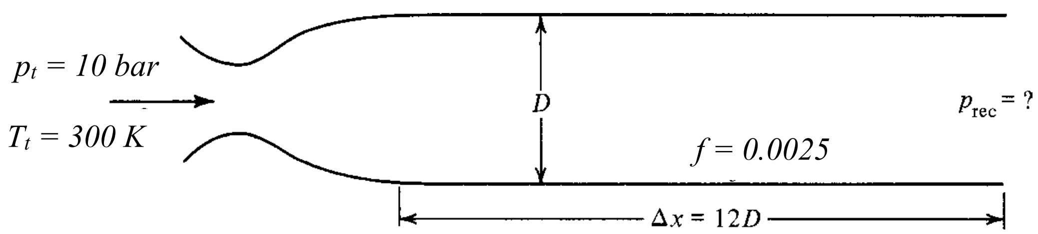
Air flows down a constant area pipe which has a diameter of 5 cm. The Mach number at the inlet of the pipe is 2 and the inlet pressure and temperature are 80kPa and 20°C respectively. The flow in the pipe can be assumed to be adiabatic. If the pipe is 0.6 m long and the average friction factor is 0.005, find the Mach number, pressure, and temperature at the exit of the pipe.

When leaving the pipe, the air flows through a convergent-divergent nozzle which has an exit area that is three times the throat area. If the stream leaves the nozzle at a subsonic velocity, find the pressure and the Mach number at the exit of the nozzle in case the flow in the nozzle can be assumed to be isentropic.

Problem 11.3

A converging–diverging nozzle (see figure below) has an area ratio of 3.0. The stagnation conditions of the inlet air are 10 bar and 300 K. A constant-area duct with a length of 12 diameters is attached to the nozzle outlet. The friction factor in the duct is 0.0025.

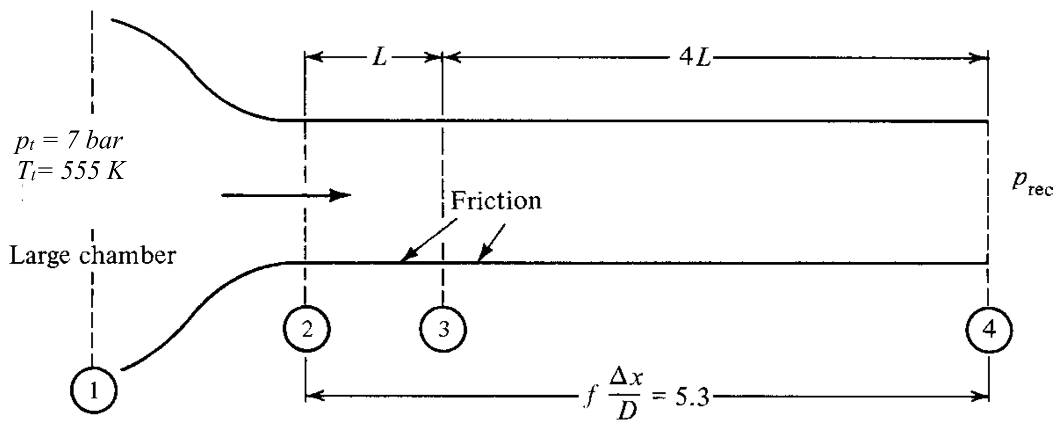
a) Compute the receiver pressure that would place a shock
   I. in the nozzle throat;
   II. at the nozzle exit;
   III. at the duct exit.
b) What receiver pressure would cause supersonic flow throughout the duct with no shocks within the system (or after the duct exit)?
c) Make a sketch showing the pressure distribution as a function of the streamwise coordinate for the various operating points of parts (a) and (b).



Problem 11.4

A constant-area duct is fed by a converging-only nozzle as shown in figure below. The nozzle receives oxygen from a large chamber at $p_t = 7$ bar and $T_t = 555$ K. The duct has a friction length of 5.3 and it is choked at the exit. The receiver pressure is exactly the same as the pressure at the duct exit.

a) What is the pressure at the end of the duct?
b) Four-fifths of the duct is removed. (The end of the duct is now at 3.) The chamber pressure, receiver pressure, and friction factor remain unchanged. Now what is the pressure at the exit of the duct?
c) Sketch both of the cases above on the same T –s diagram.



Chapter 12: Rayleigh flow

Problem 12.1

Fuel and air are thoroughly mixed in the proportion of 1:40 by mass before entering a constant area combustion chamber. The pressure, temperature, and velocity at the inlet to the chamber are 50 kPa, 30°C, and 80 m/s respectively. The heating value of the fuel is 40 MJ/kg of fuel. Assuming steady flow and that the properties of the gas mixture are the same as those of air, determine the pressure, the stagnation temperature, and the Mach number at the exit of the combustion chamber. Neglect the effects of friction

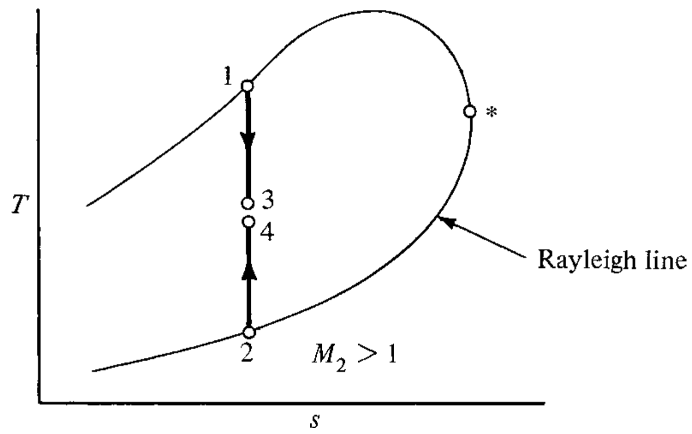
Problem 12.2

Air at a temperature of 300 K, flowing at a Mach number of 1.5, enters a constant area duct which feeds a convergent nozzle. At the exit of the nozzle the Mach number is 1.0 and the ratio of the nozzle exit area to the duct area is 0.98. If a normal shock occurs in the duct just upstream of the nozzle inlet, calculate the amount and direction of heat exchange with the air flow through the duct. Ignore the effect of friction on the flow in the duct and assume that the flow downstream of the shock is isentropic.

Problem 12.3

In the figure below, points 1 and 2 represent flows on the same Rayleigh line (same mass flow rate, same area, same impulse function) and are located such that $s_1 = s_2$ as shown. Now imagine that we take the fluid under conditions at 1 and isentropically expand to 3. Further, let's imagine that the fluid at 2 undergoes an isentropic compression to 4.

a) If 3 and 4 are coincident state points (same T and s), prove that A_3 is greater than, equal to, or less than A_4.
b) Now suppose that points 3 and 4 are not necessarily coincident but it is known that the Mach number is unity at each point (i.e., $3 \equiv 1_s^*$ and $4 \equiv 2_s^*$).
    I. Is V_3 equal to, greater than, or less than V_4?
    II. Is A_3 equal to, greater than, or less than A_4?



Problem 12.4

In the system shown in the figure below, friction exists only from 2 to 3 and from 5 to 6. Heat is removed between 7 and 8. The Mach number at section 9 is unity. Draw the T –s diagram for the system, showing both the static and stagnation curves. Are points 4 and 9 on the same horizontal level, justify your answer?