Problems of Chapter 5

Yi-Chao XIE

October 22, 2024

Due Nov 12^{th}, 2024

5.1 A supersonic wind tunnel is designed to produce flow in the test section at Mach 2.4 at standard atmospheric conditions. Calculate:
(a). The exit-to-throat area ratio of the nozzle.
(b). Reservoir pressure and temperature.

5.2 The reservoir pressure of a supersonic wind tunnel is 10 atm. A Pitot tube inserted in the test section measures a pressure of 0.627 atm. Calculate the test section Mach number and area ratio.

5.3 The reservoir pressure of a supersonic wind tunnel is 5 atm. A static pressure probe is moved along the centreline of the nozzle, taking measurements at various stations. For these probe measurements, calculate the local Mach number and area ratio:
(a). 4.00 atm.
(b). 2.64 atm.
(c). 0.50 atm.

5.4 Consider the purely subsonic flow in a convergent–divergent duct. The inlet, throat, and exit area are 1.00 m^2, 0.70 m^2, and 0.85 m^2, respectively. If the inlet Mach number and pressure are 0.3 and 0.8×10^5 N/M^2, respectively, calculate:
(a). M and p at the throat.
(b). M and p at the exit.

5.5. Consider the subsonic flow through a divergent duct with area ratio $A_2/A_1 = 1.7$. If the inlet conditions are $T_1 = 300K$ and $u_1 = 250m/s$, and the pressure at the exit is $p_2 = 1atm$, calculate:
(a). Inlet pressure p_1.
(b). Exit velocity u_2.

5.6 The mass flow of a calorically perfect gas through a choked nozzle is given by

$$\dot{m} = \frac{p_0 A^*}{\sqrt{T_0}} \sqrt{\frac{\gamma}{R} (\frac{2}{\gamma + 1})^{\frac{\gamma+1}{\gamma-1}}}$$

Derive this relation.

5.7 When the reservoir pressure and temperature of a supersonic wind tunnel are 15 atm and 750 K, respectively, the mass flow is 1.5 kg/s. If the reservoir conditions are changed to $p_0 = 20$ atm and $T_0 = 600$ K, calculate the mass flow.

5.8 A blunt-nosed aerodynamic model is mounted in the test section of a supersonic wind tunnel. If the tunnel reservoir pressure and temperature are 10 atm and 800°R, respectively, and the exit-to-throat area ratio is 25, calculate the pressure and temperature at the nose of the model.

5.10 Consider a supersonic nozzle with a Pitot tube mounted at the exit. The reservoir pressure and temperature are 10 atm and 500 K, respectively. The pressure measured by the Pitot tube is 0.6172 atm. The throat area is 0.3m^2. Calculate:
(a). Exit Mach number M_e.
(b). Exit area A_e.
(c). Exit pressure and temperature p_e and T_e.
(d). Mass flow through the nozzle.

5.14 In a supersonic nozzle flow, the exit-to-throat area ratio is 10, $p_0 = 10.00$ atm, and the back pressure $p_B = 0.04$ atm. Calculate the angle θ through which the flow is deflected immediately after leaving the edge (or lip) of the nozzle exit.

5.17 We wish to design a Mach 3 supersonic wind tunnel, with a static pressure and temperature in the test section of 0.1 atm and 400°R, respectively. Calculate:
(a). The exit-to-throat area ratio of the nozzle.
(b). The ratio of diffuser throat area to nozzle throat area.
(c). Reservoir pressure.
(d). Reservoir temperature.