SPC 407

Quiz 1 - Solution

30/10/2016

Air enters a converging–diverging nozzle of a supersonic wind tunnel at 10.03 x 10^5 Pa and 37.7 C with a low velocity. The flow area of the test section is equal to the exit area of the nozzle, which is 6 ft^2. Calculate the pressure, temperature, velocity, and mass flow rate in the test section for a Mach number Ma = 2.

Solution:

Assumptions: 1. Air is an ideal gas.
2. Flow through the nozzle is steady, one-dimensional, and isentropic.

Properties: The properties of air are k = 1.4 and R = 287 KJ/kh.K

The stagnation properties in this case are identical to the inlet properties since the inlet velocity is negligible. They remain constant throughout the nozzle since the flow is isentropic.

$P_0 = P_i = 10.03 \times 10^5$ Pa and $T_0 = T_i = 37.7$ C = 37.3+273 = 310.3 K

Then,

$$T_e = T_o \left(\frac{2}{2 + (k-1)M^2}\right)$$

$$T_e = 310.3 \times \left(\frac{2}{2 + (1.4-1)\times 2^2}\right) = 172.389\ K$$

$$P_e = P_o \left(\frac{T}{T_o}\right)^{k/(k-1)}$$

$$P_e = 10.03 \times 10^5 \left(\frac{172.389}{310.3}\right)^{1.4/(1.4-1)} = 1.28188 \times 10^5\ Pa$$

$$\rho_e = \frac{P_e}{RT_e}$$

$$\rho_e = \frac{1.28188 \times 10^5}{287 \times 172.389} = 2.583\ Kg/m^3$$

$$V_e = M_e c_e = M_e \sqrt{kRT_e}$$

$$V_e = 2\sqrt{1.4 \times 287 \times 172.389} = 526.368\ m/sec$$

$$\dot{m} = \rho_e \times A_e \times V_e = 2.583 \times 6 \times 0.3048 \times 0.3048 \times 526.368$$

$$= 757.871\ Kg/sec$$