Problems of Ch3 Part 2

2023 年 10 月 9 日

Relation between the units:

1 ft=0.3048m;1lb=0.454 kg; 1lb/ft^2=47.89N/m^2=47.89 Pa; 1^{o}R=5/9K

Due October 17^{th}, 2023

3.8 Consider air entering a heated duct at $p_1 = 1$ atm and $T_1 = 288$ K. Ignore the effect of friction. Calculate the amount of heat per mass (in joules per kilogram) necessary to chock the flow at the exit of the duct, as well as the pressure and temperature at the duct exit, for an inlet Mach number of (a) $M_1 = 2.04$ and (b) $M_1 = 0.2$.

3.9 Air enters the combustor of a jet engine at $p_1 = 10atm$ and $T_1 = 1000^oR$, and $M_1 = 0.2$. Fuel is injected and burned, with a fuel-air ratio (by mass) of 0.06. The heat released during the combustion is 4.5×10^8 ft-lb per slug of fuel. Assuming one-dimensional frictionless flow with $\gamma = 1.4$ for the fuel-air mixture, calculate M_2, p_2 and T_2 at the exit of the combustor.

3.10 For the inlet condition of Prob 3.9, calculate the maximum fuel-air ratio beyond which the flow will be choked at the exit.

3.11 At the inlet to the combustor of a supersonic combustion ramjet (SCRAMjet, 冲压发动机，无需涡轮涡扇结构), the flow Mach number is supersonic. For a fuel-air ratio (by mass) of 0.03 and a combustor exit temperature of $4800^o R$, calculate the inlet Mach number above which the flow will be unchoked. Assuming one-dimensional frictionless flow with $\gamma = 1.4$ with the heat release per slug of fuel equal to $4.5 \times 10^8 ft - lb$ (assuming one-dimensional flow).

3.12 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 $M_2 = 0.5$, $p_2 = 1atm$, and $T_2 = 270K$. Assuming adiabatic, one-dimensional, with a local friction coefficient of 0.005, calculate M_1, p_1 and,T_1.

3.13 Consider the adiabatic flow of air through a pipe of 0.2-ft inside diameter and 3-ft length. The inlet flow conditions are $M_1 = 2.5$ and $p_1 = 0.5$ atm, and $T_1 = 520^o R$. Assuming the local friction coefficient equals a constant of 0.005, calculate the following flow conditions at the exit: M_2, p_2, T_2, and p_{02}.

3.14 The stagnation chamber of a wind tunnel is connected to a high-pressure air bottle farm which is outside the laboratory building. The two are connected by a long pipe of 4-m inside diameter. If the static pressure ratio between the bottle farm and the stagnation chamber is 10, and the bottle farm static pressure is 100 atm, how long can the pipe be without choking? Assume adiabatic, subsonic, one-dimensional flow with a friction coefficient of 0.005.

3.16 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 percent of the total enthalpy at the entrance to the duct. Calculate the Mach number at the exit of the duct. Comment on the fluid dynamic significance of this problem, where the exit Mach number does not depend on a number for the actual heat added, but rather only on the dimensionless ratio of the heat added to the total enthalpy in the inflowing gas.