MAE 112 Fall 2024
Homework Assignment #4
Due: 11:59 pm, Sunday, November 3, 2024
Follow submission instructions from TAs

1. . Compare a normal shock with an oblique shock. Suppose the inflowing velocity of the air had a Mach number of 2.0 at a temperature of 250 K and an ambient pressure of 0.70 atm.
(a) With the normal shock, determine the pressure, stagnation pressure, temperature, velocity, and Mach number behind (downstream of) the shock.
(b) Suppose we aim for a downstream stagnation pressure that is 15% higher than the value found in part (a). What is the angle of oblique shock here to the incoming velocity vector? Use the charts from Chapter 3, making the best interpolations you can.
(c) Determine the downstream values for the temperature, Mach number, velocity component normal to the oblique shock, and velocity component parallel to the oblique shock.

2. Consider a Kantrowitz-Donaldson diffuser designed for a flight Mach number of 1.75. The entrance area equals 1.5 ft^2 and the ambient air temperature and pressure are 500°R and 0.7 atmosphere. The flow is isentropic everywhere except across the normal shockwave. Determine:
(a) the minimum cross-sectional area of the throat such that a normal shock may be stabilized at the entrance,
(b) the maximum mass flow, and
(c) the maximum stagnation pressure possible at the end of the diffuser (with subsonic flow only in the divergent portion).
In each of these optimizations, consider the flight Mach number fixed at the design value while the final pressure (at the end of the diffuser) is allowed to adjust.

3. Consider a ramjet in flight at a Mach number of 2.75 with ambient conditions at 298 K and 0.9 atmosphere of pressure. The air capture area is 0.70 square meters. The inlet design involves first a wedge that deflects the stream by an angle of 15 degrees followed by a Kantrowitz-Donaldson (K-D) diffuser. Operation is at design conditions except for part (h).
(a) What is the mass flow through the ramjet?
(b) What is the stagnation temperature for that flow through the inlet / diffuser?
(c) What are the stagnation-pressure values ahead of and immediately behind the first shock?
(d) What is the flow Mach number immediately behind the first shock? What is the flow Mach number at the entrance to the K-D diffuser?
(e) What is the Mach number at the diffuser throat?
(f) What is the final stagnation pressure?
(g) Determine the value of the polytropic efficiency for this inlet design.
(h) Determine the polytropic efficiency value for a shock at the entrance of the K- D diffuser.

4. Suppose a particular compressor has a compression ratio $P_3/P_2 = 25$; the incoming air temperature is 300 K and its pressure is 1.2 atm. 20 kgm per sec. of air flows through the compressor.

(a) If the adiabatic efficiency is 90%, what is the final temperature?

(b) What is the power required?

(c) What is the minimum number of stages (pairs of rotor and stator sections) required to protect against separation due to adverse pressure gradients?

5. Do a preliminary design on a ramjet engine which produces 5000 1bf of thrust. Size constraints limit the intake cross-sectional capture area to 0.80 square feet. The engine is intended to cruise at a Mach number of 2.5. Assume ambient air conditions are one atmosphere of pressure and 500°R. Indicate your choices of inlet type, fuel, temperature at entrance to nozzle, and extent of expansion in nozzle. All choices must be rational and defensible, of course. Indicate mass flows of air and fuel, mixture ratio(s), thrust specific fuel consumption, exhaust velocity, stagnation pressure ratios across each component, throat area, nozzle exit area, and nozzle exit pressure.

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