Nozzle Theory

1. The reservoir temperature and pressure are 300 K and 10 atm. There are two locations in the nozzle where A/A^*=6. Calculate Mach number, pressure, temperature and velocity at those locations.

2. A supersonic nozzle stream has exit Mach number of 2.5 while operating at sea level condition. Calculate exit area ratio and reservoir conditions.

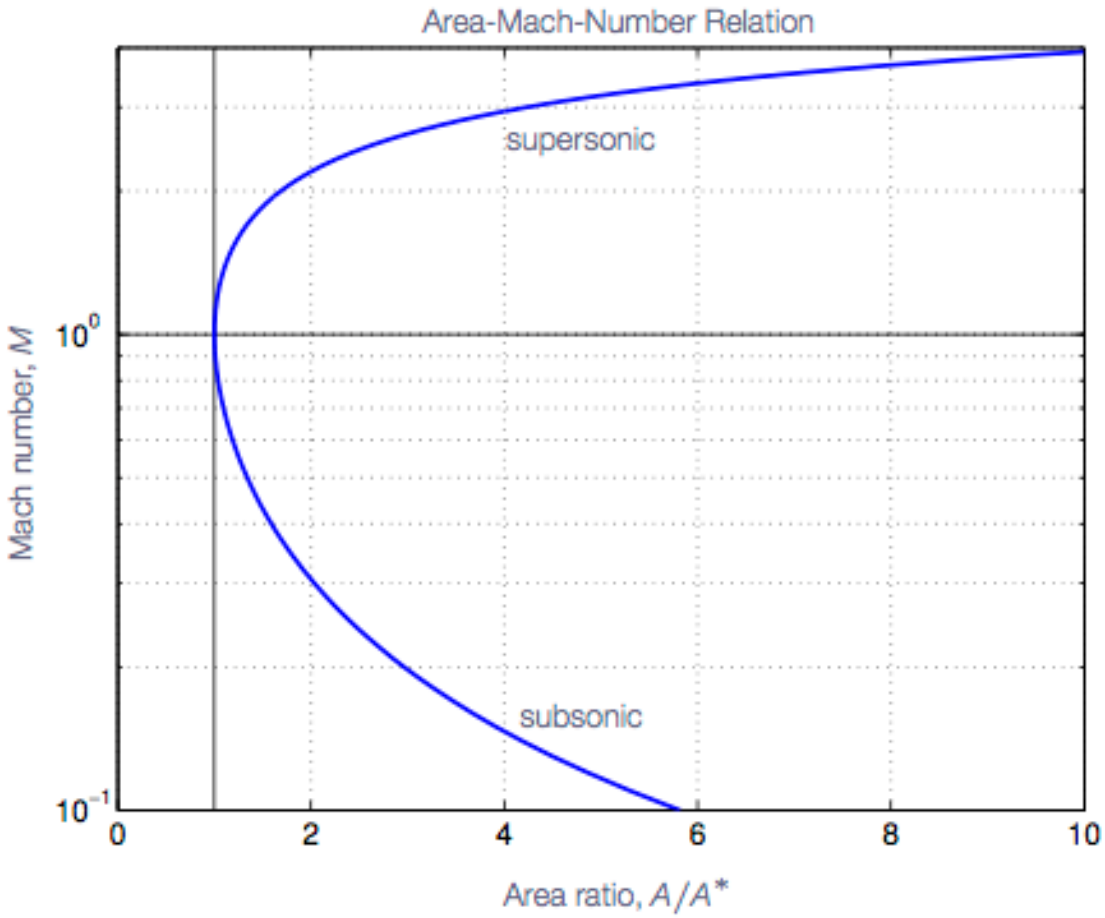
3. Using a propellant of molecular weight 15 and flame temperature 3300 K, determine the rocket throat and exhaust areas required for a thrust of 55 kN and an ideal specific impulse of 300 sec. The ambient pressure is 0.1 MPa and the specific heat ratio of the propellant is 1.4. How much thrust would this rocket develop if the ambient pressure were changed to 0.03 MPa? How much thrust would be developed by a rocket designed to expand to 0.03 MPa if it had the same stagnation conditions, thrust area and propellant?

4. The actual conditions for an optimum expansion nozzle operating at sea level are given below. Calculate v_2, T_2, and C_F. The mass flow = 3.7 kg/sec; P_1 = 2.1 MPa; T_1 = 2585 K; MW = 18.0 kg/kg-mol; and k = 1.30.

5. Design a nozzle for an ideal rocket that has to operate at 25 km altitude and give 5000 N thrust at a chamber pressure of 2.068 MPa and a chamber temperature of 2800 K. Assuming that k = 1.30 and R = 355.4 J/kg-K, determine the throat area, exit area, throat velocity, and exit temperature. (At 25 km, pressure is 0.002549 MPa)

6. For an ideal rocket with a characteristic velocity c* = 1500 m/sec, a nozzle throat diameter of 18 cm, a thrust coefficient of 1.38, and a mass flow rate of 40 kg/sec, compute the chamber pressure, the thrust, and the specific impulse.

7. Design a supersonic nozzle to operate at 10 km altitude with an area ratio of 8.0. For the hot gas take To = 3000 K, R = 378 J/kg-K and k = 1.3. Determine the exit Mach number, exit velocity, and exit temperature, as well as the chamber pressure. If this chamber pressure is doubled, what happens to the thrust and the exit velocity? Assume no change in gas properties. How close to optimum nozzle expansion is this nozzle? (Pressure at 10 km altitude is 265 millibars)


Area-Mach-Number Relation
supersonic
subsonic
Mach number, M
Area ratio, A/A*
10^0
10^-1
0
2
4
6
8
10