Midterm Assignment **AE 5535** **Assigned: March 31, 2021**

Due: April 16, 2021

Consider general quasi-one-dimensional air flow in a propulsive duct which is 1 meter long unless otherwise noted. Note that the duct can have internal wall friction, convective heat transfer, radiative heat transfer, and shaft work interaction, as well as area change. For shaft work and radiative heat transfer, 'spread' the energy interaction over all differential steps (equal differential amounts in each differential step).

1. Assume isentropic flow with no work interaction. For entrance static pressure, static temperature, Mach number, and cross-sectional area of 101325 N/m^2, 288K, 0.7, and 0.1 m^2, respectively and an exit cross-sectional area of 0.532 m^2, use differential analysis with 100000 axial steps, to produce the conditions (pressure, temperature, velocity, Mach, total conditions) at the exit of the duct. Also compute the force on the internal wetted surfaces of the duct. Compare results to the analytical result.

2. Assume Rayleigh flow with 1×10^6 J/kg of radiated heat (inviscid and no work interaction and no area variation in the duct). For entrance static pressure, static temperature, Mach number, and cross-sectional area of 101325 N/m^2, 288K, 0.2, and 0.1 m^2, respectively, use differential analysis with 100000 axial steps to produce the conditions (pressure, temperature, velocity, Mach, total conditions) at the exit of the duct. Also compute the force on the internal wetted surfaces of the duct. Compare results to the analytical result.

3. Assume 'Fanno' flow with skin friction coefficient = 0.1 (adiabatic and no work interaction and no area variation in the duct). **For this case only use a duct length of 10 meters.** For entrance static pressure, static temperature, Mach number, and cross-sectional area of 101325 N/m^2, 288K, 0.2, and 0.1 m^2, respectively, use differential analysis with 100000 axial steps to produce the conditions (pressure, temperature, velocity, Mach, total conditions) at the exit of the duct. Also compute the force on the internal wetted surfaces of the duct. Compare results to the analytical result. Comment on why there is a difference.

4. Assume convective heat transfer in the duct with no area variation with wall temperature equal to 3000K and a skin friction coefficient equal to 0.08. For entrance static pressure, static temperature, Mach number, and cross-sectional area of 101325 N/m^2, 288K, 0.2, and 0.1 m^2, respectively, use differential analysis with 100000 axial steps to produce the conditions (pressure, temperature, velocity, Mach, total conditions) at the exit of the duct. Also compute the force and the total convective heat transfer rate on (and through) the internal wetted surfaces of the duct.

5. Assume positive shaft work interactions (total work per mass = 1.0e06 J/kg)) to the adiabatic flow in the duct for two cases with work effectiveness of 1.0 (isentropic) and 0.9. Assume no friction on walls. For entrance static pressure, static temperature, Mach number, and cross-sectional area of 101325

N/m^2, 288K, 0.5, and 0.1 m^2, respectively and an exit cross-sectional area of 0.005 m^2, use differential analysis with 100000 axial steps, to produce the conditions (pressure, temperature, velocity, Mach, total conditions) at the exit of the duct for the two efficiencies. Also compute the forces on the internal wetted surfaces of the duct for the two efficiencies. Check the isentropic work interaction result against the analytical result for the same case.

6. Assume negative shaft work interactions (total work per mass = -1.5e05 J/kg) to the adiabatic flow in the duct for two cases with work effectiveness of 1.0 (isentropic) and 1.07. For entrance static pressure, static temperature, Mach number, and cross-sectional area of 101325 N/m^2, 288K, 0.9, and 0.1 m^2, respectively and an exit cross-sectional area of 0.7 m^2, use differential analysis with 100000 axial steps, to produce the conditions (pressure, temperature, velocity, Mach, total conditions) at the exit of the duct for the two efficiencies. Also compute the forces on the internal wetted surfaces of the duct for the two efficiencies. Check the isentropic work interaction result against the analytical result for the same case.

7. Assume a positive shaft work interaction (total work per mass = 1.5e05 J/kg) to flow in the duct with work efficiency of 1.0. Also assume a wall temperature of 1000K and a skin friction coefficient of 0.01. For entrance static pressure, static temperature, Mach number, and cross-sectional area of 20,000 N/m^2, 1000K, 3.0, and 0.1 m^2, respectively and an exit cross-sectional area of 0.3 m^2, use differential analysis with 100000 axial steps, to produce the conditions (pressure, temperature, velocity, Mach, total conditions) at the exit of the duct. Also compute the force and the heat transfer on (and through) the internal wetted surfaces of the duct for this case.