

## MAE 112 Fall 2024

### Homework Assignment #5

Due: 5 pm, Sunday, November 10, 2024

Follow submission instructions from TAs

1. Consider one-stage of a compressor with an 8% static pressure rise across the rotor followed by another 9% pressure rise across the stator (compounded to be 17.7%). The incoming flow has a velocity of 75 ft/sec in the axial direction, a temperature of 560°R and a pressure of 2.0 atmospheres.  $\gamma = 1.4$ ;  $c_p = 0.24$  Btu/lbm°R; polytropic efficiency = 0.95 for the compressor stage. (a) What is the power per unit mass flow of the compressor? (b) If the rotor blade speed averages 1000 ft/sec, what is the tangential component of velocity exiting the rotor?
2. Suppose a particular compressor has a compression ratio  $P_2/P_1 = 15$  and the incoming air temperature is 300K. If the adiabatic efficiency is .95, what is (a) the final temperature, (b) the average polytropic efficiency, and (c) the entropy change? (d) What is the power required, if 25 kgm per sec. flow through the compressor?
3. Consider a turbine stage that has a polytropic efficiency of 0.95 for the stator (nozzle) and for the rotor flow. 30% of the total static enthalpy drop through the stage occurs in the rotor portion. The initial and final velocities for the stage are axial and have no swirl (tangential component). Assume that only the tangential component of velocity changes through the stator (nozzle) portion. The flow has  $\gamma = 1.3$  and  $c_p = 0.30$  Btu/lbm°R; the incoming flow has a static temperature of 2400°R, a static pressure of 25 atmospheres, and a velocity of 200 ft/sec. The average rotational velocity of the rotor blade is 1100 ft/sec. The flow exiting the stage has a temperature of 1900°R.
  - (a) What are the enthalpy drop and pressure drop across the stator?
  - (b) What is the tangential velocity at the position between the stator and the rotor measured in a frame of reference fixed to the stator?
  - (c) What is the Mach number of the flow at the position between the stator and rotor measured in a frame of reference fixed to the rotor?
  - (d) What are the enthalpy drop and the pressure drop across the rotor?
  - (e) What is the power output per unit mass flux?
4. Suppose we had a gas turbine engine driving a propeller. Consider takeoff only where flight velocity is 120 ft/sec. Consider the product of gearbox efficiency and propeller efficiency to be 0.8. The pressure ratio across the compressor is ten and the pressure ratio across the turbine is ten. The pressure drops across the combustor and the nozzle are negligible. The fuel heating value is 10,000 Btu/lbm and the mixture ratio is 28. For air or products, consider  $\gamma = 1.4$  and  $c_p = 0.24$  Btu/lbm°R. Ambient temperature is 550°R. (a) What is the propeller power per unit mass flow of air? (b) What is the propeller thrust per unit mass flow of air? Assume isentropic compression and expansion.
5. Do a preliminary design on a turbojet engine which produces 250,000 newtons of thrust. Size constraints limit the intake cross-sectional capture area to 0.3 square meters.

The engine is intended to cruise at a Mach number of 2.5. Assume ambient air conditions are one atmosphere of pressure and 270 K. Indicate clearly your choice of fuel, temperature at entrance to turbine, diffuser type, and extent of expansion in nozzle. Also indicate whether you elect to have an afterburner. 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, work done by compressor, work done on turbine, stagnation pressure ratios across each component, throat area, nozzle exit area, and nozzle exit pressure.

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