Due: 26 Oct 2007

Assignment 5: Aircraft Gas Turbines I

Notes:
1. ***These problems are best solved using a computer. A Matlab script or spreadsheet will work***
2. ***You may use GASTURB 10, but you must explain your results with sample calculations.***
3. ***You should work in groups of 2-3 on these problems.***

1. Estimate the propulsive and thermal efficiencies of a turbojet during subsonic cruise. The flight Mach number is 0.8 and the ambient temperature is 225 K. The compressor pressure ratio is 12 and the turbine inlet temperature is 1300 K. The respective adiabatic efficiencies of the diffuser, compressor, combustor, turbine and nozzle are 0.92, 0.85, 0.98, 0.89 and 0.95. The burner pressure ratio is 0.97 and AFTER combustion the specific heat and molecular weight of the gas is 1.1 kJ/kg-K and 29 – you must calculate γ. Use air properties for the cold section.

2. Rework example problem 5.1 (p-130 of notes) using the properties below and the changes in parts a-c:

a. Use T_{t4} = 3200 R (recall T_{t4} was 2600 R) maintaining constant specific thrust (you must find the new P_{t3}/P_{t2}).
b. Repeat part a, but hold P_{t3}/P_{t2} constant and allow specific thrust to vary.
c. For parts a. and b. above, discuss the effects of raising T_{t4}. To assist in this, calculate thermal, propulsive and overall efficiencies for each case including the original example 5.1 calculations. Compare specific thrust, fuel consumption and efficiencies.

3. For a turbojet operating with LHV = 43,000 kJ/kg (Lower Heating Value) and assuming c_p = 1.005 kJ/kg-K and γ = 1.4:

a. Plot Specific thrust (F/mdot) and TSFC as a function of P_{t3}/P_{t2} ($1 \le P_{t3}/P_{t2} \le ?$) for T_{t4}'s of 1000, 1400, and 1800K. Comment on the behavior of thrust and TSFC.

b. Plot Specific thrust (F/mdot) and TSFC as a function of P_{t3}/P_{t2} ($1 \le P_{t3}/P_{t2} \le ?$) for Mach numbers of 0.4, 0.8 and 1.2. Comment on the behavior of thrust and TSFC.

c. Plot Specific thrust (F/mdot) and TSFC as a function of P_{t3}/P_{t2} ($1 \le P_{t3}/P_{t2} \le ?$) for three different altitudes; sea level, 10,000 ft and 20,000 ft. Comment on the behavior of thrust and TSFC.

d. Repeat part a using the following data (plot along with the ideal case for at least one T_{t4}):

$\eta d = 0.9$
$\eta c = 0.85$
$\eta b = 0.98$, $\pi_b = 0.97$, $c_{ph} = 1.1$ kJ/kg-K, $\gamma_h = 1.33$
$\eta t = 0.9$
$\eta n = 0.97$

e. At what value of P_{t3}/P_{t2} does thrust reach a maximum or a minimum? Comment on the behavior of specific thrust and TSFC with respect to what you learned in Chapter 4. Use the following for Tc* criteria[1]:

$$Tc^*_{ideal\_turbojet} = \left(\frac{c_{p\_hot} Tt_4}{c_{p\_cold} T_0} \right)^{1/2} \frac{T_0}{Tt_0}$$

Comment on why the Tc* criteria for the turbojet is different than that found in Chapter 4 and how would the above equation change for the non-ideal turbojet?

[1] Mattingly, J. D., *Elements of Propulsion: Gas Turbines and Rockets*, AIAA Education Series, AIAA, Reston, VA, 2006, p-289