16.50 Spring 2001
Problem Set 10
Assigned: 4/20/01
Due: 4/27/01

The intent of this problem set is for you to go through the steps required to carryout a "prelimimary design" for a single stage turbine that is to drive the core compressor of a new turbofan engine. To keep things simple we will do only a "meanline" design, at sea level static conditions. Then to set the turbine requiremenents, let's assume the following about the engine as a whole:

a) The overall pressure ratio of the compression system is 30, while the pressure ratio of the core compressor is 10, the remaining factor of 3 being in the fan and low pressure compressor. The adiabatic efficiency of the fan-low compressor combination is 0.90 and the adiabatic efficiency of the core compressor is 0.85.
b) The stagnation temperature at exit from the turbine nozzles is 1800 K.
c) The core compressor is driven by a single-stage turbine with zero swirl at its exit.

Now let's do the following:

Velocity Triangles & Blade Shapes

1) Find the stagnation temperature ratio required for the turbine.
2) For a degree of reaction, R=0.5, and Mb=1, find the required MT, and the corresponding blade speed in m/s.
3) Draw the velocity triangle for the turbine rotor. Assume constant axial velocity.
4) For a Zweifel coefficient of 0.9, find the required solidity of the rotor blades, and make a sketch of the blade shapes, with the proper spacing.

Cooling

5) Find the rotor-relative stagnation temperature.
6) Assuming the blade surface temperature is 1200 K, find the heat flux to the blades if the Stanton number St=0.003. (here, assume the ρu is that for choked flow (Mach number =1) at the turbine-inlet conditions)
7) Now find the film cooling Adiabatic Effectiveness required to reduce the heat flux to 100 watt/cm2 (10^6 watt/m2), assuming the cooling air is at core compressor discharge temperature.
8) Now assuming m=0.43, find the hole spacing (as equivalent slot widths) required to meet this requirement.
9) Finally, estimate the required film cooling air flow as a fraction of turbine air flow, assuming you must cool both surfaces of the blade.