DEPARTMENT OF MECHANICAL ENGINEERING
I.I.T. KANPUR

ME – 401A: Energy System II
Assignment #4

Instructor: S. Sarkar

Due Date: 09.11.2018, 5pm

Note: Please submit in time.

(1) Gases expand in a propulsion nozzle from 3.5 bar and $405^{\circ}C$ to a back pressure of 1.0 bar at the rate of 18 kg/sec. Taking a coefficient of discharge of 0.99 and a nozzle efficiency of 0.94, calculate the required throat and exit area of the nozzle. Neglect inlet velocity and take $\gamma = 1.33$, and $C_p = 1.113$ KJ/kg K for the gas.

(2) A convergent-divergent nozzle receives steam at 7 bar and $200^{\circ}C$ and expands it adiabatically into space at 3 bar. Neglecting the inlet velocity and friction; calculate the exit area required for a mass flow of 0.1 kg/sec for the following conditions:
a) When the flow is in equilibrium throughout
b) When the flow is supersaturated with $PV^{1..3}=$constant. Calculate also the degree of under cooling and supersaturation.

(3) The throat diameter of a nozzle is 0.5 cm. If the dry saturated steam at 10 bar is supplied to the nozzle, calculate the mass flow in kg/sec. The exhaust pressure is 1.5 bar. Assume frictionless and adiabatic flow with index n = 1.135. If 10% of the isentropic heat drop is lost in friction, what should be the current outlet diameter for the steam to issue at the same exhaust pressure?

(4) The velocity of steam entering a simple impulse turbine is 1000m/s, and the nozzle angle is 20°. The mean peripheral velocity of blades is 400m/s and the blades are symmetrical. If the steam is to enter the blades without shock, what will be the blade angles?
a) Neglecting the friction effects of the blades, calculate the tangential forces on the blades and the diagram power for a mass flow of 0.75 kg/s. Estimate also the axial thrust and the diagram (blade) efficiency.
b) If the relative velocity at the exit is reduced by friction to 80% of that at inlet, estimate the axial thrust, diagram power and diagram efficiency.

(5) An impulse steam turbine has a number of pressure stages, each having a row of nozzles and a single ring of blades. The nozzle angle in the first stage is 20° and the blade exit angle is 30° with reference to the plane of rotation. The mean blade speed is 130 m/s and the velocity of steam leaving the nozzle is 330 m/s.
a) Taking the blade factor as 0.8 and a nozzle efficiency of 0.85, determine the work done in the stage per kg of steam and the stage efficiency.

b) If the steam supply to the first stage is at 20 bar, $250^\circ C$ and the condenser pressure is 0.07 bar, estimate the number of stages required, assuming the stage efficiency and work done are the same for all stages and that the reheat factor is 1.06.

[42.55 KJ/kg; 66.4%, 15]

(6) The first stage of a turbine in a two-row velocity compounded wheel, steam at 40 bar and $400^\circ C$ is expanded in the nozzle to 15 bar and exit velocity of the nozzle is 700m/s. The inlet velocity to the stage is negligible. The relevant exit angles are: nozzle 18°, first row of blades 21°, fixed row of blades 26.5°, and second row of blades 35°. The velocity coefficient for all blades is 0.9. The mean diameter of blades is 750 mm and the turbine shaft rotates at 3000 rpm. Draw the velocity diagram and calculate:

a) The diagram (blade) efficiency.

b) The stage efficiency. [78.85%; 66%]

(7) The inlet rotor blade angle of a 50% reaction turbine with symmetrical velocity triangles, is 60° and speed ratio $(U/V_1) = 0.7$. The static steam pressure and temperature at stage inlet are 2 bar and $130^\circ C$. The rotor mean diameter is 70 cm and blade height is 5 cm. The rotational speed of the turbine is 6000 rpm. Find the stage efficiency, the power output and the steam static enthalpies at the inlet and exit of the rotor assuming the static pressure at the stage exit to be 1.2 bar and the leakage loss around the rotor to be 6% of the total steam flow. Assume the same blade height at the mean blade diameter of the stator. [83.8%; 862.8 KW; 2680.6 KJ/kg; 2641 KJ/kg]