DEPARTMENT OF MECHANICAL ENGINEERING
I.I.T. KANPUR

ME – 401A: Energy System II
Assignment #3

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Due Date: 25.10.2018, 5pm

Note: Please submit in time.

1. An aircraft engine is fitted with a single-sided centrifugal compressor. The aircraft flies with a speed of 230 m/s at an altitude where the pressure is 0.23 bar and the temperature is 217 K. The intake duct of the impeller eye contains fixed which give the air pre-whirl of 25^0 at all radii. The inner and outer diameters of the eye are 18 and 33 cm respectively, the diameter of the impeller periphery is 54 cm and the rotational speed is 270 rev/s. Estimate the stagnation pressure at the compressor outlet when the mass flow is 3.60 kg/s.

   Neglect losses in the inlet duct and fixed vanes, and assume that the isentropic efficiency of the compressor is 0.80. Take the slip factor as 0.9 and the power factor as 1.04.

   [1.75 bar]

2. The following results were obtained from a test on a small single-sided centrifugal compressor:

Compressor delivery stagnation pressure	2.97 bar
Compressor delivery stagnation temperature	429 K
Static pressure at impeller tip	1.92 bar
Mass flow	0.60 kg/s
Rotational speed	766 rev/s
Ambient conditions	0.99 bar and 288 K

   Calculate the overall isentropic efficiency of the compressor.

   The diameter of impeller is 16.5 cm, the axial depth of the vaneless diffuser is 1.0 cm and the number of impeller vanes (N) is 17. Making use of the Stanitz equation for slip factor, namely $\sigma = 1 - (0.63\pi / N)$, calculate the stagnation pressure at the impeller tip and hence find the fraction of the overall loss which occurs in the impeller.

   [0.75; 3.35 bar; 0.60]

3. An axial flow compressor has an overall pressure ratio of 4.0 and mass flow of 3 Kg/s. If the polytropic efficiency is 88% and the stagnation pressure rise per stage must not exceed 25 K, calculate the number of stages required and the pressure ratio of the first and last stages. Assume equal temperature rise in all stages. If the absolute velocity approaching the last rotor is 165 m/s, at an angle of 20^0 from the axial direction, the work done factor is 0.83, the velocity diagram is symmetrical, and the mean diameter of the last stage rotor is 18 cm, calculate the rotational speed and the length of the last stage rotor blade at inlet to the stage. Ambient conditions are 1.01 bar and 288 K.

   [7; 1.273; 1.178; 414 rev/s; 1.325 cm]

4. A single jet pelton turbine is required to drive a generator to develop 10 MW. The available head at the nozzle is 762 m. Assuming electric generator efficiency 95%, Pelton wheel efficiency 87%, coefficient of velocity for nozzle (C_v) 0.97, mean bucket velocity as 0.46 of jet velocity, outlet angle of buckets 15^o, and the friction of the bucket reduces the relative velocity by 15% (K = 0.85). Find
   (a) The diameter of the jet.
   (b) The rate of flow of water through the turbine.
   (c) The force exerted by the jet on the buckets.

   If the ratio of the mean bucket circle diameter to the jet diameter is not to be less than 10, find the best synchronous speed for generation at 50 cycles per second and the corresponding mean diameter of the runner.

   [132 mm; 1.62 m^3/s; 188.546 kN; 750 rpm; 1.39m]

5. A Francis turbine has a diameter of 1.4 m and rotates at 430 rpm. Water enters the runner without shock with a flow velocity of 9.5 m/s and leaves the runner without swirl with an absolute velocity of 7 m/s. The difference between the sum of the static and potential heads at entrance to the runner and at the exit from the runner is 62 m. The turbine develops 12.25 MW. The flow rate through the turbine is 12 m^3/s for a net head of 115 m. Find the following:
   (a) The absolute velocity of water at entry to the runner and the angle of the inlet guide vanes.
   (b) The entry angle of the runner blades.
   (c) The loss of head in the runner.

   [33.8 m/s; 16.3^o; 84.77^o; 13.5 m]

6. When a laboratory test was carried out on a pump, it was found that, for a pump of total head of 36 m at a discharge of 0.05 m^3/s, cavitation began when the sum of the static pressure and the velocity head at inlet was reduced to 3.5 m. The atmospheric pressure was 750 mm of Hg and the vapor pressure of water was 1.8 kPa. If the pump is to operate on a location where atmospheric pressure was reduced to 620 mm of Hg and the temperature is so reduced that the vapor pressure of water is 830 Pa, what is the value of the cavitation parameter when the pump develops the same total head and discharge? Is it necessary to reduce the height of the pump and if so by how much?

   [0.092; 1.67 m]

Note that Prob. 1-3 to be submitted by 25.10.2818.