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06ME55

Fifth Semester B.E. Degree Examination, Dec.08/Jan.09
Turbomachines

Time: 3 hrs. Max. Marks:100

Note: 1. ***Answer any FIVE full questions, selecting at least TWO questions from each part.***
2.Use of Thermodynamic data handbook is permitted.

PART – A

1 a. Define Turbomachines. Give at least 4 different classifications of turbomachines. **(06 Marks)**

b. Define specific speed of pumps. Show that specific speed of pump is given by $N_s = \frac{N\sqrt{Q}}{H^{3/4}}$ **(06 Marks)**

c. A turbine model of 1:10 develops 2.0 kW under a head of 6mts at 500 rpm. Find the power developed by the prototype under a head of 40m. Also find the speed of prototype and its specific speed. Assume the turbine efficiencies to remain same. **(08 Marks)**

2 a. Draw the inlet and exit velocity triangles for a radial flow power absorbing turbomachine with (i) Backward curved vane (ii) Radial vane (iii) Forward vane. Assume inlet whirl velocity to be zero. Draw and explain the head-capacity relations for the above 3 types of vanes. **(10 Marks)**

b. Show that for maximum utilization the work output per stage of an axial flow impulse machine (with equiangular rotor blades) is double that of a 50% reaction stage which has the same speed. Assume that axial velocity remains constant for a 50% reaction machine. **(10 Marks)**

3 a. Define degree of reaction and utilization factor with mathematical expressions. Show that $\epsilon = \frac{V_1^2 - V_2^2}{V_1^2 - RV_2^2}$ where ϵ is utilization factor, R is degree of reaction and V_1 & V_2 are absolute velocities at the inlet and exit. **(10 Marks)**

b. Air enters a rotor in an axial flow turbine with a tangential component of absolute velocity equal to 600 m/s in the direction of rotation. At the rotor exit, the tangential component of absolute velocity is 100 m/s in a direction opposite to that of rotation. The tangential blade speed is 250 m/s. Draw inlet & exit velocity triangles. Find

(i) Change in total enthalpy.
(ii) Change in total temperature across the rotor.
(iii) Power in kW for a flow rate of 10 kg/s. **(10 Marks)**

4 a. Show that polytropic efficiency (infinitesimal stage efficiency) is given by (Draw the T-S diagram) $\eta_p = \left(\frac{n-1}{n}\right)\left(\frac{\gamma}{\gamma-1}\right)$,

where n = polytropic process of index n, γ = ratio of specific heat. **(10 Marks)**

b. A low pressure air compressor develops a pressure 1400 mm of water gauge (WG). If the initial and final states of air are P_1=1.01 bar, T_1=305 K and T_2=320 K, determine compressor and infinitesimal stage efficiencies. **(10 Marks)**

PART – B

5 a. Explain the surging phenomena in compressors with the help of head-discharge curves. (08 Marks)

b. An axial-flow compressor stage draws air with inlet stagnation condition of 1 bar and 35°C. Assuming a 50% reaction stage with a flow coefficient of 0.52 and the ratio $\Delta V_u/u = 0.25$, find the rotor blade angles at the inlet and exit as well as mean rotor speed. The total-to-total efficiency of the stage is 0.87 when the stage produces a total-to-total pressure ratio of 1.23. Find the pressure coefficient and power input to the system, assuming work input factor to be 0.86. The mass flow rate is 12 kg/s. (12 Marks)

6 a. Applying Bernoulli's equation between the inlet and exit of the impeller of a centrifugal pump, show that the static pressure rise is given by

$$p_2 - p_1 = \frac{\rho}{2}\left[V_{m1}^2 + U_2^2 - V_{m2}^2 \operatorname{cosec}^2\beta_2\right]$$

Where, V_{m1}= velocity of flow at inlet = V_1, V_{m2}= velocity of flow at exit.
β_2= Blade angle at exit, U_2= Blade speed at exit.
ρ = density of fluid, p1 & p2 = Static pressure at inlet & exit. (08 Marks)

b. A centrifugal pump discharges 0.15 m^3/sec of water against a head of 12.5m. Speed of impeller is 600 rpm. The outer & inner diameters of impeller are 500mm and 250mm respectively and the vanes are bent back at 35° to the tangent at exit. If the area of flow remains 0.07 m^2 from inlet to outlet, find (i) Manometric efficiency of pump (ii) Vane angle at inlet (iii) Loss of head at inlet to impeller when discharge is reduced by 40% without changing the speed. (12 Marks)

7 a. For a single stage impulse turbine, prove that the maximum blade efficiency is given by

$$(\eta_b)_{max} = \frac{\cos^2\alpha_1}{2}(1+KC)$$ Where $K = V_{r_2}/V_{r_1}$ and $C = \cos\beta_2/\cos\beta_1$, α_1 = nozzle angle, β_1, β_2 = are rotating blade angles at inlet & exit.
V_{r_1}, V_{r_2} are relative velocities at inlet and exit. (08 Marks)

b. The following particulars relate to a two-row velocity compounded impulse wheel.
Steam velocity at nozzle outlet = 650 m/s
Mean blade speed = 125 m/s
Nozzle outlet angle = 16°
Outlet angle of first row of moving blades = 18°
Outlet angle of fixed guide blades = 22°
Outlet angle of second row of moving blades = 36°
Steam flow = 2.5 kg/s
The ratio of relative velocity at outlet to that at inlet is 0.84 for all blades. Determine
(i) Axial thrust on blades (ii) Power developed (iii) The efficiency of the wheel. (12 Marks)

8 a. State the functions of a draft tube. Show that the efficiency of draft tube is given by $\eta_d = \frac{v_1^2 - v_2^2 - 2gh_f}{v_1^2}$; where v_1 is absolute velocity of water at rotor exit; v_2 is absolute velocity of water at draft tube exit, h_f is loss of head due to friction. (08 Marks)

b. A Kaplan turbine working under a head of 20m develops 11772 kW of shaft power. The outer diameter of runner is 3.5m & hub diameter is 1.75m. The guide blade angle at the extreme edge of the runner is 35°. The hydraulic and overall efficiencies of the turbines are 88% and 84% respectively. If the velocity of whirl is zero at outlet, determine:
(i) Runner vane angle at the inlet & outlet at the extreme edge of the runner.
(ii) Speed of turbine. (12 Marks)

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06ME55

Fifth Semester B.E. Degree Examination, June-July 2009
Turbomachines

Time: 3 hrs. Max. Marks:100

Note : ***Answer any FIVE full questions, selecting atleast TWO questions from each Part***

PART – A

1 a. Define Turbomachine and Positive displacement machines. **(04 Marks)**

b. Differentiate between a turbomachine and a positive displacement machine under the following headlines : i) Action ii) Operation iii) Mechanical features iv) Efficiency of conversion v) Volumetric efficiency vi) Fluid phase change. **(06 Marks)**

c. Obtain an expression for i) Flow coefficient ii) Head coefficient and iii) Power coefficient of a turbomachine using Buckingham –π theorm. **(10 Marks)**

2 a. Derive alternate form of Euler's turbine equation and explain the significance of each energy component. **(10 Marks)**

b. The velocity of fluid flow from the nozzle in an axial flow impulse turbine is 1200m/s. The nozzle angle is 22^0. If the rotor blades are equiangular and the rotor tangential speed is 400m/s, find i) The rotor blade angles ii) The tangential force on the blade ring iii) Power output iv) Utilization factor. Assume $Vr_1 = Vr_2$. **(10 Marks)**

3 a. Define the following : i) Degree of reaction ii) Utilization factor. **(04 Marks)**

b. Draw the velocity triangles at inlet and outlet of an axial flow turbine when i) R is –ve ii) R = 0 iii) R = 0.5 iv) R = 1 v) R > 1. Discuss the energy transfer in each case. **(10 Marks)**

c. Air flows axially through an axial flow turbine at a mean radius of 0.2m. If the tangential component of absolute velocity is reduced by 20m/s during its passage through the rotor, find the power developed by the turbine for a flow rate of $100m^3/s$ at a point, where the pressure and temperature are 1 bar and 27^0C. The rotational speed of rotor is 3000 rpm. **(06 Marks)**

4 a. What is Reheat factor? Show that the reheat factor is greator than unity in a multistage turbine. **(10 Marks)**

b. The output of a three stage gas turbine is 30MW at the shaft coupling at an entry temperature of 1500K. The overall pressure ratio across the turbine is 11.0 and efficiency 88%. If the pressure ratio of each stage is the same, determine : i) Pressure ratio of each stage ii) Polytropic efficiency iii) The mass flow rate iv) The efficiency and power of each stage. Assume $\gamma_{air} = 1.4$, $C_p = 1.005$ kJ/kg K, $\eta_{mech} = 91\%$. **(10 Marks)**

PART – B

5 a. What is the function of a diffuser? Name different types of diffusers used in centrifugal compressor and explain them with simple sketches. **(10 Marks)**

b. A backward swept centrifugal fan develops a pressure of 75mmWG. If has an impeller diameter of 89cm and runs at 720 rpm. The blade angle at the tip is 39^0 and the width of the impeller is 10cm. Assuming a constant velocity of flow of 9.15m/s and density of $1.2kg/m^3$, determine the fan efficiency, discharge, power required, stage reaction and the pressure coefficient. **(10 Marks)**

6 a. Obtain an expression for the minimum starting speed of a centrifugal pump. **(10 Marks)**

b. The outer diameter of the impeller of a centrifugal pump is 40cm, and width of the impeller at outlet is 5cm. The pump is running at 800 rpm and is working against a total head of 15m. The vane angle at outlet is 40^0 and manometric efficiency is 75%. Determine

i) Velocity of flow at outlet ii) Velocity of water leaving the vane iii) Angle made by the absolute velocity at outlet with the direction of motion at outlet

iv) Discharge. **(10 Marks)**

7 a. Show that the maximum efficiency for an impulse turbine is given by $Cos^2\alpha_1$, where α_1 is the angle at which steam enters the blades, with the help of combined velocity triangles. **(10 Marks)**

b. A single stage impulse turbine rotor has a diameter of 1.2m running at 3000 rpm. The nozzle angle is 18^0. Blade speed ratio is 0.42. The ratio of relative velocity at outlet to relative velocity at inlet is 0.9. The outlet angle of the blade is 3^0 smaller than the inlet angle. The steam flow rate is 5kg/s. Draw the velocity diagram and find the following :

i) Velocity of whirl ii) Axial thrust on the bearings iii) Blade angles

iv) Power developed. **(10 Marks)**

8 a. Obtain an expression for the workdone / sec by water on the runnee of a peltonwheel. Hence derive an expression for maximum efficiency of peltonwheel giving the relationship between the jet speed and bucket speed. **(10 Marks)**

b. A three Jet pelton turbine is required to generate 10,000 kW under a net head of 400m. The blade angle at outlet is 15^0 and the reduction in the relative velocity while passing over the blades is 5%. If the overall efficiency of the wheel is 80%, $C_v = 0.98$ and the speed ratio is 0.46 then find:

i) Total flow in m^3/s ii) Discharge through each Jet iii) Diameter of the Jet

iv) Force exerted by Jet on the wheel. **(10 Marks)**

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06ME55

Fifth Semester B.E. Degree Examination, Dec.09-Jan.10
Turbo Machines

Time: 3 hrs. Max. Marks:100

Note: ***Answer any FIVE full questions, selecting atleast TWO questions from each Part.***

PART - A

1 a. Distinguish between a turbo machine and a positive displacement machine. **(06 Marks)**

b. Using Buckingham's π theorem, show that the discharge Q consumed by an oil ring is given by $\varphi = N d^3 \varphi\left[\frac{\mu}{\rho N d^2}, \frac{\sigma}{\rho N^2 d^3}, \frac{\omega}{\rho N^2 d}\right]$; where 'd' is the internal diameter of ring, 'N' is rotational speed, 'ρ' is the density, 'μ' is viscosity, 'σ' is surface tension and 'ω' is the specific weight of oil. **(10 Marks)**

c. A hydraulic turbine has a head of 9m and average discharge of 11,200 lits/S for a generator speed of 200 rpm. What is the specific speed of the turbine? Assume efficiency = 92%. **(04 Marks)**

2 a. Define degree of reaction (R). For an inlet blade angle of 45^0, blade speed at exit as twice of that at inlet and an inlet whirl velocity of zero value, prove that $R = \frac{2+\cot\beta}{4}$ for a radial outward flow turbine, where R is the degree of reaction and β is the blade angle at exit. **(10 Marks)**

b. In an inward flow turbine, the water falls with a velocity of 30m/s on a runner with a series of curved vanes. The runner rotates at 280rpm. The vanes have inlet and outlet diameters of 1.7m and 0.85m respectively. The angle the guide vanes make with the periphery of the wheel is 30^0. The water after doing work on the runner discharges with an absolute velocity of 3m/s at an angle of 130^0 to the wheel tangent. Find the power developed by the runner if the rate of flow is 380 lits/S. Also find the vane angles at inlet and outlet. **(10 Marks)**

3 a. Define utilization factor of a turbine. Derive an expression relating utilization factor with degree of reaction. **(10 Marks)**

b. In a turbine stage with 50% reaction, the tangential blade speed is 98.5 m/s. The steam velocity at the nozzle exit is 155 m/s and the nozzle angle is 18^0. Assuming symmetric inlet and outlet velocity triangles, compute the inlet blade angle for the rotor and the power developed by the stage for a flow rate of 10kg/s. Also find the utilization factor ($\in$). **(10 Marks)**

4 a. Define the term 'infinitesimal' stage efficiency of a turbine. Show that the polytropic efficiency during the expansion process is given by $\eta_p = \frac{\ell n\left(\frac{T_2}{T_1}\right)}{\frac{v-1}{v}\ell n\left(\frac{P_2}{P_1}\right)}$. **(08 Marks)**

b. Air enters a compressor at a static pressure of 1.5bar, a static temperature of 15^0C and a flow velocity of 15m/s. At the exit, the static pressure is 3 bar, the static temperature is 100^0C and the flow velocity is 100m/s. The outlet is 1m above the inlet. Evaluate i) the isentropic change in enthalpy ii) the actual change in enthalpy and iii) efficiency of compressor. **(08 Marks)**

c. Write a note on Mach number. **(04 Marks)**

PART – B

5 a. With a neat schematic diagram, explain an axial flow compressor. Also sketch, the general velocity triangles for an axial flow compressor. **(10 Marks)**

b. A centrifugal compressor runs at 15,000 rpm and produces stagnation pressure ratio of 4 between the impeller inlet and outlet. The stagnation conditions of air at the compressor intake are 1 bar and 25^0C respectively. The absolute velocity at the compressor intake is axial. The compressor has radial blades at the exit, such that the relative velocity at the exit is 135m/s and the total-to-total efficiency of the compressor is 0.78. Draw the velocity triangles at the exit of the rotor and compute the slip as well as slip coefficient. Take rotor diameter at outlet ad 58cm. **(10 Marks)**

6 a. Define the following with respect to centrifugal pumps : i) Overall efficiency ii) Static head iii) Manometric head iv) Net positive suction head v) Manometric efficiency. **(10 Marks)**

b. For a centrifugal pump, show that the pressure rise in the impeller neglecting the friction and other losses is given by $\frac{1}{2g}\left[V_{f_1}^2 + u_2^2 - V_{f_2}^2 \text{cosec}^2\varphi\right]$ where V_{f_1} and V_{f_2} are velocities of flow at inlet and outlet, u_2 is tangential velocity of impeller at outlet and φ is vane angle at outlet. **(10 Marks)**

7 a. What is the necessity for compounding steam turbines? Discuss any two methods of compounding with neat sketches. **(10 Marks)**

b. Steam issues from the nozzle of a Delaval turbine with a velocity of 1200m/s. The nozzle angle is 20^0 and the mean blade velocity is 400m/s. Inlet and outlet angles are equal. Mass of steam flowing through the turbine is 900 kg/h. Calculate i) blade angles ii) relative velocity of steam entering the blades iii) tangential force on the blades iv) power developed v) blade efficiency. Assume K = 0.8. **(10 Marks)**

8 a. Draw a neat sketch of Francis Turbine. Explain the function of draft tube. Also draw the typical velocity triangles of Francis turbine. **(08 Marks)**

b. A pelton wheel is working under a gross head of 400m. The water is supplied through penstock of diameter 1m and length 4km from a reservoir to pelton wheel. The coefficient of friction for the penstock is given as 0.008. A jet of water of diameter 150mm strikes the buckets of the wheel and gets deflected through an angle of 165^0. The relative velocity of water at outlet is reduced by 15%, due to friction between inside surface of the bucket and water. If the velocity of the buckets is 0.45 times the jet velocity at inlet and mechanical efficiency is 85%, determine i) power given to the runner ii) shaft power iii) hydraulic efficiency and iv) overall efficiency. **(12 Marks)**

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06ME55

Fifth Semester B.E. Degree Examination, May/June 2010
Turbomachines

Time: 3 hrs. Max. Marks:100

Note: 1. ***Answer any FIVE full questions, selecting atleast TWO questions from Part – A and TWO questions from Part - B.***
2. ***Use of Thermodynamic data hand book is permitted.***

PART - A

1 a. Define a turbo machine. Explain the principal components of a turbo machine. **(06 Marks)**

b. With the help of h – s diagram, explain various efficiencies of power generating turbo machines. **(06 Marks)**

c. Obtain an expression for T, using dimensional analysis, where T is the frictional torque of a disc of diameter D rotating at a speed N in a fluid of viscosity μ and density ρ in a turbulent flow. **(08 Marks)**

2 a. Representing all the components of velocity in a generalized turbo machine diagram, derive Euler turbine equation. **(06 Marks)**

b. Derive an expression for the utilization factor for an axial flow impulse turbine stage which has equiangular rotor blades, in terms of the fixed inlet blade angle and speed ratio and show the variation of utilization factor and speed ratio in the form of a graph. **(08 Marks)**

c. Determine the energy input to the fluid for a mixed flow pump for the given data :
i) Inlet hub diameter = 7cm ii) Speed : 50 rps iii) Impeller tip diameter = 28cm iv) $V_{axi} = V_{rad.out}$. Assume that the relative velocity at the exit equals the inlet tangential blade speed. **(06 Marks)**

3 a. Define degree of reaction for an axial flow machine. Prove that degree of reaction for an axial flow device (assuming constant velocity of flow) is given by $R = \frac{V_f}{2U}\left(\frac{\tan\beta_1 + \tan\beta_2}{\tan\beta_1 \tan\beta_2}\right)$. **(10 Marks)**

b. An axial flow compressor of 50% reaction design has blades with inlet and outlet angles of 44^0 and 13^0 respectively. The compressor is to produce a pressure ratio 5 : 1 with an overall isentropic efficiency of 87% when the inlet temp is 290K. The mean blade speed and axial velocity are constant throughout the compressor. Assume that blade velocity is 180m/sec and work input factor is 0.85. Find the number of stages required and the change of entropy. **(10 Marks)**

4 a. Derive an expression for an overall isentropic efficiency for finite number of stages of compression in terms of pressure ratio, stage efficiency, number of stages and ratio of specific heats for a compressor. **(10 Marks)**

b. In an axial flow compressor, air is taken at 1 bar and 288K. The delivery pressure of the compressor is 6.4 bars. The final temperature of air is 578K. Determine the following :
i) Overall isentropic efficiency ii) Polytropic efficiency iii) Number of stages required if the actual temp. rise per stage is limited to 14.5K assuming that the polytropic efficiency is equal to the stage efficiency. **(10 Marks)**

PART - B

5 a. With a neat sketch and velocity triangles, explain different vane shapes of the centrifugal compressor. Draw the inlet velocity triangle assuming $V_{U1} = 0.0$. **(10 Marks)**

b. Write a note on the following for an axial flow compressor :
i) Workdone factor ii) Radial equilibrium condition iii) Pressure ratio. **(10 Marks)**

6 a. Define the following terms for a centrifugal pump :
i) Manometric head ii) Manometric efficiency iii) NPSH. **(06 Marks)**

b. Derive an expression for the minimum starting speed for a centrifugal pump. **(06 Marks)**

c. A centrifugal pump is running at 1000 rpm. The output vane angle of the impeller is 45^0 and the velocity of flow at outlet is 2.5m/sec. The discharge thro' the pump is 200 lit/sec when the pump is working against the total head of 20m. If the manometric efficiency of the pump is 80%, determine i) diameter of the impeller ii) width of the impeller at outlet. **(08 Marks)**

7 a. Explain briefly a two stage pressure compounded impulse turbine and show the pressure and velocity variations across the turbine. **(06 Marks)**

b. Prove that the maximum rotor efficiency with equiangular rotor blades for impulse turbine is $\eta_{r\,max} = \text{Cos}^2\,\alpha_1$. **(06 Marks)**

c. What is meant by reaction staging? Prove that the maximum stage efficiency of Parson's (50% reaction) turbine is given by $\eta_{s\,max} = \dfrac{2\text{Cos}^2\alpha_1}{1+\text{Cos}^2\alpha_1}$. **(08 Marks)**

8 a. How do you classify the hydraulic turbines? **(04 Marks)**

b. Design a Pelton wheel for a head of 80m and speed 300 rpm. The Pelton wheel develops 103 kW shaft power. Take coefficient of velocity 0.98, speed ratio 0.45 and overall efficiency 0.80. **(08 Marks)**

c. A Kaplan turbine develops 9000 kW under a head of 10m. Overall efficiency of the turbine is 85%. The speed ratio based on outer diameter is 2.2 and flow ratio 0.66. Diameter of the boss is 0.4 times the outer diameter of the runner. Determine the diameter of the runner, boss diameter and specific speed of the runner. **(08 Marks)**

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