B. Tech. Degree III Semester Supplementary Examination in Marine Engineering December 2015

MRE 303 THERMODYNAMICS AND HEAT TRANSFER

Time: 3 Hours Maximum Marks: 100

(5×20=100)

I. (a) A reversible engine operates between temperature limits of T_1 and T, where T_1 is the higher temperature. The heat rejected by this engine is received by a second reversible engine at the same temperature T, which in turn rejects heat to a sink at temperature T_2. (i) If the two engines have equal efficiencies, show that $T = \sqrt{T_1 T_2}$ (ii) If the two engines have equal work output, show that $2T = (T_1 + T_2)$. (3+4=7)

(b) A 5-kg block initially at 350°C is quenched in an insulated tank that contains 100 kg of water at 30°C. Assuming the water that vaporizes during the process condenses back in the tank and the surroundings are at 20°C and 100 kPa, determine (i) the final equilibrium temperature (ii) the energy of the combined system at the initial and final states (iii) the wasted work potential during this process. (13)

OR

II. (a) Explain the following: (i) gravimetric analysis and volumetric analysis (ii) stoichiometric combustion (iii) effect of dissociation on IC engines. (3+2+3=8)

(b) The products of combustion of an unknown hydrocarbon has the following composition as measured by Orsat apparatus. $CO_2 = 8\%$, $CO = 0.9$, $O_2 = 8.8\%$ and $N_2 = 82.3\%$ (by difference). Determine (i) the empirical formula and the composition of the fuel (ii) the air-fuel ratio (iii) the percentage excess air used. (12)

III. (a) What is meant bleeding? How does it affect the cycle efficiency of a steam power plant? (6)

(b) The capacity of a boiler is 2 m^3. Initially it contains 1.5 m^3 of water and 0.5 m^3 of steam in equilibrium condition at 1 bar. Heat is supplied to the boiler from outside keeping inlet and outlet valves closed. The relief valve on the boiler operates only when the absolute pressure in the boiler becomes 50 bar. Calculate the heat supplied to the boiler before the relief valve operates. (14)

OR

IV. (a) Describe the construction of temperature-entropy and Mollier diagrams. Explain the use and importance of Mollier diagram in practice. (8)

(b) Steam at 40 bar and 450° C is supplied to a steam turbine and it is exhausted at 0.06 bar. The turbine develops 4000 kW. The expansion take place in two stages. The steam is reheated to 410°C after leaving the H.P stage. Assuming both stages develop equal power and neglecting the pump work and other losses in the system, find (i) the pressure at which the reheating done (ii) steam consumption per minute (iii) thermal efficiency of the cycle. Take efficiency ratio of each cycle as 0.8. (12)

V. (a) What are the conditions that produce supersaturation of steam in nozzles? How does the area of the throat of a turbine – nozzle for supersaturated flow compare with the area determined for normal flow? (6)

(b) A steam turbine develops 160 kW with a consumption of 19.4 kg/kWh. The pressure and temperature of the steam entering the nozzle are 12 bar and 220°C. The steam leaves the nozzles at 1.2 bar. If the diameter of the nozzle at throat is 7 mm, find the number of nozzles required. If 8% of the total enthalpy drop is used up in frictional reheating in the diverging part of the nozzle, determine the diameter at the exit of nozzle and quality of steam leaving the nozzle. (14)

OR

VI. (a) Prove that the diagram or blade efficiency of a single stage reaction turbine is given by $\eta_b = 2 - \dfrac{2}{1 + 2\rho\cos\alpha_1 - \rho^2}$ where α_1 is the nozzle angle and ρ is the speed ratio. Also indicate the assumptions used. (9)

(b) Steam reaches the nozzle of a single stage impulse turbine at 2.5 bar with a velocity of 60 m/sec and dryness fraction of 0.96. The pressure drop in the nozzle is 0.7 bar and 5% of the isentropic enthalpy drop is absorbed in overcoming friction. The nozzles are inclined at an angle of 15° to the plane of wheel and the ratio of blade speed to the tangential component of steam speed is 0.4. If the relative velocity of steam at outlet is 0.85 times the relative velocity of steam at the inlet, find (i) the blade angles so that the steam may enter them without shock and leave them in an axial direction (ii) the power input to the turbine (iii) frictional losses over the blades per kg of steam flow. (11)

VII. (a) A plane wall is constructed by a material having a thermal conductivity that varies as the square of the temperature according to the relation $k = k_0\left(1 + \beta T^2\right)$. Derive an expression for the heat transfer in such a wall. (6)

(b) (i) A steam boiler furnace is made of a layer of fireclay 12.5 cm thick and a layer of red brick 50 cm thick. If the wall temperature inside the boiler furnace is 1100°C and that on the outside wall is 50°C. Determine the amount of heat loss per square metre of the furnace wall (k for fire clay = 0.533 W/mK and k for red brick = 0.7 W/mk). (ii) It is desired to reduce the thickness of the red brick layer in this furnace to half by filling in the space between the two layers by diatomic whose k = 0.113+0.00023T W/mK. Calculate the thickness of the filling to ensure an identical loss of heat for the same outside and inside temperatures. (14)

OR

VIII. (a) Derive an expression for the thermal resistance for the hollow cylinder of inner radius r_i, outer radius r_o, length L and the thermal conductivity of the material of the cylinder is k. State the assumptions. (11)

(b) Establish a relation for the time taken to form a layer of ice on the surface of a pond. How much time will it take for a layer of ice of thickness 20 cm to increase by 1 mm on the surface of a pond when the temperature of surroundings is -20°C. (9)

IX. (a) Explain the physical significance of the following non-dimensional numbers (i) Prandtl number (ii) Grashof number (iii) Stanton number (iv) Reynolds number (v) Nusselt number (vi) Grates number. (6)

(b) A two shell pass and four tube passes heat exchanger is used to heat glycerin from 20°C to 50°C by hot water, which enters thin walled 20 mm diameter tube at 80°C and leaves at 40°C. The total length of the tube in the heat exchanger is 60 m. The convection coefficient on shell side is 25 W/m^2 and that on water (tube) side is 160 W/m^2. Calculate the rate of heat transfer in the heat exchanger (i) for clean surfaces of tubes (ii) after fouling with fouling factor of 0.0006 m^2. K/W on outer surface of tubes. (14)

OR

X. (a) What are the limitations of LMTD method? How is NTU method superior to LMTD method? (6)

(b) For experimental purpose, a steam surface condenser is to be designed to transfer 300 kW of thermal energy at a condensing temperature of 45°C. The cooling water enters the condenser at 20°C with a flow rate of 25000 kg/h. Calculate the surface area required to handle this load, if the overall heat transfer coefficient for the condenser surface is 1400 W/m^{2}K. If the outside tube diameter is 30 mm and the tube length is 1 m, calculate the number of tubes. Compare the result with the use of arithmetic mean temperature difference. (14)

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