INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Department of Mechanical Engineering

Date :	Time : **2 hours**	Full Marks : **100**	No. of students : **105**
Mid-Sem. 2015	Sub. name: **Applied Thermo-Fluids II**		Sub.No.: **ME40701**

Both Part-A and Part-B are compulsory

Part-A (60 marks)

Answer all questions. Make suitable assumptions, and state them clearly

1) A thermal power plant based on Rankine cycle operates at an average heat addition temperature of **900°C**, while rejecting heat to the environment which is at an average temperature of **32°C**. If the overall thermal efficiency of the plant is **36 %**, then **per MW** of **net power output** estimate: a) Fuel consumption per day (**kg/day**), if the heating value of the fuel is **20 MJ/kg**; b) Heat rejected to the environment in **MW**; c) Entropy generation rate in **MW/K**; d) Lost work in **MW**, and e) Condenser cooling water requirement (in **kg/s**), if the temperature rise of cooling water across the condenser is **5 K** and the specific heat of water is **4.2 kJ/kg.K**. **(10)**

2) Derive an expression for thermal efficiency of a simple Brayton power cycle (considering non-isentropic compression and expansion) in terms of maximum and minimum cycle temperatures, pressure ratio, isentropic index of compression/expansion and component efficiencies. Show that when the isentropic efficiencies of compressor and turbine become 100%, then the efficiency of the cycle depends only on the properties of the working fluid and the pressure ratio. **(10)**

3) In a steam power plant, dry, saturated steam at a temperature of **200°C** enters the Open Feed Water (OFW) heater and mixes with subcooled water coming from the condenser pump. The water flow rate through the condenser pump to the OFW is **400 kg/s**. The resulting mixture which is fed to the boiler pump is saturated liquid at **200°C.** If the heat losses from the OFW to the surroundings (surrounding temperature = **35°C**) is **4.8 MW,** find the required flow rate of the dry, saturated steam to the OFW. What is the entropy generated in the OFW? Neglect condenser pump work. The condensing temperature is **40°C**. Use the property data given below. **(15)**

Temperature (°C)	Dryness fraction	*h* (kJ/kg)	*s* (kJ/kg)
200	0	852.4	2.331
200	1	2793	6.431
40	0	167.5	0.5723
40	1	2573	8.255

4) The riser tube of a natural circulation, drum type boiler receives saturated liquid at a velocity of **0.75 m/s** from the downcomer. The riser has to be designed to absorb **3.6 MW** of heat from the furnace gases with an exit void fraction of **0.9.** The boiler operates at **160 bar.** Assume that the velocity of vapour to be equal to that of the liquid in the riser tube. Find a) the required riser diameter, b) riser height, and c) heat flux. The saturated liquid and vapour densities at 160 bar pressure are **585 kg/m³** and **108 kg/m³**, respectively, and the latent heat of vaporization at 160 bar is **930 kJ/kg**. The buoyancy pressure head required for the boiler is **32 kPa**. **(15)**

The void fraction α is related to the dryness fraction x as: $\alpha = \frac{1}{1+\left[\frac{(1-x)}{x}\right]\psi}$; where $\psi = \frac{\rho_g}{\rho_f} S$ and S is the slip ratio. The average density of the two-phase mixture in the riser is given by:

$$\bar{\rho}_{2-\varphi,R} = \rho_f - \frac{\left(\rho_f - \rho_g\right)}{(1-\psi)} \left\{ 1 - \left[\frac{1}{\alpha_e (1-\psi)} - 1 \right] \ln \frac{1}{\left(1 - \alpha_e(1-\psi)\right)} \right\}$$

where α_e is the void fraction at the exit of the riser. Acceleration due to gravity (g) is **9.81 m/s²**.

5) Determine the higher and lower heating values (**in kJ/kg**) of methane (**CH_4**) for combustion in an open system. The standard enthalpies of formation are: **CH_4** (molecular weight: 16 kg/kmol), **–4669.8 kJ/kg, CO_2** (molecular weight: 44) **–8946.8 kJ/kg,** and **H_2O** (molecular weight: 18) liquid: **–15875.5 kJ/kg**, vapour: **–13430.8 kJ/kg.** **(10)**

End of Part-A

Part-B (40 marks)

<u>Answer any 2 questions</u>

1. In an air compressor, the static pressure and static temperature at inlet are 100 kPa and 27°C respectively. The ratio of outlet pressure to inlet pressure is 2. The required compressor work is 90 kW and mass flow rate is 1 kg/sec. The air velocity at inlet is 20 m/s whereas the air velocity at outlet is 120 m/s. (a) Draw the process in an enthalpy-entropy identifying the state points. Find out the compressor efficiency (b) if the compressor is located in an intermediate stage, (c) last stage of a multistage compressor, (d) inlet and exit Mach number. Take γ=1.4 and c_p=1.005 kJ/kg-K.

5x4=20

2. For a one-fourth scale model pump, the model speed is 2000 rpm and the impeller diameter of the model is 100 mm. The head developed by the model pump is 15 m water column and its flow rate is 60 litres per minute. The design speed of the prototype is 600 rpm. Find out the (a) head in m of water column, (b) volume flow rate (in litre per minute) and (c) power required to the model pump and the prototype (in kW). Consider the efficiency remains same for both the model and the prototype which is equal to 85%. (d) Find out the specific speed of the pump in radians per sec.

5x4=20

3. A turbine handling water is located 118 m below the reservoir level. At the entry to the turbine, the head loss is 9 m of water column because of the piping and bends. The flow rate is 1 m³/s. The bearing loss is 40 kW and the frictional loss in the impeller is 75 kW. The water velocity at exit is 10 m/s. Due to tip leakage, 0.05 m³/s water is leakage out of the blades without doing any work. Find out the (a) mechanical efficiency, (b) hydraulic efficiency, (c) volumetric efficiency and (d) the overall efficiency.

5x4=20

End of the paper