Seat No.: ________ Enrolment No.___________

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–VI (NEW) EXAMINATION – SUMMER 2022

Subject Code:3161911 Date:06/06/2022

Subject Name:Design of Heat exchangers

Time:10:30 AM TO 01:00 PM Total Marks: 70

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**
4. **Simple and non-programmable scientific calculators are allowed.**

MARKS

Q.1 **(a)** In what way Boiling & Condensation differs from other types of heat exchange? **03**

(b) Double tube counter flow heat exchanger is used to cool hot oil. The Copper inner tube have a diameter of 2 cm and negligible thickness. The inner diameter of outer tube (shell) is 3 cm. Water flows through outer tube at the rate of 0.5 kg/sec and oil through outer shell at rate of 0.8 kg/sec. Taking average temperature of water and oil to be 45°C and 80°C respectively. Calculate Inner side heat transfer coefficient using given properties. **04**

Use Dittus Boelter equation for turbulent flow

$$Nu = 0.023\, (Re)^{0.8}\, (Pr)^{0.4}.$$

Properties (Unit)	Water
Density (kg/m^3)	990.1
Thermal Conductivity (W/m K)	0.637
Viscosity (m^2/s)	0.602×10^{-6}
Prandtl number (-)	3.91

(c) What is fouling in heat exchanger? Discuss its effect on heat transfer and pressure drop. **07**

Q.2 **(a)** What is the correction factor? When it is used in heat exchanger? **03**

(b) List out the main selection criteria of a heat exchanger. State requirements of good heat exchangers. **04**

(c) Water at a flow rate of 5000 kg/h will be heated from 20 to 35°C by hot water at 140 °C. A 15 °C hot water temperature drop is allowed. A number of 1.5 m hairpins of 3 in (annulus inner diameter, Di= 0.0779 m) by 2 in (inner tube do=0.0603 m and di = 0.0525 m) double pipe heat exchangers with annuli and pipes each connected in series will be used. Hot water flows through inner tube. Fouling factors are Ri = 0.000176 m^2-K/W and Ro = 0.000352 m^2-K/W. Assume that pipe is made of carbon steel (k = 54 W/m-K). Calculate: (1) Heat transfer coefficient for the fluid flowing through inner tube and annulus (2) The number of hairpins required. Use following properties data and correlation for calculation. **07**

Correlation:

$$Nu_b = \frac{\left(\frac{f}{2}\right)(\mathrm{Re}_b)\mathrm{Pr}_b}{1+8.7\left(\frac{f}{2}\right)^{0.5}(\mathrm{Pr}_b - 1)}$$

$$f = (1.58 \ln \mathrm{Re} - 3.28)^{-2} \text{ for Inner tube}$$

$$f = (3.64 \log_{10} \mathrm{Re} - 3.28)^{-2} \text{ for annulus}$$

Properties (Unit)	Inner Tube	Annulus
Density (kg/m^3)	932.53	996.4
Specific heat (kJ.kg K)	4.268	4.179
Thermal Conductivity (W/m K)	0.687	0.609
Dynamic viscosity (Pa S)	0.207×10^{-3}	0.841×10^{-3}
Prandtl number (-)	1.28	5.77

OR

(c) In an open heart surgery under hypothermic conditions, the patient's blood is cooled before the surgery and rewarded afterwards. It is proposed that a concentric tube counter flow heat exchanger of length 0.5m is to be used for this purpose with a thin walled inner tube having a diameter of 55mm. If water at 60°C and 0.1kg/s is used to heat blood entering the heat exchanger at 18°C and 0.05kg/s, what is the temperature of blood leaving the heat exchanger and the heat flow rate. Take U_o = 500 W/m^2K,c_p of blood = 3.5 kJ/kg K and c_p of water = 4.183 kJ/kg K. **07**

Q.3 **(a)** Derive expression for hydraulic and equivalent diameter for hairpin heat exchanger. **03**

(b) Feed water heater of a steam generator is in the form of a single pass, shell and tube heat exchanger consisting of 100 tubes (25mm ID, 31mm OD). 500 Lpm of water is heated from 30°C to 70°C by condensing steam at standard atmosphere pressure on shell side. The shell side heat transfer coefficient is 5000W/m^2K. On waterside, heat transfer coefficient is 1270W/m^2K and fouling factor is 0.0002m^2K/W. Neglect fouling factor on shell side and resistance offered by tube wall. Calculate the required length of the tubes. **04**

(c) Explain the procedure of calculating total pressure drop in double pipe heat exchanger. **07**

OR

Q.3 **(a)** Consider two double pipe counterflow heat exchangers that are identical except that one is twice as long as the other one. Which of the exchangers is more likely to have a higher effectiveness? **03**

(b) What is the effect in design of heat exchanger when **04**

1) Pressure drop on the tube side is greater than allowable pressure drop?
2) Shell side pressure drop is greater than allowable pressure drop?

(c) A 3 m long Shell and tube heat exchanger which is designed to heat raw water by the use of condensed water at 67°C and 0.2 bar, which will flow in the shell side with a mass flow rate of 50,000 kg/hr. The heat will be transferred to 30,000 kg/hr of city water coming from a supply at 17^0C (cp = 4184 J/kg K). A single shell and a single tube pass is preferable. A fouling resistance of 0.000176 m2 K /W is suggested and the surface over design should not be over 40 %. A maximum coolant velocity of 1.5 m/s is suggested to prevent erosion. A maximum tube length of 5 m is required because of space limitations. The tube material of carbon steel (k=60 W/m K). Raw water will flow inside straight tubes whose outer diameter is 19 mm and inner diameter is 16 mm. Tubes are laid out on a square pitch with a pitch ratio of 1.25. The baffle spacing is approximated by 0.6 of shell diameter and the baffle cut is set to 25%. The water outlet temperature should not be less than 40°C. Consider shell side heat transfer co-efficient 5000 W/m^2 K, tube side it is 4000 W/m^2 K, correction factor 0.90 and tube calculation constant CTP = 0.93 and CL =1. **07**

Calculate:

1) Outlet temperature of hot fluid
2) Overall surface design
3) Shell diameter
4) Number of tubes

Q.4 **(a)** If we have to process a corrosive liquid in a heat exchanger, where will you prefer to send it, tube-side or shell-side of the heat exchanger. Support your answer with the reasoning. **03**

(b) Draw the diagram for following tube arrangement in shell and tube heat exchanger: **04**

1) Equilateral triangle
2) Square
3) Rotated square

Compare them in terms of tube density, heat transfer coefficient and fouling liquid (mechanical cleaning).

(c) Air enters the core of a finned-tube heat exchanger of the type shown in Figure 1 at 1 atm and 30°C. The air flows at a rate of 1,500 kg/h perpendicular to the tubes and exits with a mean temperature of 100°C. The core is 0.5 m long with a 0.25 m^2 frontal area. The air densities at the inlet and outlet are 1.177 and 0.954 kg/m^3. The properties of air at bulk temperatures are density = 1.038 kg/m^3, Pr = 0.719, viscosity = 2.04 x 10^{-5} kg/m s and specific heat 1.007 kJ/kg K. Calculate the total pressure drop between the air inlet and outlet and the average heat transfer coefficient on the air side for friction factor 0.057. **07**

OR

Q.4 **(a)** What is the heat capacity rate? What can you say about the temperature changes of the hot and cold fluids in heat exchangers if both fluids have the same capacity? **03**

(b) Explain the effect of following parameter on heat transfer and pressure drop. **04**

1) Number of tubes at tube side
2) Baffle spacing at shell side
3) Baffle cut at shell side
4) Tube pitch at shell side

(c) In a compact heat exchanger, air at 2 atm and 500 K with the velocity (u_∞) of 20 m/s flow across a compact heat exchanger matrix (where ratio of minimum free-flow area to frontal area is 0.78). Calculate 1) the heat transfer coefficient and 2) the frictional pressure drop. Length of the matrix is 0.8 m. Take ρ = 1.41 kg/m^3, D_h = 0.3434 x 10^{-2} m, C_p = 1030 J/kg.K, μ = 2.69 x 10-5 kg/m.s and Pr = 0.718. Refer given table for appropriate property selection. **07**

Effect of Reynolds number on heat transfer and pressure drop characteristics

Re	$\frac{h}{GCp} Pr^{2/3}$	f	Density Ratio at Inlet and Outlet
3000	0.0040	0.012	0.8
4000	0.0045	0.018	0.9
4500	0.0056	0.023	1.0
5000	0.0065	0.030	1.0

Q.5 **(a)** Why compact heat exchangers are more suitable for gaseous fluid? **03**

(b) When is a heat exchanger classified as being compact? Name the specific exchanger construction type that may be used in the following applications: (a) Air Preheater (b) Automotive Radiator (c) Condenser of an air conditioner. **04**

(c) What is the use of pinch analysis. Explain its principal taking reference of hot and cold stream. **07**

OR

Q.5 **(a)** What is the use of tie rods and spacers in shell-and-tube heat Exchangers ? **03**

(b) List out different application for plate type heat exchanger and explain its advantages and disadvantages over other heat exchanger. **04**

(c) Enlist different active and passive technique for heat transfer enhancement. What is the effect of following parameter on heat transfer performance? **07**

1) Coated surface
2) Surface roughness
3) Extended surface
4) Displaced insert
5) Swirl flow
6) Coiled tubes
7) Additives for liquid and gases

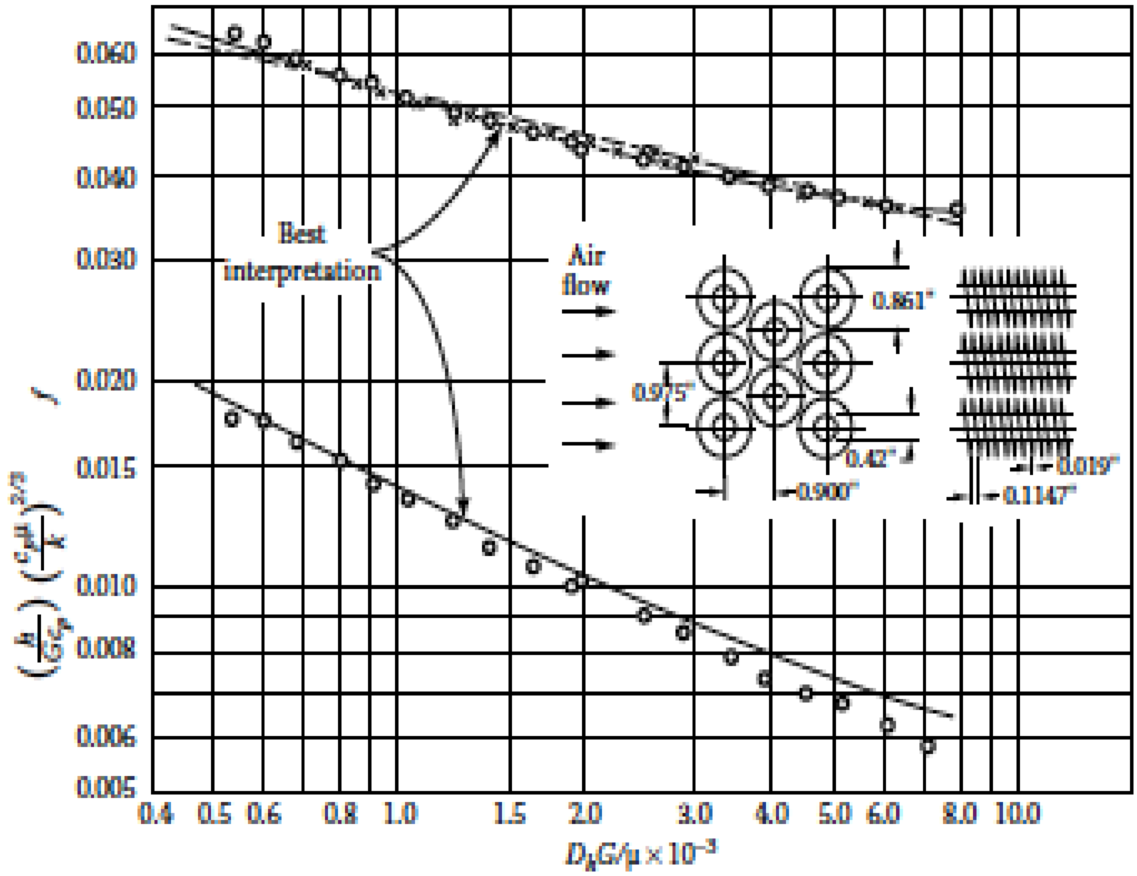

Figure 1. Heat transfer and friction factor for flow across circular finned-tube matrix. Surface CF-8.72(c): tube OD = 1.07 cm; fin pitch = 3.43/cm; fin thickness = 0.048 cm; fin area/total area = 0.876; air passage hydraulic diameter, dh = 0.443 cm; free-flow area/frontal area, σ = 0.494; heat transfer area/total volume = 446 m^2/m^3.

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