Mansoura University
Faculty of Engineering
Mechanical Department

Heat Exchangers
January 2013

Final Exam
Fourth Year
Time allowed 3 Hrs

Question (1)

1.a Mention only the different ways used in classification of heat exchangers.

1.b Name the different direct contact type of heat exchangers.

1.c If the overall heat transfer coefficient at the beginning of the heat exchanger operation is 2000 W/m^{2}K. Suppose seawater above 52°C and a fouling factor of 0.0002 m^{2}K/W is experienced. What is percentage reduction in the overall heat transfer coefficient?

1.d What is the advantage of using Fakheri chart (2003) for the determination of the log mean temperature correction factor for shell and tube heat exchangers?

Question (2)

A surface condenser is designed to handle 30000 kg of steam per hour when the steam enters the condenser at 4 kPa (T_s = 28.96°C and h_{fg} = 2432.9 J/kg) and 90% dry. The cooling water (ρ = 998.2 kg/m^3 and c_p = 4186.8 J/kg.K) enters the condenser at 15°C and leaves at 25°C. Assume the overall heat transfer coefficient is 3500 W/m^{2}K. If this condenser has two water passes composed of tubes of 2 cm outside diameter and 1.2 mm thick with water velocity of 1.5 m/s. Determine:

i. Arithmetic mean temperature difference.
ii. Log mean temperature difference (LMTD).
iii. The heat transfer rate.
iv. The mass flow rate of the cooling water.
v. The surface area required.
vi. The total of tubes in each pass.
vii. The length of each tube.

Question (3)

Heated oil enters a heat exchanger at 150°C to be cooled by water entering at 30°C. If the two fluids flow in parallel, the exit temperatures of oil and water are 90°C and 60°C respectively. Determine:

i. Exit temperatures of oil and water if the two fluids flow counter to each other.
ii. Lowest temperature to which oil could be cooled in parallel flow and counter flow operations by making the heat exchanger long enough.

$$\varepsilon = \begin{cases} \dfrac{1-\exp[-NTU(1+C)]}{1+C} & \textit{Parallel} \\ \dfrac{1-\exp[-NTU(1-C)]}{1-C\exp[-NTU(1-C)]} & \textit{Counter} \end{cases}$$

Question (4)

The following readings of the friction factor (f) and the Colburn factor (j) versus the Reynolds number (Re) are obtained in a compact heat exchanger with the flow passage hydraulic diameter of 3.6 mm using air (k = 0.026 W/mK and Pr = 0.7) as the working fluid.

Re	500	600	800	1000	1200	1500	2000	2500	3000	4000
f	0.180	0.170	0.156	0.151	0.150	0.151	0.158	0.164	0.165	0.166
j	0.0222	0.0218	0.0209	0.0200	0.0190	0.0183	0.0168	0.0155	0.0145	0.0130

Plot the relation of the friction factor (*f*) versus the Reynolds number (*Re*). Also, determine at *Re* = 1000

i. The Stanton number (*St*).
ii. The Nusselt number (*Nu*).
iii. The heat transfer coefficient (*h*).

Question (5)

5.a Mention the different sources of the entropy generation in heat exchangers.

5.b Plot the relation of the Bejan number versus the irreversibility ratio.

5.c If the entropy generation due to pressure drop is 90% of the total entropy generation. Determine:

i. The Bejan number.
ii. The irreversibility ratio.

Question (6)

6.a 10 kg/s of water-steam mixture at 180°C flows in a 0.1 m ID horizontal tube. The thermophysical properties of water can be taken as, $\rho_l = 887.31$ kg/m^3, $\rho_g = 5.1597$ kg/m^3, $\mu_l = 1493\times10^{-7}$ N-s/m^2, $\mu_g = 149\times10^{-7}$ N-s/m^2, $\sigma = 42.19\times10^{-3}$ N/m. If the mixture viscosity (μ_m) based on MacAdams et al. (1942) definition of two-phase viscosity is equal to the arithmetic mean of the liquid viscosity (μ_l) and the vapor viscosity (μ_g). Determine:

i. The mass quality of the mixture (x).
ii. The superficial velocity of the vapor phase (U_g).
iii. The superficial velocity of the liquid phase (U_l).
iv. The two-phase frictional pressure gradient using the homogeneous model ($(dp/dz)_{f,m}$).
v. The Froude number of the mixture (Fr_m).
vi. The Weber number of the mixture (We_m).

$$\rho_m = \left(\frac{x}{\rho_g} + \frac{1-x}{\rho_l}\right)^{-1} \qquad \mu_m = \left(\frac{x}{\mu_g} + \frac{1-x}{\mu_l}\right)^{-1}$$

$$f_m = \begin{cases} \dfrac{16}{\mathrm{Re}_m} & Laminar \\ \dfrac{0.079}{\mathrm{Re}_m^{0.25}} & Turbulent \end{cases}$$

6.b If the single-phase liquid frictional pressure gradient, the single-phase vapor frictional pressure gradient and the interfacial component of two-phase frictional pressure gradient are equal ($(dp/dz)_{f,l} = (dp/dz)_{f,g} = (dp/dz)_{f,int}$). Determine:

i. The Lockhart-Martinelli parameter (X).
ii. The two-phase frictional multiplier for liquid alone flow (ϕ_l^2).
iii. The two-phase frictional multiplier for gas alone flow (ϕ_g^2).
iv. The Chisholm constant (C).

Gook Luck
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