ME341A-HEAT AND MASS TRANSFER

Experiment - 8

Study of Shell and Tube Type Heat Exchanger System

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<u>Group – G1(a)</u>

Shikhar Shivraj Jaiswal – 150670
Anutosh Nimesh – 150125
Avinash Kumar - 150169

Objective:

The main objective of the experiment is to study a shell and tube heat exchanger by

1. Evaluating the rate of heat transfer from hot oil to cold water.
2. Calculating the LMTD of the shell and tube heat exchanger at different oil/water flow rates.

Procedure

To start the equipment initially and thus the experiment, the following steps were adhered:

1. Ensure sufficient oil and water level in respective sumps and that for oil sump we confirmed that the heater and the RTD were in the oil.
2. Oil bypass valve i.e. valve-1 was kept open and valve-2 initially was kept closed.
3. Then we started the pump, we here checked oil is circulating properly without any leakages in the bypass line. Then the valve-2 was gradually opened, to the extent that there was some flow of oil in the heat exchanger exit line. The air plug on the shell was opened and oil was made to overflow for some time and then it was closed.
4. When we got sure that there were no leakages and entire air from the shell was plugged out, we started the ON-OFF controller.
5. On switching the controller on, we first set the temperature with the help of buttons on the display device. If the RTD in the oil was showing temperature of oil below that of the set value, the heater turned ON and as the oil started heating and temperature about to reach set value, the heater started turning ON and OFF, and later on the temperature of the oil sump was constant at the set value with (±1°C) variation.
6. Later with the help of valve-1 and valve-2, we adjusted the flow rate in the rotameter to about 12 LPM, so that after calibration, we got the oil flow rate at 0.164 kg/s.
7. On similar lines, water circuit was also started. After checking the water level in the tank, the valve-1 was kept open and pump was started. Then the valve-2 was gradually opened, here too after letting the water flow through air plug, the plugs were tightened. We ensured there were no leakages in water line too.
8. Since, we wanted to use water at ambient temperature; there was no requirement of ON-OFF controller for water tank.
9. Lastly, before taking the readings of the inlet and outlet temperatures of oil and water, correct and accurate working of the LabVIEW data acquisition interface was ensured.

Observations:

Viscosity of oil at 75ºC is 8.72 mPa-s.

Viscosity of water at 30ºC is 0.7978 mPa-s.

S. No.	T_1 (ºC) Water Inlet	T_2 (ºC) Water Outlet	T_3 (ºC) Oil Inlet	T_4 (ºC) Oil Outlet	Flow Rate of Oil (LPM)	Flow Rate of Water (LPM)	Time (min)

1.	25.60	29.52	75.24	64.69	16	13	0
2.	26.56	29.48	75.29	64.74	16	16	10
3.	27.51	29.93	75.25	64.69	16	19	20
4.	27.95	30.04	74.92	64.35	16	22	30

Results and Calculations

Calculation of tube side heat transfer coefficient

<u>Sample calculation:</u>
For set 1,
$Re = \rho_w * v_{tube} * D_i / \mu_w$
ID of tube = D_i = 0.00811 m
Area of tube = 5.166 x 10^{-5} m^2
v_{tube} = V/A*6 = 0.699 m/s

Re = 1000*0.699*0.00811/(0.7978*10^{-3}) = 7105.65
$Pr = C_{pw} * \mu_w / k_w$ = 5.522

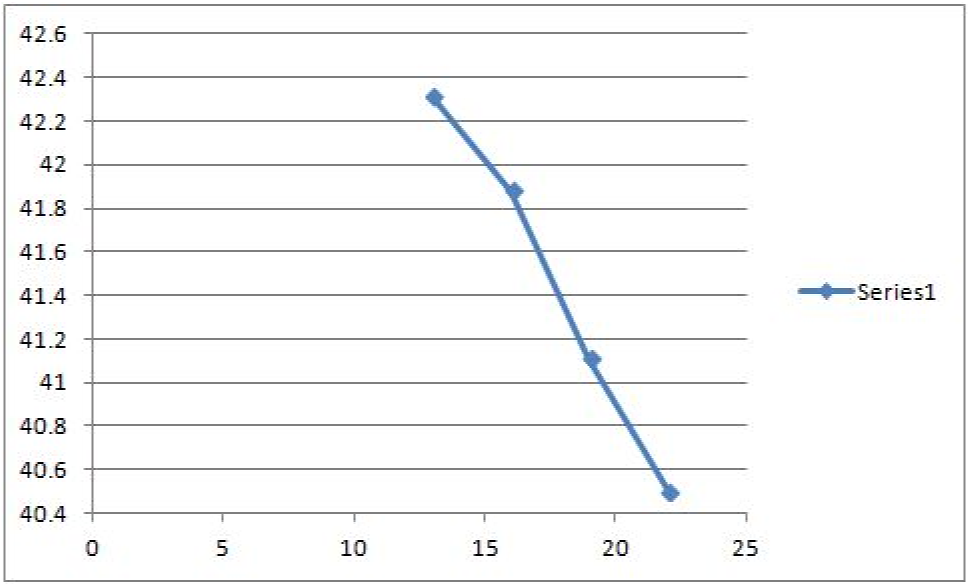
$Nu_{turb10^4} = 0.023(Re)^{4/5}(Pr)^n$, n=0.4
Nu_{turb10^4} = 54.93
χ = (Re-2300)/(10^4-2300) = 0.624
$Nu_{lam2300}$ = 3.66
Nu_m = (1-0.624)3.66 + 0.624(54.93) = 35.65

$h = Nu_m . k_w / D_i$ = 2659.02 W/m-K

Set	Tube side heat transfer coefficient (W/m-K)
1	2659.02
2	4093.66
3	5550.76

4	6241.43

Graph of LMTD vs Water flow:



Calculation of LMTD:

LMTD = $\frac{\Delta T_1 - \Delta T_2}{\ln\frac{\Delta T_1}{\Delta T_2}}$, where $\Delta T_1 = T_3 - T_2$ and $\Delta T_2 = T_4 - T_1$

Sr. No.	$\Delta T_1 = T_3 - T_2$	$\Delta T_2 = T_4 - T_1$	LMTD (K)
1.	45.72	39.09	42.31
2.	45.81	38.18	41.88
3.	45.31	37.18	41.11
4.	44.89	36.4	40.50

Uncertainty Analysis

<u>Sample Calculation:</u>

For Set 1:

$U_{LMTD} = [(\partial LMTD/\partial \Delta T_1 * U\Delta T_1)^2 + (\partial LMTD/\partial \Delta T_2 * U\Delta T_2)^2]^{1/2}$

$= [(*0.02)^2 +(*0.02)^2]^{1/2}$
$=6.49$

Hence, LMTD = 42.31 ± 7.13 K

Set	LMTD (K)
1	43.58 ± 7.13
2	41.88 ± 6.87
3	41.11 ± 6.59
4	40.50 ± 5.98

Discussion

LMTD decreases with water flow rate, which is expected. Since the flow rate of oil remains constant throughout the experiment, the value of h_o also remains constant. Heat transfer coefficient h_w of water increases as flow rate of water increases. Also, the experimental and theoretical values of effectiveness are very close with very little experimental error.

Sources of Error:

1. Steady state was not achieved even with 10 minutes of waiting. There was some fluctuation.
2. Parallax error in measuring flow rates of oil and water.
3. The insulation on the apparatus may not have been sufficient to stop all heat transfer.