Theoretical and Experimental Analysis of Fabricated U-Tube with Two Shell Heater

Cardoso Benroy Elton[1], Chethan B S[2], Dr. Suresh Boraiah[3]
[1]PG Student, Alpha College of Engineering, Bangalore, Karnataka, India
[2]Assistant Professor, Alpha College of Engineering, Bangalore, Karnataka, India
[3]Professor & HOD, Alpha College of Engineering, Bangalore, Karnataka, India

Abstract— Heat transfers in small channels is receiving increased attentions due to a very high transfer rates possible with such geometries. Number of studies has attempted to understand the physics behind the heat exchange process. The project attempts to make use of the heat energy which is formed first to heat the water in the shell. So we can reuse the heat energy and by this we can reduce the power required to heat the system. More heat can be generated my less power supply.

Index Terms— heat transfer, heat energy reuse, power supply,logarithmic mean temperature difference,mass flow rate, overall heat transfer coefficient, heater .

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1 INTRODUCTION

THE means of a heat exchanger is to transfer the heat between flowing fluids. A heat exchange is the process to transfer heat from one fluid to another fluid. The heat exchanger is device used for the transfer of internal thermal energy between two or more fluids at different temperatures. Heat exchangers are used in the process, power, petroleum, transportation, air conditioning, refrigeration, cryogenic, heat recovery, alternate fuels and in other industries.

The literature showed that the rate of heat transfer is dependent upon the temperature difference between the two fluids and the mass flow rate of both the fluids. A Number of investigations are carried out to determine the heat transfer coefficients. Jay Bhavsar, V.K. Matawala [1] gives the analysis of spiral tube heat exchanger over shell and tube heat exchanger. S. Satyan, Murali Rangarajan and S. Ramachandran [2] presented new predictive correlations for liquid heat transfer to immiscible liquid liquid mixtures in a spiral plate heat exchanger. Ebieto, C. E. and Eke G.B. [3] presented the performance analysis of the shell and tube heat exchangers. Analytical method was used to develop correlations for the performance analysis. Ahmad Fakheri [4] provided the solution of the problem of defining thermal efficiency for heat exchangers based on the second law of thermodynamics. It was shown that corresponding to each actual heat exchanger, there is an ideal heat exchanger that is a balanced counter flow heat exchanger. Lu Linping, Liang Ying [5] had done various experiments and found heat transfer coefficient, pressure drop and thermal stress for corrugated tubes and straight tubes. by comparing and analyzing the pressure drop, heat transfer in tube side and shell side and stress and axial forces the found that the corrugated tube heat exchangers has better heat transfer coefficient, higher pressure drop and much lower stress caused by temperature difference. Jamshid Khorshidi, Salman Heidari [6] demonstrated the performance and application of a spiral plate heat exchanger. Also, the governing equation of heat transfer phenomena in such heat exchangers is discussed. Regarding the governing equations, a LAB-sized model of this type of heat exchanger was designed and constructed. Two galvanized iron sheets were rolled together around a central core and, as a result, two separate channels are made. Also a pre-design simulation of the heat exchanger was done using the fluent software to predict the performance of a heat exchanger. Susheel Pote and Prasad Kulkarni [7] studied the experimental method to find the performance of spiral of the heat exchanger over the shell and tube heat exchanger.

2 EXERIMENTATION OF THE SYSTEM

2.1 Fabrication of the shell and tube heater

Fig 1: Assembly of the inner tube

A copper tube is bent at three places to formthe tube of the heater. The end of the tube is welded to the flange. The flange also supports the rod heaters. The inner and the outer shell is made up of stainless steel of 3” and 4” respectively.

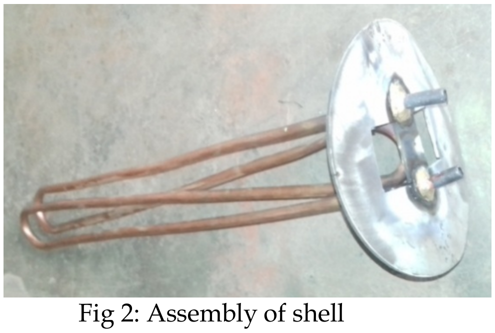


Fig 2: Assembly of shell

The shells ar made by bending a stainless steel sheet to form a cylindrical shell. The flange is welded to the inner and outer shell and the setup is made leak proof.

2.2 Location of thermocouple

Temperatures are measured at four different locations using thermocouples which are connected to a temperature selector which finally displays the temperatures on the digital temperature indicator. T1 measures the temperature at the inlet of the copper tube and T2 measures the temperature at the outlet of the copper tube. T3 meaasured the temperature at the intel of the space between the inner and the outer shell and T4 measures the temperature of the outlet from the shell. K type thermocouples are used for the experiment.

2.3 Flow diagram of experimental setup

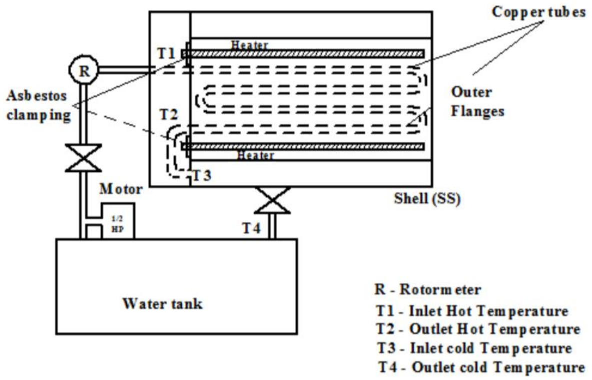


Fig 3: Flow Diagram of Experimental Setup

A test was conducted in which the temperature of water is raised by using the setup. Initially the rod heaters are put on so that the air in the inner shell gets heated to an optimum temperature. The cold water from the tank is passed to the inner copper tupe using a motor the flow rate of which is controlled by a bypass valve. The water flowing in the copper tube gets heated due to the heat transfer from the hot air in the shell to the cold water in the tubes. The water from the inner tube comes out heated and flows in the sbace between the inner shell and the outer shell. Here again the water gets more heated due to the heat transfer between the hot air in the inner shell to the water flowing in the outer shell. This raises the overall temperature of the water and the water flowing out from the outer shell is collected in the tank.

2.4 Experimental setup

As per the flow diagram shown in fig 3 the actual experimetal setup is fabricated. All the components are mounted on the setup frame itself. The digital voltmeter and digital ammeter indicates the voltage and current from which the heat input can be calculated. The heat input can be controlled by regulating the voltage using a voltage regulator. The mass flow rater of water can be measured by the flow meter. The actual fabricated experimental setup is shown in figure. The heater is also clamped to the frame using nuts ant bolts.the pressure gauge indicates the pressure of the water at the input to the inner copper tubes. The water flows outside the heater in flexible PVC pipes. The same water that gets collected in the tank after the shell flows back in the heater in the next cycle thereby increasing the temperature of the water futher. The fabricated experiment setup is shown in fig 4.

2.4 Experimental Procedure

1. Initially liquid leak test was carried out to ensure leakages in the system.
2. The heater is switched ON. The heat input is regulated by voltage and current.
3. Once the heater heats the inner shell the pump is started and the flow rate is measured by the flow meter.
4. The experiment is allowed to reach steady state. The steady state is identified when the readings of the thermocouples remain unchanged.
5. The time is started to get the readings for the time interval of 20 mins.
6. After reaching the steady dtate all the temperatures, pressures, flow rates are measured.
7. For the next time interval the input heat is varied.
8. Tests were also conducted by varying the mass flow rate keeping heat input constant.

Fig 4: Experimental Apparatus

2.5 Basic Equations for calculations

1. Heat input to the rod heater (Q_{in})

$$Q_{in}=V*I \qquad (1)$$

Where V is the voltage (V)
I is the current (A)

2. Mass of air in the inner shell

$$m_h = \frac{Area*Leangth}{Time} \qquad (2)$$

3. Rate of heat transfer in the tubes

$$Q_t=m_c*c_{pc}*(T_2-T_1) \qquad (3)$$

Where m_c=mass flow rate of water

4. Rate of heat transfer in the shell

$$Q_t=m_c*c_{pc}*(T_4-T_3) \qquad (4)$$

5. Logarithmic mean temperature difference

$$\Delta T=\frac{(T_h-T_{ci})-(T_h-T_{co})}{\ln(\frac{T_h-T_{ci}}{T_h-T_{co}})} \qquad (5)$$

6. Overall Heat transfer coefficient

$$U=\frac{Q}{A\Delta T} \qquad (6)$$

Where $Q=Q_t+Q_s$

2.6 Experimentation Table

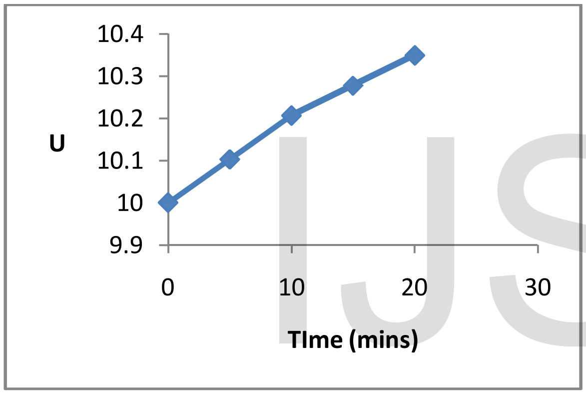
Table 1

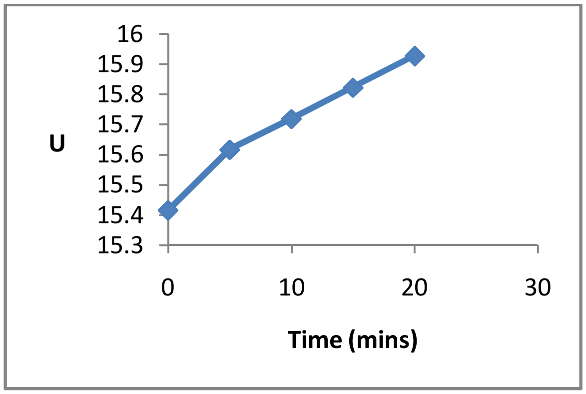
Voltage	Current	Flow rate	Time	Temperature			
				T1	T2	T3	T4
10	2.15	2.5	0	33	34	34	35
			5	34	35	35	37
			10	36	37	37	38
			15	37	38	38	39
			20	38	39	39	40
134	2.86	2.6	0	32	33	33	34
			5	34	35	35	36
			10	35	36	36	37
			15	36	37	37	38
			20	37	38	38	39

3 RESULTS AND DISCUSSION

Effect of time on the overall heat ransfer coefficient

From the graphs it can be seen that the as the time increases the overall heat transfer increases keeping the voltage and current constant. The mass flow rate is also kept constant.





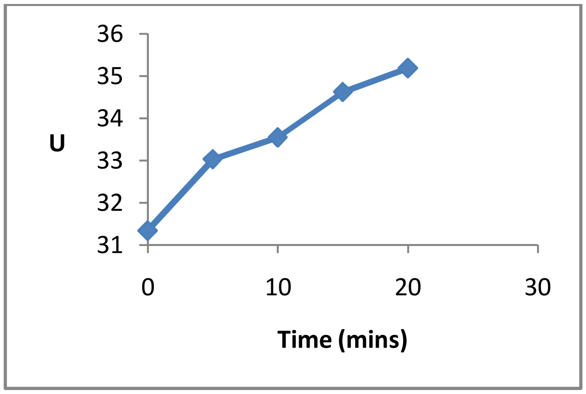
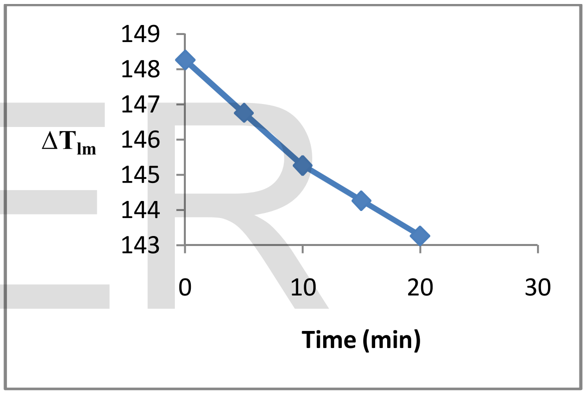
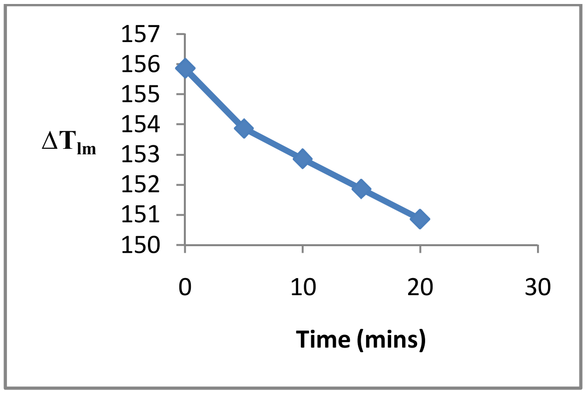


Fig 5: Overall heat transfer coefficient versus time

Effect of time on the logarithmic mean temperature difference

From the graphs it can be seen that the as the time increases the logarithmic mean temperature difference decreases keeping the voltage and current constant. The mass flow rate is also kept constant.





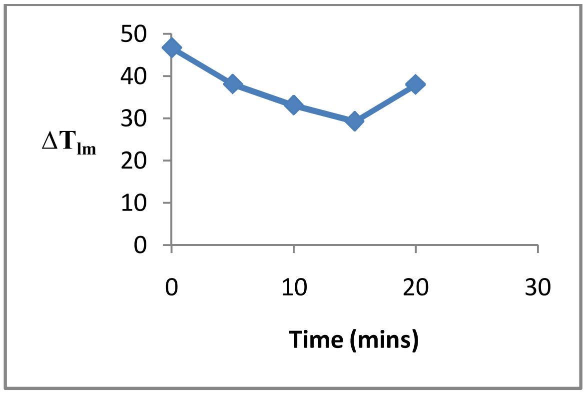


Fig 6: Logarithmic mean temperature difference versus time

Effect of mass flow rate on logarithmic mean temperature difference

From the graph it can be seen that the as the mass flow rate increases the logarithmic mean temperature difference increases.

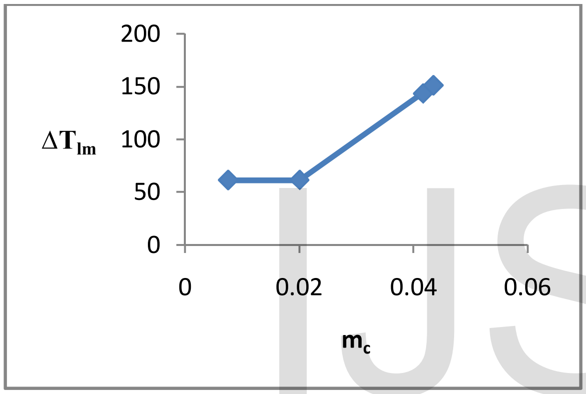


Fig 7: Logarithmic mean temperature difference versus mass flow rate

Effect of heat input on the Overall heat transfer coefficient

The overall heat transfer rater increases with the heat input upto a limit after which it rapidly decreases.

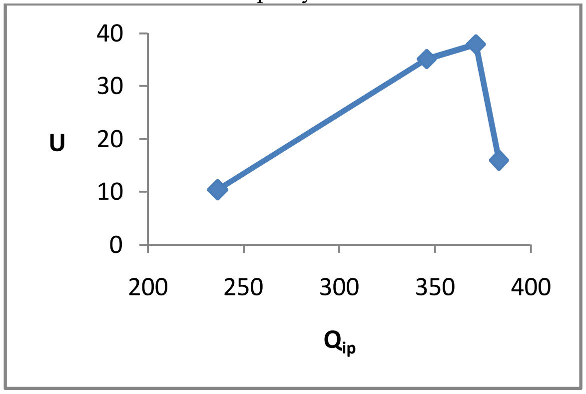


Fig 5: Overall heat transfer coefficient versus Heat input

Effect of overall heat transfer coefficient on the mass flow rate

The overall heat transfer coefficient decreases as the mass flow rate decreases.

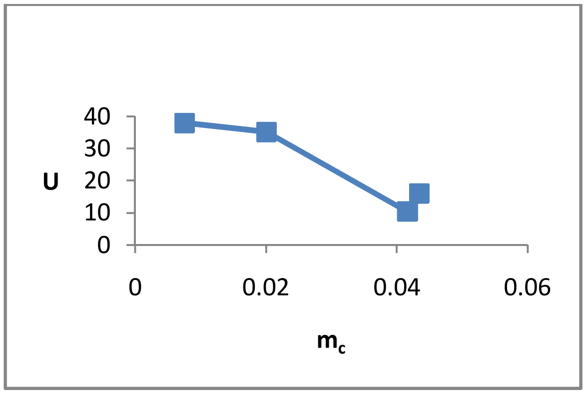


Fig 5: Overall heat transfer coefficient versus mass flow rate

4 CONCLUSION

This paper attempts to determine the heat transfer coefficients by the use of the experimental setup. It shows that the rise in temperature of water is much more than the rise in temperature due to only one shell.

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