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PERFORMANCE ANALYSIS OF A U TUBE TYPE BFU HEAT EXCHANGER USING DIFFERENT MATERIALS

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Abstract- *Heat Exchanger is an appointment used for transferring heat from one medium to another. There is a wide application of U tube type heat exchanger in the field of industrial applications. The objective of this research work was to design and fabricate a U tube type counter flow heat exchanger, to find the log mean temperature difference, overall heat transfer coefficient and the effectiveness of the heat exchanger using stainless steel tube and copper tube, and compare the heat transfer efficiency by using stainless steel tube and copper tube. LMTD, overall heat transfer coefficient and effectiveness of heat exchanger were calculated for both stainless steel tube and copper tube. Copper has the higher thermal conductivity than stainless steel. It was observed that the efficiency of the heat exchanger was increased by using a copper tube as U tube.*

Keywords: U- tube heat exchanger, LMTD, Stainless steel tube, Copper tube, Effectiveness.

1. INTRODUCTION

Heat exchangers facilitate heat transfer between two or more fluids at different temperatures. In most heat exchangers, the fluids are separated by a heat transfer surface and ideally, they do not mix. Heat exchangers are used in the process, petroleum, power, transportation, refrigeration, air conditioning, cryogenic, heat recovery, alternative fuels, and other industries.

In U tube (BFU) heat exchanger, one of the fluids flows through a bundle of U shaped tubes enclosed by a shell. The term BFU is a designation system authorized by TEMA (Tubular Exchanger Manufacturing Association) where the first letter narrates the front header type, the second letter the shell type and the third letter the rear header type. This type of arrangement is employed where reliability and heat transfer effectiveness is important. With the use of multiple U shaped tubes, the heat transfer rate is simply improved due to the increased surface area. It is simple to design and has an effective and advantageous application in cooling hydraulic fluid and oil in engines, transmissions, and hydraulic power packs.

Shell and tube heat exchangers are the most common and popular type of heat exchanger due to the flexibility they allow for a wide range of pressure and temperature. It has U shaped tubes which are enclosed by a shell. One fluid flows inside the tubes while the other liquid flows over the outside walls of the tubes which, basically, are the shell. It's highly recommended for places where there's a need for high heat transfer coefficient and unlimited thermal expansion. For its unique shape, it finds better use in high pressure applications.

2. LITERATURE REVIEW

A lot of research work has been done about designing heat exchangers, and especially shell-and-tube heat exchangers. Than et al. [1] evaluated their data for heat transfer area and pressure drop and checking whether the
assumed design satisfies all requirement or not. The primary aim of their design was to obtain a high heat transfer rate without exceeding the allowable pressure drop. Mukherjee et al. [2] explained the basics of heat exchanger thermal design, covering various topics like STHE components; classification of STHEs according to construction and according to service; data needed for thermal design; tube side design; shell side design. The basic equations for heat transfer and pressure drop in tube side and shell side along with. correlations for the optimal condition were also focused and explained with some tabulated data. Their research provided an overall idea to design optimal shell and tube heat exchanger. Yusuf et al. [3] produced a computer-based design model for the preliminary design of shell and tube heat exchangers with single-phase fluid flow both on shell and tube side. The program regulated the overall dimensions of the shell, the tube bundle, and optimum heat transfer surface area required to meet the specified heat transfer duty by calculating minimum or allowable shell side pressure drop. They found that circulating cold fluid in the shell-side tube has some advantages rather than the hot fluid in the shell-side tube. Andre et al. [4] presented a study about the design optimization of shell-and-tube heat exchangers. They formulated problem consists of the minimization of the thermal surface area for a certain service, involving discrete decision variables. Their obtained results illustrated the capacity of the proposed approach to direct the optimization towards more effective designs. Kern [5] provided a simple method for calculating shell-side pressure drop and heat transfer coefficient. However, this method is restricted to a fixed baffle cut (25%) and cannot adequately account for baffle-to-shell and tube-to-baffle leakage. Kern method is not applicable in laminar flow region where shell-side Reynolds number is less than 2000. The concept of considering the various streams through the exchanger was originally proposed by Tinker [6]. He suggested a schematic flow pattern, which divided the shell-side flow into a number of individual streams. Baghban et al. [7] analyzed the thermal behavior of the shell-side flow of a shell-and-tube heat exchanger using theoretical and experimental methods. The experimental method provided the effect of the major parameters of the shell-side flow on thermal energy exchange. GopiChand et.al. [8] has proposed a simplified model for the study of thermal analysis of shell-and-tubes heat exchangers of water and oil type.

3. EXPERIMENTAL SETUP

Constructed model has been proposed because of its having certain advantage as compared to the conventional heat exchanger. It is possible to open it part by part which will aid in cleaning effectively and manually. It is one of the most needed things for heat exchanger handling dirty fluid. Using U shaped tubes will allow more heat to be exchanged because of having increased surface area and heat transfer can be further increased by increasing the number of tubes. Two types of material have been used for made up U tube. Cooper and Stainless steel has been selected for made up this tube. As a result, heat transfer rate by applying two types of U tube easily can be measured. Mainly stainless steel has been selected for manufacture the U tube heat exchanger. But for U tube’s material selection, there are two types of material used for comparison heat transfer efficiency. For F-type shell stainless steel material is used. The length of the shell is 685.8 mm, diameter is 203.2 mm and thickness is 1.5 mm. For B-type front header stainless steel material is used. The length of the shell is 127 mm, diameter is 101.6 mm and thickness is 1.5 mm. For U-tube stainless steel and copper material have been used. the length of the tube is 1219.2 mm and diameter us 12.7 mm. Hot and cold water have been used to measure required parameters. A gas stove was used to heat the water to make it considered to be hot water. Normal tap water was used as cold water. Hot water was supplied through the header side of U tube and cold water was supplied through the shell side of U tube. Bucket were connected with the rubber tube to the inlets of hot water and cold water to carry water. The water was supplied to the heat exchanger using the force of gravity without using pump. The temperatures were measured using digital thermometers.

Fig.1: Experimental setup

4. MATHEMATICAL FORMULATION

A heat exchanger can be designed by the LMTD when inlet and outlet conditions are specified. When the problem is to determine the inlet and outlet temperatures for a particular heat exchanger, the analysis is performed more easily by using a method based on effectiveness of the heat exchanger and number of transfer units (NTU).
The heat exchanger effectiveness is defined as the ratio of actual heat transfer to the maximum possible heat transfer.

$$\epsilon = \frac{Actual\ heat\ transfer}{Maximum\ possible\ heat\ transfer} = \frac{Q}{Q_{max}}$$

The actual heat transfer rate Q can be determined by energy balance equation,

$$Q = m_h c_{ph(t_{h1}-t_{h2})} = m_c c_{pc(t_{c2}-t_{c1})} \qquad (1)$$

Log mean temperature difference for pure counter flow,

$$\Delta T_m = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{ln[(T_{hi} - T_{co})/(T_{ho} - T_{ci})]}$$

Overall heat transfer co-efficient can be calculated from the following equation,

$$Q = UA\,\Delta T_m \qquad (2)$$

5. RESULTS AND DISCUSSION

The objective of this research work was to design and fabrication of a U tube heat exchanger and find the log mean temperature difference, overall heat transfer coefficient, amount of heat transferred, effectiveness and compare the heat transfer efficiency by using Stainless steel tube and copper tube.

For Stainless steel tube, LMTD was calculated & varied between 14.1^o C to 29^o C. The effectiveness of heat exchanger varied from 0.26 to 0.32. Overall heat transfer coefficient was calculated & found varying from 870 W/m^2 ^{o}C to 1150 W/m^2 ^{o} C.

For Copper tube, LMTD was calculated & varied between 20^o C to 34^o C. The effectiveness of heat exchanger varied from 0.27 to 0.37. Overall heat transfer coefficient was calculated & found varying from 920 W/m^2 ^{o}C to 1198 W/m^2 ^{o} C.

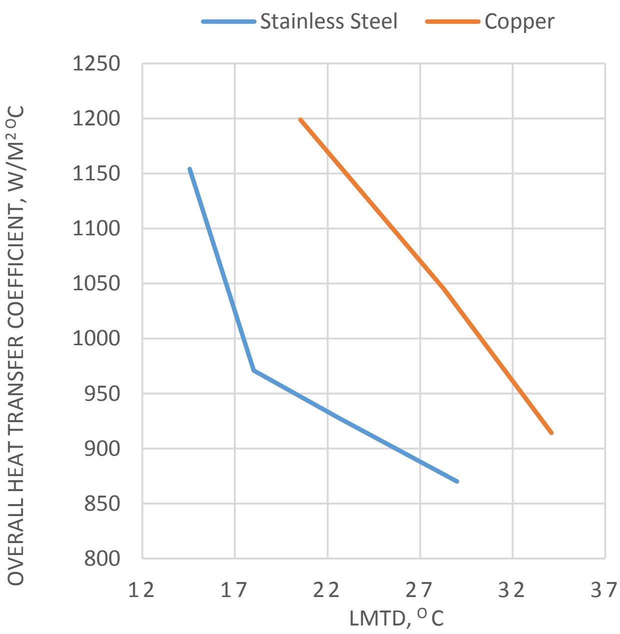

Fig.2: LMTD vs Overall heat transfer coefficient graph

The graphical representation shows the comparison of overall heat transfer coefficient using stainless steel tube and copper tube. Using copper tube give higher overall heat transfer coefficient than using stainless steel tube.

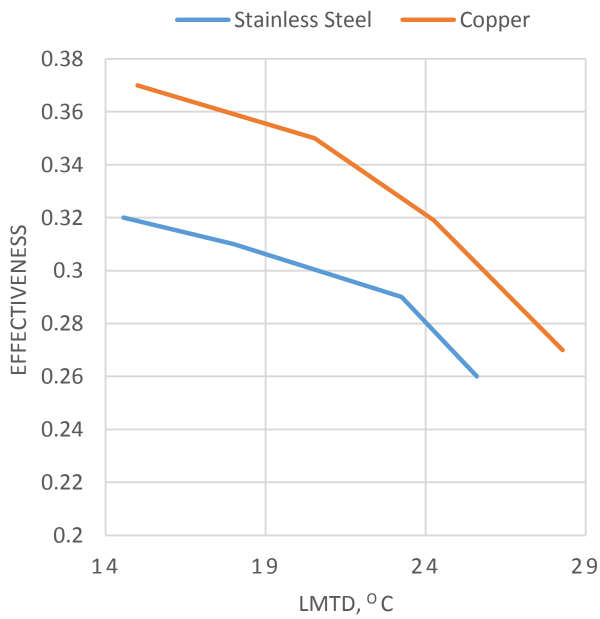

Fig. 3: LMTD vs Effectiveness graph

The graphical representation shows the comparison of effectiveness using stainless steel tube and copper tube. Using stainless steel tube as U tube, the efficiency was found 32% and it will have increased to 37% when we used copper tube as U tube. So using copper tube provide more effectiveness than using stainless steel tube in heat exchanger.

6. CONCLUSION

The major purpose of my research work was to compare the heat transfer efficiency of a heat exchanger by using stainless steel tube and copper tube.
Following are the conclusion drawn:

- Using stainless steel tube as U tube, the maximum efficiency of the heat exchanger was found 32%.
- Using copper tube as U tube, the maximum efficiency was found 37%.

Using copper tube gives greater performance than using stainless steel tube in the heat exchanger, because copper material has higher thermal conductivity than stainless steel material.

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9. NOMENCLATURE

Symbol	Meaning	Unit
ϵ	Effectiveness	Dimensionless
Q	Heat transfer rate	W
U	Overall heat transfer coefficient	$W/m^2 \, ^oC$
A	Area	m^2
ΔT_m	Log Mean Temperature Difference	^oC
m_c	Mass flow rate of cold water	Kg/s
m_h	Mass flow rate of hot water	Kg/s
c_{pc}	Specific heat at constant pressure for cold water	J/K kg
c_{ph}	Specific heat at constant pressure for hot water	J/K kg
t_{c1}	Inlet temperature for cold water	^oC
t_{c2}	Outlet temperature for cold water	^oC
t_{h1}	Inlet temperature for hot water	^oC
t_{h2}	Outlet temperature for hot water	^oC