Experimental Investigation of Helical Tube Twisted Tape Heat Exchanger

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Abstract- *In this paper, we are modifying our college setup of counter flow heat exchanger with our modified design of it. considering changes in temperature of water and changes in results are to be studied. By going through research paper we came to know that heat exchanger performance varies from fluid to fluid and temperature to temperature. Also we have calculated LMDT, overall heat transfer coefficient and effectiveness of two different counter flow heat exchanger by design optimization. Present world is always attract toward the improved effectiveness with minimum cost and reduction in size. Due to continuous improvements in design and construction using different techniques there is huge scope in design optimization material optimization as well as optimization in cost.*

In our paper we took effort for improved heat transferred rate for counter flow heat exchanger. In this we are improved heat transferred rate by increasing heat transferred are by using threaded pipe and improve turbulence by using twisted tape inserted in pipe. Also we are compare our result with conventional experimental setup and derive results from that.

The performance of Counter flow are compared. The performance of such heat exchangers under different operating conditions is calculated in this paper

Keywords- Counter flow, heat transfer coefficient, LMTD, effectiveness.

I. INTRODUCTION

Helically coiled-tube heat exchangers are one of the most common equipment found in many industrial applications ranging from solar energy applications, nuclear power production, chemical and food industries, environmental engineering, and many other engineering applications. Heat transfer rate of helically coiled heat exchangers is significantly larger because of the secondary flow pattern in planes normal to the main flow than in straight pipes.

Aim of Project

To study and compare the following:

1. Temperature distribution in conventional and modified counter flow heat exchanger.
2. Heat transfer rate in conventional and modified counter flow heat exchanger.
3. Overall heat transfer coefficient in conventional and modified counter flow heat exchanger.
4. To obtain cost reduction, material reduction and obtain digitalisation of temperature indication.

II. LITRATURE SURVEY

S. Pradeep Narayanan et al. [1] studied on Performance of a counter-flow heat exchanger with heat loss through the wall at the cold end.

The performance of high effectiveness heat exchangers used in cryogenic systems is strongly controlled by irreversibility such as longitudinal heat conduction and heat leak from ambient. In all heat exchanger analyses, it is assumed that no heat is lost through the heat exchanger walls. In the case of small J-T refrigerators such as micro miniature refrigerators, the heat exchanger cold end is almost directly connected to the evaporator, which may result in a large amount of heat loss through the heat exchanger wall at the cold end. The rate of heat loss through the wall at the cold end is also strongly dependent on the longitudinal thermal resistance of the wall.

In this paper, they present the relationship between the effectiveness of a heat exchanger losing heat at the cold end and other resistances such as number of transfer units (NTU), longitudinal thermal resistance etc. The performance of such heat exchangers under different operating conditions is also discussed.

Prabhat et al. [2] studied on a performance evaluation of counter flow heat exchanger considering for low temp application. He found those Counter flow heat exchangers are commonly used in cryogenic systems because of their high effectiveness. They observed that losses such longitudinal conduction through wall, heat in leak from surrounding, flow maldistribution etc. They extended their study to understand quantitative effect of heat in leak and axial conduction parameters on degradation of heat exchanger performance for 300-80k and 80-20k temperature range.

III. DESIGN OPTIMIZATION IN COUNTER FLOW HEAT EXCHANGER

A. Simple Counter Flow Heat Exchanger Setup

Heat exchangers are typically classified according to flow arrangement and type of construction. The simplest heat exchanger is one for which the hot and cold fluids move in the same or opposite directions in a concentric tube (or double-pipe) construction. In the parallel-flow arrangement of Figure 3(A1), the hot and cold fluids enter at the same end, flow in the same direction, and leave at the same end. In the counter flow arrangement of Figure 3(A2), the fluids enter at opposite ends, flow in opposite directions, and leave at opposite ends.

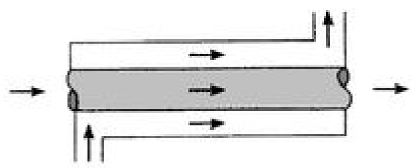

Figure 1. Parallel Flow

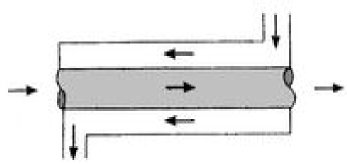

Figure 2. Counter Flow

B. Helical Tube Twisted Tape Counter Flow Heat Exchanger

Many different active techniques exist to increase the heat transfer rate mostly for straight pipes. In case of passive techniques heat transfer enhancement by chaotic mixing in helical pipes has great importance and investigated by Kumar and Nigam and Acharya et al. Helical screw-tape inserts have been investigated in straight pipes experimental by Sivashanmugam and Suresh. There is considerable amount of work reported in the literature on heat transfer augmentation in straight pipes with different corrugation techniques; helical tape Experimental investigation of thermosyphon solar water heater with twisted tape inserts has been carried out by Jaisankaretal. According to the author’s knowledge a few examinations are considered in helically coiled tubes with different passive heat transfer augmentation techniques like inside wall corrugation, helical tape inserts.

Improving in heat transfer rate in our project due to:

1. Helical tube used instead of simple extruded copper tube.

Figure 3. Helical Copper Pipe

2. Twisted tape of aluminum to increases the surface area

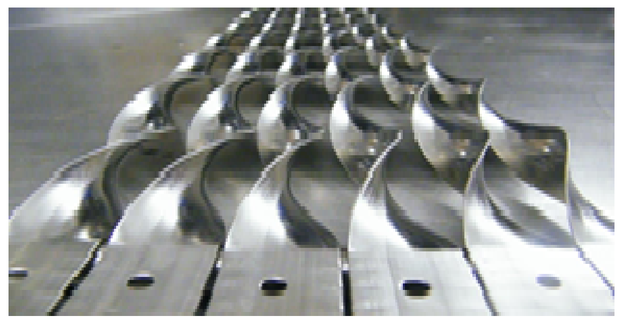

Figure 4. Aluminium Twisted Tape

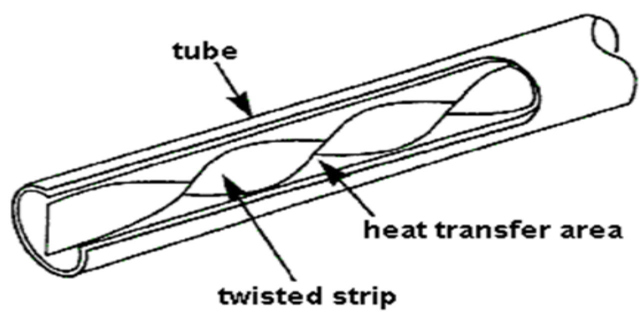

Figure 4. Twisted Tape In Copper Pipe

C. Working Principle

A heat exchanger is a device used to transfer heat between a solid object and a fluid, or between two or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact.

For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger. The exchanger's performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence.

The driving temperature across the heat transfer surface varies with position, but an appropriate mean temperature can be defined. In most simple systems this is the "log mean temperature difference" (LMTD). Sometimes direct knowledge of the LMTD is not available and the NTU method is used.

Why counter flow heat exchanger is better than parallel flow?

The figure below depicts heat exchanger schematics and the temperature profiles for both cocurrent (or parallel) and countercurrent designs

- Hence, in a concurrent design, the temperature of the cold stream outlet, Tc, is always lesser than that of the hot stream outlet, Th Therefore, the heat transfer is restricted by the cold stream's outlet temperature, Tc.
- On the other hand, in a countercurrent design, the restriction is relaxed and Tc, can exceed Th out. Hence in this design, the heat transfer is restricted by the cold stream's inlet temperature, Tc,in.
- Therefore, to achieve greater heat recovery, a countercurrent design is preferred to that of a concurrent design.

IV. CONCEPT TO REVIEW AND ASSUMPTION

Assumption in Design of Set Up

- There is no energy loss to the environment
- Heat exchanger is at a steady-state Unit Operation
- There are no phase changes in the fluids
- Heat capacities of the fluids are independent of temperature.

Concepts To Review

- Heat exchanger configurations; parallel vs. counter-current flow
- LMTD and NTU methods for analysis of heat exchangers
- Convective and conductive heat transfer
- Reynolds, Prandtl, and Nusselt numbers
- Energy balance closure.

You will investigate effects of these variables on the following performance indicators:

- Return temperatures Th,o and Tc,o of the hot and cold water
- Heat flow rate q
- Overall heat transfer coefficient

Objective

- To demonstrate the working principles of a concentric flow heat exchanger under counter flow conditions.
- To demonstrate the effect of hot water inlet temperature variation on the performance characteristics of a concentric tube exchanger.
- To find the effect of flow rate variation on the performance characteristics of a concentric tube heat exchanger operating under counter flow.

Setup Specifications

1. Digital Temp. Indicator: 0-110 ºC -4 Nos.
2. Geyser for hot water
3. Inner tube: I. D of copper. – 10mm
4. Outer tube: O.D of copper. –14mm
5. Inner tube: I.D of GI. – 28mm
6. Outer tube: O.D of GI. – 33mm
7. Copper tube helical external threaded of 2000mm
8. Twisted tape of aluminum of 2000mm into copper tube
9. Length of the heat exchanger – 2000 mm.
10. Ball valves for flow arrangement.

Procedure

1) Place the thermometer in position and note down their reading when they are at room temperature and no water is flowing at either side. This is required to correct the temperature, if necessary.
2) Start the flow on hot water side.
3) Start the flow through annulus and run the heat exchanger as counter flow unit.
4) Switch ON the geyser.
5) Adjust the flow rate on hot water side (about 0.8 to 1.0 l/min)
6) Adjust the flow rate on cold water side (about 1.0 to 1.2 l/min)
7) Record the temperature on hot and cold water side and also flow rates accurately at different times.
8) Keeping the flow rate same, till steady state condition is reached

V. OBSERVATION TABLE AND CALCULATIONS

1. Conventional counter flow heat exchanger

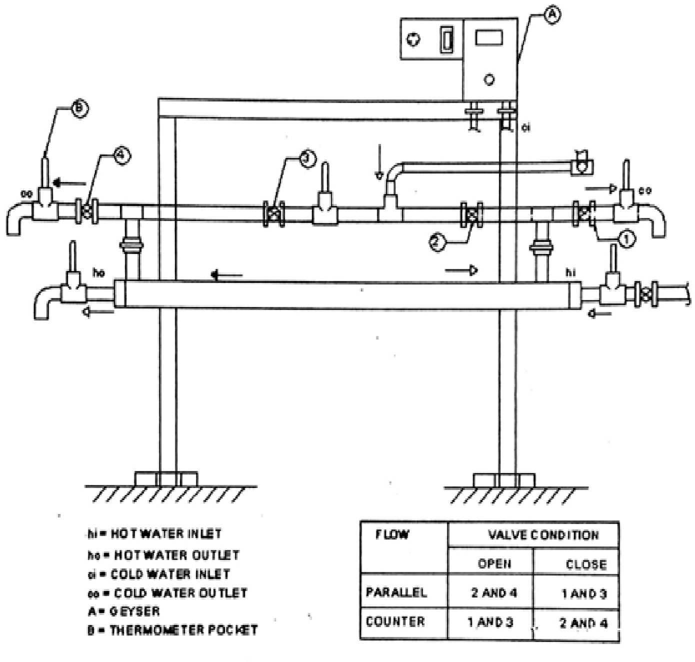

Figure 5. Conventional Counter Flow Heat Exchanger

Table 1.

Counter flow	Hot water side			Cold water side		
	Flow rate (l/min)	THi (°c)	THo (°c)	Flow rate (l/min)	TCi (°c)	TCo (°c)
1.	860	77	52	1300	31	40

Calculations:-

- $Qh = m_h.Cp_h.\ (T_{hi} - T_{ho})$

$$= \frac{860 \times 4.187}{60} \times (77 - 52)$$

= 1500.38 watts

- $Qc = m_c.Cp_c.\ (T_{hi} - T_{ho})$

$$= \frac{1300 \times 4.187}{60} \times (40 - 31)$$

= 816.46 watts

- $Qm = \frac{(Qc+Qh)}{2}$

$$= \frac{(1500.38+816.46)}{2}$$

=1158.42 watts

Now calculating LMTD,

- $\Delta Tm = \frac{\Delta T1 - \Delta T2}{ln \frac{\Delta T1}{\Delta T2}}$

$$= \frac{37-21}{ln \frac{37}{21}}$$

= 28.25 °c

- $Q = UA\Delta T_m$

- $U_i = \frac{Q}{Ao\Delta Tm}$

where, $Ai = 2\pi RiL$

$$U_I = \frac{1158.42}{(2\pi * 0.005 * 2 * 28.25)}$$

= 652.63 w/m^2k

$$U_o = \frac{Q}{Ao\Delta Tm}$$

where, $Ao = 2\pi RoL$

$$= \frac{1158.42}{(2\pi * 0.007 * 2 * 28.25)}$$

U_O = 466.16 w/m^2k

$$\varepsilon = \frac{Thi - Tho}{Thi - Tci}$$

$$\varepsilon = \frac{77-52}{77-31}$$

ε = 0.543

2. Modified counter flow heat exchanger

Table 2.

Counter flow	Hot water side			Cold water side		
	Flow rate (l/min)	THi (ºc)	THo (ºc)	Flow rate (l/min)	TCi (ºc)	TCo (ºc)
1.	860	77	49	1300	31	43

Calculations:-

$Qh = m_h.Cp_h.(T_{hi} - T_{ho})$

$$= \frac{860 \times 4.187}{60} \times (77 - 49)$$

= 1680.38 watts

$Qc = m_c.Cp_c.(T_{hi} - T_{ho})$

$$= \frac{1300 \times 4.187}{60} \times (43 - 31)$$

= 1088.62 watts

Qm= $\frac{(Qc+Qh)}{2}$

$$= \frac{(1680.38+1088.62)}{2}$$

=1384.5 watts

Now calculating LMTD,

$$\Delta Tm = \frac{\Delta T1 - \Delta T2}{ln\frac{\Delta T1}{\Delta T2}}$$

$$= \frac{34-18}{ln\frac{34}{18}}$$

= 25.15 ˚c

$Q = UA\Delta T_m$

$$U_i = \frac{Q}{Ao\Delta Tm}$$

where, $Ai = 2\pi RiL$

$$= \frac{1384.5}{(2\pi * 0.005 * 2 * 25.15)}$$

= 876.14 w/m^2k

$$U_o = \frac{Q}{Ao\Delta Tm}$$

Where, $Ao = 2\pi RoL$

$$= \frac{1384.5}{(2\pi * 0.007 * 2 * 25.15)}$$

= 625.81 w/m^2k

$$\mathcal{E} = \frac{Thi - Tho}{Thi - Tci}$$

$$\mathcal{E} = \frac{77-49}{77-31}$$

$\mathcal{E}$ = 0.604

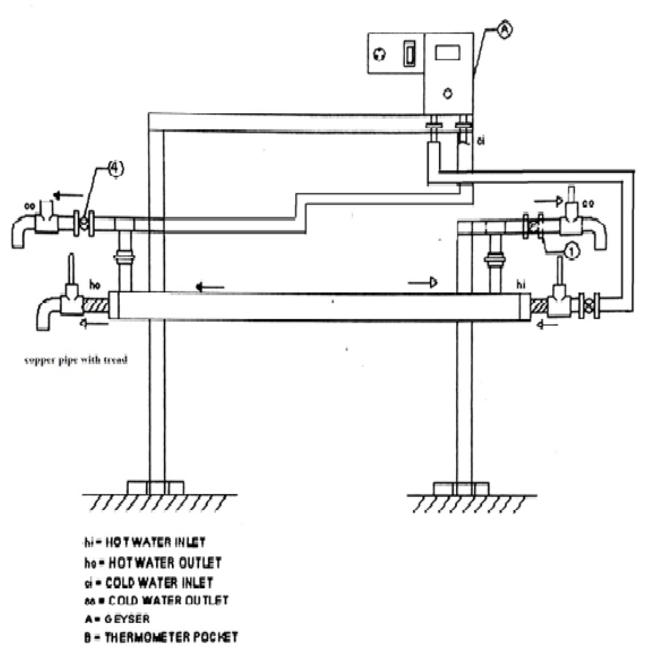

Figure 6. modify set up for counter flow heat exchanger using helical copper coil and aluminum twisted tape

V. CONCLUSION AND FUTURE SCOPE

From the experimental analysis and literature review of experimental investigation of performance of counter flow heat exchanger we came to the conclusion that

1) Heat transfer is more in case of counter flow heat exchanger using water or any other oil as heat carrying medium.
2) By using twisted tape and helical tube in our set up improving overall heat transfer rate by % and heat transfer rate by %.
3) Heat transfer can be enhanced by changing the material of construction of pipes, taking liquid as a heat absorbing medium having high specific heat, changing mass flow rates.

From the result and conclusion we can conclude that,

1. Heat transfer is more in case of counter flow heat exchanger by 20 %.
2. As LMTD increases discharge increases and so efficiency increases.

Future work may be extended to;

- Change the tape material from Aluminum to Copper.
- Compound enhancement techniques maybe applied i.e., the tape inserts can be coupled with coil wire inserts for better enhancement.
- Other reduced width twisted tapes along with variation in Reynolds numbers.
- Develop further correlations by considering lower Reynolds numbers and Nessult number.
- Change the working fluid from water to air in order to enhance the rate of heat transfer and reduce pipe leakages.

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