EXPERIMENTAL INVESTIGATIONS OF DOUBLE PIPE HEAT EXCHANGER WITH TRIANGULAR BAFFLES

Madhav Mishra[1], U. K Nayak[2]
[1] *M. Tech student, Department of Mechanical engineering, BIT, Sindri, Dhanbad, India, madhavmisra89@gmail.com*
[2] *Assistant Professor, Department of Mechanical engineering, BIT, Sindri, Dhanbad, India, ujjwalnayak77@gmail.com*

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Abstract - *A set of the experiments were carried out for this dissertation to investigate and compare the heat transfer behaviour in a double pipe concentric tube heat exchanger with and without triangular baffles for both parallel and counter flow arrangements. The test section is a horizontal annular passage formed by two concentric tubes with an inner to outer diameter ratio of 3.17 and length of 2438 mm. Heat is only transferred from the inner tube in which hot fluid is flowing to the annulus which is well insulated. Triangular baffle with dimensions of 4 mm base, 8mm height and 1.5 mm thickness are used in the present study. In the beginning we conducted the experiment without any baffle to get the performance parameter for plane heat exchanger and then with baffle of pitches 50 mm and 100 mm. The effects of the baffles spacing and mass flow rate of fluid is examined on the thermal performance of heat exchanger. It is found that the effectiveness increases with increase in flow rate of cold fluid and average effectiveness also increases when pitch of baffles are 100 mm and 50 mm by 1.42 and 1.62 times in parallel flow and 1.34 and 1.62 in counter flow that of smooth tube respectively. The other performance parameter like heat transfer coefficient and heat transfer rate obtained through experiment is also increases. The effectiveness method is used for calculation of overall heat transfer coefficient and effectiveness.*

Key Words: Double pipe, Heat capacity, LMTD ($\Delta\theta m$), Triangular baffles heat exchanger, Overall Heat Transfer Coefficient, Effectiveness ($\in$) etc.

1. INTRODUCTION

Heat exchangers are the equipment that is commonly used to transfer heat between two flowing fluids at different temperatures without any mixing of fluid with each other. Transfer of the energy from one fluid to another fluid can be done either by conduction, convection or radiation or with all modes of heat transfer. Heat exchangers are very important components in engineering systems, ranging from the heavy industries, such as power or metallurgy, chemical, automotive, through the high technique ones such as electronics, to production of every day consumers goods like refrigeration, air conditioning systems, etc. [1]

Here an experimental investigation has been performed to study the effects of the baffles on a concentric tube heat exchanger. Baffles are attached to the heated surface so that it provide an additional heat transfer surface area and to promote useful turbulence. Due to the presence of baffles the flow is separated, reattached and creates reverse flow. Recently, many experiments have been carried out. Most investigation tells about the optimal baffle geometry that increases heat transfer performance for a flow rate.

An investigation had been carried out to compare the heat transfer performance of hexagonal pin-fin heat sinks with various commonly used fin geometries. It is found that for the given flow rate and pressure gradient, the Nusselt number of hexagonal fin geometry yield a higher in comparison to square fins, and a lower in comparison to circular fins. The heat transfer performance in staggered hexagonal fin geometry is similar in-line circular performance at most Reynolds numbers in the range considered here[2].Experimental investigation is performed to know the effects of the baffle alignment (staggered and in-line), open area ratio, Reynolds number, baffle height and baffles pitch on the heat transfer increment, friction factor and the different thermal performance parameter for turbulent flow of air in a rectangular duct with perforated baffles[3]. Reported experimental and numerical analysis of hydrodynamic and heat transfer characteristics of a heat exchanger with single- helical baffles. CFI model is used and compared the performance of heat exchanger with single - segmental baffles [4]. Experimental and analytical study has been carried out on water-to-water heat transfer in tube-tube heat exchanger. These tube–tube heat exchangers are successfully demonstrated for condenser and evaporator in heat pumps, milk chilling and pasteurizing application [5]. In this paper the study of shell and tube heat exchanger is carried out also the factors which affect the performance of heat exchanger and its details discussion is given. The investigation is carried out in small shell and tube heat exchanger with counter flow arrangement. The parameters used for thermal analysis are baffle inclination, baffle spacing, flow rates of cold and hot fluids, diameter of tube etc. by using CFD [6].

After the study of large number of literature it is found that various experiments have been carried out for improvement in heat transfer rate in heat exchanger by using different methods. But, I hardly found any experiment that has been carried out with triangular baffles in double tube heat exchanger to enhance heat transfer rate from hot fluid to cold fluid.

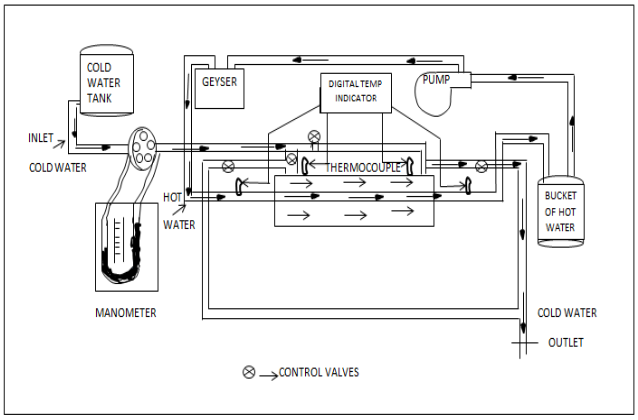

Figure 1: The Schematic diagram of experimental set-up

2. EXPERIMENTAL APPARATUS AND PROCEDURE

The schematic diagram of experimental set-up of double concentric tube heat exchanger is shown in above figure 1 and the photograph of experimental set up is in figure 2 respectively. The devices used in this set ups are orifice meter to measure flow rate with the help of Vertical U-tube Manometer, however the flow rate of hot fluid is also calculated by measuring the time to fill a known volume of bucket. Digital thermal indicator (DTI) and Thermocouple are fitted to measure temperature at inlet and outlet of fluids. The end of thermocouple wires connected with standard male plug in order to connect them with the digital thermometer. Geyser and Pump is used to heat and circulates the hot fluid in inner Copper tube at a temperature range of 40 to 55°C. The ID and OD of inner copper tube is 14 mm and 16 mm respectively. G.I pipe of ID 50.8 mm is used as outer tube and cold water is flowing in the annulus between these two tube had a constant inlet temperature of 28°C. Length of heat exchanger is 2438 mm. Triangular copper baffles of 4 mm base, 8 mm height and 1.5 mm thickness are used at a pitch of 100 mm and 50 mm at the outer surface of inner tube. Six-six numbers of baffles are used at a single peripheral space. Working fluid water is stored in in two tanks in which hot and cold water is stored. Figure 3, 4 and 5 illustrate the inner tube of heat exchanger i.e. Cu-pipe without triangular baffles and, Triangular baffled with 100 mm and 50 mm pitches.

Figure 2: Experimental setup of triangular baffled heat exchanger

Figure 3: Cu-pipe without triangular baffles

Figure 4: Triangular baffles with 100 mm pitch on cu-pipe

Figure 5: Triangular baffles with 50 mm pitch on cu-pipe

2.1 Mathematical Analysis

Assuming that there is no heat loss to the surroundings and potential and kinetic energy

Changes are negligible from the energy balance in a heat exchanger.

We have

Heat given up by the hot fluid

$Q = m_h C_{ph}(t_{h1} - t_{h2})$ .... (1)

Heat picked up by the cold fluid

$Q = m_c C_{pc}(t_{c2} - t_{c1})$ .... (2)

Total heat transfer rate in the heat exchanger

$Q = U.A.\Delta\theta_m$ .... (3)

Where, $\Delta\theta_{m,} = \frac{(\theta_2 - \theta_1)}{\ln(\theta_1/\theta_2)}$ .... (4)

Heat Exchanger Effectiveness

The heat exchanger effectiveness (ϵ) is defined as the ratio of actual heat transfer to the maximum possible heat transfer,

Thus,

$$\epsilon = \frac{\textit{actual heat transfer}}{\textit{maximum possible heat transfer}} = \frac{Q_{actual}}{Q_{maximum}} \quad (5)$$

The actual heat transfer rate Q can be determined by writing an energy balance over either side of the heat exchanger

$Q = m_h C_{ph}(t_{h1} - t_{h2}) = m_c C_{pc}(t_{c2} - t_{c1})$ .... (6)

Maximum heat transfer rate for both parallel flow or courtier flow heat exchanger

$Q_{max} = C_{min}(t_{h1} - t_{c1})$ .... (7)

Thus, Effectiveness,

$\epsilon = \frac{C_h(t_{h1} - t_{h2})}{C_{min}(t_{h1} - t_{c1})} = \frac{C_c(t_{c2} - t_{c1})}{C_{min}(t_{h1} - t_{c1})}$ ....(8)

Now the effectiveness is known, the heat transfer rate can be very easily calculated by using the equation

$Q = \epsilon\ C_{min}(t_{h1} - t_{c1})$ .... (9)

Thus, Overall heat transfer coefficient

$U = \frac{Q}{A\Delta\theta_{m,}}$ .... (10)

3. RESULTS AND DISCUSSION

To compare the different performance parameter of heat exchanger without baffles and with baffles of pitches 100 mm and 50 mm some graphs are plotted.

Figure 6 and **figure 7** shows the variations of effectiveness with different mass flow rate of cold fluid for parallel and counter flow respectively. The plot clearly shows that the effectiveness decreases with increasing mass flow rate. Effectiveness of both triangular baffled heat exchangers is greater than the plane tube heat exchanger. However from two graphs it is also clearly seen that the effectiveness of heat exchanger with 50 mm triangular baffled pitch is more than 100 mm baffled pitch. So it can be concluded that using of baffles in heat exchanger effectiveness increases however if baffles pitch decreases effectiveness also increases.

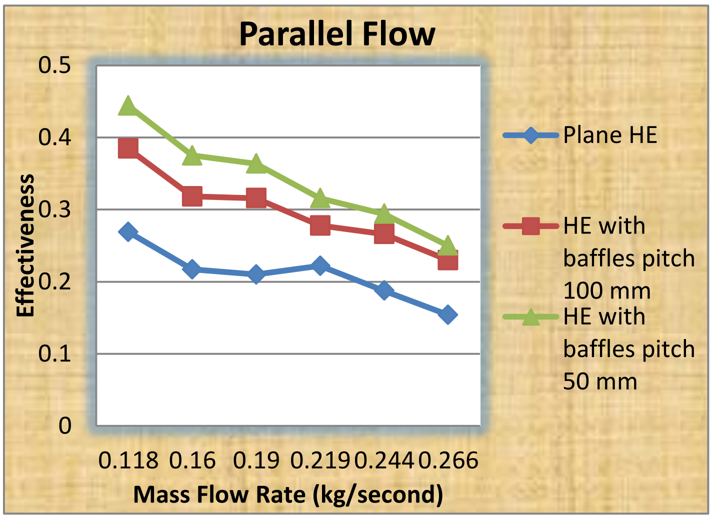

Figure 6: Variation of effectiveness with mass flow rate of parallel flow

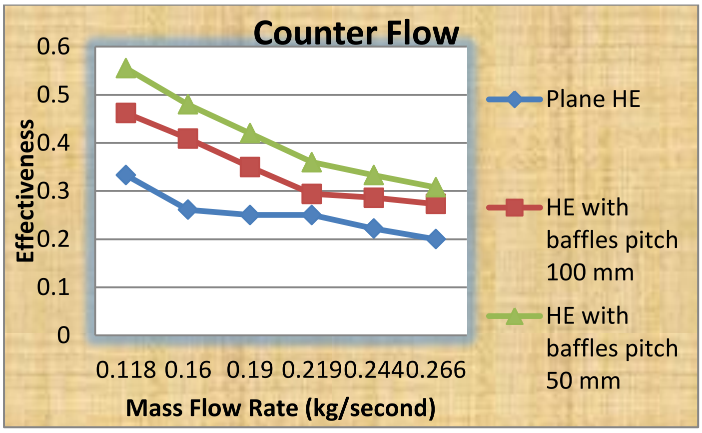

Figure 7: Variation of effectiveness with mass flow rate of counter flow

The variations of overall heat transfer coefficient with mass flow rate which is calculated by experimentally observed data for parallel and counter flow heat exchanger is shown in **figure 8** and **figure 9** respectively. The plot clearly shows that the heat transfer coefficient increases by using triangular baffles in both set-ups as compare to heat exchanger without baffles. However from two graphs it is also clearly seen that the heat transfer coefficient of triangular baffle heat exchanger with 50 mm pitch is more than 100 mm baffled pitch. So it can be concluded that using of baffles in heat exchanger heat transfer coefficient increases however it also increases when pitch of baffles decreases.

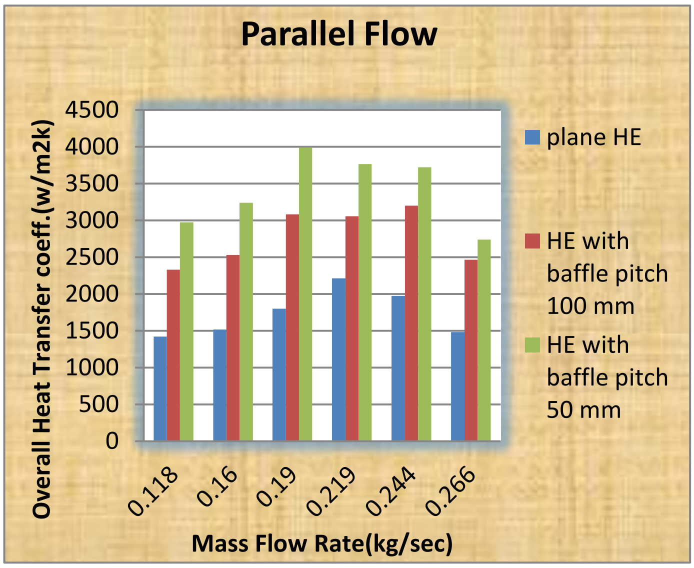

Figure 8: Variation of Overall heat transfer coefficient with mass flow rate of parallel flow

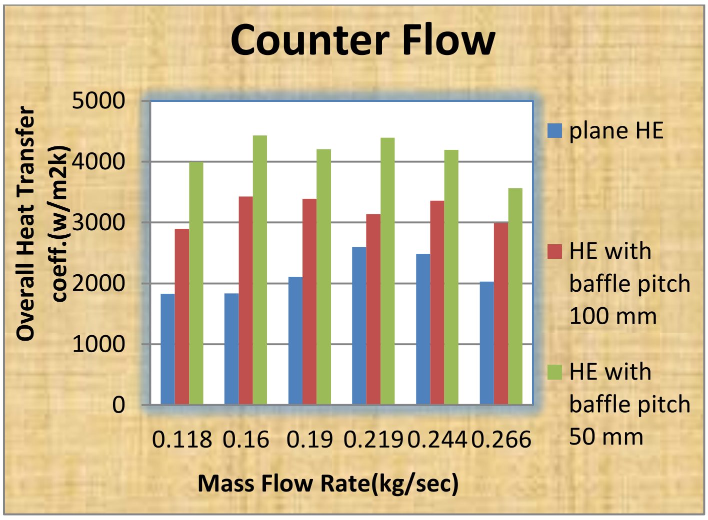

Figure 9: Variation of Overall heat transfer coefficient with mass flow rate of counter flow

The value of effectiveness for parallel and counter flow arrangements are compare in plot for increasing mass flow rates are shown in the **figure 10, 11 and 12** for all three experimental set up of heat exchanger without baffles, with baffle pitches of 100 and 50 mm respectively. From the plot it is clearly seen that the value of effectiveness for counter flow is more than parallel flow for the all three set of heat exchanger. From the graph it is seen that there is an optimum mass flow rate at which gap of effectiveness for parallel counter flow is minimum

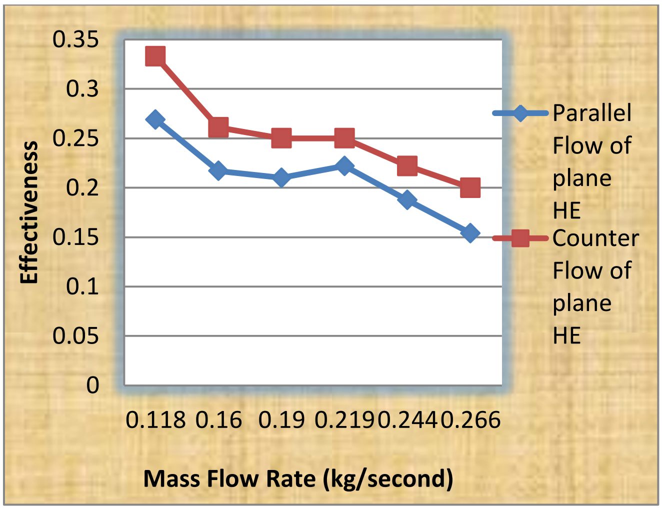

Figure 10: variation of effectiveness with mass flow rate of parallel and counter flow of plane heat exchanger i.e. without baffles

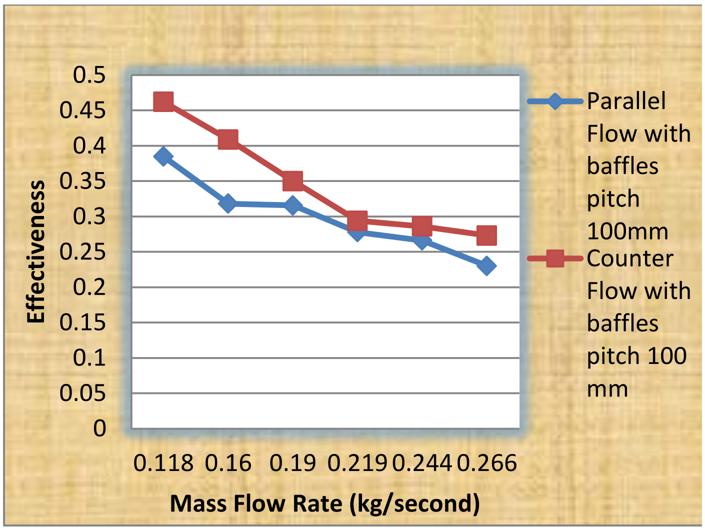

Figure 11: variation of effectiveness with mass flow rate of parallel and counter flow of plane heat exchanger with baffles pitch 100 mm

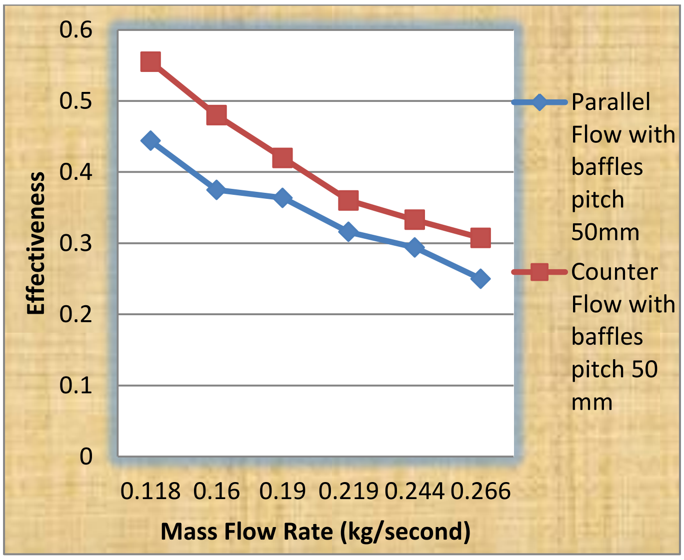

Figure 12: variation of effectiveness with mass flow rate of parallel and counter flow of plane heat exchanger with baffles pitch 50 mm

4. CONCLUSION

Experimental investigations of effectiveness and overall heat transfer coefficient of double pipe heat exchanger without triangular baffles and with baffles spacing of 100 mm and 50 mm carried out for both parallel and counter flow. The following conclusion could be made:

- The effectiveness, heat transfer coefficient and heat transfer rate increases with the decrease in baffle spacing and baffled tube heat exchanger have batter thermal performances than smooth tube for both the cases.
- Triangular baffles of 100 and 50 mm pitches enhance the average effectiveness by 1.42 and 1.62 times in parallel flow and 1.338 and1.62 in counter flow that of smooth tube respectively
- Triangular baffles of 100 and 50 mm pitches enhance the average heat transfer rate by 1.6 and 1.9 times in parallel flow and 1.48 and 1.67 in counter flow that of smooth tube respectively.
- We found that the insulation has a significant effect on heat exchanger performance. From the calculation it can be seen that in many observations the heat loss by hot fluid is more than the heat gain by cold fluid this is because of insulations provided is not sufficient to stop heat loss.
- From the results it can be concluded that the performance of triangular baffled heat exchanger is much better than that of smooth tube HE, therefore improvement in the energy saving lead to validate its use in different applications. Also similar results had been found by Sarmad A. Abdal Hussein when he carried out the investigation of double pipe heat exchanger by using semi-circular disc baffles.

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