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Experimental investigation on heat transfer in double pipe heat exchanger employing triangular fins

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Abstract. Various experiments were carried out for this dissertation to investigate and compare the heat transfer in a DPHE for counter flow arrangement studying with and without usage of longitudinal triangular fins. The test section is a horizontal annular passage formed by copper tube with an inner diameter 15 mm to outer diameter 19 mm with a length of 1000 mm. Triangular fin with dimensions of 9 mm base, 8 mm height and 2 mm thickness are used in the present study. In the beginning we conducted the experiment with the traditional DPHE to analyze the effectiveness parameter for plane heat exchanger and then with 4 longitudinal triangular fins with difference in spacing of fins angle 90 degrees of length 1000 mm. The effects of the fins spacing and mass flow rate of fluid is examined on the thermal performance of heat exchanger. Increase in flow rate of cold fluid results in increase of heat transfer and effectiveness increases to 0.505 in longitudinal triangular finned tube from the value 0.405 in the traditional DPHE of counter flow respectively. Another performance parameter like overall heat transfer coefficient increases and LMTD throughout the experiment decreases respectively.

KEYWORDS. Counter flow, Double pipe heat exchanger (DPHE), longitudinal triangular fins

1. Introduction

Shiva Kumar [1] varying the mass flow rate of hot water with constant mass flow rate of cold water, rectangular finned tubes showed an average improvement of 6.1% over the triangular and 9.2% over parabolic fins. Vinous M. Hameed [2] analysis numerical simulation, addition of triangular fins to outer surface of the tube resulted in increase in heat transfer. A.Falavand Jozael [3] Discussed about the effect of fins per inch. Heat dissipation increased with increase of fins per inch (FPI). Madhav Mishra [4] compare the heat transfer behavior in a double pipe concentric tube heat exchanger with and without triangular baffles for both parallel and counter flow arrangements various experiments were carried out. It is found from the work they done 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 Debasis Das [5] evaluated the optimum design for heat transfer analysis through triangular fin within a vertically oriented rectangular enclosure. [6] N. A. Mir During numerical simulation, the laminar, steady, forced convection heat transfer in the finned annulus was carried out. For values of the ratio of radii of inner and outer pipes, fin height and number of fins various heat transfer and fluid flow characteristics are investigated. Sameer H. Ameend [7] with parabolic fins fixed on the outer surfaces of the inner pipe at different angles a DPHE is constructed out of a copper alloy. Parabolic fins improved the local heat convection to about 2.42 more than pipes without fins. They used heat exchanger for the transfer of thermal energy between two or more fluids that are at different temperatures. Their work demonstrates the application of triangular fins to heat exchanger which enhances the effectiveness of the heat exchanger.

2. Heat exchanger

A heat exchanger transfers heat between solid and fluids or between two or more fluids. Fluids may be separated from intermixing by tubes or solid surfaces. They are used in refrigeration, power plants chemical engineering, petroleum plants, and food industries. An example of heat exchanger is engine coolant which flows through radiator coils and air cools the coils and in turn the incoming air from the radiator fan gets heated by heat dissipiated by coolant coils.

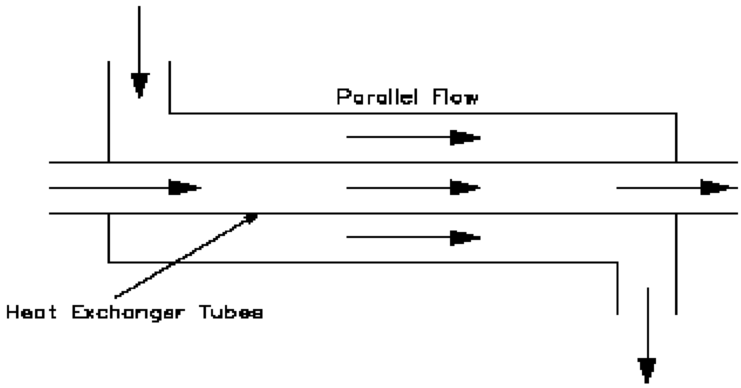

Figure 1. Parallel Flow in DPHE

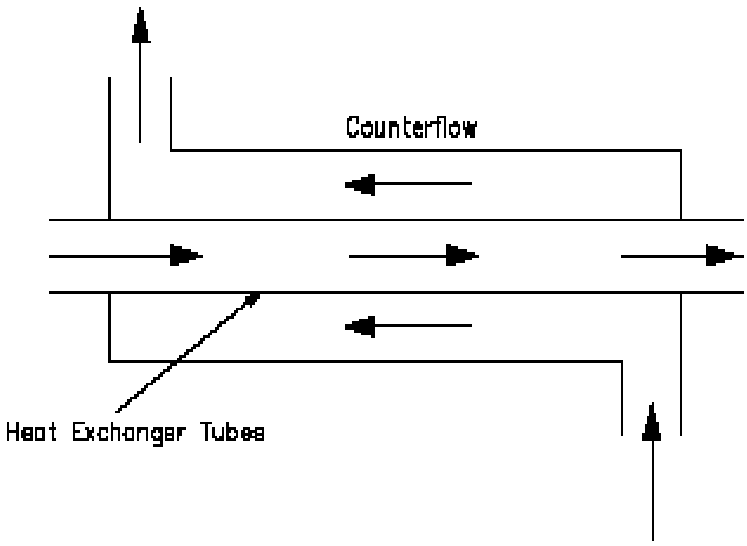

Figure 2. Counter Flow in DPHE

In general a DPHE consists of a pipe which is enclosed in other pipe the having the larger diameter than the former. The heat transfer surface the inner pipe. Usually the pipes are multiple or double packed in order to make the overall unit more compact.

Using the basic heat exchanger equation, we can determine the heat transfer area required for the design basic heat exchanger.

$$Q = U\ A\ \Delta T_{lm} \quad (1)$$

Where,
Q rate of heat transfer between the two fluids in the heat exchanger (°C)
U overall heat transfer coefficient (W/m^2K)
A heat transfer surface area (m^2)
By the value obtained by calculating heat transfer area, we can determine the diameter and the length of inner and outer tubes. Length of sections and number of bends can be finally evaluated.

3. Methodology

In this process of double pipe heat the outer pipe made up of galvanized steel inner annulus made up of copper metal. To keep fins we have to study and have to eliminate in order to various readings.The triangular fin material was selected as copper due to its high thermal conductivity and it's availability within the economic cost. There are several heat exchangers and their types are discussed in the introduction above. Upon extensive review of the literature survey DPHE was chosen as the heat exchanger in the present work. Due to low initial low initial cost, low maintenance and better results output DPHE was taken into the consideration. As DPHEs works with the parallel as well as the counter flow, the present work was done under counter flow because counter flow shows the better results when compared to the other heat exchangers. Cold water taken from tank through pipe line and hoses. From the tank two lines are taken one for Geyser inlet. Another one for cold water inlet of plain pipe heat exchanger. The heat exchanger is having inlet cold water from the above pipeline. From the geyser outlet, the hot water is given as input to the inner pipe. The inlet of hot water line is connected through shut off valve. So, we can supply the water either plain pipe heat exchanger (or) finned pipe heat exchanger. The inlet of cold water line is connected through shut off valve. So, we can supply the water either plain pipe heat exchanger (or) finned pipe heat exchanger. Thermocouples are mounted in-between the inlet & outlet of both hot water line and cold water line. We can measure the temperature of the required area. All 4 thermocouples are connected with electric power supply and connected with 6 channel indicator. The experimental setup consists of inner tube made of copper and hot water flows from a geyser. To run as a counter flow heat exchanger, cold water can be admitted from either of the ends. Valves are provided to operate according to the requirement. Specifications are mentioned below. Digital display allows us to measure the temperature of the fluids with thermocouples attached to the pipes. Time taken for collecting one liter of water determines the mass flow rate of the fluids. Insulation is provided for the outer tube in order to minimize the heat losses to the surroundings. Inlet of cold fluid is maintained at 30˚C whereas the hot fluid is maintained at 70˚C. Various mass flow rates of cold water (mc) ranging from 0.019 kg/s to 0.072 kg/s with an uniform increment for counter flow arrangement were carried out at each time keeping the mass flow rate of hot water (mh) through the annulus constant at 0.016 kg/s. Range of the Reynolds's number in the present study was 3000 to 20000. Temperatures of both the fluids at the outlet are noted. Similarly the experiments were repeated by changing the cold water flow.

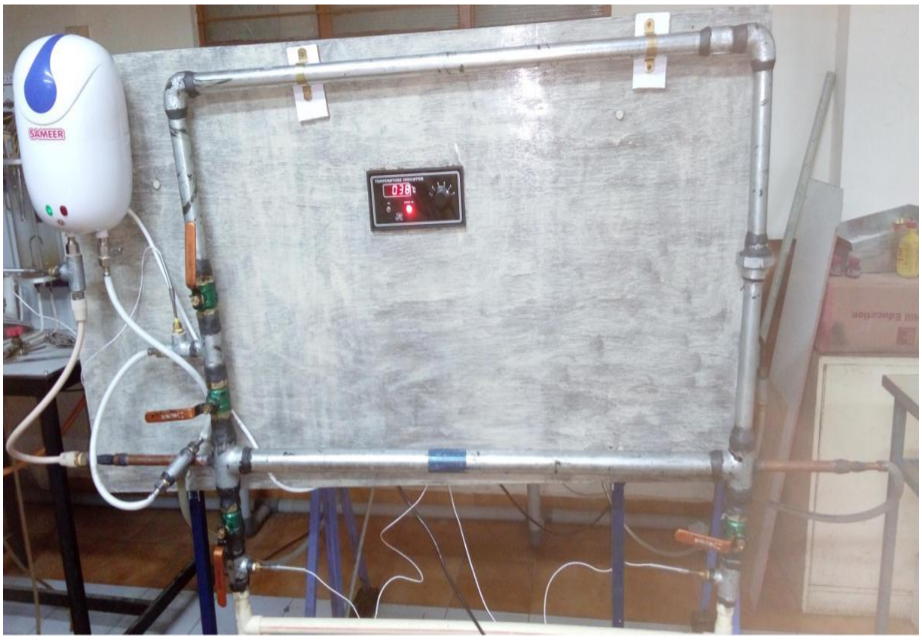

Figure 3. Experimental setup

3.1 . Heat exchanger specifications

The DPHE was chosen according to the dimensions taken as shown below. The inner pipe was chosen based on the dimensions available in the market and also which were able to fit inside the fabricated outer pipe with and without fins. The fin material as well as its dimensions were selected based upon the required parameters and it's availability in the market. The fins used are longitudinal and triangular in shape.

Table 1. Specification of fins

	Inner Pipe	Outer Pipe	Fins
Material Used	Copper	Galvanised Iron	Copper
Length	1000 mm	1000 mm	1000 mm
Inner	15 mm	37 mm	-
Outher	19 mm	41 mm	-
Height	-	-	7.8 mm
Thickness	-	-	2 mm

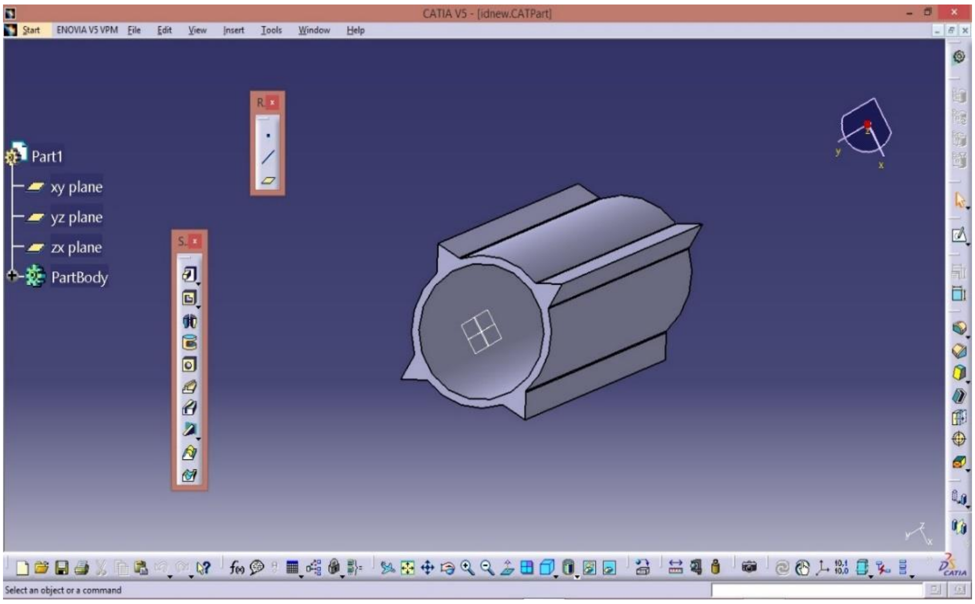

Figure 4. Design of finned tube using ansys

The finned tube selected has 4 longitudinal fins and they are arranged with the orientation of angle 90 degrees. The length of each fin is 9 mm, height of the fin is 7.8mm and thickness of each fin is 2mm. The fin is designed using CATIA software.

`**Figure 5**. Design of finned tube

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4. Result and Discussion

Table 2. Experimental output of Plain DPHE:

DESCRIPTION	WITHOUT FINS	FINNED PIPE
Heat transfer rate(Q)	1263.698 watts.	1580.409 watts.
LMTD	33.5827°C	29.5004°C
Overall heat transfer coefficient (U)	798.901 W/m^2.k	1137.419W/m^2.k
Effectiveness	0.405	0.505

Heat transferred coefficient for the triangular finned tube shows approximately 1.5 times the value of the traditional DPHE. Effectiveness increases as the volumetric flow rate increases. The effectiveness of the triangular fin varies from 0.405 in DPHE to 0.505 in triangular finned heat exchanger. The effectiveness increases due to the increment in the area of the heat transfer.

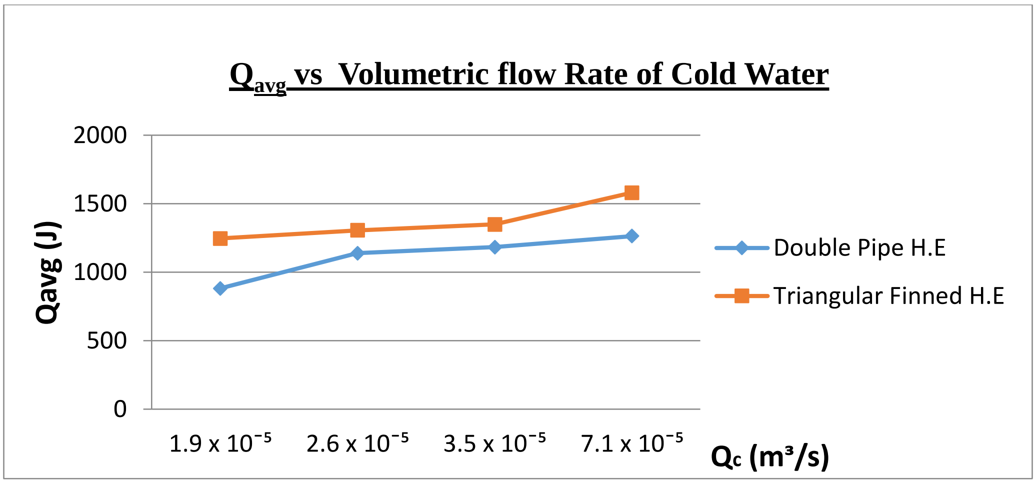

Figure 6. Average heat transferred Vs volumetric flow rate

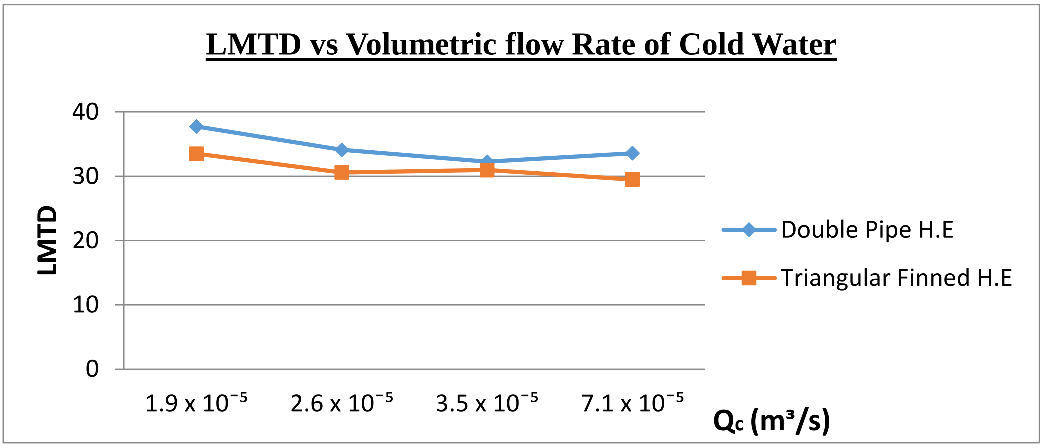

Figure 7. LMTD vs Volumetric flow Rate

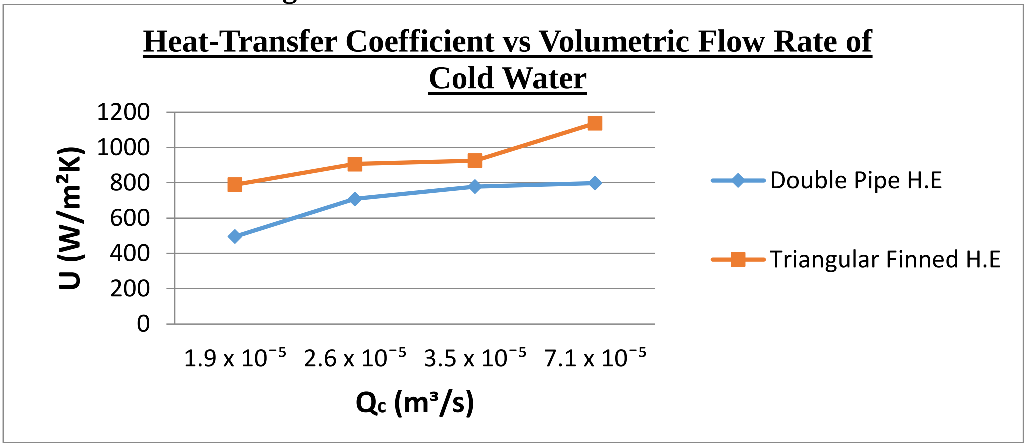

Figure 8. Heat-Transfer Coefficient vs Volumetric Flow Rate of Cold Water

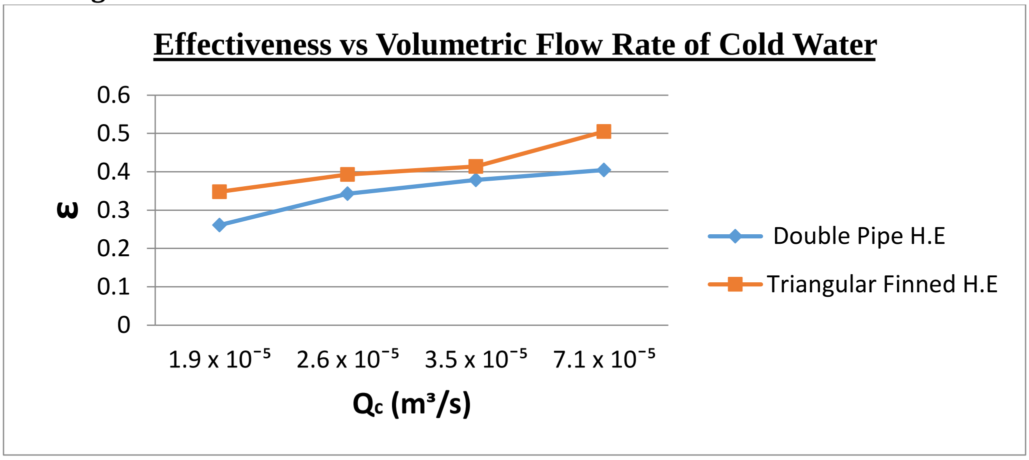

Figure 9. Effectiveness vs. Volumetric Flow Rate

The Reynolds number varies from 2000 to 4000 and the flow is laminar. The Reynolds number decreases as the volumetric flow rate of cold water increases. Triangular finned DPHE shows the decrease in the Reynolds number compared to the traditional DPHE. The decrease in the Reynolds number corresponds to the decrease in the Nusselt number.

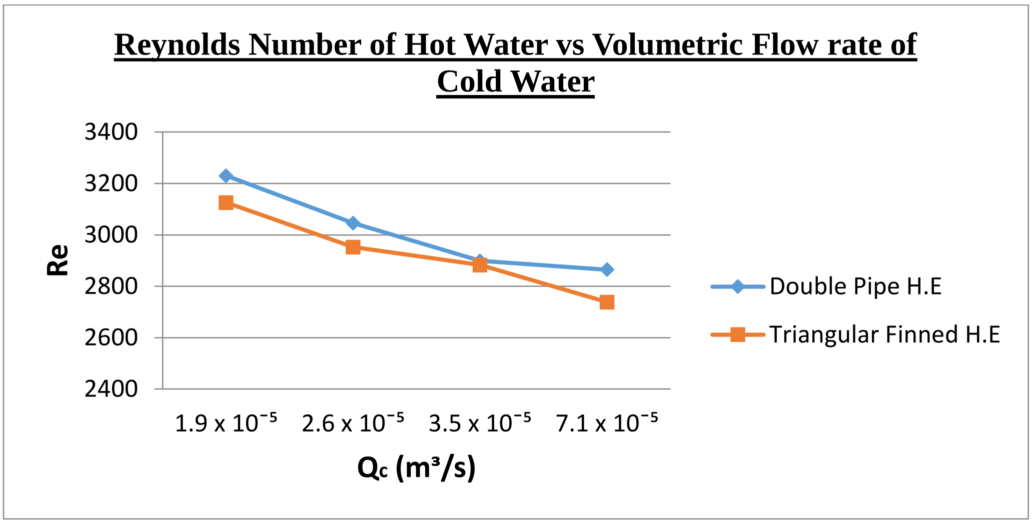

Figure 10. Reynolds number of hot water vs. Volumetric Flow Rate

5. Conclusion

Heat transfer through the plain type heat exchanger and the finned type heat exchanger are calculated in this work. It's observed that the heat transferred through the finned type heat exchanger was much greater than that of the plain type heat exchanger. The effectiveness of heat exchanger was increased from 0.405 to 0.505 which was approximately 25% increment in its effectiveness. This kind if heat exchangers are useful in the places where more heat should be extracted within a compact size. On using the copper material as the fins it helps to extract more heat within economical cost when compared to other materials. The heat transfer coefficient was also increased from 798.901 W/m^2K to 1138.401W/m^2K which was 1.5 times increase from the value obtained from plain type heat exchanger.

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