Heat Transfer Studies of Corrugated Plate Heat Exchanger using Oil

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Abstract - *Corrugated plate heat exchangers are more efficient in both heat transfer and efficiency when compared to standard smooth tube heat exchangers. In the present experiment three different angles (30^0, 40^0, 50^0) of corrugated plate heat exchangers with a channel spacing of 15 mm, length of 30 cm and width of 10 cm are considered to investigate the heat transfer studies. As a heat transfer medium, an oil was taken as hot fluid and water was taken as cold fluid. The heat transfer analysis was conducted on the corrugated plate heat exchangers to find the behavior of heat exchanger using oil and water. This was done by comparing the results of heat transfer coefficients. The outcome of this study will give the overview of corrugated plate heat exchanger for oil.*

Key Words: Corrugate plate heat exchanger, corrugation angle, oil, heat transfer coefficient.

1. INTRODUCTION

In large scale industries heat exchangers are commonly used for both heating and cooling purposes. Depending on the type of fluid and many other properties like temperature, viscosity, pressures etc., the size and shape of the heat exchanger is selected. Heat exchangers are commonly used in most of the industries like waste water treatment, Refrigeration, wine and beer making, petroleum refinery etc., because of its advantages like self-cleaning, easy maintenance. There are many types of heat exchangers like shell and tube, chevron type, gasketed type, corrugated type. Each type has its own advantages and corrugated plate is the one which is proved to be better because of its large surface area which increases heat transfer coefficient. Even at low Reynolds number highly turbulent flow regimes are introduced because of these corrugations.

B. Sreedhara Rao et. al., [1] conducted experimental studies on pressure drop in a sinusoidal plate heat exchanger considering the effect of corrugation angle. A corrugated plate Heat Exchanger fabricated with stainless steel sheets having thickness of 1mm, channel clearance of 5mm and length 30mm. By considering water as test fluid experiment is done with three such plates of different angles (30^0, 40^0, 50^0).It is observed that with the increase in corrugation angle there is increase in pressure drop of fluid which decreases friction factor. Heggs et al. [2] done experiment calculate heat transfer coefficient in corrugated channels at angles 30^0, 45^0, 60^0 and 90^0 by developing electrochemical mass transfer techniques. From the analysis of mass transfer coefficient, it is revealed that pure laminar flow will not occur in the range of 150 to 11500 of Reynolds number. Nema and Pandey [3] considered flow of water and air passing in alternate corrugated ducts to determine heat transfer characteristics. A test section of three similar corrugated channels with an angle of 300with cold air flowing in the middle one and hot water equally divided in the adjacent channels. For air and water various correlations of Nusselt number are obtained. B. Sreedhara Rao et.al., [4] conducted experiments to investigate heat transfer studies in plate heat exchanger with corrugation angles 30^0, 40^0, 50^0. Water and Glycerol (40%, 50% and 60%) are taken as test fluid and water as hot fluid. From the results calculated with the help of temperatures noted it is observed that with the increase in corrugation angle Nusselt number and heat transfer rate increased along with Reynolds number. Liombas et al [5] studied theoretically the gas-liquid two phase flow in range of Reynolds number and it is drawn from the experiments that flow exhibits basics of turbulent flow for a very low value of Reynolds number like 400.

From the above literature it can be seen that, there are limited studies available on the corrugated plate heat exchangers using oil as a fluid. Thus in this study, the heat transfer study was conducted to analyze the heat transfer rate by means of heat transfer coefficient of a corrugated plate heat exchanger using oil. Also, the study was conducted for different corrugation angle and compared with the flat plate heat exchanger.

2. METHODOLOGY

The experimental setup which is used for conducting experiment is as shown in the figure:1. It consists of hot water tank, test fluid tank, rotameter, test box, digital temperature indicator and manometer. Each test box is made up of three corrugated plates of sinusoidal shape which are welded together to form a horizontal channel. Three different test boxes of 15*10 spacing are considered to conduct experiment with three different angles of $30^{0,}$ 40^0, 50^0. To measure the pressure drop of the test fluid used a manometer is used and to control the flows of both hot water and test fluid rotameters are used. The dimensions of the corrugated heat exchanger used in test box are given in table :1

Table:1 Dimensions of PHE

Sl.No.	Specification	Dimension
1	Length of each plate	30cm
2	Width of each plate	10cm
3	Plate spacing	15cm
4	Corrugation Angle	$30^0, 40^0, 50^0$

2.1. MATERIALS USED:

The test fluid considered here is the Sunflower Oil. Its properties are tabulated in the table:2 and Water is used as hot fluid.

Table:2 Sunflower oil properties

Sl.No	Properties	Value
1	Density (Kg/M^3)	918.8
2	Viscosity (Ns/M^2)	0.004194
3	Thermal Conductivity, (W/M-K)	0.168
4	Specific Heat, (Kj/Kg-K)	1833

2.2. EXPERIMENTAL PROCEDURE

The experiment was carried out in the corrugated plate heat exchanger having 10mm channel spacing with angles 30^0, 40^0 and 50^0. Sunflower oil with viscosity 0.004194 Ns/M^2 is taken as test fluid at 35^0c. Water is taken as hot fluid at $70^0$and constant flow rate is maintained throughout the experiment. At each experimental reading, the wall temperatures of the corrugated plate were noted through digital temperature indicator where thermocouples are welded at seven different locations as well as inlet and outlet temperatures of the fluid are also noted. The test fluid is passed through the bottom channel at different flow rates varying from 0.5 to 6 lpm with the help of rotameter. Along with the seven thermocouples inserted in the middle plate, four more thermocouples are inserted to measure the hot and cold fluid inlet and outlet temperatures with the help of digital temperature indicator having an accuracy of 0.1^0c.At each flow rate starting from 0.5, the inlet and outlet temperatures and temperatures of the middle plate are noted from the digital indicator after it shows a constant value. Flow rate is varied with an increase of 0.25 to the previous flow rate. For all the heat transfer studies the inside film heat transfer coefficient (h_i) is calculated by making an energy balance with log mean temperature difference (LMTD).

3. DATA ANALYSIS

The effect of Reynolds number on Nusselt number is more significant than that of any other parameters [9].The arithmetic mean temperature of wall measured at seven different locations is $T_{w,\ avg}$, using this temperature the log mean temperature difference (LMTD) is calculated using equation (1).

$$LMTD = \frac{(T_{avg}-T_{c,in})-(T_{avg}-T_{c,out})}{\ln\frac{T_{avg}-T_{c,in}}{T_{avg}-T_{c,out}}} \quad (1)$$

The rate of heat transfer is calculated using equation (2) applied for cold fluid (test fluid)

$$Q = MFR \times C_p \times \Delta T_{cold} \quad (2)$$

The average heat transfer coefficient is calculated using equation (3)

$$Q = hA(LMTD) \quad (3)$$

Where $T_{c,in}$ and $T_{c,\ out}$ are inlet and outlet temperatures of cold fluid (test fluid) and MFR is mass flow rate of water in kg/s. C_p is specific heat capacity of water in KJ/Kgk. All the temperatures are measured in °c.

Once heat transfer coefficient is known, the Nusselt number were calculated using equation (4)

$$Nu = \frac{hD_H}{k} \quad (4)$$

Where D_H is hydraulic diameter of channel and this was calculated by use of equation (5)

$$D_H = \frac{4A}{p} = \frac{2wx}{w+x} \quad (5)$$

K is thermal conductivity of water in KW/m^2k.

4. RESULTS AND DISCUSSION

In this section, the performance of corrugated heat exchanger is studied against the Reynolds number. Fig. 1 to 4 shows the heat transfer versus the Reynolds number for flat plate, 30^0, 40^0 and 50^0 corrugation angles. It can be seen from all the figures that the heat transfer coefficient increases with increase in Reynolds number. But the magnitude of heat transfer coefficient is different for all the four cases. Thus the comparison study is required to compare the heat transfer rates (i. e. heat transfer coefficients).

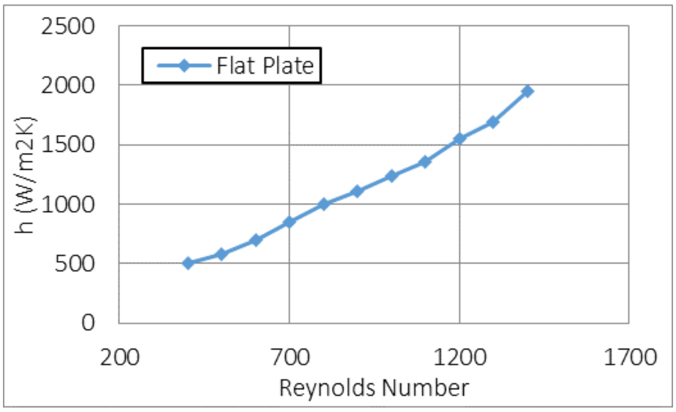

Fig. -1: Heat transfer coefficient Vs Reynolds number, with oil for flat plate.

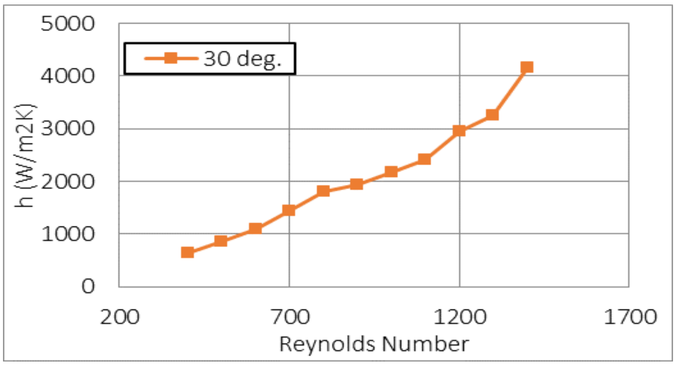

Fig -2: Heat transfer coefficient Vs Reynolds number, with oil for 30^0 corrugation angle

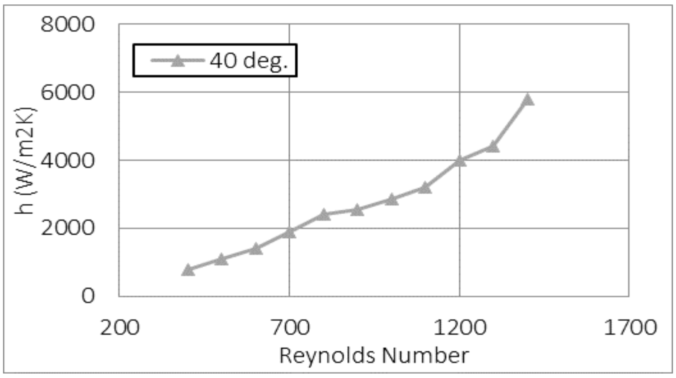

Fig -3: Heat transfer coefficient Vs Reynolds number, with oil for 40^0 corrugation angle

Therefore, the comparison analysis was done as shown in Fig. 5. As it can be seen from the figure that, the flat plate has very low magnitude of heat transfer coefficient. The results reveled that, the heat transfer coefficient for 50^0 corrugation angle are higher than other all cases. The increased in heat transfer coefficient is observed for flat plate, 30^0, 40^0 and 50^0. Our previous study on CFD analysis by Premkumar et. al [6] showed that the lower heat transfer coefficient for flat plat. The behavior of flat plate, 30^0, 40^0 and 50^0 was also similar to the results obtained from this study. Hence it can be concluded that, the experimental results obtained in this study are more realistic.

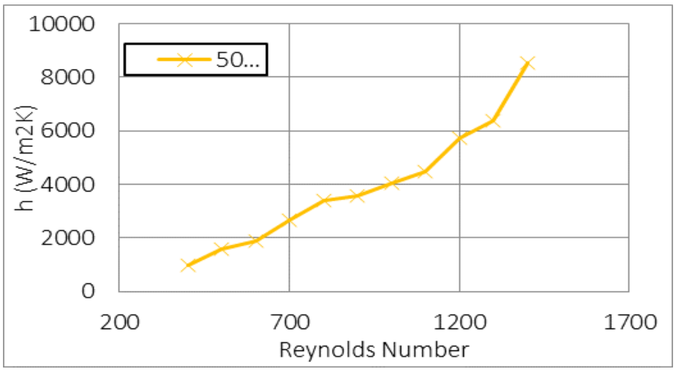

Fig -4: Heat transfer coefficient Vs Reynolds number, with oil for 50^0 corrugation angle.

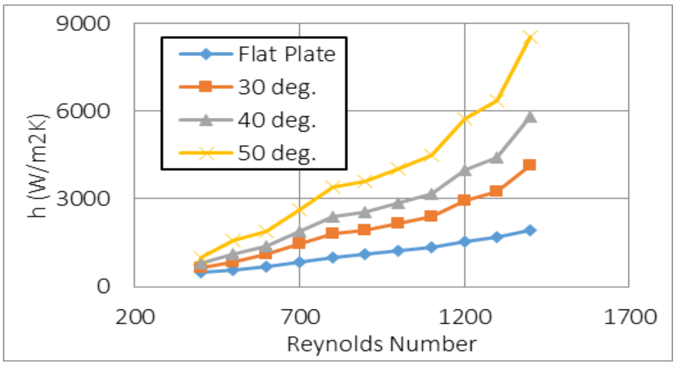

Fig -5: Heat transfer coefficient Vs Reynolds number, with oil for flat, 30^0, 40^0 and 50^0 corrugation angle

5. CONCLUSIONS

Experimentally determined heat transfer coefficient at different corrugation angles are compared with the results obtained for flat plate. It is observed that heat transfer coefficient is higher at a given Reynolds number for 50^0 corrugation angles when compared to 30^0 and 40^0 corrugation angles. The higher heat transfer rates are due to high turbulence that is created at high corrugation angles. It is also found that the percentage increase in heat transfer coefficient for water for 30^0 to 40^0 corrugation angle is 14%, for 40^0 to 50^0 corrugation angle is 30% and for 30^0 to 50^0 corrugation angle is 40%. At higher corrugation angles, higher heat transfer rates are achieved. It is also noticed that, when the oil is used as test fluid the heat transfer coefficient and nusselt number are increased to 10% when compared with the results of water as test fluid depending on results observed from previous papers.

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