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Studies on Nusselt Number for Corrugated Plate Heat Exchanger using Oil

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***Abstract*—** the corrugated plate heat exchangers were more efficient in both heat transfer and efficiency when compared to standard smooth tube heat exchangers. In the present experiment, three different angles (300, 400, 500) of corrugated plate heat exchangers with a channel spacing of 15 mm, length of 30 cm and width of 10 cm were considered to investigate the heat transfer studies. As a heat transfer medium, an oil was taken as hot fluid and water were taken as cold fluid. The heat transfer analysis was conducted on the corrugated plate heat exchangers to find the behaviour of a heat exchanger using oil and water. This was done by comparing the results of the Nusselt number. The outcome of this study will give the overview of corrugated plate heat exchanger for oil.

Keywords- *Corrugate plate heat exchanger, corrugation angle, oil, Nusselt number.*

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I. INTRODUCTION

In large scale industries, heat exchangers were 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 was selected. Heat exchangers were commonly used in most of the industries like wastewater treatment, Refrigeration, wine and beer making, petroleum refinery etc., because of its advantages like self-cleaning, easy maintenance. There were many types of heat exchangers like shell and tube, chevron type, gasket type, corrugated type. Each type has its advantages, and the corrugated plate was the one who was proved to be better because of its large surface area which increases the Nusselt number. Even at low Reynolds number, highly turbulent flow regimes were 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 a thickness of 1mm, channel clearance of 5mm and length 30mm. By considering water as fluid test experiment was done with three such plates of different angles (300, 400, 500).It was observed that with the increase in corrugation angle there was an increase in pressure drop of fluid which decreases friction factor. Heggs et al. [2] done experiment calculate the Nusselt number in corrugated channels at angles 300, 450, 600 and 900 by developing electrochemical mass transfer techniques. From the analysis of mass transfer coefficient, it was revealed that pure laminar flow will not occur in the range of 150 to 11500 of Reynolds number. Nema and Pandey [3] considered the 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 were obtained. B. Sreedhara Rao et al., [4] conducted experiments to investigate heat transfer studies in plate heat exchanger with corrugation angles 300, 400, 500. Water and Glycerol (40%, 50% and 60%) were taken as test fluid and water as the hot fluid. From the results calculated with the help of temperatures noted it was 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 the range of Reynolds number, and it was 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 were 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 using a Nusselt number 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.

II. METHODS AND METHODOLOGY

An experimental setup has been developed to investigate the heat transfer and pressure drop characteristics of the corrugated channels under different flow conditions as shown in Fig- 1. The custom designed experimental setup was manufactured

using stainless steel to prevent corrosion during operation. The primary component of the experimental setup was plate heat exchanger (PHE) unit. It was fabricated using three stainless steel plates welded in a well-specified manner to form two adjacent channels. The spacing provided for the top channel was 15 mm and that for the bottom test fluid channel was 5 mm, length of test section used was 300 mm and thickness of the thin middle plate was 1 mm. The experimental setup consists of auxiliary components like a cold fluid storage tank, hot fluid storage tank, U-tube manometer, rotameters, and centrifugal pumps. The plate heat exchanger unit, cold fluid tank, hot fluid tank and piping were thermally appropriately insulated to minimise heat loss. The experimental setup used here was shown in Figure 1. The setup was fitted with a U-tube manometer to measure the pressure changes, and a total of 13 PT-100 type temperature sensors have been used to measure the temperature at different locations of the test section. One each temperature sensor was fitted at the inlet and outlet of each channel and also at both storage tanks and remaining seven sensors was fitted on the top surface of the heat transfer plate (middle plate) which can be used to measure temperatures at different locations. The inputs from the thermocouples were fed to the digital temperature indicator (DTI) and desired temperature of hot and cold fluid inlet to the PHE has been controlled through temperature controller (on-off control mechanism). The flow pattern adopted here was countercurrent flow. Water was used as both hot fluid as well as cold fluid. Both the fluids were pumped using centrifugal pumps to maintain constant flowrates. The dimensions of the corrugated heat exchanger used in test box were given in the 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	300, 400, 500

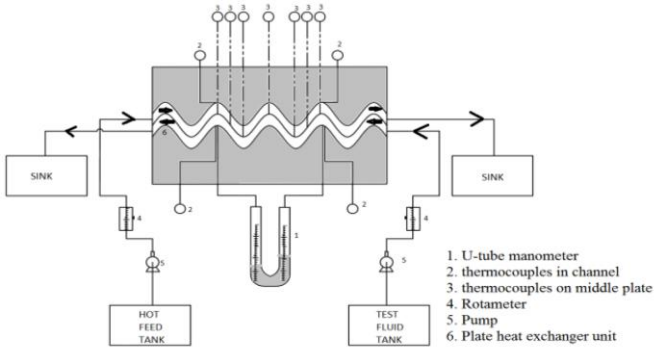

Fig. -1: Experimental setup of corrugated plate heat exchanger.

The test fluid considered here was the Sunflower Oil. Its properties were tabulated in the table - 2 and Water were used as the 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

The experiment was carried out in the corrugated plate heat exchanger having 10mm channel spacing with angles 300, 400 and 500. Sunflower oil with viscosity 0.004194 Ns/M2 was taken as test fluid at 350c. Water was taken as hot fluid at 700and constant flow rate was maintained throughout the experiment. At each experimental reading, the wall temperatures of the corrugated plate were noted through digital temperature indicator where thermocouples were welded at seven different locations as well as inlet and outlet temperatures of the fluid were also noted. The test fluid was 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 were inserted to measure the hot and cold fluid inlet and outlet temperatures with the help of digital temperature indicator having an accuracy of 0.10c. At each flow rate starting from 0.5, the inlet and outlet temperatures and temperatures of the middle plate were noted from the digital indicator after it shows a constant value. The flow rate was varied with an increase of 0.25 to the previous flow rate. For all the heat transfer studies the inside film Nusselt number (hi) was calculated by making an energy balance with log mean temperature difference (LMTD).

III. RESULTS AND DISCUSSION

In this section, the performance of corrugated heat exchanger was studied against the Reynolds number. Fig. 1 to 4 shows the Nusselt number versus the Reynolds number for flat plate, 300, 400 and 500 corrugation angles. It can be seen from all the figures that the Nusselt number increases with increase in Reynolds number. However, the magnitude of a Nusselt number was different for all the four cases. Thus the comparison study was required to compare the heat transfer rates (i. e. Nusselt numbers).

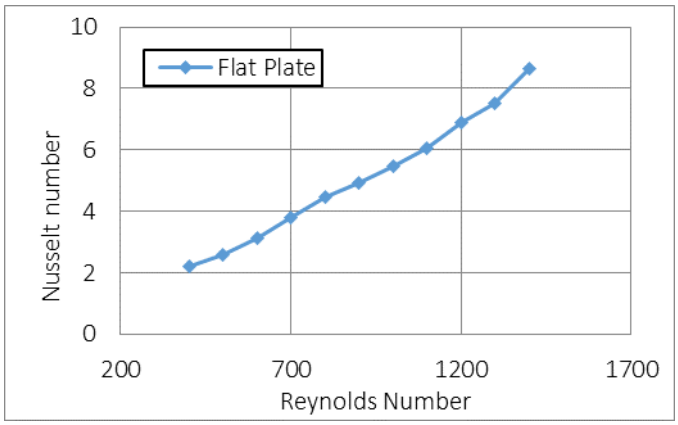

Fig. -1: Nusselt number Vs Reynolds number, with oil for a flat plate.

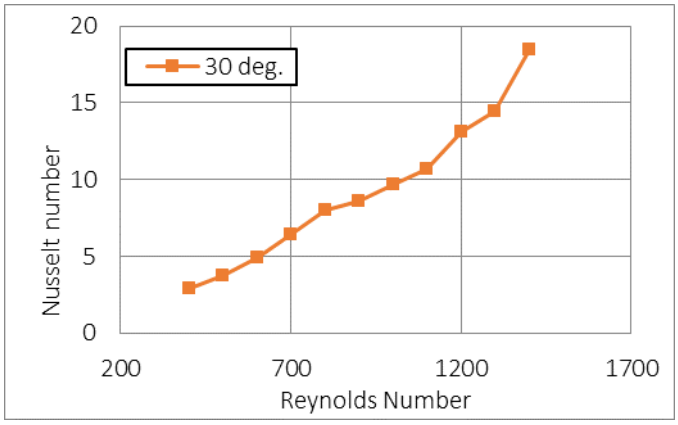

Fig -2: Nusselt number Vs Reynolds number, with oil for 300 corrugation angle

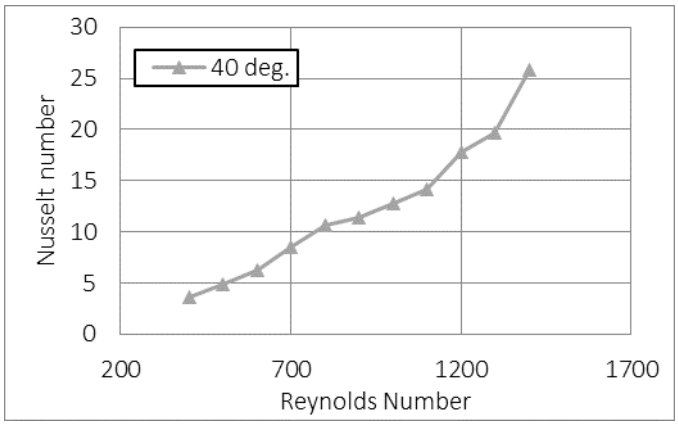

Fig -3: Nusselt number Vs Reynolds number, with oil for 400 corrugation angle

Therefore, the comparison analysis was done as shown in Fig. 5. As it can be seen from the figure that, the flat plate has a very low magnitude of the Nusselt number. The results revelled that, the Nusselt number for 500 corrugation angle was higher than other all cases. The increased in Nusselt number was observed for flat plate, 300, 400 and 500. Our previous study on CFD analysis by Premkumar et al. [6] showed that the lower Nusselt number for flat plat. The behaviour of a flat plate, 300, 400 and 500 was also similar to the results obtained from this study. Hence it can be concluded that the experimental results obtained in this study were more realistic.

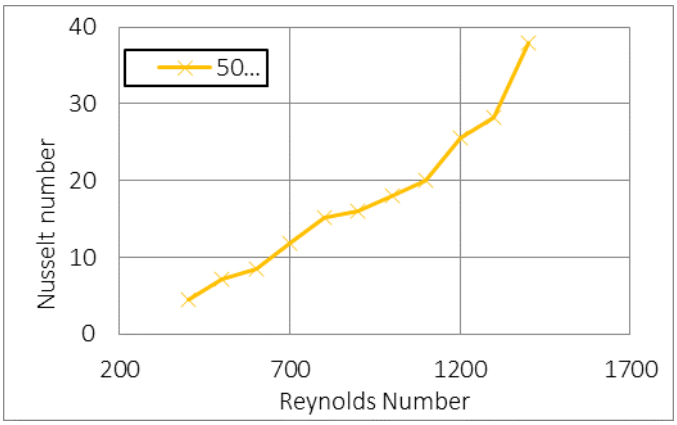

Fig -4: Nusselt number Vs Reynolds number, with oil for 500 corrugation angle.

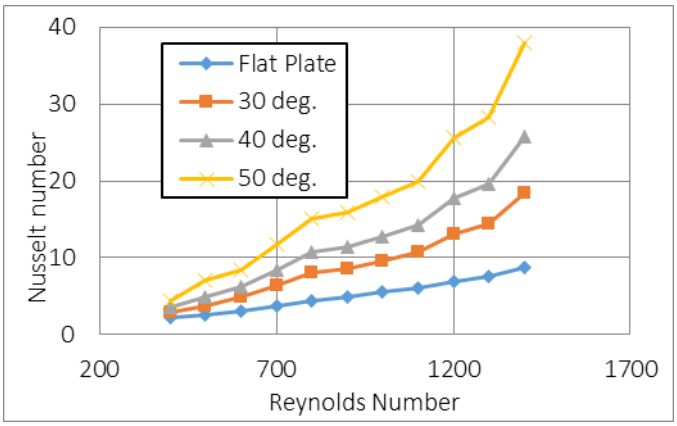

Fig -5: Nusselt number Vs Reynolds number, with oil for flat, 300, 400 and 500 corrugation angle

IV. CONCLUSIONS

The experimentally determined Nusselt number at different corrugation angles were compared with the results obtained for a flat plate. It was observed that Nusselt number was higher at a given Reynolds number for 500 corrugation angles when compared to 300 and 400 corrugation angles. The higher heat transfer rates were due to high turbulence that was created at high corrugation angles. It was also found that the percentage increase in Nusselt number for water for 300 to 400 corrugation angle was 14%, for 400 to 500 corrugation angle was 30% and for 300 to 500 corrugation angle was 40%. At higher corrugation angles, higher heat transfer rates were achieved. It was also noticed that when the oil was used as test fluid, the Nusselt number and Nusselt number were increased to 10%

when compared with the results of water as test fluid depending on results observed from previous papers.

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