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# HEAT TRANSFER ANALYSIS BY SIMULATION ON CORRUGATED PLATE HEAT EXCHANGER

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**ABSTRACT:** The flow field inside the heat exchanger is associated with maximum heat transfer rate with minimum pressure drop.In this investigations are carried out on Corrugated PHE.Plate heat exchanger is a device which is used for many applications such as dairy industries, pharmaceutical industries because of their easy cleaning and maintenance process.During the recent few decades.The use of (PHE) is now spread in to various industries like paper, Diary industries, Pharmaceutical industries mainly for the process of heating or cooling applications. The reason behind the wide spread of plate heat exchanger in today is because of easy maintenance and cleaning. But it creates higherturbulence when compared to the shell and tube heat exchanger. In present studies corrugated plate heat exchanger is considered because of their larger heat transfer surface area and it creates more turbulence when compared to the flat plate heat exchangers.

As the fluid moves through a corrugated Plate heat exchanger, the direction of flow along the length changes continuously, this will shows the higher heat transfer coefficient when compared the flat PHE of similar dimensions. And also the results shows that the heat transfer coefficient is higher for a given Reynolds number ($55^0$) corrugation angle when compared to ($35^0$)and ($45^0$) corrugation angles. This is due tothe higher turbulence of the fluid generated for the higher corrugation angles. By using computational fluid dynamics the velocity and temperature profiles inside the heat exchanger has been developed using the software. The temperature profiles by simulated and their profiles are presented in the figures.

KEYWORDS: Corrugated Plates,Reyondls Number, Corrugation Angle with ($35^0$,$45^0$,$55^0$) degrees, Nusseltnumber , CFD, ANSYS.

## 1. INTRODUCTION

Recovery of heat from process fluids through heat exchangers is receiving increasingattention by the designers of modern chemical plants. Several types of heat exchangers are now available for wide variety of applications involving high heat transfer performance. Plate Heat Exchangers (PHEs) belong to this category. These are capable of recovering heat efficiency at low temperature differentials (as low as $1^0$C) mainly because of high turbulence in such units even at low velocities.

Flat corrugated or embossed standardized plates, arranged to form a package, resultsin a compact form of a heat having less weight, requiring less space and providing high heat transfer coefficients. The concept of the

PHE was introduced during the later half of the nineteenth century. Dr. Richard Seligman, founder of APV Group, introduced the first commercially feasible PHE in 1923. The initial designs were similar to plate and frame filter presses and employed cast gunmetal plates. Plates pressed in thin gauge stainless steel were introduced in 1993primarily for heating applications in dairy, food processing and brewing industries Due to the ease of cleaning, low liquid holdup and availability to meet the hygienic demand, the PHE has become invaluable in the processing of heat sensitive materials in these industries. The initial designs were limited to operating temperatures up to100$^{0}$c and pressure of about 0.3MPa.

## 2. REVIEW OF LITERATURE

Bassiouny M.K. and Martin H. (1984) made an analytical study to calculate the actualvelocity and pressure distribution in both the intake and exhaust conduits of PHE, the flow distribution in the channels between the plates and the total pressure drop. The analysis showed that there is a general characteristic parameter for all the PHEs which determine the flow behavior.

Nishimura Tatsuo et al. (1990) investigated flow patterns and mass transfercharacteristics in symmetrical two-dimensional wavy-walled channels at moderate Reynolds number ranging from 20 to 300. They also considered two different wall shapes: sinusoidal wall and arc-shaped wall. Two wall shapes were quite different in the development from laminar to transitional flow. In particular, a new flow structure consisting of a regular threedimensionalflow was observed at a low Reynolds number for the arc-shaped wall. This phenomenon lead to an earlier transition of turbulence as compared with the sinusoidal wall. Mass transfer characteristics of wavy-walled channels differ from those of a straight-walled channel when flow separation occurred. The arc-shaped wall had a larger mass transfer rate than the sinusoidal wall because of an earlier transition of turbulence.

Roetzel W. et al. (1994) evaluated thermal parameters of plate type heat exchangersusing temperature oscillation technique by experimental methods. They presentedmathematical model for correcting the thermal penetration effect in plate edgings and thick end plates. Finally, they suggested a series of development to make the method more suitable for plate type heat exchangers.

Blomerius H. and Mitra N.K. (2000) investigated flow field and heat transfer incorrugated ducts from the numerical solutions of the Navier-Stokes equations in the laminar to transitional range of Reynolds numbers (600 - 2000). First, the geometric parameters for the best ratio of heat transfer to pressure drop had been determined for two-dimensional channels. Then for these parameters, flow structure and heat transfer had been investigated for three-dimensional (3-D) channels consisting of corrugated plates. The angles 450 and 900 between the corrugations and the main stream direction were considered. A performance evaluation criterion identifies the 3-D corrugated plate at 450 with the best ratio between heat transfer and pressure drop.

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# 3. CFD ANALYSIS

## 3.1 CFD ANALYSIS

CFD is useful for studying fluid flow, heat transfer, chemical reactions etc.., by solving mathematical equations. These equations are solved using numerical techniques. It can be effectively used for designing a heat exchanger system from scratch as well as in troubleshooting/optimization. CFD employs a very simple principle of resolving the entire system in small cells or grids and applying governing equations on these discrete elements to find numerical solutions regarding pressure distribution, temperature gradients, flow parameters and the like in a shorter time at a lower cost because of reduced required experimental work.

| PARAMETER | DIMENSIONS |
|---|---|
| Length | 40cm |
| Width | 15cm |
| Test fluid channel spacing | 0.5cm |
| Corrugation angles | $35^0$,$45^0$,$55^0$ |

**Table 3.1- Dimensions of the PHE**

The software package used for the entire numerical analysis is ANSYS CFD Package. The geometry was made using Design modeler tool present in ANSYS Workbench. A minimum value of -15, a maximum value of 15 was provided x axis constraints. Spline tool was used to generate a smooth line through the points associated with the respective angles. Once the line is obtained a 2-dimensional framework is obtained by duplicating the line at the desired intervals. This 2- dimensional framework is converted to a 3- dimensional body with the help of extrude tool. The 3-dimensional geometries created have been shown in the Figs.3.1 to 3.3.

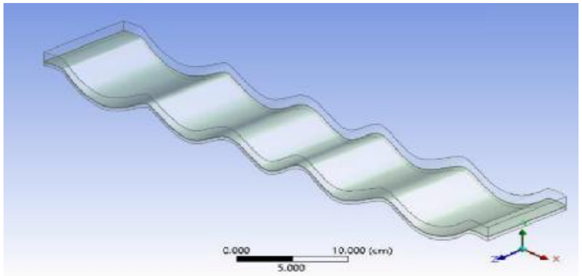

**Figure- 3.1 Geometry created for $35^0$ corrugated channel**

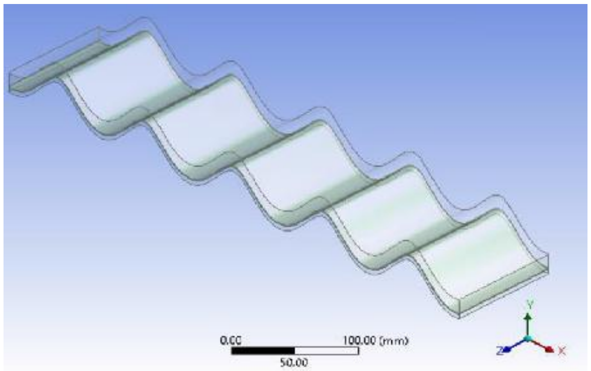

**Figure- 3.2 Geometry created for $45^0$ corrugated channel**

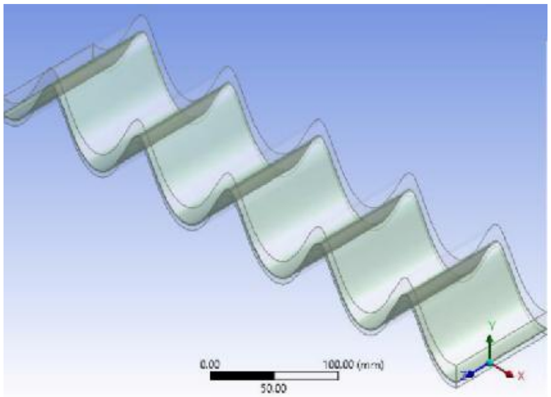

**Figure- 3.3 Geometry created for $55^0$ corrugated channel**

| Parameters | $35^0$ | $45^0$ | $55^0$ |
|---|---|---|---|
| Elements | 821762 | 823718 | 813720 |
| Orthogonality | 0.88 | 0.81 | 0.80 |
| Skewness | 0.30 | 0.40 | 0.52 |
| Mesh mode | CFD | CFD | CFD |

**Table- 3.2 Mesh Parameters**

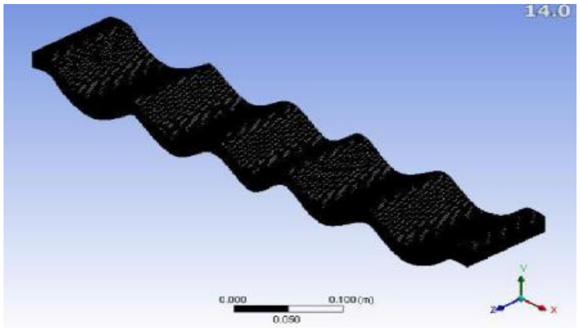

**Figure 3.4 Mesh Generated for $35^0$Corrugated channel**

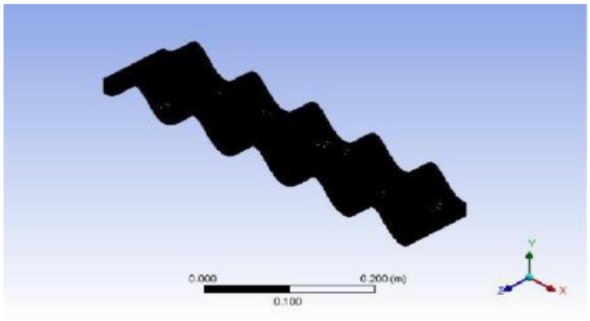

**Figure- 3.5 Mesh Generated for $45^0$Corrugated channel**

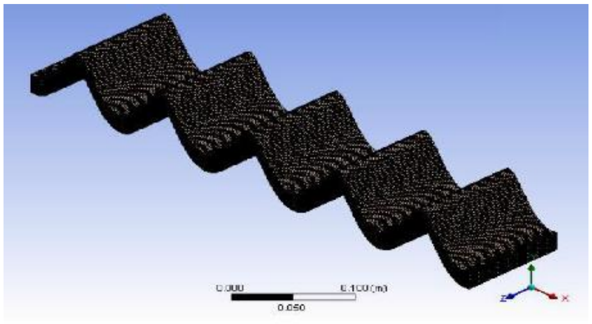

**Figure- 3.6 Mesh Generated of $55^0$ Corrugated channel**

## 3.2 Input Conditions to the Model

The governing equations were solved using CFD package FLUENT 14.5 with the following assumptions:

i. Being a small PHE, there is no mal-distribution of flow.

ii. Heat transfer surface assumed to be free from fouling. The table 5.3 shows the settings which have been used for model solution in fluent. It is assumed that the flow is uniformly distributed at the entry. Most of the choices are based on previous studies on PHEs.

| Function | Specifications |
|---|---|
| General | Default: Pressure based Steady state. |
| Viscous | Laminar: Laminar |
| Material | Fluid : Water- liquid , Solid : Steel from fluent data base. |
| Cell Zone conditions | Hot fluid : Water.<br>Cold fluid : Water.<br>plate : Stainless Steel. |
| Boundary conditions<br>Hot inlet<br>Cold inlet | Velocity Magnitude: 0.0555 m/sec, temperature: $64.6^0$C(One of the values used) and Other settings are default Velocity.<br>Magnitude: 0.03333m/sec, temperature: $53^0$ C (One of the values used) and Other settings are default |
| Operating Conditions | Enable gravity option with Y- component value -9.81 m/sec (this settings are made because convection depends on gravity). |
| Solution Initialization | Hybrid initialization, Initial values:<br>Gaugepressure:0Pa,X&Y velocity: 0m/sec,<br>Turbulent Kineticenergy: $1m^2 /s^2$ Turbulent dissipation rate: $1\ m^2 /s.^3$ |

**Table- 3.3Simulation Settings**

## 3.3 Temperature Profiles

The Temperature profiles for Water, 25% Glycerol solution, 35% Glycerol solution and for $35^0$, $45^0$, and $55^0$ corrugation angles are shown in Figs. 3.7 to 3.15

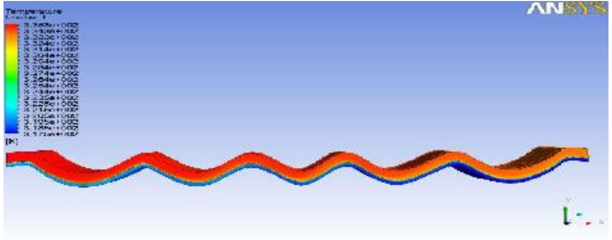

**Figure- 3.7 Temperature contours of $35^0$ corrugation angle for Water (3.25lpm)**

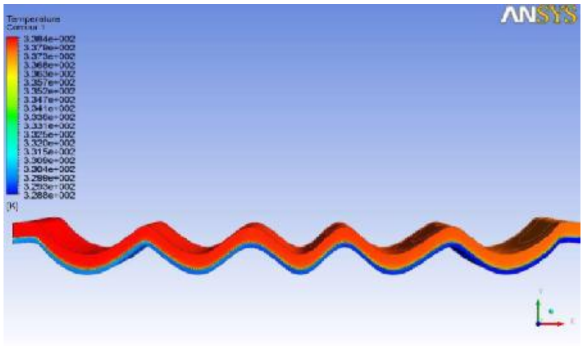

**Figure- 3.8 Temperature contours of 35$^0$ corrugation angle for 25% Glycerol soln.(3.25lpm)**

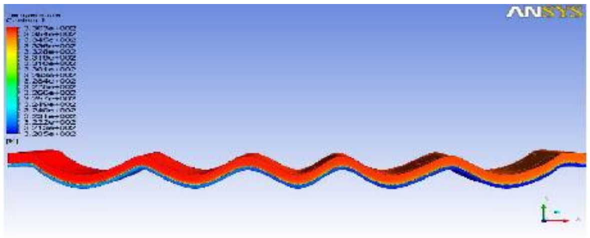

**Figure 3.9 Temperature contours of 35$^0$ corrugation angle for 35% Glycerol soln.(3.25lpm)**

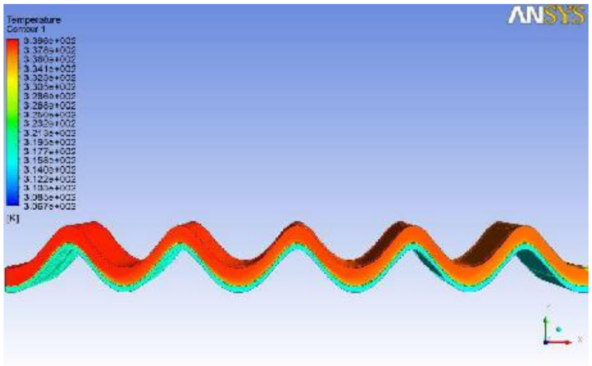

**Figure- 3.10 Temperature contours of 45$^0$ corrugation angle for (4 lpm)**

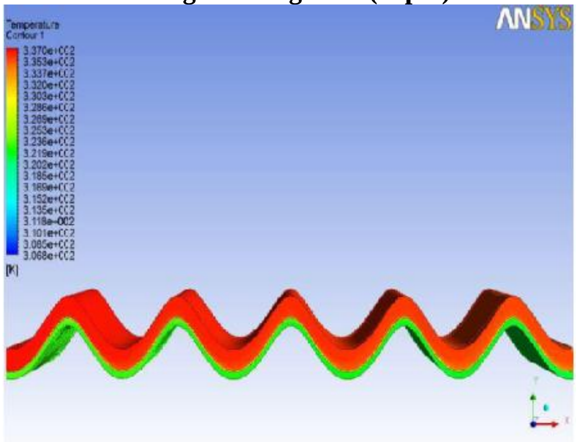

**Figure- 3.11Temperature contours of 45$^0$ corrugation angle for 25% Glycerol soln. (4 lpm)**

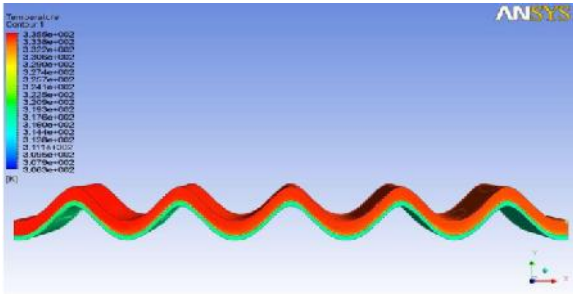

**Figure 3.12 Temperature contours of 45$^0$corrugation angle for 35% Glycerol soln. (4lpm)**

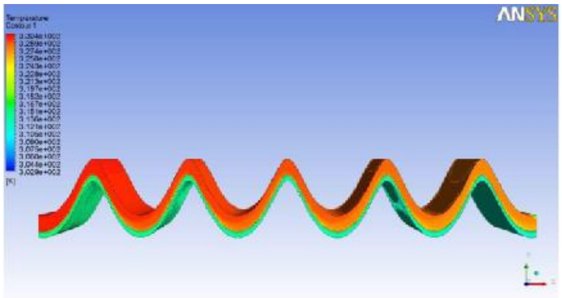

**Figure- 3.13 Temperature contours of 55$^0$ corrugation angle for Water (4 lpm)**

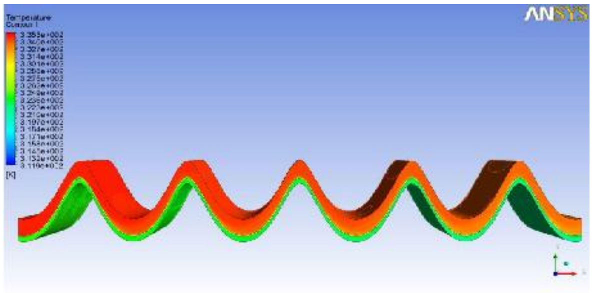

**Figure- 3.14Temperature contours of 55$^0$ corrugation angle for 25% Glycerol soln. (4 lpm)**

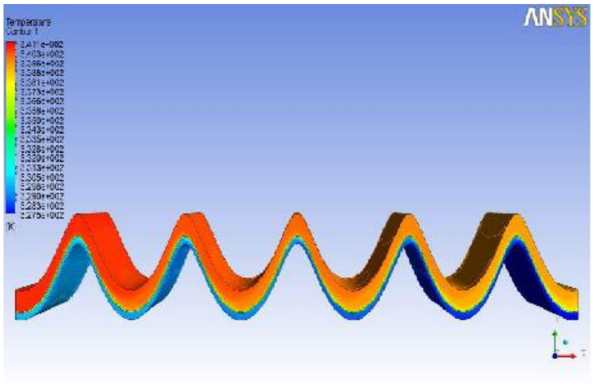

**Figure- 3.15Temperature contours of 55$^0$ corrugation angle for 35% Glycerol soln. (4 lpm)**

## 4. RESULTS

Graphs are Drawn for Re and Nu for all the conditions by using the Lab fit software.

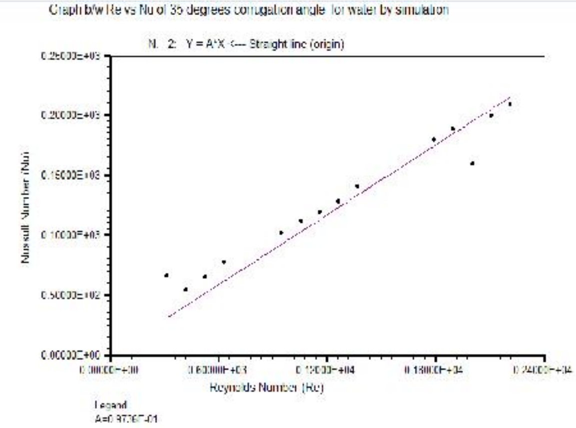

Figure-4.1 Graph b/w Re and Nu for 35 degrees corrugation angle for water

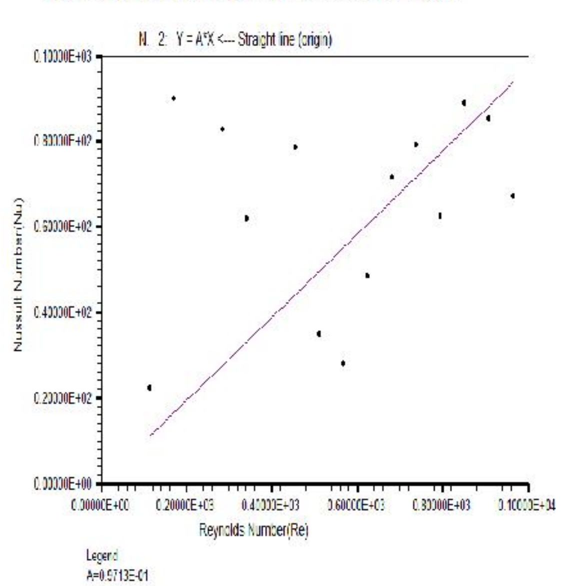

Figure- 4.2 Graph b/w Re and Nu for 35 degrees corrugation angle for 25 % Glycerol by simulation

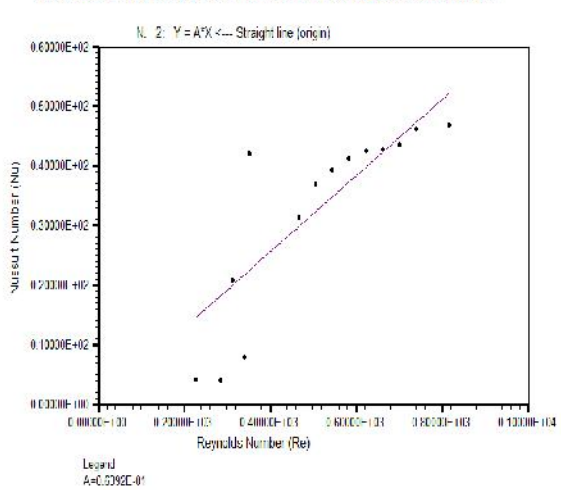

Figure- 4.3 Graph b/w Re and Nu for 35 degrees corrugation angle for 35 % Glycerol by simulation

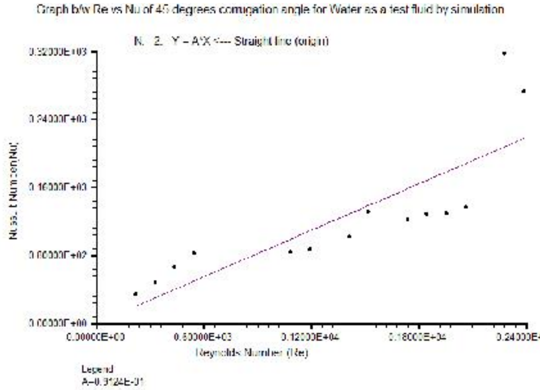

Figure-4.4 Graph b/w Re and Nu for 45 degrees corrugation angle for water

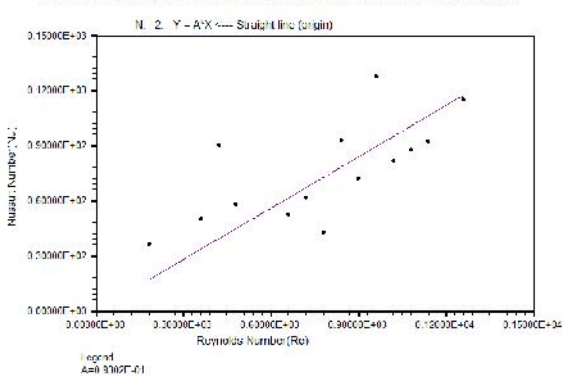

Figure-4.5 Graph b/w Re and Nu for 45 degrees corrugation angle for 25 % Glycerol by simulation

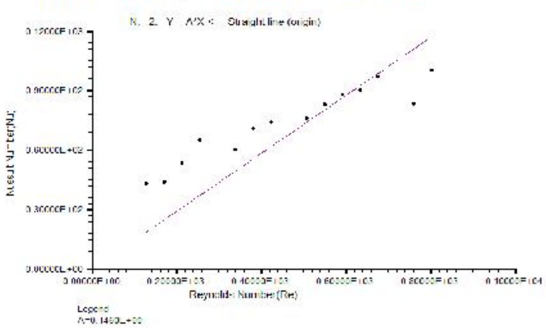

Figure-4.6 Graph b/w Re and Nu for 45 degrees corrugation angle for 35 % Glycerol by simulation

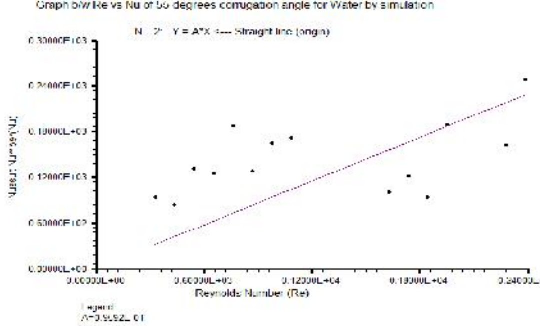

Figure -4.7 Graph b/w Re and Nu for 55 degrees corrugation angle for water

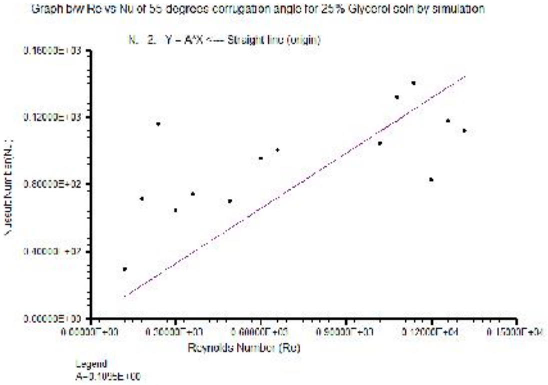

**Figure-4.8 Graph b/w Re and Nu for 55 degrees corrugation angle for 25 % Glycerol by simulation**

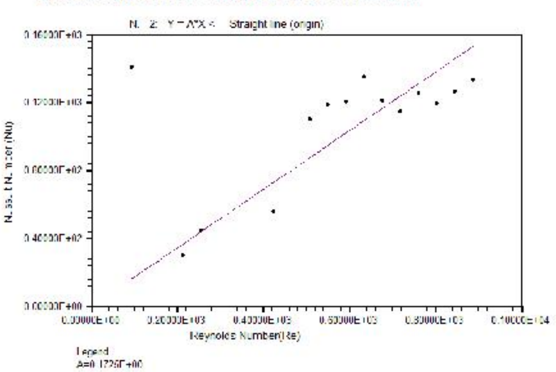

**Figure -4.9 Graph b/w Re and Nu for 55 degrees corrugation angle for 35 % Glycerol by simulation**

## CONCLUSIONS

From the heat transfer studies carried out in the corrugated PHE, the following conclusions are made:

Both heat transfer coefficient and Nusselt number increases with increase in corrugation angle for a particular fluid. It is also inferred from investigation that from $35^0$to $45^0$ corrugation angle there is an increase in heat transfer rates by 15%, for $45^0$to $55^0$ corrugation angle there is a 30% increase in heat transfer rates and for $35^0$to $55^0$ corrugation angle the increase is as high as 50% for all fluids. It can be concluded that with further increase in corrugation angle, the rates of heat

transfer that can be achieved will be much higher.

As the corrugation angle increases, there will be significant improvement in the Nusseltnumber or heat transfer rates for high viscous fluids compared to low viscous fluids.

Therefore a low viscous fluid at higher corrugation angle will result in same rates of heat transfer compared to high viscous fluids for lower corrugation angles. This aspect can be taken into consideration in choosing the type of corrugated PHE in design.

This is evident from the simulated values goodagreement. This model can be used for the simulation of rates of heat transfer for similar type of corrugated PHE by the future investigations.

## REFERENCES

[1]Abdulbasit G. A. Abdulsayid, “εodeling of fluid flow in 2d triangular, sinusoidal, and squarecorrugatedchannels”World Academy of Science, Engineering and Technology 71, 2012.

[2]B. sreedharrao Simulation studies on wavy and chevron-corrugated plate heat exchangers using fluent”, International Journal of Mechanical Engineering (IJME), ISSN (Online): 2319-2259-Vol- 2, Issue-5, Nov-2013.

[3]B.sreedharrao “Experimental studies on heat transfer of viscous fluids in corrugated plate heatexchangers: Effect of corrugation angle”, Communicated to Experimental Thermal andFluid Science, ELSEVIER Publication.

[4]B.sreedharrao “Pressure drop studies of Newtonian fluids in corrugated plate heat exchangers”,International Journal of Mechanical Engineering and Applications, Volume 2(3): pp. 38-42, May 2014.

[5] Vijaya S. Gullapalli, BengtSunden, “CFD simulation of heat transfer and pressure drop incompact brazed plate heat exchangers”, Heat Transfer Engineering, Volume 35, Issue4, pp. 358-366, 2014.

[6] Athanasios G. Kanaris, Aikaterini A. εouza, Spiros V. Paras, “Flow and heat transfer prediction in a corrugated plate heat exchanger using a CFD code”, Chemical Engineering Technol, Volume 29, No. 8, pp. 923-930, 2006.

[7] Haci Mehmet Sahin, Ali Riza Dal, EsrefBaysal, “3-D Numerical study on the correlationbetween variable inclined fin angles and thermal behavior in plate fin-tube heatexchanger”, Applied Thermal Engineering, Volume 37, Issues 11–12, pp. 1806–1816, Aug. 2007.

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