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REVIEW ON EFFECT OF CHEVRON ANGLE AND NUMERICAL INVESTIGATION OF DIMESIONLESS NUMBERS

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Abstract - Plate heat exchanger PHE) is type of heat exchanger in which heat transfer takes place between fluids through separating wall. The geometry of PHE is one of the most important factors of rate of heat transfer and pressure drop .corrugation of plate inhances heat transfer due to increasing the turbulence in flow. Now a day PHE is being used widely in heating application, food industry, chemical industry, refrigeration industry, marine application and fresh water generation system from sea water. The objective of this paper is to review the effect of chevron angles and numerical investigation of dimensionless numbers. Further we shall design the PHE by using the solid work design software with chevron angles 45◦, 61◦, 63◦, and 65◦ at constant dimensions. The rate of heat transfer coefficient, pressure drop dimensionless numbers like Nusselt, Prandtl and Reynolds numbers will be evaluated by using the Ansys simulation software.

Key Words: *plate heat exchanger, chevron angle, heat transfer coefficient, pressure drop.*

1 INTRODUCTION

A heat exchanger is device in which heat (enthalpy) is transfered from one fluid to another fluid. Plate heat exchanger (PHE) is recuperator or transfer type heat exchanger in which heat is transfered through the separating wall. PHE consist of a number of corrugated metal plates with corner portholes and gasket. The gasket prevents the leakage and mixing of the fluids. Fluids flow alternatively in different plate with counter flow. Plates are assembled between a fixed frame plate and movable pressure plate with help of nut and bolt. Due to high overall heat transfer coefficient (3 – 4 times as compare to shell and tube types), compactness, easy to removing and cleaning of plates it is used in different type of industries and plants like food and beverage , petrochemical, pharmaceutical, hydrocarbon processing, polymers etc.[1]

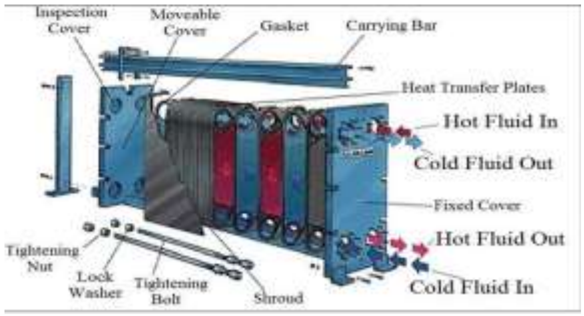
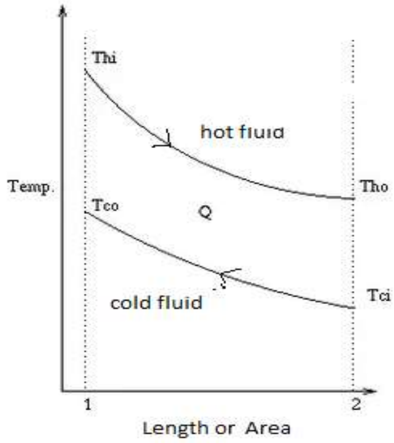


Figure 1: 1Various parts of plate heat exchanger [2]

THERMAL ANALYSIS

The rate of heat transfer is given by



$Q^* = UA\,(\Delta T)_m$ ....[1]

$= UA\,F\,(\Delta T_{lm})_{counterflow}$

$\Delta T_{lm} = (\Delta T_1 - \Delta T_2) \,/\, \ln(\Delta T_1 / \Delta T_2)$

$\Delta T_1 = T_{ho} - T_{ci}$

$\Delta T_2 = T_{hi} - T_{co}$

Where

U= overall heat transfer coefficient (w/m^{2}k)
A= heat transfer area (m^2)
F= correction factor
ΔT_{lm} = log mean temperature difference (k)
Q* = rate of heat transfer (w)

Overall heat transfer coefficient (U)

It refers to how fast heat is conducted over a series of medium. its depends on thermal property of material ,flow situation , and thickness of material .

$1/U = 1/h_i + \Delta x/k + 1/h_o + R_f$ [1]

Where

h_i = the heat transfer coefficient between the hot medium and the heat transfer surface (w/m^2 k)

h_o = the heat transfer coefficient between the heat transfer surface and cold medium(w/m ^2k)

Δx = thickness of heat transfer surface (m)

R_f = fouling factor (w /m k)

Dimensionless numbers and correlation

Nusselt number – it is the measure of energy transfer by convection occurring at the surface and defined as the ratio of heat transfer by convection to rate of heat transfer by conduction.

$Nu = hl/k_f$

Nu= f (Re, Pr) for forced convection

Prandtl number (Pr) – it provides a measure of relative effectiveness of momentum and energy transport by diffusion in velocity and thermal boundary layer respectively.

Reynolds number – it's represent the number where the boundary layer changes from laminar to turbulent flow and define as the ratio of inertia force to viscous force in the velocity boundary layer [1]

PRESSURE DROP

Pressure drop refers to loss of energy, when fluid flows from one section to another section. The loss of energy is generally two types major loss (due to friction between pipe wall and flowing fluid) and minor loss (due to fittings valves, bend, expansion and contraction of piping system). In PHE pressure drop occurs due to four components pressure drop in ports, pressure drop in connecting pipe, pressure drop in elevation and core of PHE. Higher the pressure drop means that more pumping power need to operator the system .So in design consideration pressure drop is most important factor and also limit the size of plate [1].

5. LITERATURE REVIEW

Khan T.S .et al. [3] presented their experiment for single phase flow (water to water) in commercial PHE for symmetric corrugation angle $30^0/30^0$, $60^0/60^0$ and mixed angle $30^0/60^0$ .The Reynolds number and Prandtl have been taken in range of 500 Re 2500 and 3.5 Pr 6.5 respectively during the experiment. After the experimental data a correlation to estimate Nusselt number as function of Reynolds number , Prandtl number and chevron angle has been proposed.

D.Premkumar.et al. [4] has optimized the corrugation angle for heat transfer performance of PHE. They have done thermal analysis and pressure drop calculation for corrugated angle 10◦ , 20◦, 30◦, 40◦, 50◦, 55◦, 60◦,and 65◦ with fixed channel spacing of 7.5mm .By using CFD analysis optimal corrugation angle which has high heat transfer to pressure drop ratio was 50

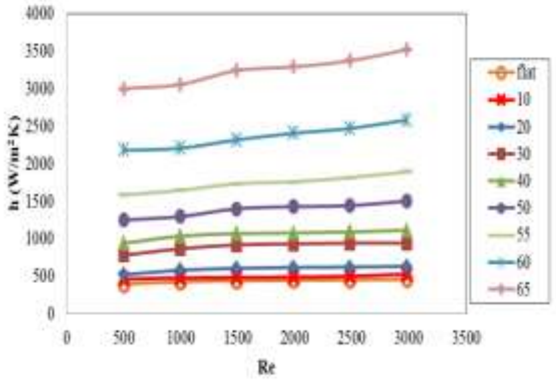


Figure 2 Comparison of heat transfer coefficient for different corrugation angles. [4]

R and M Selvam [5] performed experiment to study effect of various chevron angles using the R134Aas a refrigerant. They measured the condensation heat transfer coefficient and pressure drop in brazed plate heat exchanger with different chevron angles 45◦, 35◦ and 20◦. They took two condensation temperature of 20◦ and 30◦ in the range of mass flux of 14 – 34 kg/m^2s with heat flux of 4.7- 5.3 KW/m^2. From experimental data it has been found that both the heat transfer coefficient and pressure drop increased proportionally with mass flux and vapour quality and inversely with the condensation temperature and chevron angle.

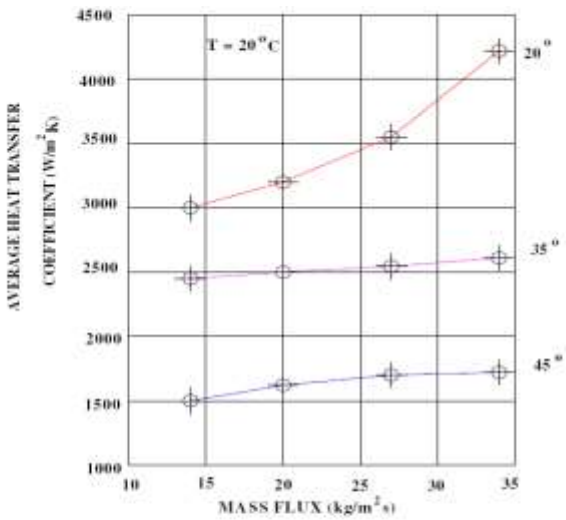


Figure 3 Geometrical characteristics of plate surface corrugation.[5]

Ayani and Saneil [6] have presented investigation of the effect of geometrical shape of PHE. They have compared heat transfer and pressure drop between rectangular and circular PHE employing numerical simulation with equivalent area .The conclusion of this project was the amount of heat transfer and pressure drop in rectangular plate more than circular plate .In this chevron angle, friction factor and flow condition had been considered .

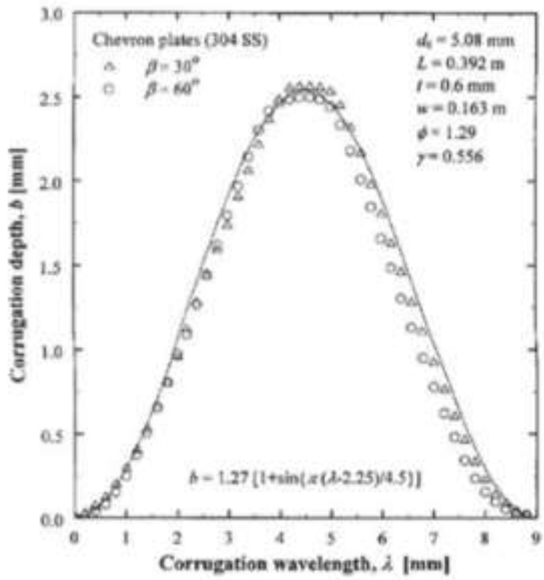


Figure 4 : Geometrical characteristics of plate surface corrugation.[6]

Jianchang Hunang [7] has presented investigation of PHE as refrigerant evapourator. They used 24 plates of same size but with different chevron angle combination of 28/28, 28/60 and 60/60. They performed two tests with the three unit single – phase performance tests test with water evapourator performance test with R134A and R507A.

K sreejith.et al. [8] has designed PHE with optimal cost. In this design they used 108 plates, area of exchanger 110.37 m^2 and calculated the overall heat transfer of PHE.

Durmus Aydm.et al. [9] has studied the effect of surface geometries of three different type of heat exchangers corrugated plate heat exchanger , flat PHE and Asteriks PHE .they investigated the heat transfer ,friction factor and energy loss. The experiment had been done for laminar flow with single phase in parallel and counter flow direction having Renolds number and Prandtl number in range of $500 \le Re \le 1000$ and $3 \le Pr \le 7$ respectively.

Kumbhare .B.Manoj and Dawande [10] performed experiment for water/water system to evaluate the performance of PHE under laminar and turbulent flow conditions. Based on experimental data they calculated the overall heat transfer coefficient, thermal properties of water (thermal conductivity, specific heat and density) at different temperature and linear correlation developed in polymath 5. During the experiment they varied the hot water temperature from 35 to80 by maintaining the temperature of cold water constant and Reynolds number from 178 to 1537.

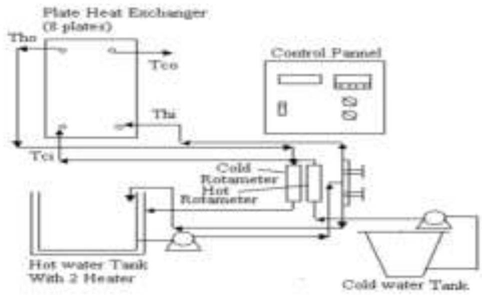


Figure 5 : Experimental setup [6]

Asadi and khoshkhoo[11] presented study on effect of chevron angle .they had evaluated the thermal- hydraulic performance in terms of the heat transfer coefficient ,friction factor and pressure drop. In this paper result shows that friction factor is rising with chevron angle and on the other hand at optimal value (chevron angle 60◦) friction factor had inverse relation with mass flow rate for both laminar and turbulent regime.

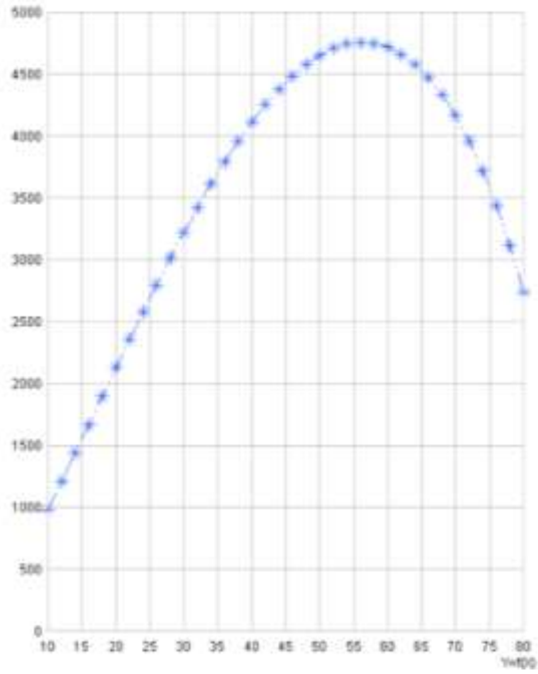


Figure 6: function of heat transfer coefficient versus mass flow rate [11]

Jinl.et.al [12] presented experiment on fresh water generation system from sea water by using PHE. The fresh water generator or desalinate had installed in ship to convert the sea water to fresh water using heat from the engines jacket. In this experiment they used the vacuum evaporator distiller which had been designed with a capacity of 1ton/day of fresh water and air inside the evaporation chamber evacuated to a near vacuum. Due to evacuation boiling point of water became 60◦.

Rao sreedhara .et .al [13] has presented study on heat transfer in three different types of corrugated plate heat exchanger having corrugation angle 30, 40 and 50. Water and Glycerol (40%, 50% and 60%) have been taken as test fluid and water as the heating medium. They measured wall temperatures along the length of the heat exchanger at seven different locations by means of thermocouples and found from experimental investigation that with increase of angle heat transfer was more. .they also found that60% glycerol has higher heat transfer compared to 50% and 40% water.

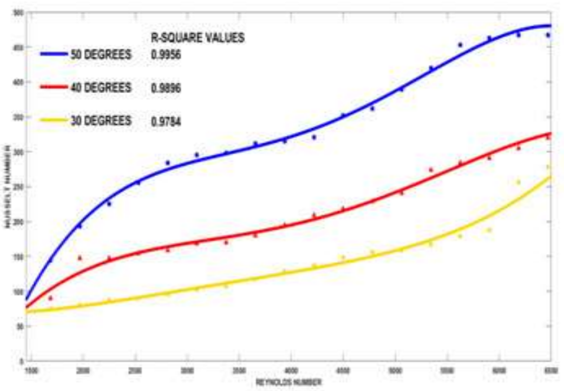


Figure 7 Nu vs. Re comparison for water [13]

Naseer faisal and rai kumar ajeet [14] has presented their study on heat transfer in a corrugated plate heat exchanger using Al_2O_3 micro particles. In this Paper three channel one – one pass corrugated plate heat exchanger in parallel flow had been taken and hot fluid has been flowed in central channel at different inlet temperature ranging from 40◦ - 60◦ to get cooled by cold fluid in upper and lower channel.Al_2O_3 has been added in the hot fluid in different proportion to enhance the system performance and found that effectiveness of heat exchanger increased by 50%.

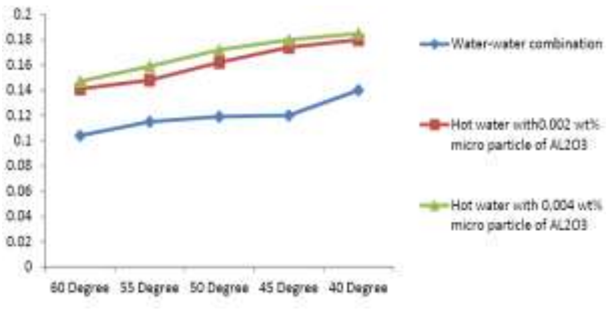


Figure 8Plot of effectiveness of heat exchanger with micro particle of Al2O3 [14]

6. CONCLUSION

Plate heat exchanger is most widely used heat exchanger now a days, it has large surface area per unit volume (compactness) which is greater than700 m^2/m^3. Our paper is concerned with the effect of chevron angle and numerical investigation of dimensionless numbers. Further we will design PHE with different chevron angles and evaluate the heat transfer coefficient, friction factor, pressure drop and dimensionless number by using simulation (Ansys software) output data.

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