EFFECT OF CORRUGATION ANGLE ON PERFORMANCE EVALUATION OF PLATE TYPE HEAT EXCHANGER

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Abstract

The design of plate heat exchanger is complicated due to large number of variables affecting the performance of the Plate heat exchanger and its geometry. Compact exchangers have many advantages over conventional heat exchangers. Compact heat exchangers are widely used for heat transfer applications in industries. Plate heat exchanger is one such type of compact heat exchanger which provides more area for heat transfer between two fluids. Plate heat exchangers are now a day widely used in many applications like heating and cooling application in food processing, chemical reaction processes, petroleum, pulp and paper, as well as in many water chilling application. The better heat exchanger is one that transfer's high heat rate at low pumping power with a minimum cost. In the current study I made a focus on researcher's efforts in research and developments for corrugated plate heat exchanger. Corrugation in plate increase mechanical strength of the plates and increase turbulence in the flow. It is very important to decide proper corrugation angle which give minimum number of plates at maximum effectiveness. Corrugation angle, corrugation depth these both parameters are very important to design the plate heat exchanger. The corrugations on the plates enhance turbulence at higher velocities, which improves the heat transfer.

Keyword: *Corrugation angle, Plate heat exchanger, Pressure drop, Heat transfer*

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1. Introduction

Heat exchangers are devices that facilitate the exchange of heat between two fluids that are at different temperature. Heat exchanger are commonly used in practice in a wide range of application, from heating and cooling system in a household, to chemical processing, nuclear plant and power production in large plants. Plate heat exchanger (PHE) was first introduced in 1920's in order to meet the hygienic demands of dairy industries. Design of PHE reached maturity in 1960's with development of more effective plate geometries, assembly and improved gasket material and range of possible applications has widened considerably. The PHE are built of thin metal heat transfer plates and pipe work is used to carry steams of fluids. PHE are widely used in liquid to liquid heat transfer and not suitable for gas to gas heat transfer due to high pressure drop. A PHE is a one type of heat exchanger that uses the metal plates to exchange the heat between two liquids. This has a most favorable position more than a conventional heat exchanger in that the liquids are presented to a much bigger surface range in light of the fact that the fluids spread out over the plates.

PHE consists of metal plates that are corrugated both to increase turbulence and to provide mechanical rigidity. These normally have four flow parts, one in each corner, and are sealed at their outer edges and around the ports by gaskets, which are shaped to prevent external leakages and to direct the two liquid through the relatively narrow passages between alternate pairs of heat transfer plates. The plates are clamped together in a frame that includes connections for the fluid. And all parts are accessible for inspection by removing the clamping bolts and rolling back the removable cover.

PHE are used in many applications like chemical, petroleum, HVAC, refrigeration, dairy, pharmaceutical, beverages, liquid food and health care sectors, Which is shown in Fig 1.1.

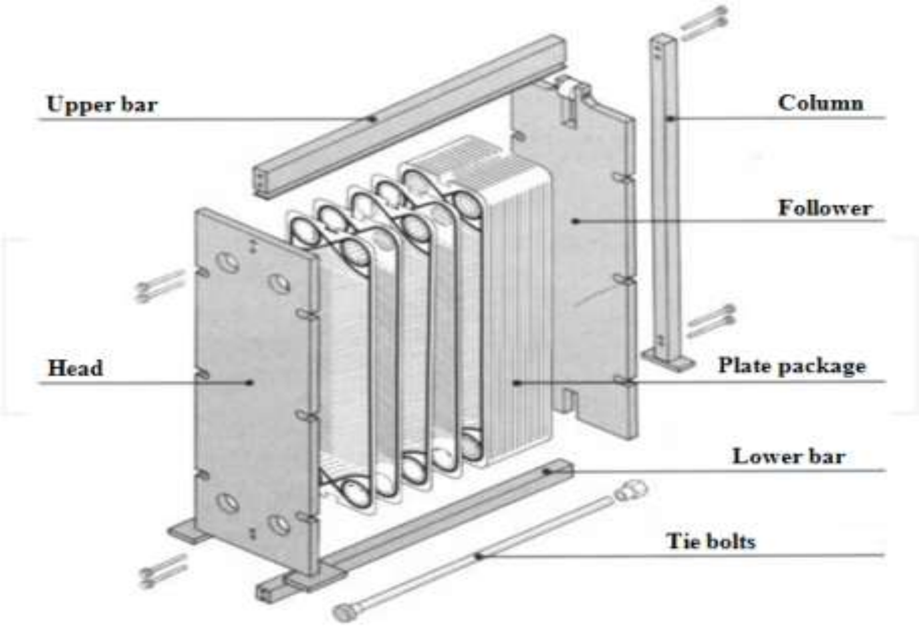

Fig -1.1 An exploded view of plate heat exchanger [W1]

1.2 Fluid Flow Path

In addition to the corrugation, each plate has a depression in the form of a channel also made by pressing near the periphery of a plate into which a gasket is placed. Thus, any two plates have an intervening gasket which prevents mixing of the liquids and directs the fluid into their respective flow paths through the portals at the corners. Each plate has four corner holes. When the plates are packed (with gaskets in between) these corners holes from four continuous flow lines for the two fluids: two of these serve as the inlet and outlet of the fluid, and the other two of the cold fluid as shown in Fig 1.2.

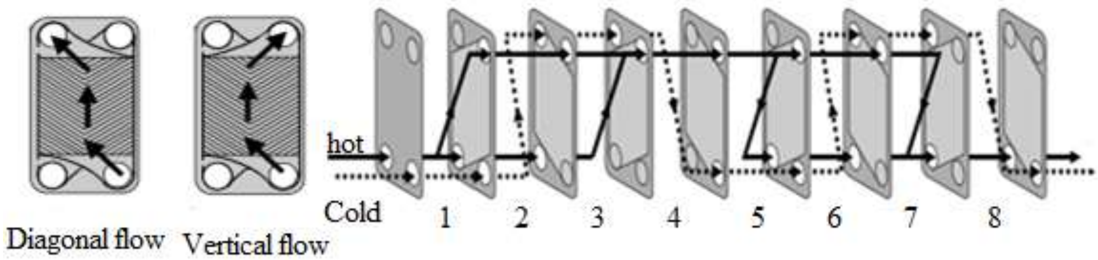

Fig -1 1 Fluid flow path [P05]

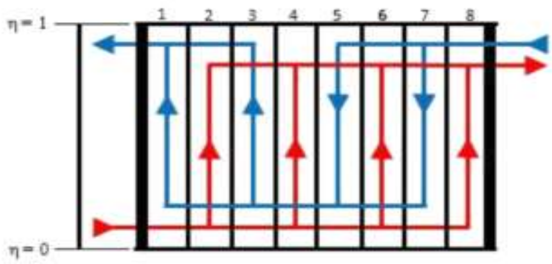

Fig -1 2 PHE streams [P05]

Typically fluid flow paths are shown in Fig.1.3 plates act as a barrier between the hot and the cold fluid streams which are in countercurrent flow on two sides of the plate. The corrugated design greatly helps in inducing turbulence in the fluids, increasing the effective surface area, and imparting additional strength and rigidity to the plates.

2. Literature Review

M, Faizal et al [1] discussed about experimental studies performed on a corrugated plate heat exchanger for small temperature difference application. Here experiment is performed on a single corrugation pattern on 20 plates arranged parallelly, with a total heat transfer area 1.16 m^2. The spacing (ΔX) between the plates was varied by 6 mm, 9 mm and 12 mm to experimentally determine the configuration that gives the optimum heat transfer. Water is used as a working fluid on cold and hot channels. The hot side water flow rate is varied and hot and cold water temperature is kept constant. It is found that for a given spacing the average heat transfer between the two liquids increasing with increase flow rates. The optimum heat transfer between the two streams obtained at minimum spacing 6 mm. It is found that pressure losses increased with increasing flow rates.

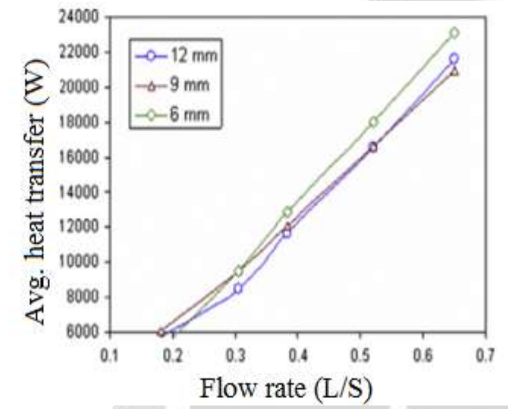

Fig -2. 1 The average heat varying with Flow rate [P01]

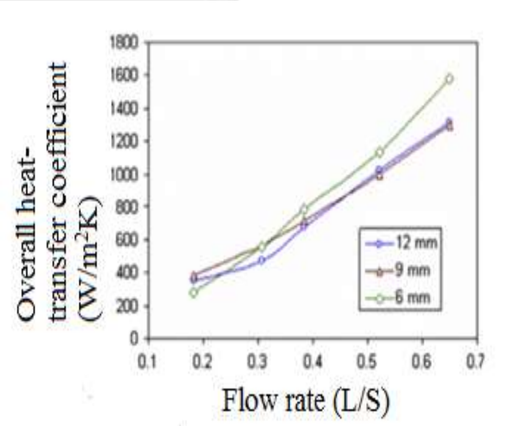

Fig -2.2 Overall heat transfer coefficient with varying flow rate [P01]

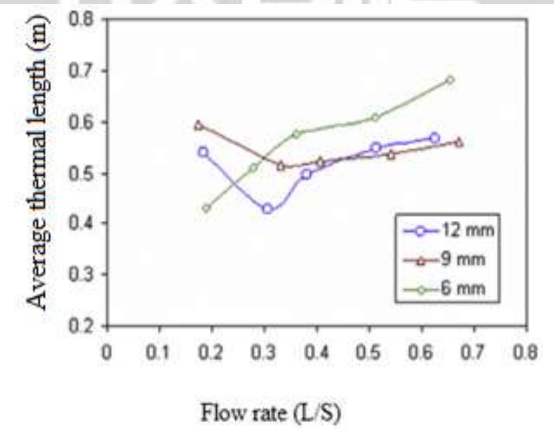

Fig -2. 3 The variation of average thermal length with varying flow rate [P01]

B.Sreedhra et al [2] discussed studies on three sinusoidal corrugated plate heat exchanger using water and 10% glycerol solution as test fluids. Three such plate heat exchangers have been fabricated with corrugation angle of 30°, 40° and 50°. And the effect of corrugation angle on both pressure drop and friction factor of the test fluids has been found.

T.S.Khan et al [3] corrugated plate heat exchangers have larger heat transfer surface area and turbulence level due to corrugation geometry. Here an experimental heat transfer data are obtained for single phase flow (water-to-water) configurations in a commercial plate heat exchanger for symmetric 30°/30°, 60°/60°, and mixed 30°/60° chevron angle plates. Nusselt number is increasing with increase in chevron angle and increase linearly with Reynolds number. Corrugated plate heat exchanger data are higher than of flat plate. Corrugated plates provide high turbulence in the flow which increase heat transfer rate.

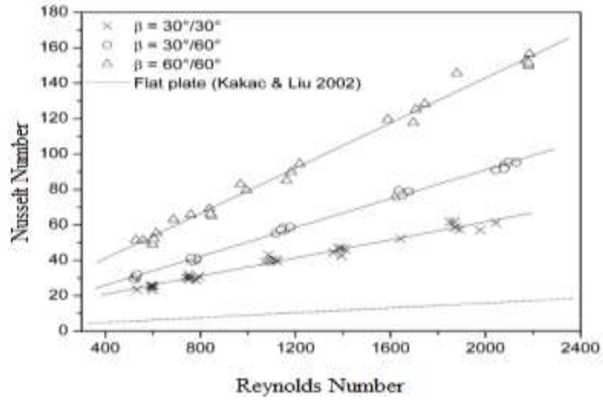

Fig -2. 4 Variation of Nusselt Number with Reynolds Number for different plate configuration [P03]

Yuhan zhao et al [4] have studied and discussed about numerical simulation is performed by using CFD software FLUENT. Then 3D geometrical model is established and mesh is generated. The fields of pressure, temperature and velocity in the computational domain are simulated. And in the last the effect of the corrugation depth on the heat transfer and flow is analyzed. It is about 50*100 mm. and the corrugation depth (H) is vary in 2 to 6 mm. The contacts are best for good heat transfer and the role of spoiler of contact makes the highest degree of the fluid turbulence around them, thus heat transfer is enhanced. Also with increasing corrugation depth pressure drop will decrease and getting best heat transfer rate. Corrugated plate with small depth is good for the cleaning effect of the high speed turbulence which can reduce the deposited dirt and also corrugation plate with higher depth are difficult to produce so reasonable corrugation depth is about 4-5 mm.

Kone Grijspeered et al [5] did 2 dimension and 3 dimension numerical calculations on the V shaped plate heat exchanger. Influence of corrugation shape was attained in the 2 dimension one and the impact of the corrugation angle was attained in the 3 dimensions. Finally the optimum corrugation model is achieved.

Fabio.A.S.Mota et al [6] discussed about optimum design of plate heat exchanger. Mathematical model is studied for optimum design. Three different corrugation angles are taken which are 30°, 45° and 60°. And simulation has been performed on these three corrugation angle and optimum angle is obtained which gives minimum number of plates at maximum effectiveness. Objective is obtained minimum number of plates with maximum effectiveness. And optimum angle is 45° which is obtained by simulation.

J.A.W.Gut et al [7] proposed the screening method to find the optimal set of configurations of a given plate heat exchanger. In this method, the objective function – which implicitly depends on six configurations parameters – is formulated to obtain the minimum numbers of channels, which are proportional to the heat transfer area. Constraints are given in order to avoid impossible or non – optimal solutions. The initial set of configurations is given by the maximum number of possible configurations for the problem and is generated by applying the constraint of channel numbers. The reduced setting is identified by verifying the pressure drop and flow rate, i.e. the subset which obeys hydraulic constraints.

S.R. Turns [8] discussed about the rate of heat transfer increased significantly by 20% - 30% when channels of a heat exchanger are constructed using corrugated sheets. These improved geometries, turbulence and strength of plates.

O.Arsenyeva et al [9] the mathematical model is developed for plate heat exchanger on its main corrugation field, which cause main effect on heat transfer and distribution zones. Model is validating on experimental data for some commercial plates. It is shown that for specified pressure drop, temperature program and heat load the geometrical parameters of plate and its corrugations, which are enable to make plate heat exchanger with minimal heat transfer area. The developed mathematical model can be used for designing of plates with geometry, which is in the best way satisfying process conditions of the certain specific range.

3. Conclusion

For different heat transfer process conditions the best values of plate geometrical parameters significantly vary. It requires designing and manufacturing the plates of different sizes and geometrical form of corrugations, which can better satisfy certain ranges of applications. In commercial PHEs the variety of corrugation inclination angles is achieved by combination of two plates with different corrugation angles in one frame. The number of plate sizes and plates with different spacing is limited. All of this leads to situation that optimal corrugation parameters cannot be reached with already available types of plates. But having the optimal plate geometry for the given process, this data can be used as a reference point of what can be achieved with PHE on certain position. Besides, the developed mathematical model can be used for designing of new plates with the geometry, which in the best way satisfies the process conditions or some range of them. By choosing proper corrugation angle which is optimum gives minimum number of plates with maximum effectiveness.

4. Acknowledgement

I express my gratitude to my guide Prof. Jignesh J Patel for their expert guidance, encouragement and suggestion throughout the preparation of this work. He has been a pillar of support and inspired me throughout this study, without him this would not have been possible. I also express my heartiest thank to Prof. Tejendra Patel(H.O.D., Mechanical Engineering Department.) for helping me throughout this work. I am grateful to the teaching faculties of Mechanical Engineering Department for their valuable suggestions and instruction regarding my work.

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