A Review on Plate Heat Exchanger with different Parametric Conditions

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ABSTRACT

Temperature concentration that are responsible for alterations in flow circulation within Plate Heat Exchangers are examined in this paper. The perseverance of this study is to magnify the acquaintance regarding fluid comportment in Plate Heat Exchangers and its outcome on efficiency. Gravity, flow velocity and Reynolds number are certain parameters which can alter flow distribution within Plate Heat Exchanger. The same was confirmed by Bernoulli equation. All the three parameters i.e. Reynolds, viscosity and gravity were Investigated via segregation and adjustment. Various research papers on Plate Heat Exchangers were studied and the detailed review paper has been prepared.

Keywords: Plate Heat Exchanger, Reynolds Number, Bernoulli equation, Heat Exchanger, Pressure Drop.

1. Introduction

A device that permits two different mediums to interchange thermal form of energy at different temperatures is known as heat exchanger. Heat exchangers are the devices that can be utilised to transfer heat between liquids and solids. Heat exchangers are most commonly used for heating, cooling, evaporating or condensing fluids. The resolve of the heat exchanger could be to pasteurize, recuperate or discard heat, fractionate, sterilize, distillate, crystallise or controlling a fluid process thermally in the industry. Heat Exchangers (HE) are utilised in processing, power production, transport, air tailoring, cooling, cryogenics, heat retrieval and in many numerous areas

Classification of heat exchangers is based on two important factors i.e. structure and compactness. When it comes to compactness, liquid – liquid type heat exchanger is the most compact one and When it comes to structure and construction we have shell and tube type heat exchanger and plate type heat exchanger which are very common. Plate type heat exchangers are further known for their compactness when equated to shell-and-tube type heat exchangers.

Brazed Plate Heat Exchangers(BPHE)

(VBPHE)vacuum brazed plate heat exchangers are best suited for high pressure and high temperature responsibilities as it's construction doesn't consist covering case, gaskets, escort bars and constriction bolts. Its construction is simple and mainly comprises of plates which are stainless steel made and two closing plates, which are mostly copper brazed, in ammonia units they are nickel brazed. Size of the plate is usually restricted to 0.3m². There is no need for brackets and foundations as these units can directly be mounted.

Plate type heat exchangers have taken over the conventional shell and tube type heat exchangers due to their compactness. This compactness results in reduced size and weight and at the same time cost also. Titanium and stainless steel plates are widely being used in Plate heat exchanger(PHE). These plates are generally molded into similar patterns. Then these plates are arranged together. Operational status describes the number of plates to be stacked together. Subsequent plate packages are usually positioned upright as shown in **Figure 1.1**. Various patterns have been established over the time, but the most commonly used pattern is herringbone pattern which is shown in **Figure 1.3** The pattern angle commonly known as chevron angle changes according to the application. Throughout assemblage each plate is rotated by 180°. Many contact points are yielded from the crossing designs which provides steadiness. Space which is created between consecutive plates results in fluid flow across the channels. Heat transfer as well as pressure drop increase due to interruptive and tortuous geometry of the plate. Due to intricacy of the channels the viscous flow is unsuitable for them. Plate corners are positioned with ports. It is conceivable to alter flow plan via diverse port locations.

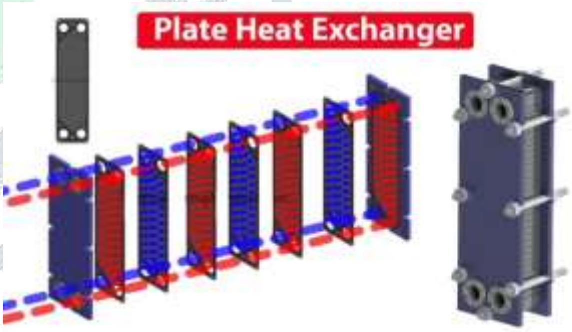

Figure1.1: Construction of heat exchanger consisting of cover plate, plate package and connections. [15]

Classification of Plate Heat Exchanger

Classification of Plate heat exchangers mostly depend upon the joining arrangement. The joining arrangement can be brazed, gasketed or welded Different arrangements have their own advantages and drawbacks. Though the principle of working is similar in all the arrangements. The drawbacks of gasketed plate heat exchanger resulted into evolution of Brazed plate heat exchanger. The gasketed plate heat exchanger are sensitive to high temperature and high pressure while as brazed plate heat exchangers are ideal for high operating conditions. Mostly copper is used for brazing but various materials can be used if the operating conditions are too hostile.

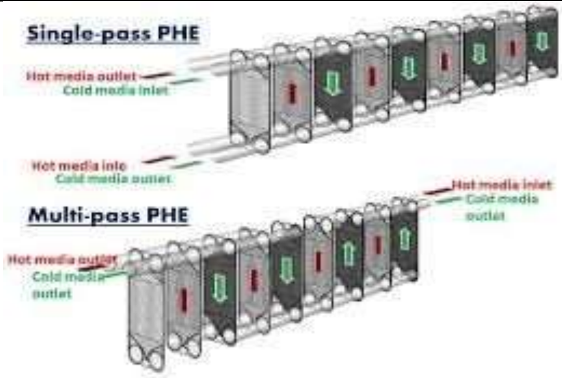

Figure1.2: Single pass and Multi pass Plate Heat Exchanger(PHE) [42]

l.3 Plate Geometries

Surface patterns which are corrugated (or wavy) are embossed on sheet metal for each plate. Special grooves can be provided on one side of each plate along the boundary of the plate and in case of a gasket it is provided around the ports. The same is designated by large dark lines in. Alternate plates are assembled in such a manner, that the corrugations on succeeding plates which are in contact with each other offer mechanical sustenance to the plate packet over a large number of contact points. The ensuing flow channels are slender, somewhat interrupted, tortuous, and enhance heat transfer rate and reduce fouling factor by means of growing the shear stress, producing secondary glide, and growing the extent of turbulence. The corrugations also enhance the rigidity of the plates and shape the desired plate spacing. Plates are targeted as tough or smooth, depending on whether or not they generate an excessive or low depth of turbulence.

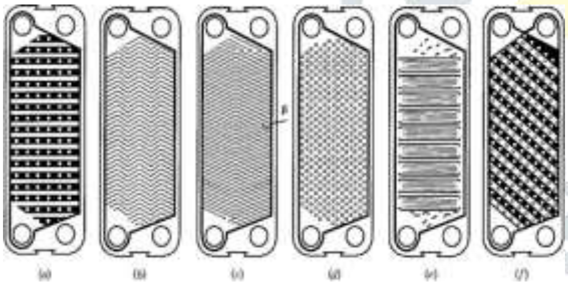

Figure1.3: Plate patterns of different plates
(a) Primary horizontal washboard
(b) zigzag pattern (c) Chevron/Herringbone pattern (d) Depression/Protrusion pattern (e) Secondary corrugation washboard (f) Washboard with oblique pattern [12]

Applications

Plate heat exchanger(PHE) were added in early 1923 and its application was mostly restricted to milk pasteurization but now find major packages in liquid–liquid heat transfer, with viscosities ranging up to 10Pa. The goal can be to sterilize, pasteurize, fractionate, distill, listen, crystallize/control technique fluid. The heat exchanger is specially used in:

- Boilers
- Milk Plant
- Chemical Process Industries
- Automobile Radiators
- Refrigerator
- Pre-Heater Economizers
- Petroleum-refining
- Air Conditioning

Selection for Plate Heat Exchangers

Plate heat exchangers which are being extensively used in various industrial regions including chemical engineering, power plant, petroleum refining, meals processing, and many others. Shell & tube type Heat Exchanger accounts for more than 35-40% due to their strong geometry, easy renovation & viable improvements. Rugged secure production, availability in an extensive range of materials, mechanical reliability in carrier, availability of standards for specs & designs, long collective operating enjoys and familiarity with the designs are a number of the motives for its huge utilization in enterprise.

Advantages of Plate heat exchanger

• The cleaning is quite easy and each individual component can be detached for washing, examination, and repairs.
• The surface area where heat transfer takes place can without problems be altered or rearranged for an exclusive challenge or for expected converting masses, through the suppleness of plate size, skip preparations and corrugation patterns.
• Fouling factor is reduced to 10-20% due to high fraternization, high turbulence, shear stresses, shear rates, secondary flow and wavy/corrugation patterns thereby increasing heat transfer.
• Due to high heat transfer coefficients, less fouling, absence of bypass and escape tributaries, and better counter flow provisions, the surface area required for a plate exchanger is 1/2rd to1/3rd that of a shell-and tube exchanger for a specified heat responsibility, consequently minimizing the cost and area requirement for the exchanger. The net weight of a plate exchanger is about 1/6th when compared to shell-and-tube exchanger.
• Subsequently, excessive overall thermal efficiency may be obtained in (PHE) Plate Heat Exchanger. High counter drift in PHEs creates temperature tactics of up to 18°C viable. High thermal effectiveness (up to approximately 93%) allows budget friendly low-grade heat retrieval.

LITERATURE REVIEW

2.1 Introduction

Literature research in the field of heat transfer improvement with more focus on the usage of Plate heat exchangers are presented. The particulars of effort undertaken by various scientists and engineers in the field of heat transfer enhancement with the use of Plate heat exchanger is presented in this chapter. The review comprises experimental work assumed from time to time along with the evolution of the Plate type heat exchanger for enhancing heat transfer rate.

Gullapalli & Sundén [1] elucidated that in order to increase the performance of the exchanger design and development should be focused more. To co-relate thermal performance to geometrical considerations there are many empirical correlations, nonetheless they all lack generalization. Plate heat exchangers have been developed through CFD in recent years and CFD has proved to be very useful for designing the exchangers. Earlier **Gullapalli & Sundén [2]** used pressure and enthalpies to develop a general valid method. They studied the outcomes of simulation methods on pressure drop and heat transfer was. The results of their study presented that CFD-tools require general valid commotion models and boundary situations. While as **Kevin M. Lunsford et al. [3]** suggested that in order to increasing heat exchanger efficiency we should follow a logical series of steps. The first step to be taken into consideration is to check whether the heat exchanger at first is operating correctly without any fault. The second step to be considered is to increasing pressure drop if offered by exchangers with single-phase heattransfer. For efficiency improvement and higher heat transfer coefficients velocity needs to be increased. Further, a critical assessment of the projected fouling factors should be taken into consideration.

Aslam Bhutta et al. [4] described Plate Heat Exchangers (PHE) exceptional with very less disadvantages and many more advantages amongst other heat exchangers. **Shah & Sekulic [5]** thorough investigation loathed that when two flows flowing at different temperatures encounter each other and exchange energy in an exchanger device cooling is accomplished. They also empathized over the advantages of plate heat exchangers over the other conventional heat exchangers like shell and tube heat exchanger. The obvious reason for giving the preference to plate heat exchanger was that they can withstand high pressure and temperature. The operational conditions for plate heat exchangers are volatile but they still withstand those conditions due to their design.

Dović et al. [6]: established a generalized relation to define hydraulic and thermal presentation in terms of friction factor and Nusselt number for a plate heat exchanger which was single pass flow. Relations were developed from chevron angles amid 15 and 65° and for chevron height to pitch ratios between 0.26 and 0.4

B. Prabhakara Rao et al. [7] studied the outcome of flow circulation within channels on the thermal Performance corresponding to plate heat exchanger. In order to obtain thermal simulation of a single pass plate heat exchanger a generalized model was presented. This model examined flow deviation within the channels in precise manner and at the same time took consultation from available data. The outcomes concluded that while considering only variable flow rate the efficiency of the exchanger is undermined. Far efficient approach is to look upon a flexible flow rate along with a flow dependent heat-transfer coefficient. The outcomes specified that the sound effects of parameters like, flow configuration, rate of heat capacity ratio, flow pattern, number of channels and plate geometry are considerably contradictory from the impractical prototype for 'uneven flow rates but identical heat-transfer coefficient' used in past.

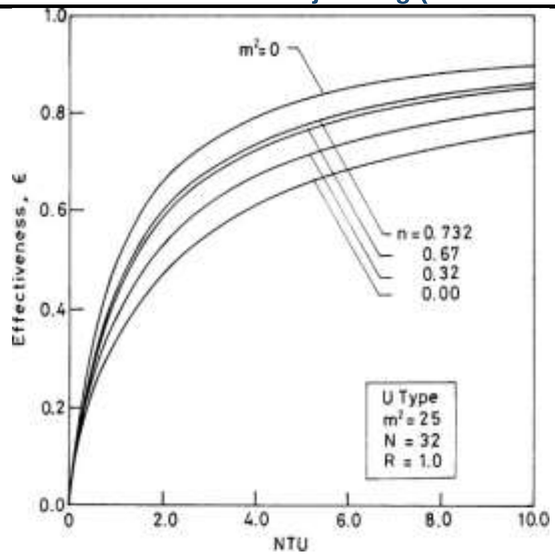

Figure.2.1: NTU vs Effectiveness character of a PHX and resultant Reynolds number (n) **[7]**

The subsequent recommendations were made grounded on above study:

- The investigation of Plate Heat Exchanger must be done with focus towards uneven flow distribution, and flow requirement of heat-transfer coefficient in each individual channel.
- Heat-transfer coefficient must be measured by determining an inverse problem by means of experimental outcome values of temperature and a standard explanation of NTU in order to obtain the value of n, as shown in Fig.2.1. With this the effect of flow distribution will not be allowed into heat transfer statistics.
- For future investigation an identical model can be constructed to determine 'correct' friction factor too.

M. K. Bassiouny and H. Martin [8] did their research on Plate Heat Exchanger for pressure drop and flow distribution. They came to the conclusion and stated that a specific parameter (m) can be used to determine pressure drop and flow distribution. Approximately even flow distribution can be achieved when m^2 is equivalent to zero. For both positive and negative values of m^2 the channel flow rates will increase. Further studies also displayed that the over-all pressure drop in Plate Heat Exchangers is almost identical for both Z-type and U-type arrangements. Their results are valid to a various combinations of Heat Exchanger dimensions, Fluid Velocity and channel geometries. Regarding nanofluids **Marjan Goodarzi et al. [9]** used MWCNT based Nano fluids to Study pressure drop as well as heat transfer for Plate Heat Exchanger with counter flow corrugated arrangement. Initially the thermo-physical properties were studied experimentally for Carbon Nanotube-based fluid to determine the effect of different functional covalent groups. Surfaces of (MWCNT) Multi Walled Carbon Nanotubes were attached with Silver (Ag) and (Cys) Cysteine covalently to investigate this issue. With the help of characterization instruments, morphology and functionality were investigated to check functionalization of surface. To compute properties related to thermal, various nanofluids based on water such as, (MWCNT-GA) Gum Arabic-treated multi-walled carbon nanotubes, functionalized MWCNT with silver (FMWCNT- Ag) and cysteine

(FMWCNT-Cys) were used as coolants to examine the Nusselt number, convective heat transfer coefficient, friction loss, pumping power and pressure drop in plate heat exchanger with counter flow corrugated arrangement. FORTRAN code was used to Calculate Nano particle weight percentages of 0.0% to 1.0% and Reynolds numbers stretching from 2500 to 10,000 (unsteady flow). Properties related to nanofluids were studied by conducting tests. The results showed that heat switch traits of nanofluids can improve by increasing Peclet number and Reynolds range. Though, in case of particular material, augmentation of nanomaterial fraction or Reynolds variety could result in rising of required pumping power even though the change is negligible. All the experiments showed that the rate of heat transfer and power consumption is less in water when compared to nanofluids. Further investigation found that heat rejection capacity of nanofluids is higher than water for a particular pumping power. Therefore, by taking MWCNT-water as a working fluid the performance of Plate heat exchanger can be enhanced.

A. Muley and R. M. Manglik [10] studied pressure drop and flow heat transfer in (PHE) Plate heat Exchanger for chevron plates. U-type counter flow Plate heat exchanger(PHE) which is single pass was considered with three dissimilar chevron plate arrangements. Similar plate arrangements for two plates with
β = 30°/30° and 60°/60°, and one blended-plate configuration with β = 30°/60°. In case of water (2 < Pr < 6) flow rates within the 600 < Re < 104 command, records are presented for f and Nu.
Surface expansion factor
(ϕ) and chevron angle (β) showed a considerable effect on results The consequences show substantial effect of the chevron angle, with any increment of (β) the value of Nusselt number(NU) is increased by three to five times. Same is the case with surface expansion factor (ϕ). Depending upon (ϕ), (β) and Re, it was found that at steady pumping power the heat transfer is improved,

Arun Kumar Tiwari et al. (2013) [11] Examined fluid flow and heat transfer of a plate heat exchanger for one pass counter movement chevron design plates taking (Al2O3 and CeO2) as coolant. ANSYS FLUENT a computational fluid dynamics tool was used for the investigation A plate heat exchanger was designed with working fluid for testing as nanofluids and water. The CFD outcomes were compared with the outcomes of the experimental study of heat exchanger, and it was established that homogeneous mixtures imitation can be successfully utilized to forecast the plate heat exchanger which is nanofluid cooled. Nanofluids are useful only if their thermal conductivity increases in spite of unwanted result of surge in viscosity their thermal conductivity should increase. Due to corrugated design of plate, turbulence progresses and heat transfer rate increases. The upper part appeared to be at high temperature when compared to while the lower part, larger temperature slope, and the result of heat transfer is extra satisfactory. The performance of Water/CeO2 as coolant was no doubt best

3. Research Gap

On the basis of above study following are the points which need to be studied in future.

1. There has been no research on pressure drop and heat transfer rate in hybrid channel plate geometries. This can be done by using three different types of plate geometries in a single plate. The plate can be designed in such a way that its inlet should be of Primary horizontal washboard pattern, the middle part of zigzag pattern and outlet of Chevron/Herringbone pattern.
2. The researchers have carried the research for heat transfer mostly via ANSYS CFD tool but have not confirmed after with MATLAB. Any CFD analysis can be first carried out in ANSYS and then with MATLAB for more clear results.
3. The material used in plates can be of different types, what we are presently using is mostly stainless steel but can be changed with Titanium, Nickle, Magnesium. Minimal work has been done on finding alternatives to Stainless steel.

4. Conclusion

The geometry and design of brazed plate heat exchanger makes them much more eligible for oil cooling. As we know that oil is highly viscous which results in uneven flow distribution in exchanger. This problem can be eradicated by making sure that the fluid flows evenly in exchanger. Though this is a difficult task to measure the even flow because the Brazed plate heat exchanger is welded and cannot be opened while working. For this we have to do more research and this is where CFD tool can be obliging.

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