A REVIEW STUDY THERMAL BEHAVIOUR OF PLATE HEAT EXCHANGER WITH VARIOUS MODIFICATIONS IN DESIGN

Abdul Taufiq[1], *P. S. Dhakar*[2]

[1]*PG Scholar NITM Gwalior, Madhya Pradesh, India,*
[2] *Asst. Professor NITM Gwalior, Madhya Pradesh, India.*

Abstract: Plate heat exchangers (PHEs) are efficient, lightweight, and commonly used in many industries. Chevron-corrugated PHEs are commonly assumed to have high performance, high fluid resistance, and high power, largely because the cross-section of the flow passage between the plates varies very complicatedly. Over the years, platform style heat exchangers have been used more widely and successfully in Manufacturing. Plate heat exchangers are widely used in the cooking, ventilating, air conditioning and cooling sectors. Detailed and comprehensive research on heat transfer and the fluid flow characteristics of these kinds of exchangers is urgently needed. On plate heat exchangers a literature review is proposed as an effort in this regard. Plate fin heat exchanger (PFHE) is a type of compact exchanger consisting of a stack of alternate flat plates called partition sheets and corrugated fins, all of which are brazed as blocks together. This review paper presents the work of numerous researchers on improving the heat transfer of a heat exchanger style plate.

Keywords: Plate heat exchanger, Overall performance, Heat transfer coefficient, thermal analysis.

I. Introduction

Plate fin heat exchanger (PFHE) is a type of compact exchanger consisting of a stack of alternate flat plates called partition sheets and corrugated fins, all of which are brazed as blocks together. Streams share heat by passing through the separating sheets in the valleys formed by the fins. Separating plates serve as the main heat transfer surfaces, and the appendages known as fins serve as the closely connected secondary heat transfer surfaces. Aluminum is the most widely used material, and it is used in high pressure and high temperature applications of stainless steel. Plate fin exchanger is a type of portable heat exchanger where the surface area of the heat transfer is increased by having an expanded metal base, interfacing the two fluids which is called the fins. Because of its superior structure and performance, plate fin heat exchangers are unique among the numerous compact heat exchangers. A plate heat exchanger is a type of heat exchanger that transfers heat between two fluids using metal sheets. This provides a big advantage over a traditional heat exchanger by exposing the fluids to a significantly greater surface area since the fluids are moving across the surfaces. This enables heat transfer, which increases the temperature shift rate considerably. Plate heat exchangers are now popular, and very small brazed versions of millions of combination boilers are used in hot-water parts. The high efficiency of heat transfer with such a limited physical scale has improved the flow rate of combination boilers in domestic hot water (DHW). The small plate heat exchanger has profoundly affected indoor heating and hot water. Larger consumer models use the gaskets between the plates, and smaller ones prefer to be brazed. The fins and side bars are fastened with the partition sheets to ensure strong thermal relation and mechanical stability.

The idea behind a heat exchanger is to heat or cool one fluid by moving heat between it and another fluid using pipes or other cooling vessels. The exchanger usually consists of a coiled pipe containing one fluid which passes through a chamber containing another fluid. The pipe walls are typically made of metal or another material with a high thermal conductivity to allow the swap, whereas the exterior lining of the wider chamber is made of plastic or covered with thermal insulation to prevent heat from escaping from the exchanger. Dr Richard Seligman developed the plate heat exchanger (PHE) in 1923 and revolutionised methods of indirect heating and fluid cooling. APV was founded in 1910 by Dr Richard Seligman as the Aluminum Plant & Vessel Company Limited, a specialist manufacturer that supplies welded vessels to the brewery and vegetable oil industry. Plate heat exchangers (PHEs) are not modern inventions or concept. In 1890, one of the first patents was given to Langem and a German firm, Hundhanssen. This form of exchanger has been used successfully in industries like food, manufacturing, paper / pulp, and heating, ventilation, and air conditioning (HVAC) in the past. The key aim of this article is to direct future researchers to the topic of PHE, as there is a shortage of fundamental knowledge about them in current industries. This type of evaporators is used on a daily basis in the heating, ventilation, air conditioning and refrigeration (HVAC&R) industries, but there are no standards at all. Here the goal is to present the current situation.

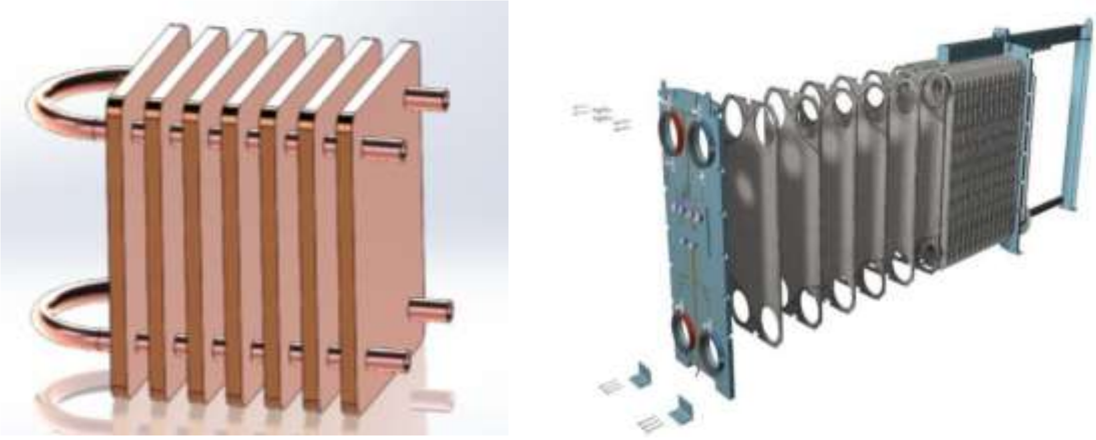

Figure 1: 3d Model of Plate Heat Exchanger

II. Plate fin heat transfer surfaces

The plate fin exchangers are mainly employed for liquid-to-gas and gas-to-gas applications. Due to the low heat transfer coefficients in gas flows, extended surfaces are commonly employed in plate-fin heat exchangers. By using specially configured extended surfaces, heat transfer coefficients can also be enhanced. While such special surface geometries provide much higher heat transfer coefficients than plain extended surfaces, but at the same time, the pressure drop penalties are also high, though they may not be severe enough to negate the thermal benefits. A variety of extended surfaces like the plain trapezoidal, plain rectangular shown in Figure 1.2 can perform such function. The offset strip fin geometry is included in the present study

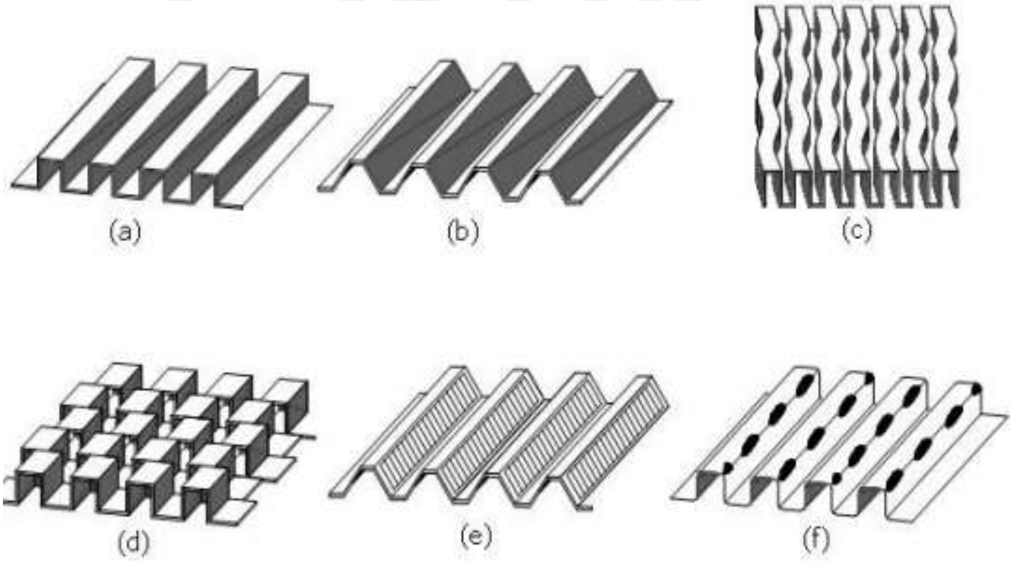

Figure 2: Types of plate fin surfaces: (a) Plain rectangular (b) Plain trapezoidal (c) Wavy (d) Serrated or offset strip fin (e) Louvered (f) Perforated

III. Literature Study

Plate fin heat exchangers, because of their compactness, low weight and high effectiveness are widely used in aerospace and cryogenic applications. Cryogenic liquefiers need heat exchangers of very high effectiveness(of the order of 0.95 or more) and the liquefiers cease to produce any liquid if the effectiveness of heat exchangers falls below the design value[1].Correct design and quality construction of heat exchangers is essential for proper functioning of such systems.

Dávalos, et. Al. (2019) The present study shows techniques for developing spiral plate heat exchangers according to fluid structures, government movement, and whether the thermal equipment is for condensation, cooling or heating purposes. An additional study is presented seeking to determine the geometric variables which allow thermal and hydraulic efficiency to be enhanced and improved. In addition, computational fluid mechanics was conducted to verify the hydraulic and thermal approaches. Computational fluid dynamics is a powerful technique for simulating and validating scientific processes. The findings between CFD simulation and method of design approve of the system's accuracy. It enables the spiral plate heat exchanger operation to be applied as part of the industrial phase, cooling systems, heat networks, and energy recovery.

Mohanty, et. Al. (2018) This research examines the numerical analysis of a counterflow heat exchanger in a single tube in a tube heat exchanger with reverse of the flow. The analysis involves heat transfer and pressure decrease in the heat exchanger taking water as a fluid into account. Many researchers have reported on improving counterflow heat exchangers which modify the fluid temperature and use different fluids. Here a fluent CFD software was used to predict the effect of the heat exchanger in terms of temperature rise and pressure drop due to temperature variation and mass flow rate. For the double pipe counter flow heat exchanger, a series of CFD simulation is performed and the results are identified after validation of the CFD analysis methodology. In ANSYS 14, the experimental findings published in the literature are contrasted with the findings of the CFD fluent simulation.

Shinde, et. Al. (2018) In this experiment the heat exchanger is chosen for shell and tube form. The main aim was to adjust the tube cross-section to improve the heat exchanger performance. The analysis chooses Rectangle, Rectangle with fillet and a hexagonal cross section with tubing. New shell and tube heat exchanger construction is performed using normal design technique and 3D printing is conducted in 2018 at Solidworks. Finite Element Analysis programme ANSYS Workbench 18.0 is used to perform CFD analysis to find performance parameters under a standard operating environment. They found that the hexagonal cross-section allows more efficient heat exchange due to a convective surface rise. They also concluded from the results and data obtained from CFD that the K-w turbulence model provides better suitability for our simulation. Hexagonal tube model delivers better efficiency than other models. Heat transfer rate with hexagonal tube in the heat exchanger also produces strong heat transfer rate. Increasing heat exchanger efficiency increases its success in its respective application.

Zhang et. Al. (2018) This analysis measures the heat transfer efficiency of the device with or without the plug-in, allowing numeral flow and heat transfer simulation for the heat exchanger during operation. In addition, it analyses the effect of wind speed on the surface heat transfer coefficient and pressure of the plug-in tube and non-plug-in tube through the simulation of a single tube model, compares their difference in heat transfer efficiency, and points out the main parameters in the design of the heat exchanger. The computational fluid dynamics (CFD) programme, FLUENT, was used in this study to perform simulation analysis of the heat exchanger, to evaluate the heat exchanger's temperature distribution, and to analyse the effect of different environmental charges on the heat exchanger. This modern simulation approach will enhance analytical precision better, playing some leading role in the future design of the parameters. If the heat exchanger configuration is space-limited, the air velocity in the tube is greater than 20 m/s. And then can the turbulent flow phenomenon also work in the tube by placing the plug-in into some portion of the air inlet and then using the light pipes to the other parts.

Rajkamal et. Al. (2018) Heat exchangers were observed to space shuttles from smallest electronic devices. It transfers heat through direct or indirect interaction from one medium to another. Using CREO software a helical coil heat exchanger with a helix angle of 30o was developed. Currently the goal is to use ANSYS CFX 15.0 programme to infer copper replicability with two separate internal tube materials such as POCO HTC graphite and ASTM SA 179 carbon steel which also has substantial heat transfer characteristics and good corrosion resistance relative to copper. It is proven that the POCO HTC absorbs heat better than standard carbon steel, and other properties are very comparable such that the current copper tubes in the industries can be replaced. It has a high resistance to corrosion than the copper and carbon steel. The simulation was performed for water to water heat conversion properties, and multiple inlet temperatures were investigated. The heat transfer characteristics were also tested for the constant temperature for various mass flow rates and it reported that the heat transfer characteristics often increase as the mass flow increases.

Marija Lazarevikj et. Al. (2018) The prospect of optimising heat transfer in a counterflow plate heat exchanger using Al2O3 / water nanofluid is being studied using the CFD technique in the present investigation. The corrugated plates is called practical geometry. Turbulent flow and heat transfer of nanofluid in the channel of the plate heat exchanger was modelled. Simulations were performed for nanofluid with optimum concentration of Al2O3 nano-particles in water, based on the premise that the nanofluid is a homogeneous mixture with thermo-physical properties depending on temperature. The findings obtained from the CFD study will be compared with the model validation experimental data. The prepared numerical model indicates simulation can be done with appropriate precision to determine the efficiency of the plate heat exchanger. Using theoretical associations the CFD effects are used to measure the heat transfer and hydrodynamic properties of nanofluid. The findings show improvement of heat transfer properties using nanofluid as a working medium instead of water with a slight penalty in pressure reduction.

Mohanty Shuvam, et. Al. (2018) The heat transfer, mean temperature differential log and thermo-physical characteristics of a counterflow heat exchanger were investigated in the present study. The tests were performed in counter-current mode, and the fluid is extracted with vapour. Although the hot fluid in the inner tube enters and the cool fluid in the outer tube enters out. The tubes are not heated evenly because of the low mass flux in the centre of the heat exchanger. The CFD simulations were in accordance with established literature 's current experimental data. For the flow analysis the Realizable model of k-epsilon turbulence is used. For a novel heat exchanger of the shell-tube kind, computational fluid dynamics and heat transfer simulations are carried out. The heat exchanger is a tube with a narrow opening, angled in the direction of the current. The counterflow heat exchanger's LMTD is 29.65 while the current literature reduces the cold fluid temperature with an average error of 8.5 per cent. However, when rising the temperature of the hot inlet fluid, the LMTD increases more quickly along the length with an average of 26.58 and an error of 8.9 percent.

Sravan et. Al. (2018) Research is carried out in this sample to compare the heat transfer rates between the two plates: 1) flat plate and 2) flat plate with improved surfaces. Thermal analysis is achieved by taking hot lubrication oil and cooling water, titanium oxide, and aluminium oxide on the various plate heat exchangers with different fluids. 3D models are implemented in CATIA and evaluated in ANSYS. A plate heat exchanger used to cool the lube oil used in turbines is studied in this study, few updated prototypes of plate heat exchangers are developed and studied so that by providing cool lubrication we can increase the life of the turbine components. In this study the heat transfer rates between the heat plate heat exchanger models are measured using ANSYS work bench. Using Nano fluid in place of water as coolants will help to decrease the high temperature in lube oil by an average of 6o C. Variations in efficiency are comparable when dealing with cooling fluids in all heat plate heat exchanger types.

Patil, et. Al. (2017) Studies carried out by various researchers in order to improve the performance of heat exchangers was addressed in the present report. Via thorough study it was found that the heat transfer capacity of the corrugated plate exchanger has been maximised. There has been a lot of study in the area of heat exchangers. It is found that conventional methods are very expensive, and time consuming. CFD has emerged as a boon for investigators. With the aid of CFD one can easily determine efficiency, precise parameters of the heat transfer rate. Corrugated heat exchangers are found to be providing the highest heat transfer capacity of all forms of heat exchangers.

Sethi, et. Al. (2017) This thesis reflects on the use of the plate style heat exchanger as operating fluids for seawater and engine oil. This test work handles analysis of the plate-type heat exchanger with measurement of convective heat transfer coefficient, total heat transfer coefficient, efficacy of the exchanger, fluid output temperatures. The enhancement of this function is finished by taking the amount of Low, Medium and Large Reynolds and additionally the turbulence of K-Epsilon. Completing this work consists of thin metal Titanium welded plates with a thickness of 7 mm, rectangular shape and a gap of 1 mm between two plates. Tests are driven by adjusting operating parameters such as mass flow rate, hot & cold fluid inlet temperatures. In this study the overall effectiveness obtained is 0.61. The use of the heat exchanger form plate is more lucrative than the heat exchanger form of tube with the same adequacy, because it requires less volume. The study was carried out using methods from ANSYS 12 CFD. Distinctive parameters are seen from the acquired data, and graphs are plotted from various parameters.

Aydın, et. Al. (2017) Optimal configuration of the heat exchanger is to achieve a high heat transfer capacity with low pumping power and low cost. In this report, the emphasis is on the research and development activities on the efficiency of plate heat exchangers of various plate materials, different types of fluids, their flow regimes and the plate grooving angle. The Computational Fluid Dynamics (CFD) is used for this purpose. The findings show that the heat efficiency is the highest performing heat exchanger which can be constructed from the perspective of parallel- and counter-flow, geothermal fluid, titanium plate and 60 ° groove angle. In this research, 3-dimensional CFD analysis studied the change in working conditions of a plate heat exchanger used in geothermal applications based on flow system, plate groove angle (β), type of fluid, and plate content. A plate heat exchanger model with the parallel-counter flow has been found to be the best operating conditions for heat transfer.

Luan, et. Al. (2017) A computational and experimental research on heat transfer and fluid flow in two types of welded plate heat exchangers (PHEs) was performed. A new solution is proposed ensuring adequate separation between two adjacent corrugated plates to increase the consistency of the mesh across the touch points. Carefully study the clearance value and the influence on the quality of the mesh and the computational results. Results suggest a relative clearance of 0.02 is sufficient. The findings of the computational fluid dynamics (CFD) are in line with the experimental results with a 15 per cent variance. The suggested solution is proven successful and realistic, as it can improve the efficiency of the grid without compromising the precision of the data. This paper reveals that CFD is a powerful method for testing the impact on the optimal geometry of a PHE from different geometrical configurations.

Katarki, et. Al. (2017) The construction of a heat exchanger in ANSYS programme with an inner diameter of 330 mm and an outer diameter of 350 mm for shell was carried out in this experiment. Similarly, for the inner tube diameter is 21.18 mm and the outer diameter is 25.4 mm, the tubing length is 1500 mm, it comprises 36 tubes. Here the shell and tube assembly is performed as a tool of water and steam. The specification can be altered for greater performance with the use of data. Achievable model k – ÿ (RKE) displays first-rate performance. It is clear that if we increase the shell side area so that the mass flow rate of cold fluid increases the heat transfer rate and the distribution of copper(cu) to the entire assembly, the best possible value of the heat transfer rate is therefore obtained for the above mentioned materials; nevertheless, this will also be a very expensive affair. It is concluded that cold fluid temperature was rising from 356 to 359 oK. Hot fluid is down 404-403 fine. The heat transfer capacity achieved for hot fluid is 11475.76 KW and the cold fluid is 64221.52 kW.

Wanga, et. Al. (2017) Plate-type heat exchanger based on computational fluid dynamics approach is simulated in this analysis. The determined model is developed for fluid flow and heat transfer of a chevron-type plate heat exchanger in cold and hot flow channels. Under water-to - water heat transfer the flow pattern and heat transfer effect of cold and hot fluids are studied using the simulation programme, ANSYS. At the same time, 3D computational model of the local computing domains for the plate-type heat exchanger is simulated at various parameters including the corrugated angle, corrugated width, and corrugated pitch. With the advancement of CFD (Computational Fluid Dynamics) technologies, numerical guidance can be given for plate-type heat exchanger enhancement and system optimisation.

IV. Conclusion

In this literature review different forms of feasible and cost-effective heat transfer amplification strategies have been discussed. It's clear that the vortex generator technique is one of the promising heat transfer enhancement approaches. Lots of work on diverse projects and the use of modelling tools has made it simpler. A study on the methodology and interpretation of various plate heat exchanger parameters was carried out using various computational approaches such as experimental, numerical and simulation. Thermal – hydraulic efficiency, flow pattern, material and structure, pressure drop and heat transfer characteristics, fin geometry and heat transfer correlations, and pressure drop correlations are the parameters considered here in this review article. There is also a clear need to suggest more techniques to develop the parameters in the plate fine heat exchanger, which will have a direct effect on operating costs, and last but not least, the use of nano fluids and their role in the exchanger's design aspects, which is considered to be a new rising research field.

References

1. Lázaro Canizalez Dávalos, Edilberto Murrieta Luna, Mario Alberto Rodríguez, "Designing Spiral Plate Heat Exchangers to Extend Its Service and Enhance the Thermal and Hydraulic Performance", Low-temperature Technologies, Intech technologies, 2019, DOI: http://dx.doi.org/10.5772/intechopen.85345.
2. Shuvam Mohanty, Shofique Uddin Ahmed, "Performance prediction of Counter flow Heat Exchanger by using CFD technique", International Journal of Engineering Development and Research, Volume 6, Issue 2, 2018.
3. Avinash P. Shinde, Mahadev L. Shinde, Sagar S. Yadav, "Performance Analysis of Heat Exchanger using CFD", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 7, Issue 3, March 2018.
4. Chengjun Zhang, Qiang Guo, Jialiang Sun, "Comparative Analysis for Heat Transfer Performance of Heat Exchanger Single Tube Model with and without Plug-in", Chemical Engineering Transactions, The Italian Association of Chemical Engineering, VOL. 66, 2018.
5. M.D.Rajkamal,M. Mani Bharathi, Shams Hari Prasad, "Thermal Analysis Of Shell And Tube Heat Exchanger", International Journal of Pure and Applied Mathematics, Volume 119 No. 12 2018, 14299-14306.

6. Marija Lazarevikj, Risto V. Filkoski, Zoran Markov, "CFD analysis of heat transfer and fluid flow in plate heat exchanger with nanofluid", Conference Paper, July 2018.
7. Shuvam Mohanty, Shofique Uddin Ahmed, "Computational Modeling of Counter Flow Heat Exchanger for LMTD Analysis", International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 6 Issue IV, April 2018.
8. T.S.R.Sravan, K.L.Kishore, DVVS B Reddy Saragada, "Design And Analysis Of Plate Heat Exchangers", International Journal of Research and Analytical Reviews, VOLUME 5, ISSUE 2, APRIL – JUNE 2018.
9. Ankush S. Patil, H. S. Farkade, "Advances in Design and Development of Heat Exchangers: A Review", International Research Journal of Engineering and Technology (IRJET), Volume: 04, Issue: 05, May -2017.
10. Chandan Kumar Sethi, "CFD Analysis on Effectiveness of a Plate Type Heat Exchanger Using Sea Water and Engine Oil", International Journal of Advanced Mechanical Engineering, Volume 12, 2017, pp. 191-198.
11. Kutay Aydın, Onur Vahip Güler, Ali Keçebaş, "Parameters Affecting the Performance of a Plate Heat Exchanger using the CFD, Energy Research Journal, Science publication, volume 8, 2017.
12. H. B. Luan, J. P. Kuang, Z. Cao, Z. Wu, W. Q. Tao, "CFD analysis of two types of welded plate heat exchangers", Numerical Heat Transfer, Taylor and Francis, 2017, VOL. 71, NO. 3, 250–269.
13. Santosh K Katarki, Anandkumar S Malipatil, "CFD Analysis of Shell and Tube Heat Exchanger for Heat Transfer Capabilities", International Journal of Engineering and Techniques, Volume 3 Issue 6, Nov - Dec 2017.
14. Ya-Nan Wang, Jong-Pyo Lee, Min-Ho Parka, "A Study on 3D Numerical Model for Plate Heat Exchanger", 13th Global Congress on Manufacturing and Management, Elsevier, GCMM 2016.