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IMPROVEMENT OF HEAT TRANSFER IN HEAT PLATE EXCHANGER CONVERTERS FOR SINGLE PHASE APPLICATIONS IN INDUSTRIAL PROCESSES

Prof. Jamadar Saiphan L

Bramhdevdada Mane Polytechnic, Belati, Solapur, India

Prof. Phulari Shashikant. S

Bramhdevdada Mane Polytechnic, Belati, Solapur, India

ABSTRACT

Plate Heat Exchanger (PHE) is a modern, efficient heat exchanger that increases heat recovery and energy efficiency. For plate heat exchangers, existing observations and information in the literature can be used to continue using the heat recovery process. This article examines the major advances in the development and research of hot plate transformers and the development of heat transfer systems and examines important developments such as plate and frame, brazed and welded plate heat exchangers. The differences between modification models and their effects on the thermal and hydraulic performance of plate heat exchangers are discussed. Most modern plate heat exchangers have curved grooves on the surface of the plates, creating a strong, rigid structure with many points of contact between the plates. Methods for investigating PHE are generally surveying and/or CFD modelling. What does not affect the performance of plate heat exchangers are the main groove, the groove inclination angle relative to the main direction, and the groove aspect ratio. Optimizing these parameters is one way to improve the performance of plate heat exchangers. Other ways to improve heat transfer are also being considered, including the transfer case of corrugated plates, the use of nanofluids, and active processes. Future research directions such as better understanding, development of new corrugated image images, and optimization and area and cost estimation are suggested.

Keywords: Plate Heat Exchanger; Heat Transfer; Pressure Drop; Energy Efficiency; Heat Recuperation

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1. INTRODUCTION

The constant increase in energy demand is necessary to meet the energy needs of the world population and the comfort standards of individuals. Even today, the trend towards renewable energy leads to a significant portion of energy being obtained from the combination of fossil fuels. This leads to large amounts of greenhouse gases (GHG). According to the US Environmental Protection Agency, the United States produced approximately 6 Gt of carbon dioxide equivalent in 2020 [1]. 89.0% of this comes from burning fossil fuels in various sectors. The European Environment Agency [2] also reports a similar situation; 77% of greenhouses use energy from electricity and 9% from industry. In order to reduce greenhouse gas production, the EU plan foresees a 32.5% energy requirement by 2030 [2]. One of the measures to realize this plan is to improve the recovery of electricity, which can be achieved through the wider use of energy-efficient products, electronic devices, which are constantly changing the way electricity is used [3]. The best and most commonly used type of heat exchanger is the plate heat exchanger (PHE). The structure and operation of heat transfer plates are described in detail in many books, including those devoted to this type of heat exchange (e.g., [4]). The total number of documents containing the word "heat exchanger" in the title and abstract published in the SCOPUS database between 1956 and 2022 is 8112, and more than half of them (4245) were published in the last 10 years. As can be seen from Figure 1, the first growth in annual production occurred after the energy boom of the 1970s, and there has been significant growth in recent years. The number of publications in 2020 is approximately 500, which is twice the number of 10 years ago. This reflects increasing scientific interest in this agreement. Analyzing all this information is not easy. The review of the literature over the past decade includes a review of progress in PHE at the time of publication [5], a review of heating changes in PHE [6], and experimental studies to ensure that such reviews become widespread [7]. Across all submissions in these reviews (including nearly 200 sources), much of the data on PHE remains unavailable.

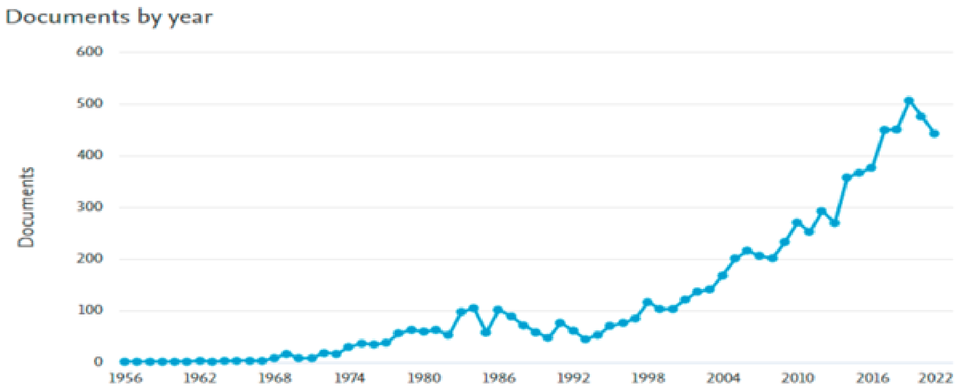

Fig.1 The number of publications on PHEs in the SCOPUS database.

2. PLATE HEAT EXCHANGER TYPES OF CONSTRUCTION

First, let's explain our understanding of the word "PHE". Plate heat exchanger is a heat exchanger whose main heat transfer area consists of several heat transfer plates formed by stamping or other strong, non- invasive deformation of thin plate information.

Detailed areas of printed circuit board and microchannel circuit board as described in are beyond the scope of the present Paper. The main feature of modern plate heat exchanger models is that they are energy saving and reliable heat exchangers in different processes.

(i)The number of connection points of adjacent plates in the ball plate creates a strong structure that can withstand large flow differences in the channel. This allows plate thicknesses as small as approximately 0.36 mm, thus reducing the use of expensive metal and the weight of the plate heat exchanger;

ii) It will change the flow direction and high levels of turbulence, eddies and vortex structures. As many researchers have shown, this occurs even at low Reynolds numbers. It creates a special heat transfer, and the transition from the laminar flow state to the turbulent flow state is very smooth;

(iii)The heat transfer coefficient of the hot plate heat exchanger is more than the traditional shell and tube type heat exchanger. Exchangers and require less heat transfer, making them more compact and requiring less space for maintenance;

2.1. Heat Exchanger Frame-and-Plate PHEs

The history of plate heat exchangers begins with the plate and frame type. Today it is a traditional building type and its basic principles have not changed during this century (see figure 2). However, research on improving electrical and mechanical properties is still on-going. Examples include studies on seal channel mechanical properties [15] and PHE structural properties [10]. Various modifications have been made to ports and connections to enable them to handle large amounts of steam for condensation and evaporation [16]. Many studies have also been conducted on the mechanical properties of paper and stamping machines. The results of these studies are mostly in the hands of leading plate heat exchanger manufacturing companies and are beyond the scope of this article. An important point to add about stamping technology is that the flexibility of the metal after stamping must be taken into account to avoid unevenness in the depth of the grooves in the sheet. Otherwise, due to the flow difference of the channel, the thermal and hydraulic performance of the heat transfer plate will be greatly affected, it will not be uniform and will be deformed according to the design.

High temperatures, dynamic loads and contact with acids, hydrocarbons, organic solvents, ozone, steam and oxygen cause aging and deformation of the seal. A better understanding of gasket aging can help expand the applications of gasketed plate heat exchangers (GPHE)

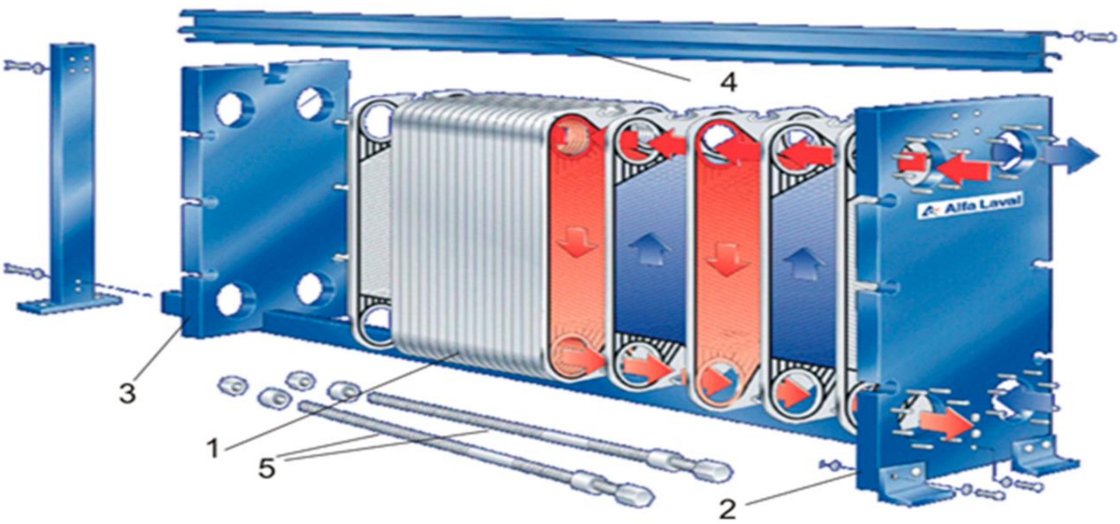

Figure 2. Plate-and-frame PHE (construction scheme): 1— gasket & stack of plates; 2—fixed-frame plate; 3—frame of moving plate; 4—carrying bar; 5—tightening bolts.

Commonly used gaskets are made from various modified nitrile rubber (NBR) and ethylene- propylene-diene rubber (EPDM). Operating temperature is between 45°C and 150°C. New gasket materials and models are being developed and can now be extended from 60°C to 200°C with the use of special gaskets. The cost for rigid gaskets may exceed the cost of all other parts of the plate heat exchanger. Plate and shaft plate heat exchangers operate in a wide range of vacuum conditions up to 25 bars. At high pressure, the heat exchanger must be made of thick plates that can account for most of the weight of the plate heat exchanger when made from cheaper steel. The frame is designed for different pressures, usually up to 10 bars, 16 bars and 25 bars, so as not to be too heavy.

2.2. Welded Plate-and-Block PHEs

The best and most commonly used plate welded plate heat exchanger is the Compabloc TM shown in Figure 4. It has a set of plates in terms of thermal and hydraulic properties. Each block has streams. However, in most cases there is an interface across the plate heat exchanger. From a thermal design perspective, the collision in different areas will reduce the average temperature difference that can be covered by the entire reverse flow in the plate heat exchanger. This depends on the desired temperature and the ratio of the heat capacity of the two streams. From a hydraulic perspective, the model provides good distribution over the entire channel width and minimal local hydraulic resistance at the channel entrance and exit. The group's special sealed welded construction allows continuous operation from 46°C to 370°C and a pressure range from vacuum to 42 bar. The absence of a seal not only increases poor performance, but also creates fatigue issues related to unstable conditions and vibrations caused by reciprocating compressors or steam hammer, which must be considered in all WPHE applications.

Currently, the plate heat exchanger parent company FunkeBlock produces FPB, GEABloc®, APV hybrid welded heat exchanger, etc. It produces welded plate heat exchangers with similar designs such as. [3]. The operating range of WPHEs is close to Compabloc, but without the seal in the housing assembly the APV Hybrid is claimed to operate at temperatures from 200°C to 900°C and pressures up to 60 bar.

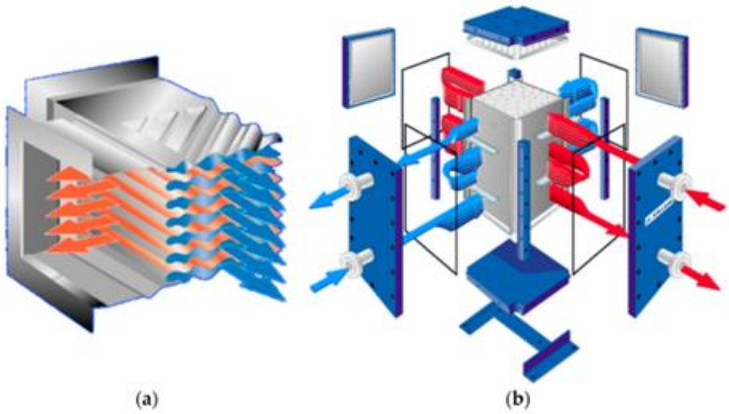

Figure 3. CompablocTM welded PHE: (a) plate pack schematic; (b) arrangement of cross-counter-current channels for stream flow (courtesy of OAO Alfa Laval Potok).

3. PHE THERMAL PERFORMANCE

Since the plate heat exchanger was first created, the only reliable method of correlating the thermal and hydraulic design of commercial plate heat exchangers has been experimental research. Nowadays, with the rapid development of technology, all new plate heat exchangers produced by manufacturers are subjected to thermal and hydraulic tests to achieve the required consistency, resulting in the plate heat exchanger design.

All of these dependencies are proprietary to the PHE manufacturer and include the software used to design the PHE. Only results and correlations obtained by independent researchers or authorized for publication are presented in the literature. Most of these publications include research on different heat exchangers using commercial plates, with this research mainly focusing on gasketed shaft plate heat exchangers. Mostly inclined corrugated sheets or herringbone sheets or herringbone sheets are used. The schematic diagram of such a board is shown in Figure 4.& fig 5.

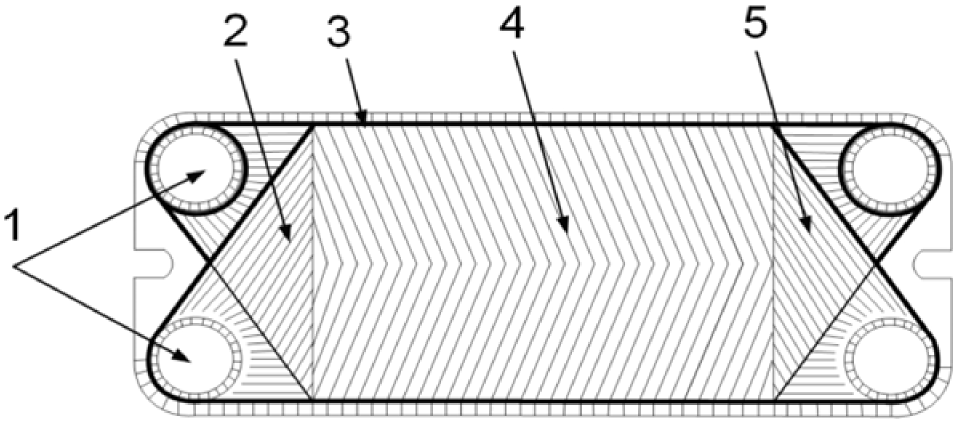

Figure 4. Schematic drawing of commercial PHE plate: 1—ports for stream flows in and out of the channel; 2 and 5—zones of flow distribution; 3—gasket; 4—the main corrugated field

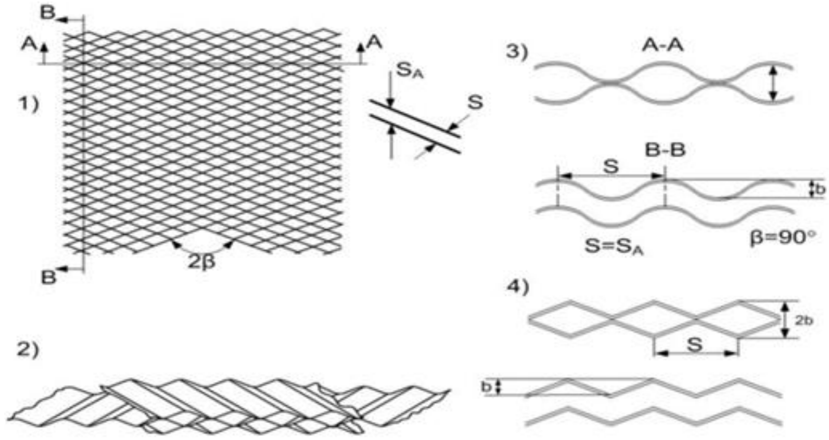

Figure 5. Schematic drawing of the main corrugated field channels: (1) corrugations crossing; (2) three-dimensional view; (3) sinusoid-shaped corrugations; (4) triangle-shaped corrugations.

The results of experiments on heat transfer and hydraulic resistance in the channels of PHEs are usually presented in the form of correlations similar to those for tubes.

$$Nu = A \cdot Re^{n} \cdot Pr^{p} \cdot (\mu_b/\mu_w)^{m}$$

$$\zeta = B \cdot Re^{r}$$

Here, Nu is the Nusselt number; Re is the Reynolds number; Pr is the Prandtl number; ζ is the friction factor; μb and μw are the dynamic viscosity at flow bulk and at wall temperatures, Pa·s; A, B, n, r, p and m are empirical parameters.

4. CONCLUSIONS

His article examines development trends and the latest technologies for heat transfer in hot plate heat exchangers. Research and data analysis show that the hot plate switch is now a mature and effective power transfer device in the industrial process. The development of modified channel seals and plate materials for plate heat exchangers allows them to be used in almost any application in industrial processes. The major developments are plate and shaft-plate heat exchangers, welded plate heat exchangers (WPHEs), brazed plate heat exchangers (BPHEs), and plate and shell plate heat exchangers (PSPHEs). Most modern plate heat exchangers use angled corrugated plates, which are assembled into a ball with a strong, rigid structure, with the various contact points of the plates adjacent to each other.

The center line of the plates of the heat exchanger has a rotation order of the intersection for the movement of heat transfer. The geometry of this channel promotes high levels of turbulence and increases heat transfer. The transition from laminar to turbulent flow occurs at lower Reynolds numbers than in walls and pipes. path. Numerous studies have shown that the main influence on the heat exchanger and hydraulic performance of plate heat exchangers is the angle of the grooves of the plates relative to the direction of the main flow. The Nusselt number in the PHE channel is higher than that in the walled column. At a 30° angle, Nu increases approximately twofold, increasing the angle from 30° to 60° increases the Nu number by seconds, depending on the Re number. The results of the studies vary depending on the experimental panel that conducted the experiment. The friction coefficients obtained with different PHE channel fluctuation field models can be generalized from the relationship. Heat transfer and shock in the heat transfer plate can be appropriately modeled by considering the process in the corrugated zone and at the inlet and outlet of the heat transfer plate separately. The design process for other types of heat exchange can be used to enhance heat. The most promising in the industrial process is the former process of improving the heat exchanger using improvements in plate corrugation and channel geometry in plate heat exchangers. These include groove parameter optimization methods. Although the use of roughness created by sandblasting for a one-time power change does not seem to be a very promising solution, another way of creating small changes in the surface may be promising. The use of nanofluids as heat exchangers can improve heat transfer in hot plate heat exchangers, but the application of this method in industrial processes is limited to electrical equipment with a closed circuit of the thermal medium. The commercial side of this development also needs to be taken into account. Active methods to improve heat transfer in plate heat exchangers are rare.

REFERENCES

[1] United States Environmental Protection Agency. Sources of Greenhouse Gas Emissions. 2022. Available online: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions (accessed on 17 July 2022).

[2] European Parliament News. EU Responses to Climate Change. 2022. Available online: https://www.europarl.europa.eu/news/en/headlines/society/20180703STO07129/eu-responses-to-climate-change (accessed on 17 July 2022).

[3] Hesselgreaves, J.E.; Law, R.; Reay, D. Compact Heat Exchangers: Selection, Design and Operation; Butterworth-Heinemann: Oxford, UK, 2016. [Google Scholar]

[4] Wang, L.; Sunden, B.; Manglik, R.M. PHEs. Design, Applications and Performance; WIT Press: Southhampton, UK, 2007. [Google Scholar]

[5] Abu-Khader, M.M. Plate heat exchangers: Recent advances. Renew. Sustain. Energy Rev. 2012, 16, 1883–1891. [Google Scholar] [CrossRef]

[6] Zhang, J.; Zhu, X.; Mondejar, M.E.; Haglind, F. A review of heat transfer enhancement techniques in plate heat exchangers. Renew. Sustain. Energy Rev. 2019, 101, 305–328. [Google Scholar] [CrossRef]

[7] Kumar, S.; Singh, S.K.; Sharma, D. A Comprehensive Review on Thermal Performance Enhancement of Plate Heat Exchanger. Int. J. Thermophys. 2022, 43, 109. [Google Scholar] [CrossRef]

[8] Ma, Y.; Xie, G.; Hooman, K. Review of printed circuit heat exchangers and its applications in solar thermal energy. Renew. Sustain. Energy Rev. 2021, 155, 111933. [Google Scholar] [CrossRef]

[9] Lalagi, G.; Nagaraj, P.B.; Veerabhadrappa Bidari, M.; Hegde, R.N. Influence of design of microchannel heat exchangers and use of nanofluids to improve the heat Transfer and Pressure drop characteristics: A review. Int. J. Ambient. Energy 2022, 43, 6849–6877. [Google Scholar] [CrossRef]

[10] Martins, G.S.M.; Santiago, R.S.; Beckedorff, L.E.; Possamai, T.S.; Oba, R.; Oliveira, J.L.G.; de Oliveira, A.A.M.; Paiva, K.V. Structural analysis of gasketed plate heat exchangers. Int. J. Press. Vessel. Pip. 2022, 197, 104634.

[11] Olga Arsenyeya 1,Leonid Tovazhnyanskyy 2,Petro Kapustenko 1 ORCID,Jiri Jaromir Klemes 1 ORCHID and andPetar Sabev Varbanov 1, Energies 2023,16 (13),4976.; https://doi.org/10.3390/en16134976

[12] Hajabdollahi, H.; Naderi, M.; Adimi, S. A comparative study on the shell and tube and gasket-plate heat exchangers: The economic viewpoint. Appl. Therm. Eng. 2016, 92, 271–282.

[13] Wang, B.; Arsenyeva, O.; Zeng, M.; Klemeš, J.J.; Varbanov, P.S. An advanced Grid Diagram for heat exchanger network retrofit with detailed plate heat exchanger design. Energy 2022, 248, 123485.

[14] Arsenyeva, O.; Kapustenko, P.; Tovazhnyanskyy, L.; Khavin, G. The influence of plate corrugations geometry on plate heat exchanger performance in specified process conditions. Energy 2013, 57, 201–207.

[15] Kabil, B. Parameter Study of the Diagonal on a Gasketed Plate Heat Exchanger. Master's Dissertation, Division of Solid Mechanics, Lund University, Lund, Sweden, 2022.

[16] AlfaLaval Types of Gasketed Plate Heat Exchangers. 2022. Available online: https://www.alfalaval.com/microsites/gphe/types/ (accessed on 24 June 2023).

[17] De Souza, E.L.; de Souza Zanzi, M.; de Paiva, K.V.; Goes Oliveira, J.L.; Monteiro, A.S.; de Oliveira Barra, G.M.; Dutra, G.B. Evaluation of the aging of elastomeric acrylonitrile-butadiene rubber and ethylene-propylene-diene monomer gaskets used to seal plates heat exchanger. Polym. Eng. Sci. 2021, 61, 3001–3016.

[18] Zanzi,M.S.; de Souza, E.L.; Dutra, G.B.; Paiva, K.V.; Oliveira, J.L.G.; Cunha, T.V.; Monteiro, A.S. Service lifetime prediction of nitrile butadiene rubber gaskets used in plate heat exchangers. J. Appl. Polym. Sci. 2022, 139, 52523.

[19] Tian, C.; Zhang, D.-W.; Zhang, Q.; Zheng, Z.B.; Zhao, S.D. A drawing-flaring process of metal bushing ring without welding seam for plate heat exchanger. Int. J. Adv. Manuf. Technol. 2022, 121, 2539–2552.

[20] Trelleborg Sealing Solutions Plate Heat Exchanger Gaskets. 2022. Available online: https://www.trelleborg.com/en/seals/products-and-solutions/engineered-molded-parts/plate-heat-exchanger-gaskets (accessed on 24 June 2023).

[21] Hashimoto, A.; Liu, S.B.; Shohji, I.; Kobayashi, T.; Hirohashi, J.; Wake, T.; Arai, S.; Kamakoshi, Y. Brazing of Stainless Steel Using Electrolytic Ni-P Plating Film and Investigation of Corrosion Behavior. Mater. Sci. Forum 2021, 1016, 522–527.

[22] Alfa Laval. Plate Heat Exchangers. 2022. Available online: https://www.alfalaval.com/products/heat-transfer/plate-heat-exchangers/plate-heat-exchangers/ (accessed on 24 June 2023).

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