Proceedings of CONF-FMCE 2025 Symposium: Semantic Communication for Media Compression and Transmission
DOI: 10.54254/2755-2721/2025.GL24420

Review of Corrugated Plate Design for Plate Heat Exchangers

Yize Zhang

National Center for Materials Service Safety, University of Science and Technology Beijing, Beijing, China
yucai1115559@163.com

Abstract. Heat exchange systems are key technologies that are widely adopted in industrial production and play an important role in many fields such as petrochemicals, aerospace, and integrated circuits. The plate heat exchanger, a crucial component in the heat transfer process, holds significant importance for design optimization to attain optimal heat transfer efficiency, given its popularity in the industrial sector. The heat exchanger plate is the most important part of the plate heat exchanger; different corrugated shapes of the heat exchanger plate have different effects on the heat transfer effect. This paper discusses common types of plate heat exchangers, including V-shaped corrugated plate heat exchangers and pillow-plate heat exchangers. It emphasizes the impact of corrugation angle, corrugation pitch, and corrugation height on the performance of V-shape corrugated plate heat exchangers, as well as the influence of weld spot distance and weld spot shape on the characteristics of pillow-plate heat exchangers. For V-shaped corrugated heat exchange plates, the ideal corrugation angle is between 60° and 70°. Heat transfer efficiency steadily declines with increasing corrugation height and pitch. For pillow-plate heat exchangers, an increase in either the horizontal or vertical distance of the weld spots will reduce the heat transfer efficiency. The heat transfer efficiency of the heat exchange plate is optimal when the weld spot shape is Elliptical 2.

Keywords: Plate heat exchanger (PHE), Heat transfer enhancement, Heat transfer plate, Structural parameters

1. Introduction

A heat exchanger is the device that transfers a portion of thermal energy from a hot fluid to a cold fluid, which is a general-purpose piece of equipment widely used in chemical, petroleum, power, food, and many other industrial sectors, playing a crucial role in production. The primary roles of heat exchangers include heating, cooling, and heat recovery. Heat recovery serves as a highly effective method for conserving energy and mitigating greenhouse gas emissions. The classification of heat exchangers based on the configuration of their heat transfer surfaces includes tube heat exchangers, plate heat exchangers (PHEs), jacketed heat exchangers, and specialized heat exchangers. Among these types of heat exchangers, PHEs stand out as a classic example [1].

© 2025 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2755-2721/2025.GL24420

Scholars have designed more than 60 different types of heat exchanger plates [2]. The improvements in corrugated plate structure design primarily focus on three aspects: embossed surfaces, secondary corrugated surfaces, and surface roughening treatments [3]. The embossed surface involves creating ordered, independent embossments on the plate surface, functioning similarly to finned plates. There are two types of embossed surfaces for heat exchange plates: concave-convex surfaces and staggered surfaces. The secondary corrugated surface is formed by machining the primary corrugated plate surface, typically adopting conventional V-shaped structures as the primary corrugation pattern. Surface roughening treatment refers to creating a roughened surface texture on the basis of smooth V-shape corrugations [4].

2. Different corrugation Geometries of heat transfer plates

2.1. V-shaped corrugated PHE

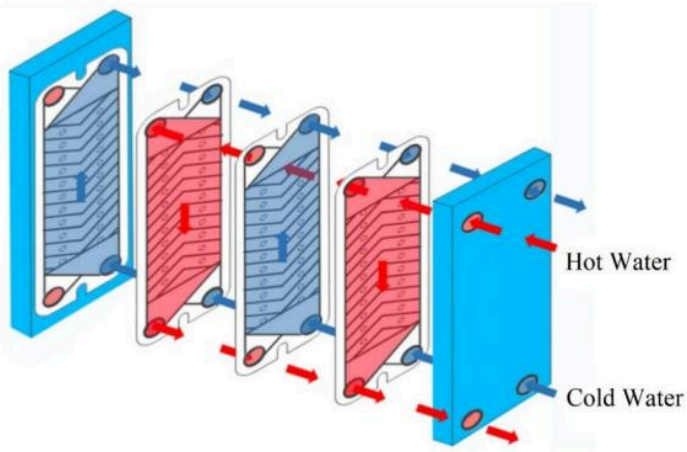


Figure 1: Schematic diagram of V-shape PHE [5]

Different corrugated plate shapes have different heat transfer and resistance properties for fluid flow. The main parameters to measure the performance of corrugated plates are heat transfer efficiency, flow resistance and pressure-bearing performance. After a long period of research and practice, the V-shaped corrugated plate is proved to have the best comprehensive effect, Figure 1 shows the V-shaped PHE schematic diagram. The V-shaped corrugations demonstrate relatively high heat transfer efficiency with a more balanced pressure drop performance, numerous contact points, and excellent pressure-bearing capacity. The primary reason lies in the complex flow channel cross-section configuration formed by the V-shaped corrugations, which subjects the fluid to irregular disturbances from the contact points. This design facilitates turbulence induction at lower Reynolds numbers, thereby enhancing heat transfer performance. However, this mechanism inevitably leads to certain energy consumption due to the induced flow resistance.

Numerous researchers have utilized CFD technology to analyze the factors affecting the heat transfer efficiency of V-shaped plate heat exchangers, encompassing parameters, such as the corrugation inclination angle, corrugation pitch, and corrugation height, as well as auxiliary structural components. Research findings indicate that the heat transfer sensitivity of these three parameters decreases in the sequence of corrugation inclination angle, corrugation height, and corrugation pitch [6]. Furthermore, among these parameters, the influence of corrugation inclination angle and corrugation depth on pressure drop is significantly less than that of corrugation pitch.

DOI: 10.54254/2755-2721/2025.GL24420

2.1.1. Effect of corrugation inclination angle

When the corrugation inclination angle β is less than 45°, the flow pattern approximates "cross-flows", where the flow directions of the two fluids are perpendicular to each other. Conversely, when β exceeds 45°, the flow pattern more closely resembles "helical flow", characterized by fluid possessing both axial and tangential velocity components. Research indicates that the corrugation inclination angle has a direct impact on heat transfer efficiency, though this relationship does not exhibit a linear correlation. An optimal inclination angle exists that maximizes performance. While different researchers have proposed varying optimal angles, these values generally fall within the range of 60° to 70°. Zhang et al. [7] employed numerical simulation methods to investigate the coupled heat transfer characteristics in dual-fluid channels of a PHE. They simulated the heat transfer performance at β of 40°, 50°, 55°, 60°, 70°, and 80°. The results revealed that the Nusselt number (Nu) reached its maximum value when the corrugation inclination angle was 60°, indicating optimal thermal performance at this specific geometric configuration [8]. However, Li et al. [9] and Lee et al. [10] similarly derived the following conclusions based on the aforementioned experiments: β is optimal at 70° and 66.5°, respectively.

2.1.2. Effect of corrugation pitch and height

The corrugation pitch and height also serve as significant factors influencing heat transfer performance. Studies have shown that as the corrugation pitch increases, the flow pattern transitions from "cross flow" to "helical flow", resulting in a gradual reduction of heat transfer effectiveness. Yan et al. [6] investigated the influence of corrugation height on heat transfer performance in plate heat exchangers. They conducted experiments using heat transfer plates with corrugation heights ranging from 3 mm to 7 mm. The results demonstrated that as the Reynolds number increased, the temperature differences across various corrugation heights exhibited an overall decreasing trend. This indicates that with increasing corrugation height, the heat transfer performance gradually deteriorates.

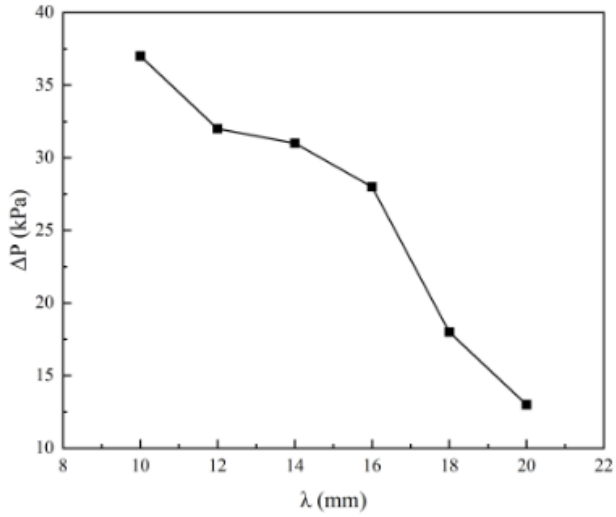


Figure 2: The variation curve of pressure drops with corrugation pitch [9]

DOI: 10.54254/2755-2721/2025.GL24420

Figure 2 illustrates the variation curve of pressure drop with corrugation pitch, showing a decreasing trend of pressure drop as the corrugation pitch increases.

Similarly, Zhang et al. [7] introduced a novel parameter - the corrugation pitch-to-height ratio (defined as the ratio of corrugation pitch to corrugation height) - in their investigation. The study revealed that for Re numbers exceeding 1085, corrugated plates with larger pitch-to-height ratios exhibit superior heat transfer performance. Conversely, when the Re number falls below this threshold, plates with smaller pitch-to-height ratios demonstrate enhanced heat transfer effectiveness.

2.2. Pillow Plate Heat Exchanger (PPHE)

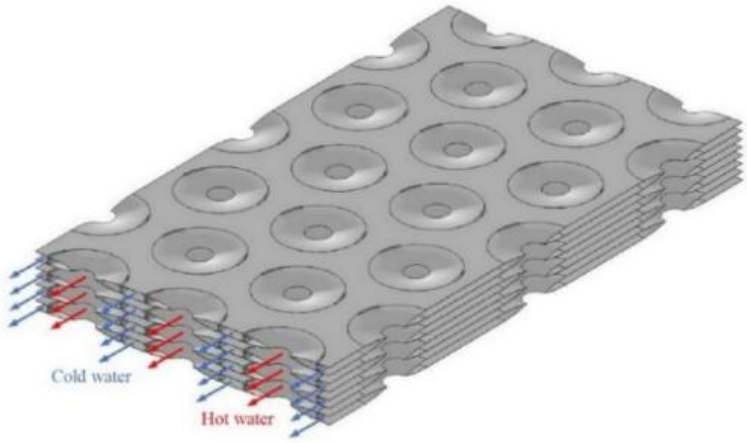


Figure 3: Schematic diagram of PPHE [11]

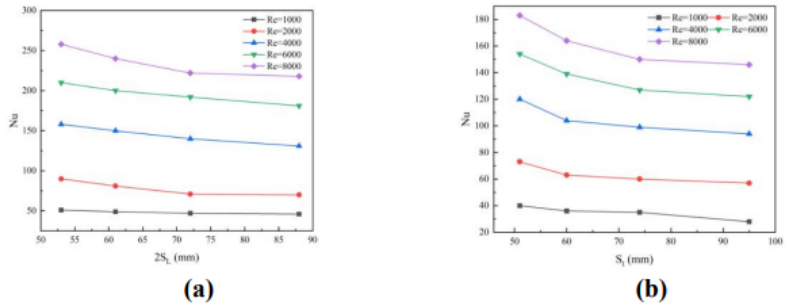
Figure 3 illustrates the heat transfer mechanism of a PPHE, which features stamped protrusions forming a pillow-like structure on the plates. As a novel type of plate heat exchanger, its corrugated channels enhance fluid turbulence to disrupt thermal boundary layers near the wall surfaces, thereby augmenting heat exchange performance. The continuous flow redirection within its internal channels induces thinning of the flow boundary layer, resulting in superior thermal performance. This design is particularly suitable for handling high-viscosity or particulate-laden fluids.

2.2.1. Effect of weld spots distance

PPHEs achieve efficient heat transfer through internal channels formed by welding spots. As a critical design parameter, weld spacing directly influences fluid dynamic characteristics, heat transfer efficiency, and equipment reliability.

Mojtaba et al. [12] investigated the effects of longitudinal and transversal distances of welding spots on PPHEs' performance under varying Re numbers. As shown in Figure 4, Nu numbers decrease with increasing longitudinal welding spot distance across all tested Re numbers. Similarly, Nu numbers exhibit a decreasing trend with elevated transversal welding spot distances under each Re condition.

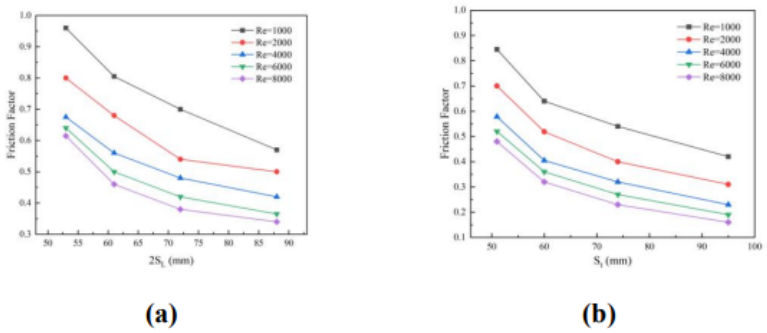
DOI: 10.54254/2755-2721/2025.GL24420



(a) Effect of longitudinal distance of the welding spots; (b) Effect of transversal distance of the welding spots

Figure 4: Variation of Nu number with welding spot distance [12]

As shown in Figure 5, the friction factor exhibits a decreasing trend with increasing longitudinal welding spot distances across all Re numbers; similarly, it also decreases with elevated transversal welding spot distances.



(a) Effect of longitudinal distance of the welding spots; (b) Effect of transversal distance of the welding spots [12]

Figure 5: Variation of friction factor with welding spot distance

2.2.2. Effect of weld spots shape

In addition to weld distance, weld spot shape also significantly impacts the heat transfer performance of PPHEs. Hu [11] investigated plate configurations with various weld spot shapes, including circular, droplet shaped, airfoil, elliptical 1, elliptical 2, and flat tube shapes. These distinct weld spot patterns are illustrated in Figure 6.

DOI: 10.54254/2755-2721/2025.GL24420

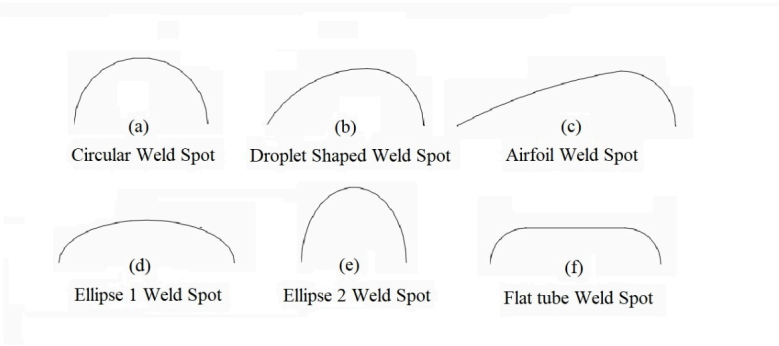


Figure 6: Weld shapes [11]

The study revealed that the elliptical 2 weld spot configuration exhibits the optimal heat transfer performance. The heat transfer efficacy diminishes in the sequence of circular, droplet, flat tube, and Elliptical 1 configuration, with the airfoil weld spot configuration demonstrating the poorest performance. Figure 7 presents the Nu number variations for different weld spot shapes across various Re numbers.

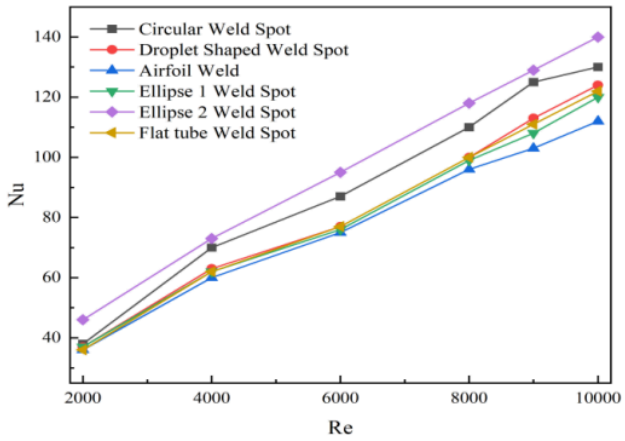


Figure 7: Investigation of the effect of weld spot shape on Nu Number

3. Prospects for the structural development of PHEs

The current structural optimization of PHEs faces a critical challenge: while enhancing heat transfer through surface topology modifications (such as corrugation angles, and corrugation pitches) and inter-plate arrangement improvements, these enhancements are often accompanied by substantial pressure drop increases, leading to elevated operational energy consumption and costs. To address this, collaborative innovation integrating multi-disciplinary algorithms and numerical simulation technologies is essential to achieve precision design of both plate surface structures and flow channel configurations.

The primary objective of heat exchanger design is to achieve optimal heat transfer performance, characterized by the maximum Nu number and minimum friction factor. However, these objectives exhibit a mutually conflicting relationship that necessitates a comprehensive evaluation to attain a compromised optimal solution. The implementation of multi-objective optimization algorithms

DOI: 10.54254/2755-2721/2025.GL24420

enables iterative computation of structural parameters and objective functions. Through coordination between output target parameters and multi-objective input variables, a Pareto optimality is achieved, representing the optimal parameter configuration identified under the premise of maintaining or improving the performance indices of target parameters. In recent years, numerous advanced optimization algorithms have been successfully applied to heat exchanger optimization research. These algorithms have demonstrated remarkable advantages in structural optimization, heat transfer performance enhancement, and cost control of heat exchangers, thereby advancing the development of more efficient and compact heat exchanger designs.

4. Conclusion

This paper focuses on the structural design of PHEs with various corrugation geometries, with particular emphasis on the impacts of corrugation angle, pitch, and height in V-shaped corrugated plates, as well as the effects of welding spot distance and shape in PPHEs. Key conclusions are summarized as follows: (1) In V-shaped corrugated PHEs, the corrugation angle is identified as the most critical factor affecting heat transfer performance, with optimal heat transfer achieved when the corrugation angle is maintained within 60-70°. (2) For PPHEs, increasing either transversal or longitudinal welding spot distance results in reduced heat transfer performance. (3) The elliptical 2-welding-spot configuration demonstrates the most favorable heat transfer characteristics among evaluated geometries.

References

[1] Borjigin, S. , et al. (2025) Review of plate heat exchanger utilized for gases heat exchange. Renewable and Sustainable Energy Reviews, 210: 115224
[2] Camilleri, R. , S. Ogaji, and P. J. A. J. Pilidis. (2011) Applying heat pipes to a novel concept aero engine. Part 2 – Design of a heat pipe heat exchanger for an intercooled-recuperated aero engine. 115(1169): 403-410.
[3] Amalfi, R. L. , F. Vakili-Farahani, and J. R. Thome. (2016) Flow boiling and frictional pressure gradients in plate heat exchangers. Part 1: Review and experimental database. International Journal of Refrigeration-revue Internationale Du Froid, (61): 166-184.
[4] Wenjing Du, et al. (2021) Review and prospect of the development of heat exchanger structure. Journal of Shandong University. Engineering Science, 51(5): 76-83.
[5] Kai Liu, Ting Fu, Liangcai Zeng, Zhaohui Wang. (2021) Numerical Simulation of Herringbone Plate Heat Exchanger with Pin-Fin Rows. Mechanical Science and Technology for Aerospace Engineering, 40(12):1829-1835.
[6] Yu Yan, Xianming Liu, et al. (2025) Structure Optimization of Corrugated Plate of Plate Heat Exchanger Based on Oil-based Drilling Fluid Cooling. Drilling & Production Technology, 48(2): 149-156.
[7] Yubao Zhang, Haiyang Xu. Numerical Simulation and Parameter Optimization on Traditional Properties of Plate Heat Exchanger. Vacuum & Cryogenics, 2016, 22(5): 296-300.
[8] Kanaris A. G. , M. A. A. , Paras S. V. (2009) Optimal design of a plate heat exchanger with undulated surfaces. International Journal of Thermal Sciences, (48):1184-1195.
[9] Can Li, et al. (2016) The influence of corrugated parameters on the heat transfer and pressure drops characteristics of the plate heat exchanger. Cryogenics and Superconductivity, 44(11): 85-92.
[10] Lee, J. , K. S. Lee. (2015) Friction and Colburn factor correlations and shape optimization of chevron-type plate heat exchangers. Applied Thermal Engineering, 89(1): 62-69.
[11] Honglei Hu. (2023) Research on performances of fluid flow and heat transfer of pillow plate heat exchanger with protrusion and ellipsoid dimple. Lanzhou Jiaotong University.
[12] Shirzad, M. , et al. (2019) Evaluation the effects of geometrical parameters on the performance of pillow plate heat exchanger. Chemical Engineering Research & Design, (150):74-83.