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A Review of Heat and Mass Transfer in Heat Exchangers

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Abstract

This study provides a comprehensive overview of how heat exchangers may be used to improve heat transmission. Many advantages may be gained by using Process Integration to improve heat transmission. As a first advantage, improved heat exchangers have smaller heat transfer areas for the same heat duty. Second, the size of a particular heat exchanger doesn't have to be raised to enhance the capacity for heat transmission. In this study, we provide a number of strategies for improving the efficiency of shell-and-tube and compact heat exchangers. The techniques take into account the exchanger's initial performance, the amount of surplus pressure drop capacity in the system, the assessment of fouling factors, the usage of augmented surfaces, and the improvement of heat transfer. The heat transfer an energy efficiency of heat exchangers are two areas where nanofluids show tremendous promise for future development. Finally, the geometries tube inserts, baffles, tube deformation, and fins might improve are addressed.

Keywords: Compact heat exchanger, Enhancements in heat exchanger, Nano fluid.

Introduction

In order to prevent the mixing of fluids of various temperatures, heat exchangers are used. No

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significant heat or work exchanges from the outside world are often seen in heat exchangers. Heat exchangers have several practical uses, ranging from HVAC systems in homes to industrial chemical processing and electricity generation. One way in which heat exchangers are distinct from mixing chambers is that they do not let the two fluids to mix. When two fluids are separated by a wall, heat may move between them through convection in both fluids and conduction along the wall. Heat transfer co-efficient U is a useful metric to use in heat exchanger analysis since it summarises the combined impact of all these factors.

Shell and Tube Heat Exchangers

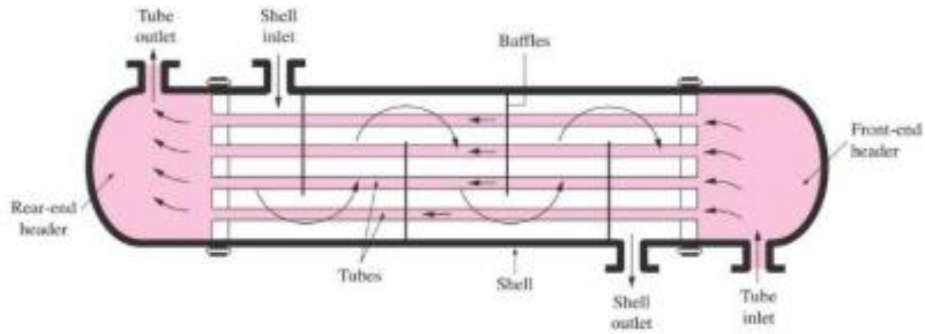

Fig.1: The schematic of a shell and tube heat exchanger

In shell-and-tube heat exchangers, hundreds or even thousands of tubes are packed tightly within a shell at right angles to the shell's axis. For a heat exchanger to function more efficiently, the load must be transferred, or the operating temperature must be brought closer to the design temperature. This may be done without resorting to a drastic increase in area. Because of this limitation, the total heat transfer coefficient, U, must be increased. The total heat transfer coefficient may be calculated by adjusting the variables surface area (A), work (W), and motive power (T). Almost every heat exchanger design uses this equation.

$$Q = UA\delta T$$

U is determined by the coefficients of heat transmission in the film (h), the thermal conductivity of the metal (k), and the presence or absence of fouling (f). If the amount of U available is more than the amount of U needed, the Anex changer should function properly. All heat transfer impediments are taken into consideration in the accurate determination of U derived from the transport relationships. The coating coefficients, thermal conductivity of the metal, and fouling are all factors in this resistance. U is determined by using an area as the metric of choice. The region is typically the tubes' exteriors in shell-and-tube heat exchangers.

Compact Heat Exchanger

Area density refers to the surface area used for heat transfer as a percentage of the total volume of a heat exchanger. In the heat exchanger industry, a compact heat exchanger has a heat transfer coefficient () of 700 m2/m3 (or 200 ft2/ft3). By definition, a small heat exchanger will have a high "area density" heat transfer surface. So, it has a lot of exposed area relative to its volume, making it good at dissipating heat. A compact heat exchanger may or may not have a tiny footprint. Compact heat exchangers contain a surface with a high area density to keep the size and weight of the unit to a minimum; without this feature, the resultant units would be significantly larger and heavier. The performance of a heat exchanger, denoted by the ratio q/Tmean, is optimised by the utilisation of compact surfaces while adhering to tolerable mass and volume restrictions.

$$\frac{q}{\Delta T_{mean}} = U\beta V$$

One of the most important processes used in modern manufacturing, consumer goods, and machinery is heat transfer between physical systems. In addition, a highly efficient and compact heat transfer system is needed to transfer the necessary amount of heat from low-performance liquids. In order to enhance the heat transmission and thermal characteristics of devices, it is common practise to apply additives to liquids containing solid particles smaller than 100nm. This innovation may be found in nanofluids or nanocomposites. Due to their low viscosity and high thermal conductivity, nanofluids are ideal for use in heat exchange applications across different physical systems. Although nanoparticles in a base fluid may move randomly, they are kept in a somewhat stable state by constant interaction with the medium's molecules. Heat conductivity describes how easily one kind of material transfers heat to another. Because of its greater conductivity compared to microfluids and other nanoparticle suspensions, nanofluid is the preferred medium for thermal heat transfer applications.

Classifications of Heat Exchangers

To raise or lower the overall heat output of a system, heat exchangers are used. Whenever there is a temperature differential between two fluids, heat is transferred between them.

The heat exchanger works by convection, where heat is transported from the wall surface to the cool fluid below. Heat exchangers are not the same as mixers, and this must be stressed. In the latter, energy is delivered by the mixing of the two fluid streams, either in a controlled volume or independently, such that the combined stream exits the device.

It is possible to classify heat exchangers according to (a) the method of transfer, (b) the quantity of fluids, (c) the method of construction, (d) the principle of heat transfer, (e) the compactness of the surface, (f) the arrangement of the flow, and (g) the type of the surface. The recuperator is used when energy transfer occurs between fluids of different temperatures flowing in a room separated by a thin, sturdy wall (a separating sheet), and the regenerator is a sort of heat exchanger in which heat is transferred from a hot fluid to a cold fluid over the same surface at regular intervals determined by a control system.

- **Nanotechnology in Heat Transfer**

Increases in convection and thermal conductivity resulted from the incorporation of nanoparticles into a base fluid. Sedimentation, erosion, clogging, and a decrease in high-pressure are only some of the problems that have prevented this technology from being put into widespread usage. Improving thermal transfer for fluid with a low concentration of nanoparticles entails raising the nanoparticles' heat conductivity and turbulence. Carbon nanotubes, graphite, and nanofibers are examples of organic functional materials, whereas inorganics include materials with dimensions more than 100 nm but less than 1,000 nm. The former consists of materials like aluminium, zinc, iron, copper, aluminium oxide, iron oxide, and titanium oxide, while the later is a kind of designed colloids that may replace conventional heat transfer media in the near future.

- **Enhancement techniques in plate heat exchangers**

Multiple teams of researchers have looked at PHEs to see whether they can improve the efficiency of single-phase heat transfer via the use of enhancement methods. In particular, the majority of the research used passive methods, with a primary emphasis on passive surface methods and nanofluids. Figure 2 displays the proportion of studies (66 journal and conference papers published between 1999 and 2018) that focused on heat transfer patterns, enhancing approaches, and research methodologies. Additional benefits, such as reduced pressure drop and improved heat transfer performance, are also assessed in these experiments. Here, we provide a summary of the many methods used to improve heat transmission in PHEs, including passive surface approaches, nanofluids, and others (the active techniques and other passive techniques different from passive surface techniques and nanofluids).

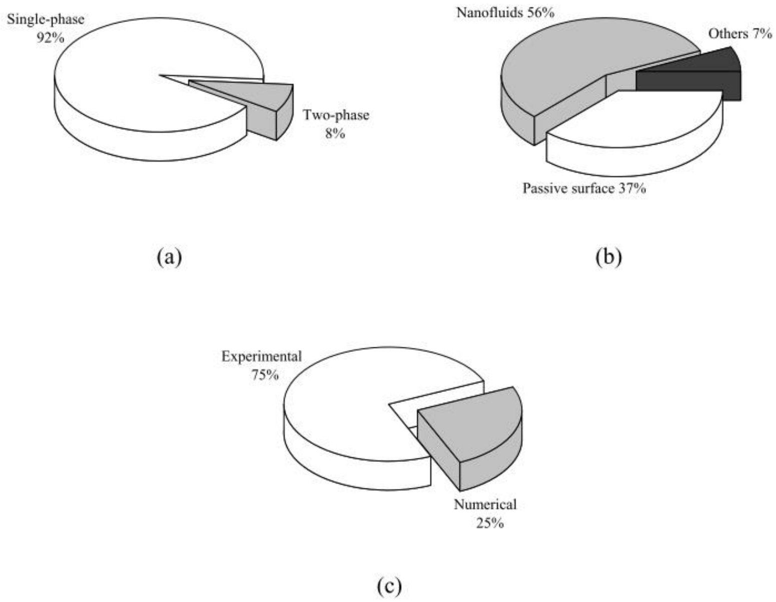

Figure 2 The percentages of the studies related to the heat transfer enhancement in (a) single-phase and two-phase and (b) enhancement techniques.

- **Single-phase enhancement Diverse**

Multiple passive surface shape/configuration proposals and implementations have been made to improve single-phase heat transmission in PHEs. Such passive methods often involve modifying the plate's surface in one of three ways: Surfaces that have been embossed, corrugated twice, or roughened are all considered to be Type I surfaces.

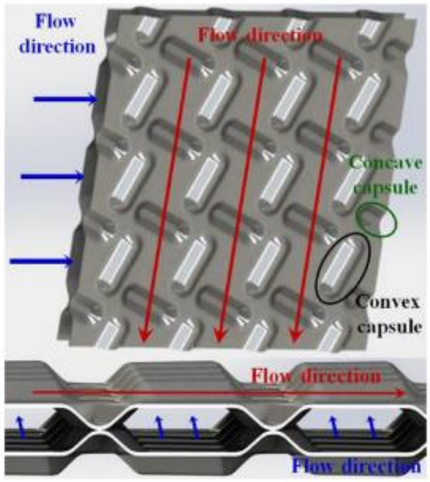

Figure 3 Schematics of a capsule-type PHE

The first category of surfaces is distinguished by a pattern of separate embossings arranged in a grid, giving the impression of a finned plate. One plate may have both a concave and a convex embossing surface, and these two surfaces are staggered from one another. A PHE shown in diagrammatic form (see Figure 3) demonstrating capsule-style embossing. Compared to traditional chevron corrugation PHEs, capsule embossing structures like these have the benefits of less deposit and fouling, decreased pressure loss, and simple cleaning and maintenance. For usage with very viscous fluids, the authors created a PHE in capsule form, which is widely used in the petroleum sector. The plate channel was modelled numerically using a shear-stress transport k- turbulent model to examine both the flow of a single phase and the heat transfer between the plates. Based on the numerical findings, capsule-type PHEs have superior thermal-hydraulic performance compared to standard chevron corrugation PHEs.

Literature Review

(Elatharasan, 2020) The heat-transfer properties of a helical coil are investigated under different boundary conditions. A variety of flow characteristics and their consequences are examined. Heat transport properties are estimated through an experimental setup.

(Ayub, 2003) Heat transfer and fluid flow properties of these exchangers need immediate and comprehensive study. In this regard, a literature review on plate heat exchangers is given as an effort. Different pressure conditions in the system and plate chevron angles are taken into account in the new correlations for the evaporation heat transfer coefficient and the friction factor.

(Rather & Yadav, 2019) STHX performance has been improved because to years of dedicated work by many people. Among these initiatives is exploring different baffle options. Having so much room to play with thanks to the many possible baffle configurations and baffle angles. Baffles may be set up in a wide variety of ways, and each one has been shown to improve performance in a specific scenario.

(Kelvin et al., 2019) The goal of this effort is to increase understanding of the workings and potential applications of nanotechnology in heat exchangers that deviate from the traditional design. This research looks at heat exchanger experiments conducted over the last decade, the information gap between those tests, and potential future uses of nanotechnology to address that knowledge gap.

(Zhang et al., 2019) Plate heat exchangers may be made more efficient by geometric optimization or by using heat transfer improvement methods. The impact of chevron corrugation geometrical parameters on plate heat exchanger performance, as well as the use of heat transfer enhancement methods in plate heat exchangers, with an emphasis on passive surface approaches and the use of nanofluids, are reviewed in detail in this study.

(Charate et al., 2015) As a first advantage, improved heat exchangers have smaller heat transfer areas for the same heat duty. Second, the size of a particular heat exchanger doesn't have to be raised to enhance the capacity for heat transmission.

(Bode et al., 2021) Although many scientific research have touched on the topic, the impinging jet is still poorly understood owing to the challenges of conducting extensive experimental and computational examinations into the nature of the events outlined above. But both passive and active tactics are used to improve heat transmission in impinging jet applications.

(Stone & Conditioning, 1996) The need to improve heat transmission is explained, and the basic concepts of small heat exchangers are outlined. Following that is a discussion of how first and second law analysis can be used to evaluate and compare different heat transfer enhancement devices.

(Bhagwan, 2021) Heat exchangers are commonly used in a variety of industrial and municipal applications, including but not limited to: space heating, air conditioning, refrigeration, power generation, chemical production, petrochemical processing, petroleum refining, natural gas processing, and wastewater treatment. In the radiator of a car, hot water from the engine coolant transfers heat to the air passing through the radiator, making the heat source the water itself.

(Musa & Wang, 2013)Shell-and-tube type of heat exchangers have been commonly and most effectively used in Industries over the years. In this paper we see a review of Outline and Types of Heat exchangers , Thermal Design and Mechanical Design by the use of ASME,TEMA standard take a case study of Modern Shell & Tube type Heat exchanger.

Conclusion

The first thing to check is whether the exchanger is functioning properly to begin with. If possible, increasing the pressure drop in single-phase heat exchangers is the next thing to think about. A speed boost may be all that's needed to boost performance, since higher velocities lead to greater heat transfer coefficients. After that, it's time to take a close look at the estimated fouling factors. With regular cleaning and less cautious fouling causes, heat exchanger performance may be improved. When added to a mixture, nano fluids, which are liquids containing well-dispersed metallic nanoparticles in small volume fractions, improve the thermal conductivity of the whole above the values for the base fluids. Finally, finned tubes, inserts, baffles, and the inculcation of Nano-fluids may all be viable options for improving heat transmission under certain situations.

This article provides a summary of the single-phase correlations known for plate heat exchangers in a manner that a working engineer may use for design and analysis. Suggestions for use in two-stage implementations are provided. For both flooded and direct expansion evaporators, new correlations between two-phase boiling and pressure drop are introduced. This article should be used as a springboard for more study in this vital field. Plate exchangers' thermal and fluid flow characteristics must be studied experimentally, and this includes the effects of plate geometry, chevron angle, chevron depth, orientation, flow direction, flow distribution, inlet quality, feed ratio, outlet superheat, system pressure, single and multi-pass configuration, refrigerant type, oil effect (miscible and non-miscible), and end-plate effects.

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