© UNIVERSAL RESEARCH REPORTS | REFEREED | PEER REVIEWED
ISSN : 2348 - 5612 | Volume : 09 , Issue : 03 | July - September 2022

A Literature Survey On The Thermal Enhancement Of Heat Exchangers

Md Sajjad Alam[1], Shivendra Singh[2]

[1]*Research Scholar, Department of Mechanical Engineering, Corporate Institute of Science and Technology*

[2]*Assistant Professor, Department of Mechanical Engineering, Corporate Institute of Science and Technology*

ABSTRACT

The process of transferring heat between fluids requires a device known as a heat exchanger. The fluids may be in separate chambers or in direct contact with one another, depending on the design of the heat exchanger. Though many of the same concepts apply to the construction of heat exchangers and other devices that use energy sources like nuclear fuel pins and fired heaters, they are often not considered heat exchangers. This paper deal with the literature survey of the recent ongoing advances in the thermal enhancement of the heat exchangers and also briefly discusses the heat transfer mechanism.

Keywords: Heat exchangers, nuclear fuel pin, fired heaters, thermal enhancement

INTRODUCTION

To put it simply, heat exchangers are mechanical systems that transfer thermal energy from one fluid (liquid, gas, or vapour) to another. Heat may be transferred from one fluid to another either via a solid separator that prevents the fluids from mixing, or by direct fluid contact, depending on the kind of heat exchanger used. Different kinds of heat exchangers may be broken down further by examining their components, construction materials, heat transfer processes, and flow arrangements. These heat exchanging devices are made in a broad variety of configurations for use in both cooling and heating operations, and they find widespread usage across many different sectors. Thermodynamics, the study of temperature, heat energy flow, and their links to other types of energy, is put to use in the construction of a heat exchanger. Thermodynamics of a heat exchanger is best grasped by first being familiar with the three modes of heat transmission (conduction, convection, as well as radiation).

When two materials are in direct touch with one another, heat is transferred from one to the other via a process known as conduction. Objects with a greater temperature have more molecular motion because the average kinetic energy of their molecules is larger. When a hotter item is in in touch with a colder one, thermal energy is transferred from the hotter to the colder object. This will go on until the temperature is just right. Convection is the process whereby heat is carried away from a surface by the flow of a heated fluid, like air or water. When heated, most fluids expand, becoming less dense and rising above cooler regions of the fluid. When a room is heated, the air rises to ceiling due to its lower dense at that temperature, and then it cools and sinks back down to the floor when it collides with the colder air below it, where it becomes denser. Through this mechanism, a free convection current is generated. Forced convection, also known as aided convection, takes place when a heat source (like hot water in a hydronic heating system) is used to move the air across a space. The emission of the electromagnetic waves from the heated surface or item constitutes the heat transmission process known as thermal radiation. There is no need for an intermediary medium when it comes to heat radiation, unlike conduction as well as convection. Objects with temperatures over -273.15 degrees Celsius generate heat radiation across a wide spectrum.

LITERATURE REVIEW

[1] (Khashi'ie et al., 2022) Reiner–Philippoff fluid flow across a nonlinearly contracting sheet is being investigated in this work to see how MHD as well as viscous dissipation affect radiative heat transfer. To translate the multivariable differential equation partial derivatives into the similarity equations, the proper similarity transformations need to be used. Use of the bvp4c approach is used in MATLAB software to explain the mathematical model that was generated.

Tables as well as graphs are used to demonstrate the effect of various input physical characteristics on the issue. When the Eckert number as well as radiation parameter are put into the working fluid, heat transfer decreases. A higher "skin friction coefficient" and a higher local Nusselt number immediately increases the heat transfer performance by raising the magnetic parameter. It's clear that raising the suction parameter's value has an impact on the performance of the "Reiner–Philip–poff" fluid in terms of both the "skin friction coefficient" as well as the heat transfer. To verify the validity of the first solution, we must do a stability analysis which takes into account both of the possible solutions.

[2] (Hossain et al., 2021) In this study, a new hybrid heat exchanger with a shell and two pipes was developed and put to use to boost the efficiency of the heat transfer process. Double pipes were used instead of plain tubes to improve the heat transmission area. A sandwich of the two fluids exchanged heat as the streams passed through the annulus. Using computer modelling and simulation, we were able to accurately predict this device's performance. Co-current, insulated, counter-current, and the non-insulated flow patterns were simulated and compared to the experimental data under the steady-state conditions. In order to heat or cool, a heat exchanger would use three fluids, like two hot fluids and one cold fluid (H-C-H) or the other way around (C-H-C). According to the findings, the temperature changes predicted by the model were in excellent agreement with experimental data. The heat exchanger's fluid flow was found to be the turbulent in all areas. It was determined that the pressure drop and the "standard uncertainty values" were modest. Heat exchanger efficiency was shown to be 60 percent higher with the suggested heat exchanger compared with alternative design configurations (such as a twin pipe, shell and tube, or an existing lab-scale shell and tube heat exchanger).

[3] (Saleh & Syam Sundar, 2021) In a two-pipe U-bend heat exchanger, the thermal performance, embodied energy, as well as environmental CO_2 emissions of a MWCNT/water nanofluid flow are experimentally assessed. Experimental conditions included varying Reynolds numbers (3500–12000) and the particle volume concentrations (0.5%–0.3%). At 70 °C, the thermal conductivity as well as viscosity increase by 15.27% & 9.15%, respectively, above water measurements. At a particle concentration of 0.3 percent and a Reynolds number of 10,005, the Nusselt number, the heat transfer coefficient, and the thermal performance factor increase by 31.3 percent, 44.17 percent, and 25.5 percent, respectively. At 0.3 percent particle concentration as well as a Reynolds number of 10,005, the pressure drop, the pumping power, as well as friction factor penalty are 17.05 percent, 15.96 percent, and 14.29 percent, respectively, compared to water. At 0.3 percent particle concentration as well as a Reynolds number of 10,005, transfer efficiency and the number of transfer units increase by 2.49 percent and 2.75 percent, respectively, compared to water data. The improved efficiency of the heat exchanger is taken into consideration when estimating costs, weight, the embodied energy, as well as CO_2 emissions. By increasing the concentration of nanoparticles in water, the heat exchanger's embodied energy decreases from 403.7 to 393.1 megajoules. Using 0.3 vol percent of nanofluid, the heat exchanger costs 61.46$, while water costs 63$. Environmental CO_2 emissions are decreased to 81 kilogramme of CO_2 when nanofluid at 0.3 vol percent is used instead of water, which is 83.3 kg of CO_2.

[4] (Rehman et al., 2020) According to experts, non-Newtonian fluid in closed containers introduces complex mathematical models, and hence it is impossible to study the flow field in detail. It's the first numerical analysis of a non-Newtonian fluid flow fitted with a hexagonal-shaped cavity that is buoyantly convective. Hexagonal cavity has a T-shaped fin placed in the bottom wall. The adiabatic state of the hexagonal cavity's top wall is clearly visible. The bottom of the container is heated evenly. The walls on both sides of the room are maintained at a constant temperature. System of the partial differential equations is used to regulate the "buoyantly convective Casson fluid flow" around an evenly heated T-shaped fin. The numerical solution is reported using the finite element technique. Triangular as well as rectangular pieces are used to discretize the hexagonal enclosure as a computing area. The Rayleigh number is used to study the velocity as well as the temperature distribution around an evenly heated T-shape. Additionally, the dimensionless Casson fluid as well as Casson temperature are reported on a T-shaped fin's centre as well as the vertical line directions through a line graph analysis as well. Line graphs are used to show the effect of Rayleigh number on the heat transfer rate along the heated fin's surface. When the Rayleigh number is raised, we see an increase in the rate of heat transmission along the T-shaped fin's surface.

[5] (Abraham et al., 2020) The passive method of improving heat transmission using fins has been employed for years. Fins are used because they enhance the total surface area accessible for heat transmission. That's why most contemporary heat exchangers utilise a variety of fin configurations to boost efficiency and minimise footprint. Most heat exchanger fin configurations promote heat transfer, but at the cost of increased pumping power required to overcome the resistance of the air or fluid. Here, we conduct an experimental investigation into the effects of a cross-

flow tube bank with staggered spacing by using longitudinal fins in the shape of splitter plates. To further improve the thermal hydraulic performance of the tube bank, the geometric arrangement of the splitter plates is changed. This includes the splitter plate length ($0.50 \leq L/D \leq 1.50$) as well as plate thickness ($0.04 \leq t/D \leq 0.20$). In addition, a three-dimensional numerical investigation is carried out to provide a more clear picture of the fluid dynamics at play. By lowering the total pressure drop across most configurations, using a splitter plate with L/D = 1.0 & t/D = 0.20 enhances the thermal-hydraulic performance of the tube bank. Furthermore, statistical correlations for the Nusselt number as well as friction factor features for the longitudinally finned tube bank throughout the complete range of Reynolds number from 5000 to 25000 are created.

[6] (Mozafarie & Javaherdeh, 2019) An inner tube heat exchanger with the helical fins was used in this study to investigate numerically the flow as well as thermal properties of a non-Newtonian fluid. A non-Newtonian power law fluid flows through the annulus side in a laminar steady state. In order to calculate the average heat transfer coefficients as well as pressure losses in the annulus, a 3D-CFD computational model was used. The Graetz number ($23 \times 10^3 \leq Gz \leq 55 \times 10^3$) as well as fin pitch ($25\ mm \leq p \leq 100\ mm$) are analysed numerically. Using a "smooth double pipe heat exchanger" as a test case, the model was shown to correlate well with experimentally derived correlations. Helicoidal fins created a vortex flow that improved heat transmission and pressure drop at the same time. In addition, the fin pitch was increased, which improved the thermal performance. In the industrial designs of twin pipe heat exchangers, useful and usable correlations for Nu & f are offered by data reduction.

[7] (Moorthy et al., 2018) This research aims to examine how different fin forms affect the efficiency of small, flat-tube heat exchangers. The three by three array of flat tube banks was studied with three different fin shapes: plain, wavy, & rectangular grooved fins. Further, both in-line and offset configurations of the tubes were used in their deployment. The thermal-hydraulic performance was examined by changing not only the fin forms, but also the air velocity as well as the tube inclination angles. However, in order to maintain a steady heat flow throughout the experiment, the surface temperatures of the tubes were kept constant at all times. The findings demonstrated that both heat transmission and friction factor rise with increasing flowrate, but that the latter decreases. More efficient heat transmission and friction factor are achieved with a staggered configuration compared to an inline fin. And although the rectangular fin offers the most heat transmission, its low efficiency might be attributed to the high friction factor that characterises it. Plain fin, on the other hand, was the most efficient while having the worst heat transmission performance. Furthermore, when efficiency is more important than maximising heat transmission, plain fin must be employed and vice versa for the rectangular fin.

[8] (Zhang et al., 2017) The heat transmission of the non-Newtonian power law fluid through pipes with varied cross sections is examined in this work. First, a quick explanation of the non-Newtonian fluid mathematical model as well as physical model, which is separated into sections by a structured mesh. After that, numerical simulations of non-Newtonian fluid laminar heat transport in various cross sections are run. To better understand the temperature field and heat transmission in a tube, this research looks at the power-law index (n), Peclet number (Pe), and other variables based on how that field is distributed. The findings suggest that the factors we discussed have an effect on the heat transfer properties of non-Newtonian fluids.

HEAT EXCHANGER DESIGN CHARACTERISTICS

As was just discussed, the aforementioned principles apply to every heat exchanger. Nonetheless, depending on their individual structural features, these gadgets may be organised in a wide variety of hierarchies. Heat exchangers may be broadly classified according to the following key characteristics:

- Flow configuration
- Construction method
- Heat transfer mechanism

1. Flow Configuration

What we mean when we talk about a heat exchanger's flow configuration (also called flow arrangement) is the relative movement of fluids inside the heat exchanger. Four primary flow configurations are used by heat exchangers:

- Cocurrent flow
- Countercurrent flow
- Crossflow
- Hybrid flow

- **Cocurrent Flow**

Cocurrent flow heat exchangers are devices for transferring heat in which the fluids circulate in the same direction as well as in parallel to one another. This setup may not be as efficient as a counter flow layout, but it does provide the most consistent temperatures throughout the heat exchanger's walls.

- **Countercurrent Flow**

Counterflow heat exchangers are heat exchangers in which the fluids travel antiparallel to one other, or in a parallel fashion but in opposing directions. Since a counter flow design permits the largest amount of the heat transference between the fluids, therefore, the greatest change in temperature, it is often the most efficient of the flow arrangements used.

- **Crossflow**

Crossflow heat exchangers have fluids moving in directions that are perpendicular to one another. In terms of heat transfer efficiency, this flow arrangement is between that of the countercurrent as well as cocurrent heat exchangers.

- **Hybrid Flow**

Heat exchangers with hybrid flows have features of both parallel and countercurrent designs. Multiple flow passages and arrangements (such as counter flow as well as crossflow arrangements) may be used in a single heat exchanger design, for instance. It is common practise to use such heat exchangers when working around the constraints of a given application, whether they spatial, financial, or based on required operating temperatures and pressures.

As seen in Figure 1, below, there are many other flow configurations that may be used. One example of a hybrid flow design is a cross/counter flow setup.

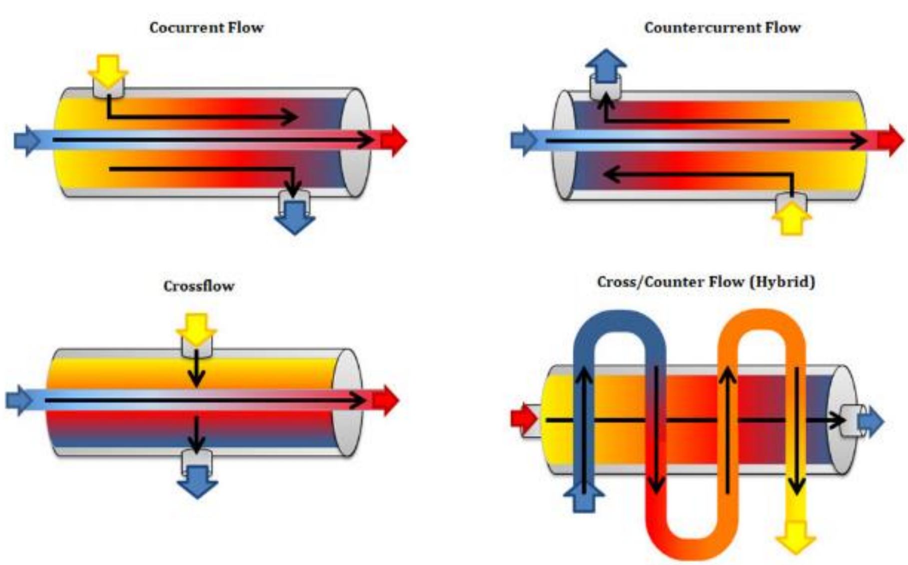

Figure -1 Heat Exchanger Flow Configurations

2. Construction Method

This section classifies heat exchangers according to its construction, as opposed to the flow configuration classification used before. These instruments may be categorised based on their constructional features like as:

- Recuperative vs. regenerative
- Direct vs. indirect
- Static vs. dynamic

Types of components and materials employed

- **Recuperative vs. Regenerative**

There are two types of heat exchangers: recuperative as well as regenerative.

Recuperative heat exchangers (also known as recuperators) are distinct from the regenerative heat exchangers in that both fluids run through the heat exchanger at the same time in separate channels. In contrast, regenerators, also known as capacitive heat exchangers, alternate the passage of hotter and colder fluids via the same tube. Direct & indirect exchangers, as well as static & dynamic exchangers, are two subsets of recuperators & regenerators, respectively. In contrast to the other kind, recuperative heat exchangers see widespread use in manufacturing.

- **Direct vs. Indirect**

Heat may be transferred between fluids in a recuperative heat exchanger in one of two ways: by direct contact or via an intermediate fluid.

Heat is transferred from one fluid to another without any separation between them in direct contact heat exchangers. However, with indirect heat exchangers, like tubes or plates, the fluids are kept at a distance from one another during the heat transfer process. When one fluid is heated, it transfers that heat to another fluid that is passing through the heat exchanger at a lower temperature. Cooling towers as well as steam injectors are examples of equipment that use direct contact transfer processes, whereas tube or plate heat exchangers are examples of devices that use indirect contact transfer processes.

- **Static vs. Dynamic**

Static heat exchangers as well as dynamic heat exchangers are the two primary varieties of regenerative heat exchangers. The material as well as components of a heat exchanger stay stationary in the static regenerators (also called fixed bed regenerators) during the heat transfer process, in contrast to the dynamic regenerators, in which the material as well as components move. Careful design and manufacturing considerations are required for both kinds because of the potential for fluid cross-contamination.

One instance of a static heat exchanger is one in which one fluid is circulated through one set of pipes while another set of pipes carries a different, colder fluid for a predetermined amount of time, and then the valves are quickly switched to allow the two fluids to exchange places. In a dynamic heat exchanger, for instance, a thermally conductive component (like a drum) rotates as warmer and colder fluids constantly flow over it (although in isolated chambers). Any particular piece of the rotating component will alternately pass between the warmer steam as well as colder streams, enabling it to simultaneously collect heat from warmer fluid and release it to the cooler fluid.

3. Heat Transfer Mechanism

Heat exchangers may use either a single-phase or a two-phase heat transfer mechanism.

There is no phase transition between the warmer and colder fluids in a "single-phase heat exchanger"; instead, the fluids in the heat exchanger stay in the same state of matter during the whole heat transfer operation. In "water-to-water heat transfer" applications, for instance, heat is transferred from the hotter to the cooler water without either phase changing.

However, fluids do undergo a phase transition during the heat transfer in two-phase heat exchangers. The fluids may undergo a phase transition from liquid to gas or gas to liquid, or both. Two-phase heat transfer mechanisms often need more intricate design considerations than a single-phase heat transfer mechanisms, however there are exceptions to every rule. Boilers, condensers, as well as evaporators are examples of two-phase heat exchangers.

CONCLUSION

This paper reviews certain thermal efficiency enhancement techniques of the heat exchangers including the arrangement of tubes, use of circular, axial or spiral fins, the flow direction of the heat exchangers etc. It also presents a brief explanation of the design characteristics of the heat exchangers which are considerable for an efficient design for maximizing the thermal performance of the heat exchanger. Staggered tube heat exchangers have been found to be the one least researched upon in the literature survey, hence it has been selected for our analysis.

REFERENCES

[1] N. S. Khashi'ie, I. Waini, A. R. M. Kasim, N. A. Zainal, A. Ishak, and I. Pop, "Magnetohydrodynamic and viscous dissipation effects on radiative heat transfer of non-Newtonian fluid flow past a nonlinearly shrinking sheet: Reiner–Philippoff model," *Alexandria Eng. J.*, vol. 61, no. 10, pp. 7605–7617, 2022, doi: 10.1016/j.aej.2022.01.014.

[2] S. M. Z. Hossain, M. F. Irfan, E. M. Elkanzi, and K. M. Saif, "Fabrication of a hybrid shell and double pipe heat exchanger by means of design and performance assessment," *Chem. Eng. Process. - Process Intensif.*, vol. 165, no. March, p. 108430, 2021, doi: 10.1016/j.cep.2021.108430.

[3] B. Saleh and L. Syam Sundar, "Thermal performance, embodied energy and environmental CO2 emissions analyses for double pipe U-bend heat exchanger working with MWCNT/water nanofluid," *Int. J. Therm. Sci.*, vol. 169, no. December 2020, p. 107094, 2021, doi: 10.1016/j.ijthermalsci.2021.107094.

[4] K. U. Rehman, M. Y. Malik, Q. M. Al-Mdallal, and W. Al-Kouz, "Heat transfer analysis on buoyantly convective non-Newtonian stream in a hexagonal enclosure rooted with T-Shaped flipper: Hybrid meshed analysis," *Case Stud. Therm. Eng.*, vol. 21, no. April, p. 100725, 2020, doi: 10.1016/j.csite.2020.100725.

[5] C. K. Mangrulkar, A. S. Dhoble, J. D. Abraham, and S. Chamoli, "Experimental and numerical investigations for effect of longitudinal splitter plate configuration for thermal-hydraulic performance of staggered tube bank," *Int. J. Heat Mass Transf.*, vol. 161, 2020, doi: 10.1016/j.ijheatmasstransfer.2020.120280.

[6] S. S. Mozafarie and K. Javaherdeh, "Numerical design and heat transfer analysis of a non-Newtonian fluid flow for annulus with helical fins," *Eng. Sci. Technol. an Int. J.*, vol. 22, no. 4, pp. 1107–1115, 2019, doi: 10.1016/j.jestch.2019.03.001.

[7] P. Moorthy, A. N. Oumer, and M. Ishak, "Experimental Investigation on Effect of Fin Shape on the Thermal-Hydraulic Performance of Compact Fin-and-Tube Heat Exchangers," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 318, no. 1, 2018, doi: 10.1088/1757-899X/318/1/012070.

[8] H. Zhang, Y. Kang, and T. Xu, "Study on Heat Transfer of Non-Newtonian Power Law Fluid in Pipes with Different Cross Sections," *Procedia Eng.*, vol. 205, pp. 3381–3388, 2017, doi: 10.1016/j.proeng.2017.09.845.