International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A Review on the Development in the Design of Pipe used in Heat Exchanger

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ABSTRACT

Heat exchangers are very important in power generation, chemical processing, oil and gas, refrigeration, and other thermal systems. Pipes in these systems need to be able to move heat quickly and be reliable. The design of pipes used in heat exchangers has changed a lot over the years. They are now better at transferring heat, less likely to rust, stronger, and cheaper. This review talks about how pipe design has changed over time, focusing on new materials, changes in shape, and ways to make the surface better. The article also talks about design ideas that help heat transfer and keep things clean, like finned tubes, corrugated pipes, twisted inserts, and surfaces with microstructures. The text also talks about modern optimization methods as tools that make it possible to use predictive modeling and improve performance when designing pipe-based heat exchangers. The review ends by listing the current problems, which include finding a balance between thermal efficiency and pressure drop, dealing with scaling issues, and making materials that last longer. It also points out places where more research is needed to make pipes for next-generation heat exchangers.

Keywords: Heat exchanger, Double Helical tape insert, Hydrothermal performance, Passive technique, Heat transfer enhancement

1. Introduction

1.1 General

A lot of engineering processes depend on double pipe heat exchangers. A basic double-pipe exchanger has two pairs of pipes that are next to each other. The two fluids that move heat through the pipes are carried by the inner and outer pipes. The fluids usually move through the exchanger in opposite directions, which is called counter-current flow. People often use double-pipe exchangers because they work well when the flow rate isn't too high and the temperature or pressure is high. Heat exchangers are used in a lot of different places, like power plants, nuclear reactors that make electricity, refrigeration and air conditioning (RAC) systems, self-propelled industries, food industries, heat retrieval systems, and chemical handling. There are two main types of ways to upgrade: active and passive. The active approach requires peripheral forces. For passive approaches, the surfaces need to be different shapes. Both methods have been used a lot to make heat exchangers work better. People are more interested in finding ways to improve heat transfer now that high-performance thermal systems are available. You can make heat exchangers work better by either increasing the convection surface area or the convection heat transfer coefficient. Adding inserts to the pipes or tubes is one way to raise the convection coefficient inside a heat exchanger. A heat exchanger is a device that lets two fluids with different temperatures share energy.

A heat exchanger uses the fact that energy moves from one place to another when the temperature changes. So, heat will move from a place that is hotter to one that is cooler. The fluids that are moving around make the temperature difference that lets energy move from one to the other. A heat exchanger can have either latent heat from moving fluids or energy that can be felt. "Hot fluid" is a term for a fluid that gives off energy. The term "cold fluid" refers to the fluid that receives energy. It's clear that the temperature of the hot fluid will go down and the temperature of the cold fluid will go up in a heat exchanger. Heat exchangers can heat or cool the fluid you want. People also call these heat exchangers "evaporators" and "condensers." In many technical settings, heat exchangers are often used to move heat through fluids inside tubes. In the last few years, a lot of people have been looking into ways to improve heat transfer so that it can handle high heat flux or to make heat exchangers smaller and cheaper. Better Transfer of Heat The rate of all kinds of thermotechnical equipment is very important for business. It also uses less energy and makes things smaller and lighter. So far, a lot of different ways to make heat transfer better have been studied. Twisted tape is a very important part of learning new skills. People often use it in heat exchangers.

1.2 Double Pipe Heat Exchanger

Double pipe heat exchangers are also called "pipe-in-pipe" exchangers. The design is "tube in tube." It has two pipes, one inside the other, as the name suggests. The inner pipe lets one fluid flow through it, and the outer pipe goes around it. The outside pipe is like the shell side of a shell and tube exchanger.

This is what the cross-section of a double pipe exchanger might look like: :

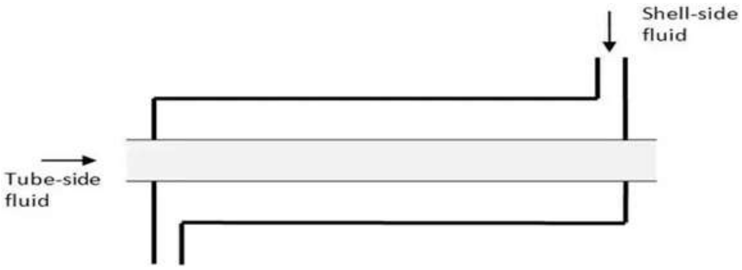

Fig. 1.1: Double pipe heat exchanger

They often look like U-tubes, which lets the tubes get bigger without needing expansion joints, as shown below: :

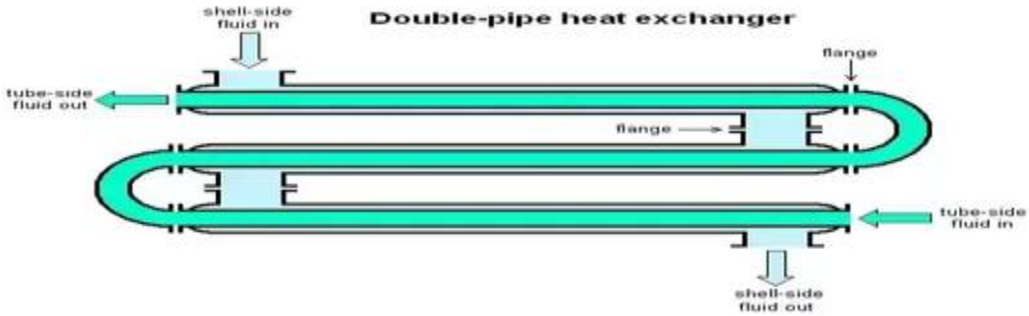

Fig. 1.2: U-type double pipe heat exchanger

They are one of the most affordable and simple kinds of heat exchangers. They work well when things are very thick, hot, and under a lot of pressure. The double pipe heat exchanger (DPHE) is one of the easiest and most useful types of heat exchangers (Fig. 1.2). Many businesses that deal with food, oil, gas, and chemicals use this type of heat exchanger. Many reliable studies have also strongly believed that this kind of heat exchanger is used in high-pressure situations because it is not very wide. They are also very important when you need to keep things at a wide range of temperatures. This type of heat exchanger is also well known to be very helpful for pasteurization, reheating, preheating, heating digesters, and heating effluent. A lot of small businesses also use DPHEs because they are cheap to build and keep up. To tackle the difficulties in pinpointing the most suitable methods of interest, we concluded that previous research on this category of heat exchanger ought to be categorized.

1.3 Heat Transfer Augmentation Techniques

There are three main types of ways to improve heat transfer: active, passive, and compound.

Active methods need power from outside sources to work. They want to make heat transfer better, which is why. Some examples are vibrations in liquids, vibrations on surfaces, mechanical assistance, and jet impingement.

You don't need any outside power for passive techniques to work. Inserts or other devices are often used to change the shape or surface of the flow channel. For example, there are rough surfaces, swirl flow devices, coiled tubes, and long surfaces.

Using both the active and passive methods at the same time can improve heat transfer more than either method can do on its own. This simultaneous use is known as "compound enhancement."

1.4 Twisted Tape Inserts

An insert is put into the flow passageways to speed up the transfer of heat and make the passages' hydraulic diameter smaller. Heat moves through a tube faster when there is secondary flow, flow partitioning, or flow blockage. Flow obstructions make the free flow area smaller, which makes the pressure drop bigger and makes the flow more viscous. The best twisted tape is the one that works best and costs the least. When designing a heat exchanger retrofit, it's helpful to compare how well different tube inserts work. If you improve how heat is transferred, heat exchangers will work better. Tape inserts are a common way to improve passive heat transfer. They are used in many heat transfer systems, such as air conditioning and refrigeration systems and food processing. There have been a lot of recent experiments to make heat transfer happen faster. In the chemical industry and in air conditioning systems, both active and passive heat transfer augmentation techniques are commonly employed to enhance the efficiency of heat exchangers while reducing their size and cost. Active methods need something from the outside, like an electric field, surface vibration, or jet impact. You need special surface shapes or devices that make swirl or vortex flow for the passive methods. Twisted tape has been employed as swirl/vortex flow devices in numerous experimental studies focused on heat transfer enhancement, as recorded in the literature.

1.5 Computational Fluid Dynamics

Partial differential equations (PDE) are the rules that control how fluids (gases and liquids) move and how mass, momentum, and energy are kept. Computational Fluid Dynamics (CFD) replaces these kinds of PDE systems with a set of algebraic equations that computers can solve. The CFD modeling method's main idea is to divide the simulated flow space into small cells. The discretized differential equations governing mass, momentum, and energy balance are expressed in relation to the variables at any specified position within or at the nucleus of the cell. These equations are solved repeatedly until the desired level of accuracy is achieved (ANSYS FLUENT 14.0).

CFD provides a qualitative prediction of fluid flows by means of

1. Mathematical modelling (partial differential equations)
2. Numerical methods (discretization and solution techniques)
3. Software tools (solvers, pre- and post-processing utilities)

1.6 Turbulence Modeling

Turbulent flows have velocity fields that change over time. These changes not only change the amounts being moved, but they also change the types of things being moved, like speed, energy, and species concentration. Unfortunately, there isn't one turbulence model that most people think is better for all kinds of problems. When picking a turbulence model, you need to think about the physics of the flow, the usual way to solve that kind of problem, how accurate you need it to be, how much computer power you have, and how long it will take to run the simulation. .

2. Literature Review

2.1 Introduction

Many studies have been done to make heat exchangers work better and faster, as well as to make industrial equipment smaller and less expensive. This is because more and more people need heat exchangers. The double pipe heat exchanger is one of many types of devices used in different fields. This kind of heat exchanger is very useful and easy to use, so a lot of people are interested in it. There have been a lot of good and helpful studies on twin pipe heat exchangers in the last few years. This review has closely examined the development process for this type of heat exchanger and the techniques employed to enhance heat transfer in the aforementioned heat exchangers. The authors collected data regarding the application of active, passive, and compound methodologies, striving to ensure the comprehensiveness of their study. It is important to note that there has been a lot of research on the use of passive methods in double pipe heat exchangers. Since the late 1940s, we have been keeping track of articles about twin pipe heat exchangers [3, 4]. The results generally support the idea that this kind of heat exchanger will make a lot of progress soon. There have been a lot of studies over the years that fall into different groups.

In certain instances, the focus was solely on the characteristics of the working fluids and the modifications applied to them [3]. Some looked at different heat enhancement methods [7–5], active techniques [8, 9], passive strategies [1, 10], compound methodologies [4], and geometric changes [6]. The following sections will give a full look at each method, which is still being worked on.

2.2 Review of past work

Table 2.1: Summary of literature survey

S. No.	Author	Paper tittle	Year	Summary
1	Abdalla Gomaa, Yehia Gamal, Mahmoud M. Abdelmagied	Enhancement of thermofluid characteristics via a triple-helical tube heat exchanger	2025	Experimental study introducing a **triple-helical** tube; reports up to ~146% Nu gain over double-helical with correlations for Nu, f, and effectiveness.
2	Wahyu D. Prasetyo, Danang Lelono, Ummy Syahida, Bhakti Prathama Wicaksono, Meutia Hasan	Critical Review of Corrugation in Tubular Heat Exchangers: Focus on Thermal and Economical Aspects	2025	A state-of-the-art **review of corrugated tubes**, summarizing thermal performance vs. pressure-drop penalties and cost considerations

S. No.	**Author**	**Paper tittle**	**Year**	**Summary**
3	J. Wang, Y. Li, J. Lv, J. Zhai, Y. Tu	Thermo-fluid characteristics and exergy analysis of a twisted tube helical coil	2024	Combines **twisted internal tube + helical coil**; details heat transfer, friction, and exergy metrics with validated CFD/experiments.
4	Dergi Park	Design and Performance Optimization of Double-Pipe Type Heat Exchangers	2023	Uses **response-surface optimization** with non-dimensional groups to tune double-pipe geometries for balanced Nu vs. Δp
5	A. Mahdi	Heat transfer characteristics of innovative configurations of double-pipe heat exchanger (circular-wavy, oval, oval-wavy	2020	Direct study of wavy/oval tube designs
6	M.R. Salem∗, M.B. Eltoukhey, R.K. Ali, K.M. Elshazly	Experimental investigation on the hydrothermal performance of a doublepipe heat exchanger using helical tape insert	2018	The results demonstrated that, in comparison to the plain annulus-case, the use of the HTI increases the annulus average Nusselt number (Nuan) and the Fanning friction factor (fan). The average increases were 69.4–164.4% and 48.6–113.1%, respectively, when δ increased from 0.275 to 1, and 78.1–183.2% and 67.6–99.2%, respectively, when δ decreased from 1 to 0.333.
7	Shailesh Dewangan	A Review of Literature on ‘Experimental Analysis of Overall Heat Transfer Coefficient in Parallel Flow Heat Exchanger by Using Helical Ribs	2018	High heat transfer rates should be the goal of the heat exchanger's tube surface design since artificial roughness causes an undesired increase in the pressure drop because of increased friction.
8	N Sreenivasalu Reddy	Experimental Investigation of Heat Transfer Enhancement of a Double Pipe Heat Exchanger with Helical Fins in the Annulus Side	2017	In comparison to basic double-pipe exchangers, the results obtained for helical fins in the annulus side give improved heat transfer performance.
9	Patel Yogeshwari	Numerical and Experimental Investigation of Heat Transfer Augmentation in Double Pipe Heat Exchanger with Helical and Twisted Tape Inserts	2017	Transformer oil, also known as hot fluid, serves as the working fluid, while water serves as a coolant. Analysis of the solution's convergence is also included.
10	Pourahmad S, Pesteei S M	Effectiveness- NTU analyses in a double tube heat exchanger equipped with wavy strip considering various angles	2016	Their results show that heat transfer qualities can be significantly improved.

S. No.	**Author**	**Paper tittle**	**Year**	**Summary**
11	K.A. Goudiya	Experimental Investigation of Heat Transfer in Heat Exchanger Using Different Geometry of Inserts – A Review	2016	provided a review of the literature on insert-based heat transfer augmentation strategies.
12	Ayush Kumar	Performance Analysis of Double Pipe Heat Exchanger using Convergent – Divergent-Divergent Spring Turbulators	2015	Friction factor was increased by 287% while Nusselt no increased by 28%.
13	Patnala Sankara Rao	Numerical and Experimental Investigation of Heat Transfer Augmentation in Double Pipe Heat Exchanger with Helical and Twisted Tape Inserts	2014	These two results have been found to be in good agreement, with the friction factor error being within ±25 percent and the Nusselt number measurement falling within ±19.78 percent.
14	Parag S. Desale	Heat Transfer Enhancement in Tube-in-Tube Heat Exchanger using Passive Techniques	2014	It has been discovered that heat transfer properties can be somewhat enhanced by increasing vibration intensities.
15	H. H. Al-Kayiem	Ribbed double pipe heat exchanger: experimental analysis	2014	The findings demonstrated that an increase in the friction factor values led to a slight penalty in the pressure drop together with an improvement in heat transmission as measured by the Stanton number.
16	Nawras Shareef Sabeeh	Thermo- Hydraulic Performance of Horizontal Circumferentially Ribbed Double Pipe Heat Exchanger	2014	The proposed correlations can predict the experimental data with average relative error of ± 6% for Nusselt number and ± 5% for friction factor.
17	Melvinraj C R	Comparative Study of Heat Exchangers Using CFD, Int. Journal of Engineering Research and Applications	2014	While correlation-based methods might suggest that the weakness exists, CFD simulations can also pinpoint its location and source. The design process could be sped up and the finished product could be improved by using CFD.
18	Antony luki	Flow Analysis and Characteristics Comparison of Double Pipe Heat Exchanger Using Enhanced Tubes	2013	According to the theoretical findings, a concentric tube heat exchanger performs better when it uses a dimpled tube. With CFD, the dimple tube cross sections, ellipsoidal, and spherical shapes are modelled and analysed. Lastly, the improved dimple tube is contrasted with the analytical, theoretical, and analysis findings.

S. No.	Author	Paper tittle	Year	Summary
19	M. Kanan	Experimental and Analytical Comparison of Heat Transfer in Double Pipe Heat Exchanger	2012	The success of these techniques is also determined by comparing the various flow rates, one of which is the maximum heat transfer that may occur in a twin pipe heat exchanger. These techniques are used to determine the heat loss from the surface and the associated temperature of fluid motions. Compared to the other three ways, the annular method transfers heat at a higher rate.
20	Halit Bas and Veysel Ozcehan	Heat transfer enhancement in a tube with twisted tape inserts placed separately from the tubewall	2012	They discovered that a lower twist ratio (y/D=2) and a lower clearance ratio (c/D = 0.0178) result in a larger heat transfer enhancement.
21	Jian Guo, Aiwu Fan, Xiaoyu Zhang and Wei Liu	A numerical study on heat transfer and friction factor characteristics of laminar flow in a circular tube fitted with centre cleared twisted tape	2011	It was discovered that, when compared to traditional twisted tapes, center-cleared twisted tape is a viable method for improving laminar convective heat transmission.
22	Paisarn Naphon and Tanapon Suchana	Heat Transfer enhancement and pressure drop of the horizontal concentric tube with twisted wires brush inserts	2011	They discovered that the plain tube with the 300 twisted wire brush insert had a higher heat transfer rate than the plain tube with the 200 and 100 twisted wire brush inserts.
23	Promvonge.P and Eiamsa Ard S	Heat Transfer Behaviors in a tube with combined conical ring and twisted tape insert	2007	They concluded that the highest heat transfer and friction factor for smaller twist ratio.
24	Smith Eiamsa Ard and Pongjet Promvonge	Thermal Characteristics in round tube fitted with serrated twisted tape	2010	They came to the conclusion that in heat transfer applications, the twin twisted tape inserts' reduced space ratio is ideal compared to the single twisted tape inserts.
25	Suresh S, Venkitaraj K.P and Selvakumar.P	Comparative study on thermal performance of helical screw tape inserts in laminar flow using Al2O3/water and CuO/water nanofluids	2011	The heat transmission rate can be efficiently increased by the tiny pitch and larger slant angle. They came to the conclusion that a narrow pitch (S=30mm) and a moderate slant angle (α=200) yield the best thermo-hydraulic performance.

3. Summary

It is evident from the analysis of numerous studies on heat transfer enhancement that many of the authors have employed both active and passive techniques to increase the heat exchanger's heat transfer rate. The majority of them have either worked on numerical or experimental analysis, but neither has been studied in tandem. The aforementioned investigations take into account twisted tape inserts with varying twisted angles and twisted ratios. In order to improve heat transfer, some of them have additionally inserted twin twisted tapes within heat exchanger tubes. It is evident from the literature review cited above that a wide variety of fin, turbulator, and insert shapes have been employed as passive heat transfer augmentation methods. It was demonstrated that the primary issue with traditional inserts is the significant rise in flow pressure drop. Furthermore, no experimental research has been done to examine how the geometrical parameters of the HTI conducted in the annulus-side affect DPHE performance.

Since it was anticipated that the HTI would improve the hydrothermal performance of the DPHEs, it was chosen for this study. Thus, the goal of the current work is to experimentally examine the properties of the pressure drop and forced convective heat transfer in the annulus-side of horizontal DPHEs when a continuous double helical tape is inserted. The purpose of this is to provide DPHE designers with correlations for the hydrothermal performance index, friction factor, and Nusselt number for a broad range of HTI geometrical parameters and annulus-side operating conditions.

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