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Review Article

A Review : Hydrothermal Performance Of Dual Pipe Heat Exchanger By Dual Helical Tape Insert

Vivek Kumar Shrivastava[1], Dr. Shyam Kumar Birla[2]

[1]M.Tech. Scholar, Oriental College of Technology, Bhopal (M.P.), INDIA
[2]Professor & HOD Oriental College of Technology, Bhopal (M.P.), INDIA

ABSTRACT

This study experimentally examines the hydrothermal performance of horizontal Double Pipe Heat Exchangers (DPHEs) with and without continuous Helical Tape Insert (HTI) conducted on the outer surface of the internal pipe. Ten DPHEs of counter-flow configurations were constructed; nine of them were with HTI fabricated with different ratios of HTI height to the clearance between the two pipes (δ), and different ratios of HTI pitch to HTI diameter (). The experiments were performed with pure water in both sides with 2050 1592 ≤ ≤ Rean 5, and Ret ≈ 26700. Compared with plain annulus-case, the results showed that using the HTI increases both annulus average Nusselt number (Nuan) and Fanning friction factor (f an), with average increases of 69.4–164.4% and 48.6–113.1%, respectively, when δ increases from 0.275 to 1, and with average increases of 78.1–183.2% and 67.6–99.2%, respectively, when decreases from 1 to 0.333. The hydrothermal performance index (HTPI) was determined to compare the performance of DPHEs with HTI to that of plain annulus case. The results demonstrated that HTI of δ = 0.667 provides the highest HTPI, while HTPI increases with decreasing λ. Finally, correlations for Nuan, f an, and HTPI for DPHEs with HTI in the annulus as a function of the investigated parameters were proposed.

KEYWORDS

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

1.INTRODUCTION

Enhancing the thermal performance of heat exchange affects directly on energy, material and cost savings. Consequently, improving the heat exchange can significantly improve the thermal efficiency in applications involving heat transfer processes as well as the economics of their design and operation [1]. DPHEs are primarily adapted to high temperature and high-pressure applications due to their small diameters. They are cheap, but the space they occupy is relatively high compared to the other types. To achieve the desired heat transfer rate in the given design and length of the heat exchanger at an economic pumping power, numerous techniques have been provided. These improvement techniques were classified as active and passive techniques [2,3]. Fins of different configurations as they are considered passive techniques were investigated to introduce the effect on the thermal performance of DPHEs. Nagarani and Mayilsamy [4] experimentally used circular and elliptical annular fins in a DPHE. They detected that heat transfer rate improved with elliptical fins than circular ones. Syed et al. [5] numerically investigated the laminar fully developed flow in the annulus-side of a DPHE employed with triangular fins. The authors found a significant enhancement in heat transfer rate and Nusselt number. For the small number of fins, fin height, ratio of radii, and half fin angle have less importance. Zhang et al. [6] experimentally studied the fluid flow characteristics in the annulus-side of a DPHE with HFs and pin fins. The results showed that for the annulus-side only with HFs at large pitch, there was a pair of vortex near the upper and lower edge of the rectangular cross-section and the weakest secondary flow occurred at the center. By installing pin fins, the three-dimensional velocity components in the helical channel were strongly affected. Kumar et al. [7] numerically studied the performance characteristics of a DPHE for three different longitudinal fin patterns, rectangular, triangular and parabolic. The results showed that fins with concave parabolic profiles owned minimum pressure drop and has reduced by 38% and 65% compared to the triangular and rectangular finned tube, respectively. Iqbal et al. [8] numerically examined the optimal pattern of a finned annulus with parabolic, triangular and trapezoidal fins. They found that no single fin shape is best in all situations and for all criteria. Hameed and Essa [9] evaluated experimentally and numerically the performance of triangular finned tube heat exchanger. The experimental results presented that the improvement of heat dissipation for the triangular finned tube is 3.25–4.5 times than that of the smooth tube, respectively.

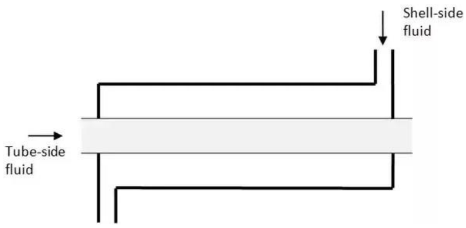

Fig. 1.1: Double pipe heat exchanger

They often have a U-tube structure to accommodate thermal expansion of the tubes without necessitating expansion joints, as illustrated below:

II. LITERATURE REVIEW

We have traced the history of publications regarding double pipe heat exchanger back to its beginnings in the late 1940s [3, 4]. The studies broadly support the view that this type of heat exchanger is heading towards a considerable progress. Through these years, a plethora of researches have been carried out which fall into various categories. In some cases, just the working fluids characteristics and their modifications were studied [3]. Some investigated active methods [8, 9], passive methods [1, 10], compound methods [4], geometry change [6] and the other heat enhancement methods [7–5]. Having been developed incessantly, each method will be thoroughly investigated in the following sections.

Exchangers (DPHEs) with and without continuous Helical Tape Insert (HTI) conducted on the outer surface of the internal pipe. Ten DPHEs of counter-flow configurations were constructed; nine of them were with HTI fabricated with different ratios of HTI height to the clearance between the two pipes (δ), and different ratios of HTI pitch to HTI diameter. The experiments were performed with pure water in both sides with $2050 \leq Rean \leq 15925$, and $Ret \approx 26700$. **Lachi et al. (2018)** studied time constant of a DPHE and a shell and tube heat exchanger. The particular purpose of this investigation was to classify the characteristics of these heat exchangers in a transient condition, especially the time when abrupt changes in inlet velocities are considered. Upon carrying out this study, a model with two parameters of time delay and time constant has been employed. It is also noted that the analytical term was derived by applying energy balance equation. Moreover, it was stated that an experimental method was used to validate the numerical data which the highest observed difference found to be less than ten percent. **Aicher and Kim (2018)** investigated the effect of counter flow in nozzle section of a DPHE which were mounted on the wall of the shell side. It turned out that the counter flow in nozzle section had a significant effect on heat transfer and pressure drop. It was also concluded that the very effect would be more conspicuous, if the heat exchanger were small and also the ratio of free cross section areas were low enough. They also presented experimental correlations to predict heat transfer rate in turbulent flow.

Ma et al. (2018) experimentally investigated the effects of supercritical carbon dioxide (SCO2) in a DPHE in which the effects of pressure, mass flux and buoyancy force of the SCO2-side were broadly studied. On one hand, it was observed that pressure increase of the gas-side conspicuously caused both the overall and the gas-side heat transfer rates to be comparison with the gas-side, was the key element of the heat transfer rate. Moreover, a mathematical correlation based on Genetic Algorithm was presented for predicting heat transfer rate. **Rennie and Raghavan (2018)** investigated a double pipe helical heat exchanger for both parallel and counter flow configurations. The corresponding heat transfer rates of inner tube and the annulus were calculated using Wilson plots. It is well worth noting that the performance evaluation criterion of both configurations was identical, while surely the heat transfer regarding to the counter flow configuration was higher than its counterpart which was due to a higher temperature difference. The above-mentioned performance evaluation criterion (PEC) is the comparison of heat transfer coefficients between the enhanced tube and smooth tube under the same pumping power condition. **Dizaji et al. (2018)** did an experimental study of heat transfer and pressure drop of corrugated tubes in a DPHE which turned out to perceive much importance in the field (Fig. 2.1). Both inner and outer tubes were corrugated in concave and convex shapes. Working fluids in the experiments were hot and cold water which flowed in the inner and outer tube of the heat exchanger, respectively. Research findings showed that the highest effectiveness was obtained for a case when the inner tube and the outer tubes had the convex and concave corrugated configurations, respectively. **Bhadouriya et al. (2018)** investigated heat transfer and pressure drop of a DPHE both experimentally and numerically in which the major objective was the effect of twist ratio of the inner tube on the flow characteristics (Fig. 2.2). A uniform wall temperature at the inner wall of annulus was a boundary condition for the outer flow. Working fluids in the experiments were water and air which flowed in the inner (square duct) and the annulus of the heat exchanger, respectively. The results showed that this geometry change led to an increase in heat transfer rate and pressure drop in all flow regimes. The results of the present paper will help the engineers design more compact heat exchangers. It was also concluded that, unlike smooth tube, Nusselt number in the laminar flow regime was dependent on the flow characteristics and physical parameters such as Reynolds number and twist ratio. **Tang et al. (2018)** investigated the effects of twisted inner tube of a DPHE which was carried out experimentally and numerically. In the experimental process, the inner tube had three 9 different cross section shapes which were circular, oval and tri-lobed (Fig. 2.3); while the outer tube was a simple cylindrical tube. Upon having a higher performance evaluation criterion, an intense concentration was shown to the above-mentioned tri-lobed cross section along with the simple outer tube. Moreover, a broad range of studies were carried out in numerical process of the study, especially in different cross-section shapes. **Dewangan (2018)** made helical ribs on the tube surface by machining the surface on the lathe So that artificial roughness can be created The artificial roughness that results in an undesirable increase in the pressure drop due to the increased friction; thus the design of the tubes surface of heat exchanger should be executed with the objectives of high heat transfer rates. **Reddy (2017)** investigated the heat transfer analysis in the horizontal double pipes with helical fins in the annulus side. The material is copper with inner tube internal diameter 10 mm, inner tube thickness 1 mm, outer tube external diameter 40 mm, outer tube thickness 1.5 mm, helical pitch of 50mm, 75mm and 100mm, heat exchanger length 1100 mm. The experimental results of plain tube are validated with numerical results. The results obtained for helical fins in the annulus side provide enhanced heat transfer performance compared to the simple double-pipe exchangers. **Bilawane (2017)** presented a review of one of the passive augmentation techniques used in a concentric tube heat exchanger using inner wavy tube. The performance of counter flow heat exchanger will be studied with inner plain tube and inner wavy tube. Then this enhanced performance due to inner wavy tube will be compared with performance of heat exchanger with inner plain tube and percentage of enhancement will be calculated in different hot fluid temperature input and different mass flow rates of hot as well as cold water. Experimentally, Overall heat transfer enhancement will be studied and also, the experimental results will be validated with CFD simulation.

Yogeshwari (2017) discussed analytical solution of the compartment based double pipe heatexchanger model obtained using Differential Transform Method for parallel flow with theoretical varying initial and boundary condition. The working fluid is transformer oil i.e. hot fluid and water act as coolant. Convergence analysis of solution is also discussed.

Pesteei (2016) experimentally investigated on double pipe heat exchanger by inserting wavy strip turbulators in the inner pipe, their findings are on considerable improvements in enhancement of heat transfer characteristics. **Pimple (2016)** investigated the heat transfer and friction factor data for single -phase flow in a shell and tube heat exchanger fitted with a helical tape insert. In the double concentric tube heat exchanger, hot air was passed through the inner tube while the cold water was flowed through the annulus. The influences of the helical insert on heat transfer rate and friction factor were studied for counter flow, and Nusselt numbers and friction factor obtained were compared with previous data (Dittus 1930, Petukhov 1970, Moody 1944) for axial flows in the plain tube. The flow considered is in a low Reynolds number range between 2300 and 8800. A maximum percentage gain of 165% in heat transfer rate is obtained for using the helical insert in comparison with the plain tube.

III. PROBLEM FORMULATION

According to salem et al. 2018, these are known to be economic heat transfer augmentation tools. The double helical twisted tapes insert is found to be suitable in a laminar flow regime and the latter is suitable for turbulent flow. The thermo hydraulic behaviour of an insert mainly depends on the flow conditions (laminar or turbulent) apart from the insert configurations. Heat transfer augmentation techniques (passive, active or a combination of passive and active methods) are commonly used in areas such as process industries, heating and cooling in evaporators, thermal power plants, air-conditioning equipment, refrigerators, radiators for space vehicles, automobiles, etc. Passive techniques, where inserts are used in the flow passage to augment the heat transfer rate, are advantageous compared with active techniques, because the insert manufacturing process is simple and these techniques can be easily employed in an existing heat exchanger. In design of compact heat exchangers, passive techniques of heat transfer augmentation can play an important role if a proper passive insert configuration can be selected according to the heat exchanger working condition (both flow and heat transfer conditions). In the past decade, several studies on the passive techniques of heat transfer augmentation have been reported. The present work is deal with the passive augmentation techniques in the recent past and will be useful to designers implementing passive augmentation techniques in heat exchange. Twisted tapes, wire coils, ribs, fins, dimples, etc., are the most commonly used passive heat transfer augmentation tools. In this work, emphasis is given to works dealing with double twisted helical tapes because,

IV. PROPOSED METHODOLOGY

In the paper of Salem et al. 2018 they performed 210 experiments were accomplished on the ten heat exchangers with single helical tape insert with different height and pitch ration because they had performed 210 experiments that"s why it is decided to change the concept and here it is decided to compare my apparatus results between simple tube without HTI and helical tape insert with the constant height and pitch distance, 10 mm and 45 mm with 16 numbers of turns. Firstly it is planned about flow diagram of experimental setup and after all study and research it is decided to follow Salem et al. 2018 paper of heat exchanger experimental apparatus design with the same dimensions of heat exchanger but with different materials of heat exchanger and different HTI.

Used material list:-

1. Heat Exchanger pipe (material- mild steel)
2. Copper tube
3. Rota meter 2 no. (4 to 40 lpm)
4. Voltmeter (0-30 amp)
5. A meter (0-30 amp)
6. U-tube manometer
7. Radiator
8. Motor switch (15 Amp)
9. MCV (240/415 v , 10000A)
10. DP switch (15Amp)
11. Radiator switch (6Amp)
12. Energy meter (5-30 Amp, 240V, ph1)
13. Centrifugal pump 2 no. (0.5hp)
14. Hot water tank (25 ltr)
15. Cold water tank (40 ltr)
16. Geyser (0-70 degree C)

V. RESULTS AND DISCUSSION

5.1 VALIDATION The validation of the procedures in determining the heat transfer coefficients and friction factors in the annulus side was done by using the above-mentioned analysis methods. The obtained results were compared with the confirmed heat transfer and friction factor correlations. For heat transfer determinations, the experimental procedures were validated by comparing the values of Nuan for the water flowing through the annulus with Nuan for transient and turbulent flow developed by Gnielinski [30], Eq. (1). This correlation is valid for 3000 ≤ Rean ≤ 5*106 and 0.5 ≤ Pran ≤ 2000 with an error less than±6% for Pran ≤ 200.

VI. CONCLUSION AND FUTURE SCOPE

The current study was performed to examine experimentally the hydrothermal performance of horizontal DPHEs with/without a continuous HTI conducted on the outer surface of the inner pipe. The HTI-geometrical parameters and operating conditions of the annulus-side were the main parameters throughout this investigation. Ten DPHEs of counter-flow configurations were constructed with/without different HTI height and pitch ratios, and tested at different water flow rates and inlet temperature. The present study was carried out to develop a new class of surfactant free Ionanofluid and thereby to assess the combined effect of Ionanofluid and twisted tape inserts on the hydrodynamic performance of a double pipe heat exchanger. A number of modified TT inserts with various geometric cuts (triangular, rectangular, and circular) were incorporated to obtain the optimum insert configuration based on a comparative performance analysis both numerically and experimentally.

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