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A Review on Thermal Performance Optimization and CFD Analysis of Double Pipe Heat Exchanger

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Abstract: One of the most simple and applicable heat exchangers is double pipe heat exchanger (DPHE). This kind of heat exchanger is widely used in chemical, food, oil and gas industries. Upon having a relatively small diameter, many precise researches have also hold firmly the belief that this type of heat exchanger is used in high-pressure applications. They are also of great importance where a wide range of temperature is needed. It is also well documented that this kind of heat exchanger makes a significant contribution to pasteurizing, reheating, preheating, digester heating and effluent heating processes. Many of small industries also use DPHEs due to their low cost of design and maintenance. As a result, we came to conclusion that the previous researches carried out on this type of heat exchanger should be categorized in order to overcome the perplexities of choosing the most appropriate methods of interest.

Keywords- Double pipe heat exchanger (DPHE), heat transfer, fins, tapes

I. INTRODUCTION

Heat exchangers were used in a wide-ranging of applications including power generation plants, nuclear reactors for generation of electricity, Refrigeration & Air Conditioning (RAC) systems, self-propelled industries, food industries, heat retrieval systems, and chemical handling. The upgrading methods can be distributed into two groups: active and passive methods. The active method requires peripheral forces. The passive methods need discrete surface geometries. Both methods have been commonly used to improve performance of heat exchangers. Due to their compact structure and high heat transfer coefficient helical tubes have been declared as one of the passive heat transfer improvement method and they are broadly used in many industrial applications.

The development of high performance thermal systems has stimulated interest in methods to improve heat transfer. In heat exchangers, enhancement of heat transfer is achieved by increasing the convection heat transfer coefficient or by increasing the convection surface area. One of the method to increase the convection coefficient within a heat exchanger is by introduces inserts within the pipes/tubes.

Heat Exchanger is a device in which the exchange of energy takes place between two fluids at different temperature. Aheat exchanger utilizes the fact that, where ever there is a temperature difference, flow of energy occurs. So, that Heat will Flow from higher Temperature heat reservoir to the Lower Temperature heat Reservoir. The flowing fluids provide the necessary temperature difference and thus force the energy to flow between them. The energy flowing in a heat exchanger may be either sensible energy or latent heat of flowing fluids. The fluid which gives its energy is known as hot fluid. The fluid which receives energy is known as cold fluid. It is but obvious that, Temperature of hot fluid will decrease while the temperature of cold fluid will increase in heat exchanger. The purpose of heat exchanger is either to heat or cool the desired fluid.

In a special case, when one of fluid undergoes change in its phase, its temperature remains unchanged. These types of heat exchanger are known as condensers or evaporators. Heat exchangers with the convective heat transfer of fluid inside the tubes are frequently used in many engineering application. The techniques of heat transfer enhancement to accommodate high heat flux i.e., to reduce size and cost of heat exchangers have received serious attention passed years. Enhancement of heat transfer Rate in all types of thermos-technical apparatus is of great significance for industry. Beside the savings of primary energy, it also leads to a reduction in size and weight. Up to the present, several heat transfer enhancement techniques have been developed. Twisted-tape is one of the most important members of enhancement techniques, which employed extensively in heat exchangers.

II. REVIEW oF PAST WORK

Bhattacherjee (2020) covered the different types of fluid flow range extending from laminar flow through the transition to the turbulent flow. The materials for the study were decided, fluid taken was water and the material for the pipe was taken to be steel for its better conducting properties.

Naik et al. (2020)represents an enhancement of heat transfer using different nanofluids containing nanoparticles ($Al2O_3$, Cu, Ag, TiO_2, SiO_2, Fe) Volume fraction $(0.02\leq \ \leq 0.05)$. Numerical simulations are conducted using CFD (Computational Fluid Dynamics) and the model is generated using Solid works. The governing equations are solved using a SIMPLE technique and discretized using finite volume approach. The results show that the heat transfer rate increases with the increase of the flow rates, also it has been observed that heat transfer rate increases with increase of operating temperature and also by the concentration of nanoparticles.

Gangwar et al. (2019) performed experiments by different mass flow rate of annulus side in the range of 0.072- 0.21 kg/s varied. In order to validate the result three dimensional CFD simulations are performed, using Fluent software. CFD simulations analysis was done under turbulent flow conditions. Key design parameters such as heat transfer coefficient and Nusselt number are evaluated in order to predict the performance of DPHE. Findings from this study shows that hydrothermal performance of double pipe heat exchanger with double helical tape is better than single HTI. Moreover both the results of CFD simulation & experimental one are in good agreement. Therefore, the present study will help the manufacturers in providing the better thermal performance of DPHE.

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.

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.

Ma et al. (2018) experimentally investigated the effects of supercritical carbon dioxide (SCO_2) in a DPHE in which the effects of pressure, mass flux and buoyancy force of the SCO_2-side were broadly studied.

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.

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.

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. 1). A uniform wall temperature at the inner wall of annulus was a boundary condition for the outer flow.

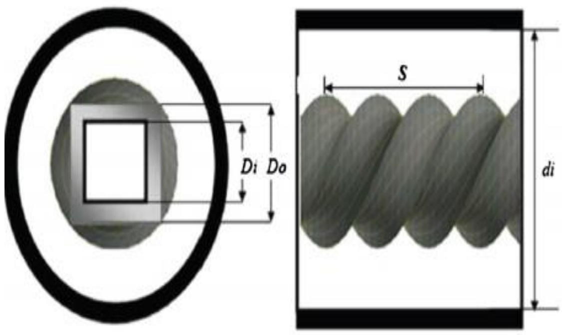

Fig. 1: Twisted inner tube of the DPHE

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 different cross section shapes which were circular, oval and tri-lobed (Fig. 2); 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.

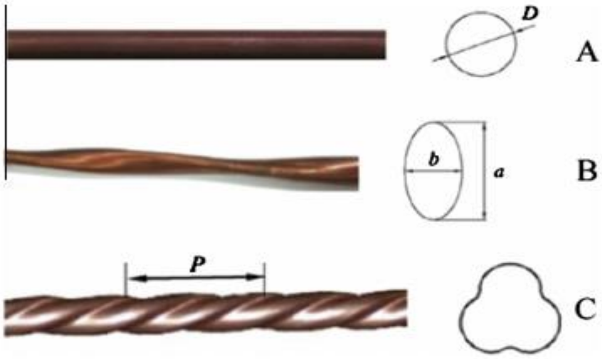

Fig. 2: Different cross sections of the inner tube in (A) Circle, (B) oval, and (C) tri-lobed.

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.
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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 heat exchanger 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.

Pourahmad and 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.

Goudiya (2016) presented the literature survey of enhancement techniques in heat transfer using inserts.

Kumar (2015) discussed with different configurations. Here CDD (convergent divergent spring tabulators) CDDSTs were placed in the inner tube of double pipe heat exchanger and effect on heat enhancement and friction factor was experimentally investigated. CDDSTs at various pitches i.e (p=0,p=15,p=16) were used for the different ranges of Reynolds number. For cold water its ranges between 9000to17000 and for hot water 18000 to 24000. Results from CDDSTs were compared with plane tube and results showed that Nusslet number increased while friction factor decreased with increased in Reynolds number. Friction factor was increased by 287% while Nusslet no increased by 28%. . However thermal performance factor was maximum for CDDSTs (p = 15) with value 0.319.

Tripathi (2015)presented a reviewon different arrangement of finned tube bundles placed on inline arrangement and staggered arrangement in cross flow. A large number of experimental and numerical works had been performed for enhancement of air-side heat transfer. A brief discussion is done on the effect of local heat transfer behaviour of circular finned tube and analysis of geometric and flow parameters included in this paper. Different parameters like fin height, fin spacing, fin thickness, tube diameter, tube spacing, effects of row and arrangement of tube bundles affect directly on the performance of solid circular finned tube. All these parameters are briefly discussed in this paper. Discussions on some important points which affect the performance of tube bundles (i.e. inline and staggered arrangement) from various authors and their problem and related issues are presented in this paper. The flow profiles and the related heat transfer characteristics in the complex geometries are still needed to be verified.

Rao (2014) studied the performance of (i) bare tube-in-tube heat exchanger, (ii) tube in tube with twisted tape insert and (iii) helical insert at annulus and twisted tape insert inside the inner tube of the heat exchanger. Numerical results have been compared with the available analytical solution. It has been observed that there is a good agreement between these two results: within ±19.78 percentage error limit for Nusselt number measurement and ±25 percentage error for friction factor.

Kumar. S (2014) studied experimentally on Heat transfer characteristics in a horizontal rectangular heat exchanger with five triangular baffles inclined at fixed angle of 200 along the channel are investigated experimentally. The same heat exchanger is also investigated with use of vibration. The experiment is done on three different vibration intensities. Effects of different vibration intensities on heat transfer are observed and compared with different heat transfer characteristics like overall heat transfer coefficient, effectiveness and heat transfer rate in absence of vibrations. It is found that with increase in vibration intensities, heat transfer characteristics can be improved to some extent.

III. OBJECTIVES OF WORK

In this work thermal performance of DPHE with straight and helical fins have been investigated. Firstly the straight and helical fins have been increased from 10 to 12 fins and after that thermohydraulic performance of DPHE have been investigated. Therefore the objectives of present study are as follows:

1. To compare the thermohydraulic performance of DPHE with straight and helical fins
2. To investigate the effect of Reynolds number on performance of DPHE with straight and helical fins
3. To plot temperature and streamline plot

IV. CONCLUSION

In the present study, a numerical model using CFD was adopted to study the thermohydraulic performance of different configurations of gas-to-liquid double-pipe heat exchangers with helical fins. Configurations with helical fins and longitudinal fins were numerically simulated and compared in terms of the heat transfer, pressure drop, unit weight, and comprehensive performance. The influences of the number fin increasing and Reynolds number on the thermohydraulic performance were also examined. In this work, the thermohydraulic performance of a proposed design of an air-to-water double pipe heat exchanger with helical fins on the annulus gas side, is numerically studied. Three-dimensional computational fluid dynamics (CFD) simulations are performed, using the FLUENT software in order to investigate the gas side fluid flow, turbulence, heat transfer, and power consumption for different configurations of the heat exchanger. CFD performance analysis was conducted under turbulent flow conditions for configurations. However the work can be extended by increasing the fin height and varying the clearance between helical insert and heat exchanger surface.

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