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Heat Transfer Characteristics of Inclined Helical Coil Tube by Forced and Free Convection : A Review

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ABSTRACT

Aim of this review work is to examine the relative advantage of using an inclined helical coil tube heat exchanger for high-pressure syngas under various industries application. It observed that the heat transfer in the helical coil tube is higher as compared to the straight tube due to their shape. Inclined helical coil tube heat exchanger offers advantageous over straight tubes due to their compactness and increased heat transfer coefficient. The increased heat transfer coefficients are a consequence of the curvature of the coil, which induces centrifugal forces to act on the moving syngas. Due to the curvature effect, the fluid streams in the outer side of the pipe moves faster than the syngas streams on the inner side of the tube. Heat transfer augmentation techniques refer to various methods used to increase the heat transfer rate without changing much the overall performance of the system. The arrangements are useful in a variety of applications where more heat transfer rates desired. Some of the claims involved in heat exchanger used in Thermal Power plants, process industries, air-conditioning equipment, heating and cooling in evaporators, radiators for space vehicles, automobiles, refrigerators. These techniques broadly of three types viz. passive, active, compound heat transfer augmentation techniques. The present paper reviews the experimental investigation of free and forced convection heat transfer from different helical coiled tubes.

Keywords : Inclined Helical Coil Tube, High-Pressure Syngas, Heat Transfer Characteristic Forced Convection, Free Convection.

I. INTRODUCTION

A heat exchanger is a part of devices developed for efficient heat transfer of one factor to different. The circumstance may be separated by a solid wall to prevent mixing, or they may be in direct contact. Heat exchange between flowing fluids is one of the most important physical processes of matter. The purpose of constructing an Inclined Helical Coil Tube is to make an efficient method of heat transfer from one syngas to another fluid, by indirect contact or by direct contact.

The colder liquid removes heat from the hotter syngas as it flows along or across it. Helical coil tube configurations are very efficient for heat exchangers and chemical reactors because of their large heat transfer rate area in a small space, with high heat transfer coefficients. Recently developments of heat exchangers, Inclined Helical Coil Tube heat exchangers are being used because the spiral coil configuration has an account of more heat removal area and more normal flow.

Going through the existing literature, it revealed that there are a few investigations on the heat transfer coefficients of this kind of heat exchangers considering the geometrical effects like coil pitch.

Recent developments in the design of heat exchangers to full fill the demand of industries has led to the evolution of inclined helical coil tube heat exchanger has many advantages over a straight tube.

Advantages :

1. Larger heat transfer surface area.
2. Compact structure. It required a small amount of floor area compared to other heat exchangers.
3. The heat transfer rate in the membrane helical coil is higher as compared to a membrane serpentine tube heat exchanger.

Applications :

The application of helically coiled exchangers proceeds to rise. Reinforcements combine fluid cooling/warming, vaporizers, vapor radiators, vent condensing, and cryogenic cooling. Enumerated here are the items for regular assistance in which helical coil tube problem.

1. In cryogenic applications, including LNG plant.
2. The most common industries where heat exchangers used a lot are heat recovery systems, power generation plants, nuclear plants, refrigeration, food processing industries, process plants, etc.
3. Heat Exchanger used for residual heat removal system in an islanded or barge-mounted atomic reactor system, where the nuclear energy used for desalination of seawater.

2. The Intention of The Work

The primary intention of the review work is to examine the performance parameters of an inclined helical coil tube heat exchanger.

II. LITERATURE REVIEW

The following research papers are a review in detail, and the extracts of relevant articles are as under:

[1] Naphon, Somchai Wongwises, The analysis of a spiral coil heat exchanger under cooling moreover dehumidifying conditions investigated. Heat exchanger comprised of a steel shell and spirally coiled tube unit. The spiral coil-unit included six layers of concentric spirally coiled tubes. Air and water used as operating liquids. The chilled water entering the outermost turn moves forward the spirally coiled tunnel and flows out at the intimate corner. The hot air begins the heat exchanger at the center of a shell and flows radially crossed spiral tubes to the periphery. Mathematical illustration based on mass and energy conservation emphasized.

[2] Paisarn Naphon, has studied the thermal performance and pressure drop of the helical-coil heat exchanger with and without helically crimped fins. The heat exchanger comprised of a shell and helically coiled tube unit with two different coil diameters. Each coil manufactured by bending a 9.50 mm diameter straight copper tube into a helical-coil container of thirteen turns. Cold and hot water used as working fluids in the shell side and tube side, respectively. The experiment performed at the cold and hot water mass flow rates varying between 0.10 and 0.22 kg/s, and between 0.02 and 0.12 kg/s, respectively. The results of the inlet conditions of both moving liquids flowing through the test section on the heat transfer characteristics discussed.

[3] Joo Hyun Park et al., The natural convection heat transfer of a helical coil in a duct was measured experimentally. The RaD fixed at 4.55 × 106, and the

pitch to diameter ratio varied from 1 to 5, the number of turns from 1 to 10, and the inclination of the helical coil from horizontal to vertical. Mass transfer experiments were performed based on the analogy between heat and mass transfer. The measured NuD for a single turn of the helical coil was close to the prediction derived from the McAdams heat-transfer correlation developed for a horizontal cylinder. The heat transfer of the helical coil varied concerning the pitch, several turns, and duct height, demonstrating the complexities associated with velocity, preheating, and chimney effects. It expected that the results from this study would contribute to a phenomenological understanding of natural convection heat transfer in compact heat exchangers.

[4] S.S.Gaddamwar et al., has studied the Heat exchangers remain one primary engineering method besides this broad category of purposes, including various waste heat recovery systems, power sectors, nuclear reactors. Natural convection is a method concerning heat transfer, during which the flow of fluid occurs by density variations in the fluid occurring due to different temperature conditions. A fluid which encompasses a heat reservoir holds heat becomes light dense and rises. Operating fluid that is enclosing the high-temperature liquid remains frozen, and water flows in to supplant it. Following this, chilling liquid gets heated, and this method persists, resulting from convection flow. Forced convection into a heat exchanger is this movement of heat from one moving water to a different stream through the surface from a pipe. The low-temperature liquid extracts heat of this comparatively high-temperature water because that flows along or over it.

[5] Xin and Ebadian, experimentally studied on natural convection heat transfer from helicoidal pipes in the air in vertical and horizontal orientations. In their experiment, three test coils tested, the tube diameter of two of them is 0.0127 m, and the third is 0.0254 m. for the coils oriented horizontally, the study was concentrated on the middle turn of each coil only. They conclude that the peripheral average Nusselt number distribution around the middle turn is almost periodic. Their correlation for the three middle turns of the three test coils is given by

$$Nu_d = 0.318\, Ra_d^{0.293}$$

This correlation is valid only at the middle turn of the coils, which neglect all the other turn effects and also the end effects on the average heat transfer coefficient. Therefore, it cannot apply to the coil as a unit to predict the heat transfer coefficient from such horizontal coils.

[6] Austen and Soliman [8] studied laminar flow and heat transfer in helically coiled tubes with substantial pitch. The influence of pitch on the pressure drop and heat transfer characteristics of helical coils explored for the condition of uniform input heat flux. Water used as the test fluid. Significant pitch effects noted in the friction factor and Nusselt number result at low Reynolds number.

[7] Sparrow and Niethammer, presented a study on natural convection from horizontal cylinders in an array set with a vertical distance separating each row. The interaction between the temperature and the flow fields around neighboring cylinders discussed. The results showed that the heat transfer from the upper cylinder was degraded for small separation distances and enhanced for large ones.

[8] Hesam Mirgolbabaei et al., had numerically investigated the forced convection heat transfer from vertical helical coiled tubes at various Reynolds numbers, different coil-to-tube radius ratios and non-dimensional coil pitch was studied. The distinct difference in this study compared to other similar studies was the boundary conditions for the helical coil. Most studies focus on constant wall temperature or constant heat flux, whereas in this study, it was fluid to the fluid heat exchanger. The influence of the tube diameter, coil pitch, and shell-side mass flow

rate over the performance coefficient and on shell-side heat transfer coefficient of the heat exchanger.

The probable conclusion from the given experiment are

- It had deduced that tube diameter had little effect on the thermal effectiveness of helically coiled tube heat exchanger.
- The heat transfer coefficient decreases by increasing the tube diameter, and coil pitch and tube diameter had no significant effect on the rise in the target fluid temperature.
- Forced convection heat transfer from vertical helical coils to water investigated. It concluded that coil pitch has a significant effect on the shell-side heat transfer coefficient, as with increasing dimensionless coil pitch in medium-range, the heat transfer coefficient decreases. In contrast, with an increasing angle to 2 tube diameter, the heat transfer coefficient increased.
- Thermal effectiveness decreases by the increment of coil pitch and increases by the raise of shell-side mass velocity.

[9] D. G. Prabhanjan, G. S. V. Raghavan, and T. J. Kenny Have done experimental study to define the relative benefit of practicing a helically coiled heat exchanger versus a straight tube heat exchanger for heating liquids. The appropriate variation in this review related to other similar studies was the boundary conditions for the helical coil. Utmost studies focus on constant wall temperature or constant heat flux, whereas in this study, it was a fluid-to-fluid heat exchanger. All experiments performed in transitional and turbulent regimes.

[10] Hessam Taherian, et al., have done an empirical examination of this combined convection heat transfer in a coil-in-shell heat exchanger signifies for various Reynolds and Rayleigh numbers, different tube-to-coil diameter ratios and dimensionless coil pitch. The purpose of this research paper is to check the influence of the tube diameter, coil pitch, shell-side and tube-side mass flow rate over the performance coefficient and modified effectiveness of vertical helical coiled tube heat exchangers. The estimates have conducted for steady-state and experiments conducted for both laminar and turbulent flow inside a coil. It remained determined that the mass flow rate of tube-side to shell-side ratio was active on the axial temperature profiles of a heat exchanger.

[11] H.Taherian, P.L.Allen, In the present study, the author has experimentally investigated the different heat transfer convection in a coil in the shell heat exchanger. This analysis described for Rayleigh and Reynolds number, separate tube to coil diameter rates, including dimensionless coil pitch. This scope of this research paper is to estimate the influence of the tube diameter, coil pitch, shell side, and side tube mass flow rate over the performance coefficient and modified effectiveness of vertical helical coiled tube heat exchangers.

[12]Sagar S.Gaddamwar et al., As analyzed to straight tubes, rounded tubes are more beneficial because of its compact structure, and it has been practiced as an ace of the passive heat transfer enhancement methods and most widely practiced in several heat transfer applications. Typically, the coil will be covered inside the case of a membrane helical coil heat exchanger, and in our area, the helix is convoluted outside the matter. That gives the convenience of withdrawing insulation outside the membrane heat exchanger coils. That research work compromises with the experimental study and CFD simulation of membrane helical coil heat exchanger using ANSYS. This fluid utilized for both loop and tube side is syngas. This flow rate of both fluids is reported here as laminar, and the flow of cold fluid (Water) retained constant while that of hot gas (syngas) changed. These readings, through experimental research, practiced once a steady state has arrived. The performance parameters are of the membrane helical coil heat exchanger, such as temperature contours, pressure contours,

effectiveness, overall heat transfer coefficient, etc. must be notified. Based on the outcomes, it understood that the heat transfer rates and additional thermal characteristics of the membrane helical coil heat exchanger are relatively more significant than that of a straight tube heat exchanger.

[13] A.Figueiredo, A.Raimundo, has done the experimental investigation on the analysis of the performance of heat exchangers used in hot water stores. In this paper, the thermal reply of a tropical water reserve and the thermal emanation characters from heat exchanger coils disposed of inside have empirically investigated. The study of the practical issues reveals that it is probably to explain the thermal performance of these methods by the use of a suitable set of dimensionless parameters. Two different geometric arrangements of the heat exchanger coils investigated, namely the standard cylindrical coil and the flat spiral coil. This last one is presenting higher heat transfer efficiency. The hypothesis of a lumped heat capacity for the thermal evolution of the water store enables the construction of a simplified theoretical model. The solution of which, obtained by a numerical method which foretells with reasonable accuracy the time developments of both the average temperature of the water tank and the inlet-outlet temperature difference of the circulating water.

[14] M.Moawed, had experimentally carried out natural convection from uniformly heated helicoidal pipes oriented vertically and horizontally. The effects of the pitch to pipe diameter ratio, coil diameter to pipe diameter ratio, and length to pipe diameter ratio on the average heat transfer coefficient found. The results showed that the overall average Nusselt number increases with the increase in pitch to pipe diameter ratio, coil diameter to pope diameter ratio, and length to pipe diameter ratio fro vertical helicoidal pipes. For horizontal helicoidal pipes, the overall average Nusselt number increases with the increase in pitch to pipe diameter ratio and length to pipe diameter ratio. Still, it decreases with the increase in coil diameter to pipe diameter ratio.

The result obtained showed that,

- For the horizontal helicoidal pipes, the local Nusselt number gave higher value at both ends of the coil turns, and it gave approximately a constant value at the middle coil turns.
- For the vertical helicoidal pipes, the local Nusselt number had higher values at the lower and upper ends of the coil turns, and it shows a constant amount in the middle of the loop turns.

[15] Devanahalli G. Prabhanjan, Timothy J. Rennie, G.S. Vijaya Raghava, An experimental investigation of the natural convection heat transfer from helically coiled tubes in water was conducted. The outside Nusselt number was compared to the Rayleigh number using various specific lengths. The connection based on a power-law equation. The constants in the comparison displayed for each of the separate terms used. The best relationship was using the total height of the coil as the appropriate length. The finished models were then used to develop a prediction model to foretell the outlet temperature of a liquid running through a helically coiled heat exchanger, bath temperature, fluid flow rate, coil dimensions, and given the inlet temperature. The prophesied outlet temperature compared to calculated values from an innovative setup. The consequences of the predicted temperatures were close to the experimental conditions and recommend that the method presented here has an agreement as a method of predicting outlet temperatures from similarly dimensioned heat exchangers.

[16] Arabi and Salman, were studied laminar natural convection from a uniformly heated surface of an inclined cylinder to air. Their correlation for the uniform heat flux of 1000 W/m^2 and the horizontal cylinder can be presented by

$$Nu_x = 0.158\, Ra_x^{1/3}$$

Their correlation for a vertical cylinder using the total cylinder length is 2% higher than those given by McAdams.

[17] Ali et al., developed correlations for turbulent natural convection from vertical helical coils in water. In this experiment, ten coils were used with four coil diameter to tube diameter ratios, and five-pitch to tube diameter ratios, the tube diameter used was 0.008 or 0.012m.

III. CONCLUSION

Review work carried out of an inclined helical coil tube heat exchanger. Based on the review, the following conclusions were drawn:

1. This review work presents a brief study of heat transfer through inclined helical coil tube heat exchangers.
2. The helical coil tube of the annular cross-section becomes utilized in a broad category of employment due to uniformity in manufacturing. Numerous researchers should describe the improvement in heat transferal due to helical spirals.
3. The intensity of secondary flow developed goes on increasing with the increase in curvature ratio. This increase in turbulence causes significant mixing of fluid inside the tube, which resultantly increases the heat transfer coefficient.
4. The heat transfer characteristics of inclined helical coil tube heat exchangers remain accessible in the review study. There is no issued empirical or philosophical investigation of an inclined helical coil tube analyzing fluid-to-fluid heat variation.
5. Heat transferal features inside an inclined helical coil tube for several boundary positions explained. They determined that the stipulation of a consistent temperature or uniform heat flux boundary position for an actual heat exchanger does not yield proper modeling.
6. Hence, the heat exchanger review regarding temperature-dependent characteristics of heat transport media and conjugate heat transferal.

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