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# A REVIEW ON HEAT TRANSFER ENHANCEMENT TECHNIQUES OF HELICAL COIL HEAT EXCHANGER

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**ABSTRACT**

*Heat exchangers are the important engineering systems with wide variety of applications including power plants, refrigeration and air-conditioning systems, heat recovery systems, nuclear reactors, chemical processing and food industries. Helical coil configuration is very effective for heat exchangers and chemical reactors because they can accommodate a large heat transfer area in a small space, with high heat transfer coefficients. This paper deals with the review on heat transfer enhancement method of the helical coiled tube with parallel and counter flow configuration of various correlations with specific data. The effect of corrugated tube, Nano fluids and geometrical parameters on heat transfer coefficient in helical double tube exchangers was studied.*

***Keywords-*** *Corrugated tubes, Dean Number, Helical coil heat exchanger, Heat Transfer, Nano fluids.*

## I. INTRODUCTION

Heat exchangers are the essential engineering systems with wide variety of applications including many power sectors, nuclear reactors, refrigeration and air-conditioning systems, waste heat recovery systems, chemical and food industries. A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. The media may be separated by a solid wall to prevent mixing or they may be in direct contact. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. Heat exchange between flowing fluids is one of the most important physical process of concern, and a variety of heat exchangers are used in different type of installations, as in process industries, compact heat exchangers nuclear power plant, food processing, refrigeration, etc. The purpose of constructing a heat exchanger is to get an efficient method of heat transfer from one fluid to another, by direct contact or by indirect contact.

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Various types of heat transfer configuration are used in practice. Most commonly used are tube in tube type and shell and tube type. However helical coil configuration is getting more and more popularity due to its compactness and better heat transfer rates compared to tube in tube configuration. Helical coil configurations are very effective for heat exchangers and chemical reactors because of their large heat transfer area in a small space, with high heat transfer coefficients. Recently developments of heat exchangers, coil type heat exchangers are being used because the spiral coil configuration has the advantage of more heat transfer area and better flow.

Heat transfer in curved and helical circular tubes has been the subject of several studies due to the relatively high heat transfer coefficients associated with them. Flow in curved tubes is different from flow in straight tubes because of the presence of centrifugal forces. The centrifugal forces generate a secondary flow, normal to the primary direction of flow, with circulatory effects, that increases both the friction factor and the rate of heat transfer. In the coiled tube, the flow modification is due to centrifugal forces. The centrifugal forces are acting on the moving fluid due to the curvature of the tube results in the development of secondary flow which enhances the heat transfer rate.

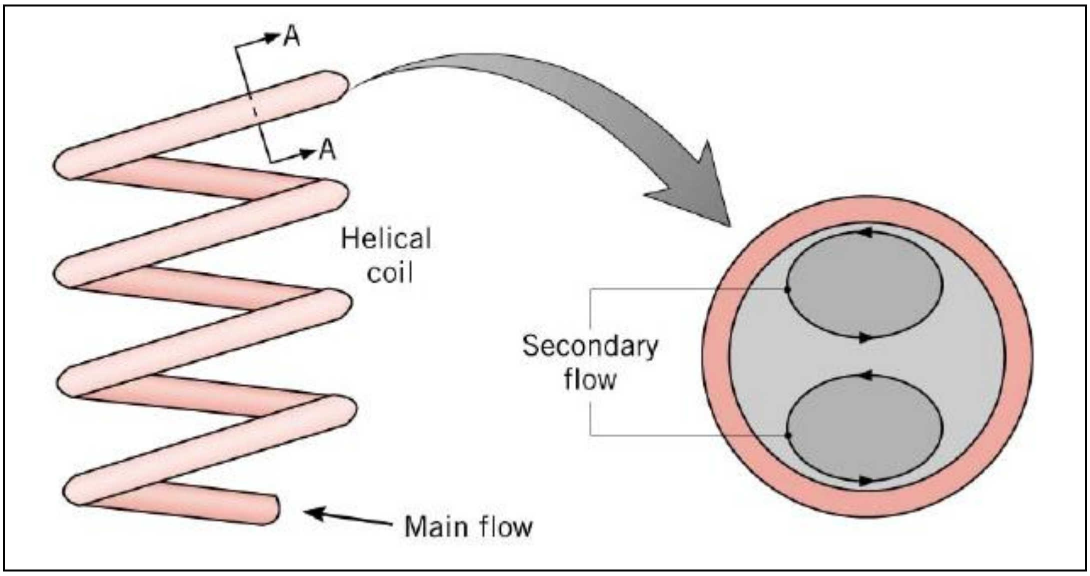


**Fig.1. Secondary flow formation**

Secondary flow can be expected to enhance heat transfer between the tube wall and the flowing fluid. Another advantage to using helical coils over straight tubes is that the residence time spread is reduced, allowing helical coils to be used to reduce axial dispersion in tubular reactors. Thus, for design of heat exchangers that contain curved tubes, or helically coiled heat exchangers, the heat transfer and hydrodynamic characteristics need to be known for different configurations of the coil, including the ratio of tube radius to coil radius, pitch, and Reynolds and Prandtl numbers and Dean Number (De).

## II. REVIEW ON WORK CARRIED OUT

The Primoz Poredos et al. [1] have studied the thermal characteristics of a concentric-tube helical coil heat exchanger which is a key element in local ventilation device. Central element of local ventilation device is concentric tube heat exchanger which is made of a corrugated tube surface. The heat transfer rate can be increased by increasing the convective heat transfer coefficient or by increasing the heat transfer surface area. So they have formed corrugated tube concentric counter flow heat exchanger which have sinusoidal, wavy surface in longitudinal direction of inner tube, which enables heat transfer enhancement. Wilson plot method is used to determine convective heat transfer coefficient on inside and outside of inner tube of concentric tube heat exchanger with different corrugation ratios. It is found that highest heat transfer rate was obtained for maximum stretched tube with corrugation ratio of 1.401, which enables greater effectiveness or a more compact design of concentric tube counter flow heat exchanger. In comparison with smooth tube, the corrugated tube had a 1.104-3.955 times higher value of heat transfer surface area and also pressure drop is 3-3.5 times higher than in smooth tube.

The Hamed Sadighi Dizaji et al. [2] had experimentally investigated heat transfer and pressure drop characteristics for new arrangements of convex and concave corrugated tube in a double pipe heat exchanger. Both of the inner and outer tubes were corrugated by means of a special machine. Convective heat transfer coefficient was determined using Wilson plots. Hot water (inner tube) and cold water (outer tube) inlet temperatures were maintained at around 40 degree and 8 degree respectively. Experiments were performed over the Reynolds number range of 3500-18,000, based on the hydraulic diameter of the annular space between the two tubes. The main purpose of this paper to compare a double pipe heat exchanger made of corrugated inner tube and smooth outer tube with a double pipe heat exchanger made of corrugated inner tube and corrugated outer tube. The results show that use of corrugated tubes is advantageous to enhance the Nusselt number and performance of heat exchanger. It is found that when both of the inner and outer tubes were corrugated, the Nusselt number and friction factor increased about 23-117% and 200-254%, while for only inner tube corrugated of double pipe heat exchanger nusselt number and friction factor were increased up to 10-52% and 150-190% respectively.

The Hamed Sadighi Dizaji et al. [3] had done exergy analysis for shell and tube heat exchanger made of corrugated shell and corrugated tube. The main of this paper is to experimentally clarify the effect of outer tube (shell) corrugations on heat transfer rate, dimensionless exergy loss and number of heat transfer units in a shell and tube heat exchanger. Various arrangements of convex and concave type of corrugated tube were also investigated. The results show that use of corrugated tube as the tube of the shell and tube heat exchanger increases the dimensionless exergy loss about 4% - 31%, while if both tube and shell are corrugated, the dimensionless exergy loss increases about 17% - 81% .In comparison with smooth tube and smooth shell if just the tube is corrugated Number of Transfer Units(NTU) increases about 12% - 19% while if in addition to the

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tube, shell is corrugated as well, the NTU increases about 34% - 60% respectively. Thus maximum NTU was obtained for the heat exchanger made of corrugated tube and corrugated shell.

The Shinde Digvijay D. et al. [4] studied the experimental investigation on heat transfer in cone shaped helical coil heat exchanger. They also compared heat transfer in cone shaped helical coil heat exchanger with simple helical coil heat exchanger. For comparative analysis they used both coils with (9.53mm outer dia.),(8.41mm inner dia.) & axial length of 6096mm. for simple helical coil 7 turns & for conical coil 10 turns with cone angle 65. The experiment is conducted for different flow rates and calculations are carried out. It was found that the effectiveness of cone shaped helical coil heat exchanger is more as compared to simple helical coil. In case of cone shaped helical coil heat exchanger Nusselt no. is higher than simple helical coil. They were found that the heat transfer rate for cone shaped helical coil is more as compared to simple helical coil. The heat transfer rate for cone shaped helical coil is 1.18 to 1.38 times more as compared to simple helical coil.

The Sagar Suryakant Pol [5] carried out the designing of helical tube in tube coil heat exchanger by taking reference of designing of helical coil in shell heat exchanger. He developed an experimental setup and carried out tests for both parallel and counter flow configuration. From observations he calculated capacity ratio, heat transfer coefficient, effectiveness, Log Mean Temperature Difference (LMTD) for both parallel and counter flow configuration and compare both the configurations. For this he considered two fluids like one is vegetable oil (SAE 20W40) oil in inner tube & cold water in outer tube. The results showed that for a heat exchanger with counter flow configuration the capacity ratio increases with increase in mass flow rate and maximum capacity ratio is 0.215. For a heat exchanger with parallel flow configuration the capacity ratio increases with increase in mass flow rate and maximum capacity ratio is 0.2. Helical coil in coil heat exchanger with counter flow configuration is 1.27 times effective than helical coil in coil heat exchanger with parallel flow configuration.

The Seyed Faramarz Ranjbar et al. [6] discussed the various parameters affecting on heat transfer characteristics of helical double tube heat exchanger by using well known Fluent Computational Fluid Dynamics (CFD) software. They considered the different parameters which affect on heat transfer rate of helical double tube heat exchanger are coil radius, coil pitch and diameter of tube. For this purpose they used pipes made up of copper with hot water in inner tube at 60 degree & cold water in annulus tube at 22.1 degree. It was found that the increase of curvature ratio increases the heat transfer coefficient. By increasing the number of coils there is decrease in heat transfer coefficient .As inner tube & inner dean number increases, the Nusselt no. also increases resulting in increase in heat transfer rate. Increasing the pitch of heat exchanger, there decrease in overall heat transfer coefficient which is negligible.

The Gabriela Huminic et al. [7] did analysis of nanofluids in helical tube in tube type heat exchanger by using two different types of nanofluids. Then Heat transfer coefficient, effectiveness, Nusselt numbers are studied by using nanofluids. They used CuO/Water &$TiO_2$/water with different concentration of nanofluids and different water flow rate through tubes. They found that thermal conductivity of CuO/water nanofluid is greater than

$TiO_2$/water. The maximum effectiveness was 91% for 2% concentration of CuO & 80% for $TiO_2$. The overall heat transfer coefficients increase with increasing nanoparticles concentration. They found reason for the increase the overall heat transfer coefficient is the higher thermal conductivity of nanofluids which lead to increases of the heat transfer coefficient and with the ratio of the mass flow rates. By keeping greater nusselt number than water as that of nanofluids heat transfer rate is increased also avoid entropy generation in heat exchanger due to heat exchange process. As nusselt number increases because of secondary flow in heliacal coil heat exchanger the performance also increases.

The S. Perumal et al. [8] reviewed on better techniques for enhancing a heat transfer rate. There are mainly two techniques active and passive techniques. They did CFD analysis and experimental studies of different techniques like treated surfaces, rough surfaces, swirling flow devices, coiled tubes. It is found that heat transfer rate of enhanced techniques is greater than that of plane tube. The CFD modelling and experimental results showed that an increase in turbulence intensity could be one of the reasons for higher performance augmentation methods with the plain tubes heat exchanger. The results of corrugated tubes, dimpled tubes and wire coils are compared with plane tube it is found that treated surfaces are having high heat transfer coefficient

The Rennie and Raghavan [9] experimentally investigated that two heat exchanger having same sizes and both parallel flow and counterflow configurations were tested. Copper tube with curvature ratio 233.5mm is used and small holes on the outer tubes to ensure that inner tube is centred, several reading are taken for parallel and counter flow arrangement it is found that heat transfer rate is large for counter flow arrangement because of large log mean temperature difference. They varied inner and outer tubes mass flow rate to modify dean number linearly, as dean number increases heat transfer rate also increases.

## III. CONCLUSION

After reviewing on literature some of the conclusions are as follows;

1) The Corrugated tube enables more compact design and higher heat transfer rate. Also by using cone shaped helical coil heat transfer rate is 1.18 to 1.38 times more than simple helical coil.
2) A Helical tube in tube heat exchanger with counter flow configuration is 1.27 times effective than helical tube in tube heat exchanger with parallel flow configuration.
3) The Dean number is an important and effective parameter in helical double tube heat exchangers.
4) By using nanofluids in a helically coiled tube-in-tube heat exchanger heat transfer performances is improved.

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