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Comparative Study and Analysis between Helical Coil and Straight Tube Heat Exchanger

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ABSTRACT
The purpose of this study is to determine the relative advantage of using a helically coiled heat exchanger against a straight tube heat exchanger. It is found that the heat transfer in helical circular tubes is higher as compared to Straight tube due to their shape. Helical coils offer 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 fluid, resulting in the development of secondary flow. The curvature of the coil governs the centrifugal force while the pitch (or helix angle) influences the torsion to which the fluid is subjected to the centrifugal force results in the development of secondary flow. Due to the curvature effect, the fluid streams in the outer side of the pipe moves faster than the fluid streams in the inner side of the pipe.
In current work the fluid to fluid heat exchange is taken into consideration. Most of the investigations on heat transfer coefficients are for constant wall temperature or constant heat flux. The effectiveness, overall heat transfer coefficient, effect of cold water flow rate on effectiveness of heat exchanger when hot water mass flow rate is kept constant and effect of hot water flow rate on effectiveness when cold water flow rate kept constant studied and compared for parallel flow, counter flow arrangement of Helical coil and Straight tube heat exchangers. All readings were taken at steady state condition of heat exchanger.
The result shows that the heat transfer coefficient is affected by the geometry of the heat exchanger. Helical coil heat exchanger are superior in all aspect studied here.
KEY WORDS: Helical coil heat exchanger, Straight tube heat exchanger, overall heat transfer coefficient.

I. INTRODUCTION

Heat exchangers are used in a wide variety of applications including power plants, nuclear reactors, refrigeration and air-conditioning systems, automotive industries, heat recovery systems,chemical processing, and food industries .Besides the performance of the heat exchanger being improved, the heat transfer enhancement enables the size of the heat exchanger to be considerably decreased. In general, the enhancement techniques can be divided into two groups: active and passive techniques. The active techniques require external forces like fluid vibration, electric field, and surface vibration. The passive techniques require special surface geometries or fluid additives like various tube inserts. Both techniques have been widely used to improve heat transfer performance of heat exchangers. Due to their compact structure and high heat transfer coefficient, helically coiled tubes have been introduced as one of the passive heat transfer enhancement techniques and are widely used in various industrial applications. Several studies have indicated that helically coiled tubes are superior to straight tubes when employed in heat transfer applications .The centrifugal force due to the curvature of the tube results in the secondary flow development which enhances the heat transfer rate. This phenomenon can be beneficial especially in laminar flow regime. Thermal performance and pressure drop of a shell and helically coiled tube heat exchanger with and without helical crimped fins have been investigated by Naphon one of the most frequent uses of helically coiled tubes is in shell and coiled tube heat exchangers. Going through the existing literature, it was 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. Also, this scarcity is more prominent for shell-side heat transfer coefficients.

II. LITERATURE SURVEY

The following research papers are studied in detail and the abstract of the work is presented here:
Timothy J. Rennie, Vijaya G.S. Raghavan [1] Have done An experimental study of a double-pipe helical heat exchanger. Two heat exchanger sizes and both parallel flow and counter flow configurations were tested. Flow rates in the inner tube and in the annulus were varied and temperature data recorded. Overall

heat transfer coefficients were calculated and heat transfer coefficients in the inner tube and the annulus were determined using Wilson plots. Nusselt numbers were calculated for the inner tube and the annulus. The inner Nusselt number was compared to the literature values. Though the boundary conditions were different, a reasonable comparison was found. The Nusselt number in the annulus was compared to the numerical data. D. G. Prabhanjan, G. S. V. Ragbavan and T. J. Kennic [2] Have done experimental study to determine the relative advantage of using a helically coiled heat exchanger versus a straight tube heat exchanger for heating liquids. The particular 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 a fluid-to-fluid heat exchanger. All tests were performed in the transitional and turbulent regimes. H. Shokouhmand, M.R. Salimpour, M.A. Akhavan-Behabadi [3] Have done an experimental investigation of the shell and helically coiled tube heat exchangers. Three heat exchangers with different coil pitches and curvature ratios were tested for both parallel-flow and counter-flow configurations. All the required parameters like inlet and outlet temperatures of tube-side and shell-side fluids, flow rate of fluids, etc. were measured using appropriate instruments. Overall heat transfer coefficients of the heat exchangers were calculated using Wilson plots. The inner Nusselt numbers were compared to the values existed in open literature. Nasser Ghorbani, Hessam Taherian, Mofid Gorji, Hessam Mirgolbabaei [4], Have done an experimental investigation of the mixed convection heat transfer in a coil-in-shell heat exchanger is reported for various Reynolds and Rayleigh numbers, various tube-to-coil diameter ratios and dimensionless coil pitch. The purpose of this article 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 calculations have been performed for the steady-state and the experiments were conducted for both laminar and turbulent flow inside coil. It was found that the mass flow rate of tube-side to shell-side ratio was effective on the axial temperature profiles of heat exchanger -Nian Chen, Ji-Tian Han, Tien-Chien Jen

III. Experimental Setup of Helical coil heat exchanger

The helical coil heat exchanger is fabricated in heat transfer lab. The schematic of the experimental set-up used for the present investigation is shown figure1. The set-up consisted of the following components:
Helical coil [Copper], Shell [G.I], Heater, Flow measuring devices, Cold water source.

Fig.1**:** Helical Coil Heat Exchanger

Fig.2: Straight tube heat exchanger Experimental setup

Hot water from hater flows inside the tube where it loses heat to cold water flowing through shell. The entry and exit of cold water in shell kept at top so shell should be filled completely and complete coil must be immersed in water. The flow of cold water is controlled by rotameter at the entry in shell, this cold water then carries heat to drainage. Hot water mass flow rate controlled after the exit of helical coil. This is done to get parallel flow and counter flow configurations. Four thermocouples are used to note down temperature at entry and exit of hot can cold water flows respectively. Following fig. shows the experimental setup.

IV. RESULTS AND DISCUSSION:

COMPARISON OF OVERALL HEATTRANSFER COEFFICIENT FOR HELICAL COIL AND STRAIGHT TUBE HEAT EXCHANGER.

Table No. 1 LMTD,Effectiveness and Overall Heat Transfer Coefficient (Straight Tube Heat Exchanger)

Sr. No.	$T_{hot\ IN}$ - $T_{cold\ IN}$ (ΔT 1)	$T_{hot\ OUT}$ - $T_{cold\ OUT}$ (ΔT 2)	LMTD= (_ΔT1-ΔT2) / ln(_ΔT1/ΔT2)	Effective-ness (ε)	OverAllHeat TransferCoef-ficient(Uo)	Max. OverAll HeatTransferCoe fficient(Uo)
1	44.4	6.0	19.186	0.444	128.52	128.88
2	47.0	6.5	20.472			
3	47.6	4.9	18.781	0.537	174.28	181.15
4	47.3	5.9	19.889			
5	52.1	9.4	24.935	0.586	154.50	162.36
6	55.8	8.6	25.240			

Table No.2 LMTD, Effectiveness And Overall Heat Transfer CoefficientFor Straight Tube Counter Flow

Sr. No.	$T_{hot\ IN}$ - $T_{cold\ IN}$ (ΔT 1)	$T_{hot\ OUT}$ - $T_{cold\ OUT}$ (ΔT 2)	LMTD= (_ΔT1-ΔT2) / ln(_ΔT1/ΔT2)	Effective-ness (ε)	OverAllHeat TransferCoef-ficient(Uo)	Max. OverAll HeatTransferCoe fficient(Uo)
1	21.7	20.1	20.890	0.571	178.45	182.67
2	23	18.1	20.452			
3	28.9	17.8	22.903	0.668	168.55	174.14
4	30.7	18.2	23.908			
5	39.1	15	25.155	0.703	212.78	214.36
6	36.9	12	22.167			

Table No.3 LMTD, Effectiveness And Overall Heat Transfer CoefficientFor Helical coil parallel flow

Sr. No.	$T_{hot\ IN}$ - $T_{cold\ IN}$ (ΔT 1)	$T_{hot\ OUT}$ - $T_{cold\ OUT}$ (ΔT 2)	LMTD= (_ΔT1-ΔT2) / ln(_ΔT1/ΔT2)	Effective-ness (ε)	OverAllHeat TransferCoef-ficient(Uo)	Max. OverAll HeatTransferCoe fficient(Uo)
1	47.2	4.4	18.038	$\boldsymbol{0.456}$	158.65	163.21
2	47.4	4	17.554			
3	46.8	4.5	18.063	$\boldsymbol{0.563}$	179.71	181.79
4	46	4.4	17.724			
5	48.7	4.1	18.022	0.607	230.76	238.69
6	46.2	3.5	16.549			

Table No.4 LMTD, Effectiveness And Overall Heat Transfer Coefficient For Helical coil Counter Flow

Sr. No.	$T_{hot\ IN}$ - $T_{cold\ IN}$ (ΔT 1)	$T_{hot\ OUT}$ - $T_{cold\ OUT}$ (ΔT 2)	LMTD= (_ΔT1-ΔT2) / ln(_ΔT1/ΔT2)	Effective-ness (ε)	OverAllHeat TransferCoef-ficient(Uo)	Max. OverAll HeatTransferCoe fficient(Uo)
1	26.6	18.3	22.192	0.557	180.72	184.97
2	24.9	19.1	21.872			
3	31.3	13.9	21.436	0.693	222.46	223.37
4	28.4	12.9	19.641			
5	33.4	11.8	20.760	0.761	224.17	228.97
6	33.8	11.7	20.832			

V. CONCLUSION

Comparative study is carried out between helical coil heat exchanger and straight tube heat exchanger, The effectiveness of heat exchanger greatly affected by hot water mass flow rate and cold water flow rate. When cold water mass flow rate is constant and hot water mass flow rate increased the effectiveness decreases.

Increase in cold water mass flow rate for constant hot water mass flow rate resulted in increase in effectiveness. For both helical coil and straight tube heat exchangers with parallel and counter flow configuration this result obtained. Helical coil counter flow is most effective in all these conditions and straight tube parallel flow heat exchanger is least effective.

Overall heat transfer coefficient on other hand increases with increase in hot water mass flow rate and cold water mass flow rate. The highest overall heat transfer coefficient is noted for cold water mass flow rate 100 LPH and hot water mass flow rate 100 LPH, in helical coil counter flow. Use of a helical coil heat exchanger was seen to increase the heat transfer coefficient compared to a similarly dimensioned straight tube heat exchanger.

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