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Experimental study on helical tube heat exchanger by varying cross section using nano Particles

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Abstract *– In large-scale industrial companies for several decades the waste heat recovery has been the topic of concern. This recovery not only makes an operation more environment friendly, but it also helps to cut costs as well as reduction in size of heat recovery device. In addition to this, it can reduce the amount of resources needed to power a facility. Many industries have implemented different methods of waste heat recovery. One popular choice is using a heat exchanger. This paper presents the study of two types of heat exchangers: straight and helical coil tube with the addition of nano particle (Tio2 & Sio2) in the working fluid. The helical coil heat exchanger has been experimented and analyzed on the basic of log-mean temperature difference (LMTD), heat transfer coefficient and Reynolds number. Based on the results, it is found that helical coil heat exchangers are efficient with the addition of nano particle in the working fluid and its overall heat transfer coefficient increases with mass flow rate.*

Key Words**: Helical coil heat exchanger, heat transfer coefficient, LMTD and Reynolds number.**

1. INTRODUCTION

The heat is a form of energy that transfers from the hot object to the cold object, and it transferred through the conduction, the convection and the radiation. The heat energy has many usages in the industry as making metals, chemicals, refining oil and processing the food. The shortage of heat energy leads to conserve or to make best use of it. In several industrial processes there is waste of energy or a heat stream that being exhausted in atmosphere. The heat exchangers plays important role to recover this heat and place it to use by heating a different stream within the process. This practice saves a lot of money in industry, as the heat supplied to other streams from the heat exchangers would otherwise come from an external source that is more expensive and more harmful to the environment. The purpose of constructing a heat exchanger is to get an efficient technique of heat transfer from one fluid to another, by direct contact or by indirect contact. In a heat exchanger the heat transfer through radiation is negligible in comparison to conduction and convection. But convection plays the major role in the performance of a heat exchanger. There are numerous applications of heat exchangers such as heat recovery systems, refrigeration, waste water treatment plants, pharmaceuticals, oil and gas industries, HVAC, food & beverage processing industries. In addition to these applications heat exchangers are also used in large scale chemical and process industries for transferring the heat between two fluids which are at a single or two states [1]. In general, the heat transfer techniques can be divided into two groups: active and passive. The active techniques need external forces like fluid vibration, electric field and surface vibration where as passive techniques requires special surface geometries like varied tube inserts. The straight tube heat exchanger has been the oldest type of heat exchanger that has been in use. The research work has been performed by various investigators on enhancing the performance of straight tube heat exchanger by changing geometric such as baffle arrangement [2], types of tube arrangement, length of the pipe etc. The main challenge in heat exchanger design is to make it compact and to get maximum heat transfer in minimum space. However, it was found that straight tube heat exchangers have restriction in terms of sizing and space which are significant parameters while designing industrial heat exchangers. In 1970 Charles Boardman and John Germer introduced helical coil tube heat exchanger as one of the best passive heat transfer enhancement techniques. The various experimental research work have indicated that helical coil tube heat exchangers are the most useful because of its spiral coil configuration which provides more heat transfer area and better flow in minimum space [3]. This configuration leads higher heat transfer coefficient as compared to straight tube heat exchanger under the same experimental conditions. Natural convection is a phenomenon that governs the exchange of heat between medium in heat exchanger is considered here. Since a complex flow pattern exist inside helically tube, as fluid flow through helical tube due curvature nature centrifugal force of fluid causes development the secondary flow pattern inside tube this led to improvement in heat transfer rate [6]. Instead of Reynolds number Dean number used in analysis as it take into account effect of curvature of helical pipe. [4].

1.1 Helical Coil Heat Exchangers.

The helical coil heat exchangers are a compact shell and tube design consisting of several layers of coiled tubes within a closed shell. The basic construction of the type used for this experimental work with the appropriate nomenclature is illustrated in Figure 1. The helical coil has:

H – Height of pitch,

2r – Diameter of tube,

2Rc – Diameter of helical coil,

i – Curvature ratio (i.e. ratio of tube and coil diameter),

2α – The helix angle (angle between its projection on a surface and measuring angle between the coils).

The flowing fluid experiences centrifugal force because of curved shape of the tube. The local axial velocity of the fluid particle and the radius of curvature of the coil decide the magnitude of centrifugal force experienced. The velocity of fluid particles flowing at the core of the tube is higher than those flowing near to the tube wall. Thus, less centrifugal force will be experienced by the fluid particles flowing close to the tube wall than in the tube core. This pushes the fluid from the core region towards the outer wall (away from the coil axis). This stream bifurcates at the wall and drives the fluid towards the inner wall on the tube bound, inflicting generation of counter-rotating vortices referred to as secondary flows [5]. This leads to produce extra transport of the fluid over the cross section of the tube. This extra convective transport will increase the heat transfer and therefore the pressure drop when compared to straight tube. It's been found that the impact of coil curvature is to suppress turbulent fluctuations arising within the flowing fluid and smoothing the emergence of turbulence. Thus it will increase the value of the Reynolds number (Re) needed to attain a fully turbulent flow, as compared to it of a straight pipe. The impact of turbulent fluctuations suppression enhances as the curvature ratio of coil increases.

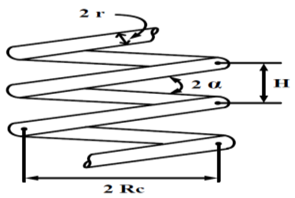

Figure1: - Helical Coil Tube.

2. EXPERIMENTAL SETUP

The schematic of the experimental set-up used for the present investigation is shown in Figure 1. The main components in the set up include helical coil tube, thermometer, hot and cold water tank, heating element, flow controlling and measuring devices. The helical coil copper tube is placed in the shell and hot water is made to flow through tube. To ensure maximum heat transfer the copper helical coil is fully immersed in the cold water flowing through the shell. The arrangement is made so that, flow direction of hot and cold water is perfectly counter by manner. The water in the storage tank is heated using a heating element, as the water reaches to a prescribed temperature the hot water circulates through the helical coil. The tube side hot water flow rate was measured using measuring jar and stop watch. The inlet and outlet temperatures of hot and cold water were recorded using thermometer. The tube and shell side thermo-physical properties of water were assessed at their mean temperatures.

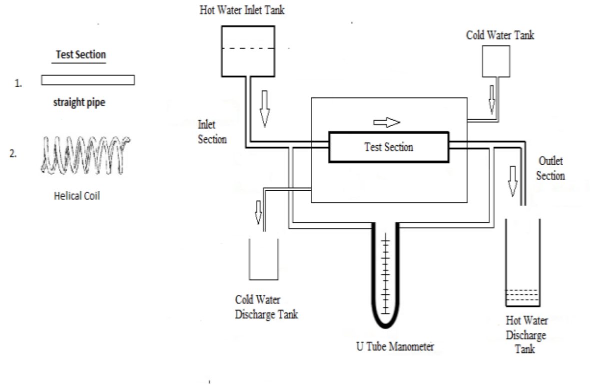

Figure 2:- experimental set-up

Table I: - Characteristics dimension of helical coil Tube

Sr. No.	Parameters	Dimension
1	Turns of helical Coil	8 Turn
2	Inner Diameter of Coil	8 mm
3	Outer Diameter	10 mm
4	Wall Thickness	2 mm
5	Stretched length of Coil	762 mm
6	Helical Diameter of Coil	50 mm
7	Fluid used	Water

Table II: - Range of operating parameters.

Sr. No.	Parameters	Range
1	Tube side water flow rate	0.0238 kg/s – 0.03571 kg/s
2	Shell side water flow rate	0.0349 kg/s – 0.04682 kg/s
3	Tube inlet Temperature	75 ^{0}C - 80 ^{0}C
4	Tube outlet Temperature	62 ^{0}C - 71 ^{0}C
5	Shell inlet Temperature	35 ^{0}C - 37 ^{0}C
6	Shell outlet Temperature	44 ^{0}C - 52 ^{0}C

Data Reduction:-

$$\text{LMTD} = \frac{\Delta T1 - \Delta T2}{\ln(\frac{\Delta T1}{\Delta T2})}$$

Where, $\Delta T_1 = Th_i - Tc_o$, $\Delta T_2 = Th_o - Tc_i$

Overall, $U_0 = \frac{Qavg}{Ao \times LMTD}$

Average Discharge, $Q_{avg} = \frac{Qh - Qc}{2}$

Reynolds No., $Re = \frac{\rho V di}{\mu}$

Effectiveness, $\epsilon = \frac{Ch\ (Thi - Tho)}{Cmin\ (Thi - Tco)} = \frac{Ch\ (Thi - Tho)}{Cmin\ (Thi - Tco)}$

Where, $C_h = \dot{m}\, C_{ph}$ $C_c = \dot{m}\, C_{pc}$

V. RESULTS

Figure 4 shows the graph of mass flow rate of hot water Vs effectiveness. It is observed that effectiveness of helical coil heat exchanger increases with addition of nano particle in the working fluid from 0.28 to 0.43 as mass flow rate of hot water increases.

Results for various mass flow rate of hot water with addition of Nano Particle.

Sr. No.	ΔT1 (^{0}C)	ΔT2 (^{0}C)	LMTD	ϵ	Uo (kW)	Re
1	35.84	40.32	38.03	0.28	376.12	403
2	34.16	38.08	39.45	0.30	499.99	512
3	30.24	33.60	31.88	0.33	785.43	603
4	33.04	35.84	34.41	0.34	519.45	557
5	30.24	33.60	31.88	0.36	761.43	709
6	25.76	30.24	27.93	0.43	1109.81	835

1) Mass flow rate vs Effectiveness With Nano Particle:-

Chart 1. Shows the graph of mass flow rate of hot water Vs effectiveness. It is observed that effectiveness of Plane pipe heat exchanger initially increases and it goes on increases from 0.28 Kg/s to 0.43 Kg/s. This one of the desirable effect. We have found after experimentation.

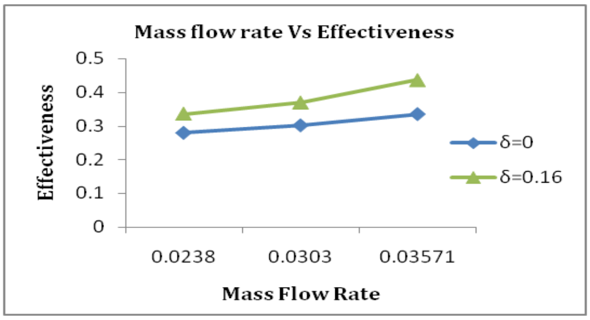

Chart 1:- Mass flow rate vs Effectiveness with Nano Particle

2) Mass flow rate vs Overall Heat Transfer With Nano Particle:-

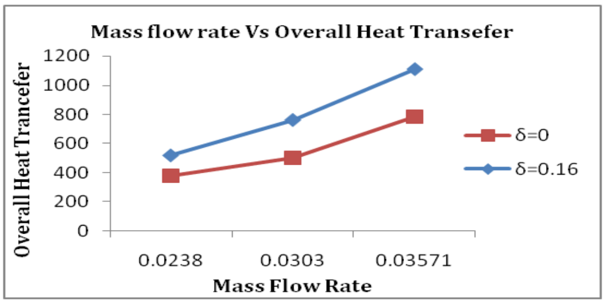

Chart 2:- Mass flow rate vs Overall Heat Transfer with Nano Particle

Chart 2 shows the graph of mass flow rate of hot water Vs overall heat transfer coefficient. It is observed that as mass flow rate of hot water increases the overall heat transfer coefficient of heat exchanger increases.

3) Mass flow rate vs Reynolds No. With Nano Particle:-

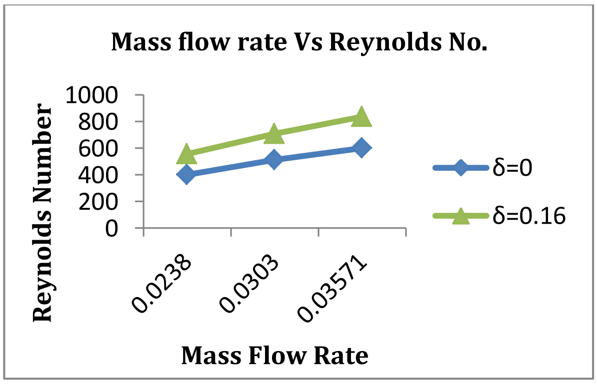

Chart 3:- Mass flow rate vs Reynolds No. With Nano Particle

Chart 3 shows the graph of mass flow rate of hot water Vs Reynolds number. As the Reynolds number is directly proportional to flow velocity, The mass flow rate of hot water with nano particle mixied increases with increase in Reynolds number, this is because the flow velocity increases.

VI. CONCLUSION

An experimental investigation was carried out to review the overall heat transfer coefficients and effectiveness of helically coiled tube heat exchangers. It is observed that, once cold water mass flow rate is constant and hot water mass flow rate is increased the overall heat transfer coefficient will increase with the addition of nano particle in working fluid. The helical tube permits the water with the addition of nano particle to be in contact for larger period of time in order that there is an enhanced heat transfer compared to that of straight tube. It is also observed that hot water mass flow rate greatly affects effectiveness of heat exchanger. The effectiveness of helical coil heat exchanger gradually increases as flow rate of hot water increases. The overall heat transfer of heat exchangers depends on its LMTD.

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