Performance Evaluation of Helical coil in Condensation Heat transfer

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Abstract*:* In this research work includes performance analysis of helical coil has investigated. The condensation heat transfer aspect of Helical coil which placed in shell and water flowing over the coil in counter direction. The testing has done on steam saturation temperature ranging from 103 – 115 Degree Celsius and pressure 0.2 – 1 Bar gauge. The test performed on two cooling water flow rate 3 LPM and 8 LPM. The influence of mass flux, heat flux and heat transfer coefficient considering three different curvature ratio of stainless steel helical coil have been investigated. The experimental outcomes from helical coil are more superior then straight tube.

Key words: Condensation, Heat transfer, Helical coil, Steam

INTRODUCTION

Heat exchanger is a heat transfer technique which transfer heat of two or more fluids at various temperature. The heat transfer improvement has done by two techniques. First Active devices include surface vibration, mechanical aids, and electrostatic field. Second passive devices include coiled devices, extended surfaces, rough surfaces, and medicate surfaces etc. In Helical coils are indirect contact or passive heat transfer devices. In coil tubes due to curvature shape centrifugal force exert on fluid and secondary flow generated and ultimately increase the convective heat transfer. Helical coil shows the packed structure, greater heat transfer coefficient because of that the coiled devices has scope in industry such as process plant, refrigeration, nuclear industry, power generation, chemical industry etc. The extensive research has done on helical coil for various configuration such as vertical, horizontal and inclined position.

Secondary flow development

The curvature shape of the coil encourages the centrifugal force which develop the extent of secondary flow and due to that increase the convective heat transfer in helical coil.

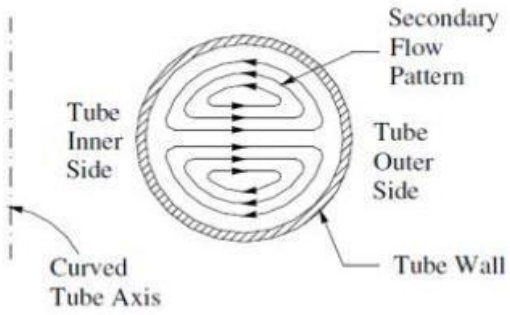

Fig.1: Secondary flow development.

Terminology of helical coil

The inner diameter of pipe 2r and coil diameter is expressed as *2RC.* The distance between successive adjacent turns named as pitch is *H*. The coil diameter and pitch circle diameter are similar terms. The fraction of pipe diameter to coil diameter (*r/Rc*) is known as curvature ratio, the fraction of pitch to developed length of one turn (*H/2Rc*) is shows non-dimensional pitch, Consider the projection of the coil on a plane passing through the axis of the coil.

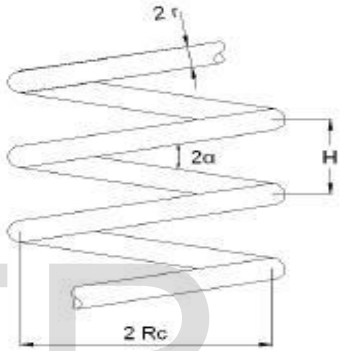

Fig.2: Terminology of helical coil.

The helix angle, which angle between projection of one turn of coil and plan perpendicular to axis.

Condensation Heat Transfer

Condensation is the process of conversion of vapor phase to liquid phase. When the surface temperature below the temperature of fluid then condensation occur. The few degree of sub cooling needed for condensation. There are two type of surface condensation film and dropwise condensation. The dropwise condensation shows 10 times higher heat transfer than film condensation.

LITERATURE REVIEW:

[A]Liang Zhao et al, [1] has performed experimental investigation of boiling heat transfer in helical coil. In this paper work correlation has proposed to compare the data. The mass flux and heat flux shows the effect on boiling heat transfer. The outcomes of the analysis were to nucleation mechanism and convective mechanism has same impact on boiling heat transfer. It concluded that heat flux does not have obvious effect on the two phase pressure drop multiplier. In this paper experimental result compared with predicted result. [B]Prabhanjan et al, [2**]** has studied the natural convection heat transfer of helical coil which placed in water.The objective of analysis is to: To evaluate the correlation for vertical helical coil in natural convection; to equate the nusselt number along the dimensionless number which shows the heat transfer outside the coil. Promote the prediction model to express the outer temperature of helical

coil in natural convection heat transfer. All the objectives are to be performed on helically coiled heat exchanger in which working medium pass through tube and without mixing.

[C]Shripad T.Revankar [3] has investigated the appearance of condensation in vertical tube condenser. The data collected from the experiment which compared with modified nusselt model along with the Blangetti model for heat transfer. For the interfacial shear, the impact of mass transfer at the interface was considered. The outcomes from the experiment well expected with modified nusselt model.

[D]Somchai Wongwises et al [4] has done testing on smooth helical coil tube in tube heat exchanger. The heat transfer and pressure drop features of HFC-134a on condensation heat transfer has reported.

[E]Ji-Tian Han et al, [5] has investigated the critical heat flux aspects in horizontal helical coiled tube. In this study new correlation has developed for CHF. The effect of wall temperature and parametric effect on CHF has analyze. The coil to diameter ratio has prominent outcome on CHF. The CHF values smoothly along with increasing mass fluxes. The CHF decrease with increase inlet vapor qualities becomes complex at high sub cooling condition.

[F]Akhavan-Behabadi, [6**]** has reported aspect of heat transfer and pressure drop in horizontal helical coil. The working fluid was CuO base Nano fluid. In this study developed correlation to relate different parameter to heat transfer such as effect of Reynolds number, fluid temperature, etc. The analysis done among straight and helical coil. It revealed that Nano fluid has better heat transfer characteristics, when pass through helical coil then straight tube which is 18.7% and 30.4% respectively.
[G]S.S.Pawar et al, [7] has performed study on helical coil for two fluid such as Newtonian and non-Newtonian fluid. The Newtonian fluids were water, glycerol water mixture; non-Newtonian fluids were dilute aqueous polymer solution, sodium alginate. The correlation was developed for heat transfer in Newtonian and non-Newtonian fluids for steady and unsteady state condition. The result reported difference between overall heat transfer coefficient and nusselt number for Newtonian and non-Newtonian fluids. The total 276 test were performed on isothermal and non-isothermal condition.
[H]Kahani et al, [8**]** has studied performance of helical coil in Nano fluid. The heat transfers and pressure drop features analyze. The effect of heat transfer coefficient observed different concentration as well as various Reynolds number. The range was 0.25-2% concentration and 500-4500 Reynolds number. The HTC is inspected 1330 and 4720 for straight tube and helical coil of 2% volumetric concentration of Nano fluid.

[I]Gupta et al, [9] has investigated the condensation in helically coiled tube. The working medium used was R-134a. The correlation evaluates in the work to analyze the two phase nusselt number and pressure drop. This analysis done for mass flux, saturation temperature and vapor quality. The mass flux, vapor quality and saturation temperature has major effect on heat transfer coefficient. The flow regimes analysis also was done during condensation.

[J]Shirgire et al, [10] has done review study on helical coil and straight tube heat exchanger. The author signifies the difference between helical coil and straight tube

Heat exchanger. Helical coil shows larger heat transfer then straight tube. Helical coil shows the dense structure, higher heat transfer coefficient, and less fouling. Due to centrifugal force, the fluid moves faster in core then the outer side. The velocity of flow signifies the secondary flow. The behavior of helical coil shows greater effect on heat transfer. The inner HTC finds out by Wilson plot method. It was developed the correlation for heat exchanger. Helical coil heat exchanger is superior then other heat exchanger.

[K]Akhavan-Behbadi et al [11] has done experimentation on tube in tube heat exchanger on various angles. The R600a is pass through inner core and cooling medium from outer core. The testing has done for different inclination of helical coil. The inclination shows major impact on heat transfer. Author has performed experiment for $0°C$, $30°C, 60°C,$ *and* $90°C$. The testing has done for the coil with diameter, pitch, and number of turns were 305mm, 36mm and 6 respectively. The testing done on saturation temperature and refrigerant mass flux 38.5 and 47, 155 to 265.5. The 30-degree inclination angle has shown more heat transfer coefficient. The pressure drop has not more impact on various inclination angle.

From literature it is revealed that most of work have been concluded for the heat transfer aspect of coil configuration and flow configuration, but the extent of work done in condensation heat transfer. Most of activities show that the many of the research done on the helical coil for different material such as mild steel and copper etc. It is seen that limited study has carried out on performance evaluation of stainless steel material in condensation. The majority of research has done on refrigerant as working fluid and few work has been reported for steam inside the helical coil. In this study steam is utilise as working medium which pass throgh the helical coil.

OBJECTIVES :

To compare the condensation heat transfer characteristics of three helical coil of diameter (125milimeter, 150milimeter, 175milimeter).

To compare the heat flux, mass flux, saturation temperature effect on condensation heat transfer.

EXPERIMENTAL SET-UP AND PROCEDURE:
The test facility is design and fabricated to investigation of condensation of steam in helical coil. The schematic diagram of experimental set-up is shown in Fig.3.

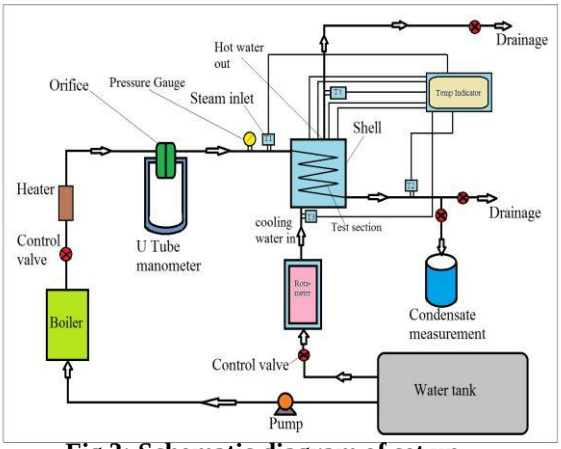

Fig.3: Schematic diagram of set up.

The test-portion such as helical coil placed in a cylindrical shell. The experimental rig consists of electric Boiler, heater, orifice meter, manometer, temperature indicator, Thermocouple sensor, RTD sensor, Rotameter, measuring flask, test specimen, and tank. The electric boiler working on 27watt and 4 bar pressure having 35kilogram per hour capacity. The manometer place across the orifice meter to measure the discharge of steam. The range of manometer 0 to 500milimeter. There are 17 T type (copper-constantan) thermocouple sensor are attached on surface of coil to measure the average surface temperature. The RTD sensor are utilize to measure temperature of water inlet, water outlet and condensate temperature. The thermocouple sensor is used to measure temperature of inlet of steam in the coil. The thermocouple and RTD sensors are calibrated using calibration test rig with calibrated glass thermometer. The rotameter used to measure flow rate of water from supply. The range of the rotameter is 0 to 20 LPM. By using rotameter adjust 3 and 8 LPM water flow rate. The condensate coming out of coil is measured by measuring flask having capacity 1litre. The tank is made of cylindrical mild steel vessel having diameter 295milimeter, height 450milimeter and vessel has a capacity approximately 30litre. It's made from the MS sheet of 3mm thickness by rolling the sheet in the rolling machine. The temperature indicator is shows the temperature of thermocouple and RTD sensor. The heater is used after boiler to heat steam so that steam become saturated. The steam is passing through coil control by valve called as throttling process. All the data has collected and graphs are plotted.

Test specimen:

The helical coils are made from the ¼ inch S.S seamless pipe having outer diameter of 13.7 mm and internal diameter of 9.22 mm. Three helical coils are made of coil diameter of 175, 150, and 125 mm respectively. Number of turns are 5.5. Pitch is kept 20mm.The helical coil is place in vertical orientation. The steam enters the coil at apex of the tank and leaves from bottom. While passing through the helical coil steam get condensed and pass through bottom of tank. In this experiment steam has pass at different flow rate which is controlled by ball valve. The flow rate of water is constant for different steam flow rate.

RESULT AND DISCUSSION:

The experiment has done for the three coil diameter helical coil, from the experiment reading are taken at the different flow rate of steam and keeping constant water flow rate. The finding from the experiment different graph and result are plotted for the three helical coil at 3 and 8 LPM water flow rate.

A) Effect of saturation temperature of steam on heat transfer coefficient.

In this section the effect of saturation temperature of steam on heat transfer coefficient has studied.

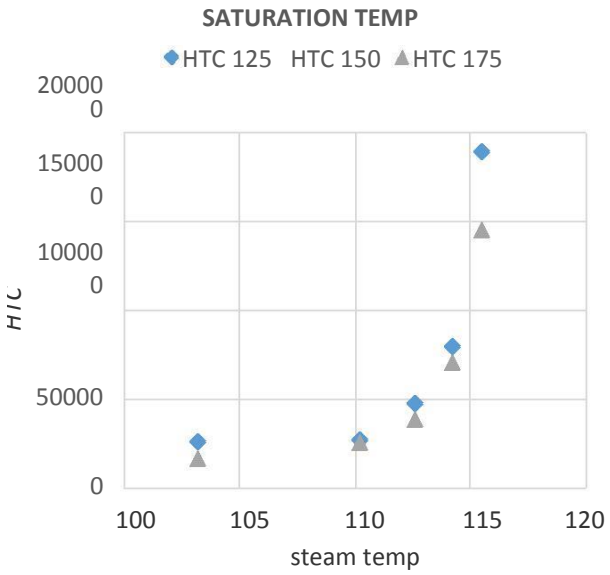

Fig.4: Saturation temp Vs HTC (W/m^2k) at 3LPM.

The deviation of heat transfer coefficient due to inlet temp of steam has shown in fig.4.at 3LPM. The heat transfer coefficient increases with increase in inlet steam saturation temperature. Also the heat transfer coefficient higher for smaller coil diameter and lower for bigger coil diameter.

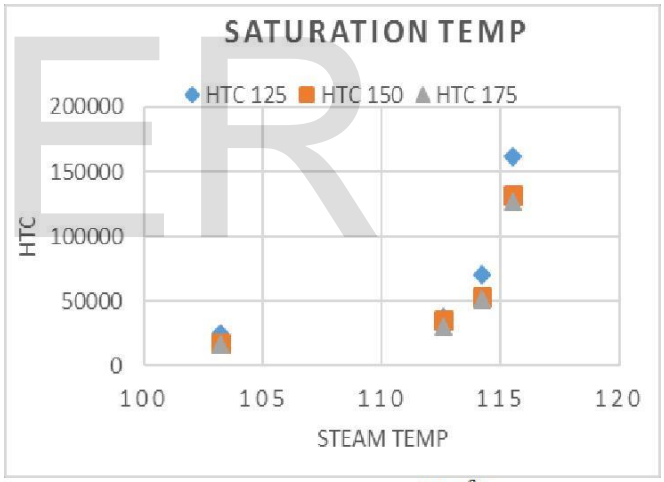

Fig.5: Saturation temp Vs HTC (W/m^2k) at 8LPM.

The deviation of heat transfer coefficient due to inlet temp of steam has shown in fig.5. at 8LPM. The heat transfer coefficient increases with increase in inlet steam saturation temperature. Also the heat transfer coefficient higher for smaller diameter and lower for bigger diameter coil.

B) Effect of heat flux on heat transfer coefficient

In this section the effect of heat flux of steam on heat transfer coefficient has studied.

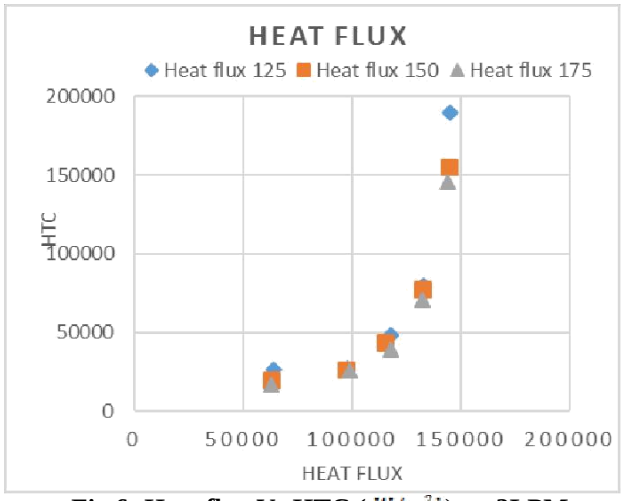

Fig.6: Heat flux Vs HTC (W/m^2k) at 3LPM.

The deviation of heat transfer coefficient due to heat flux of steam has shown in fig.6. at 3LPM. The heat transfer coefficient increases with increase in heat flux of steam. Also the heat transfer coefficient higher for smaller coil diameter and lower for bigger coil diameter.

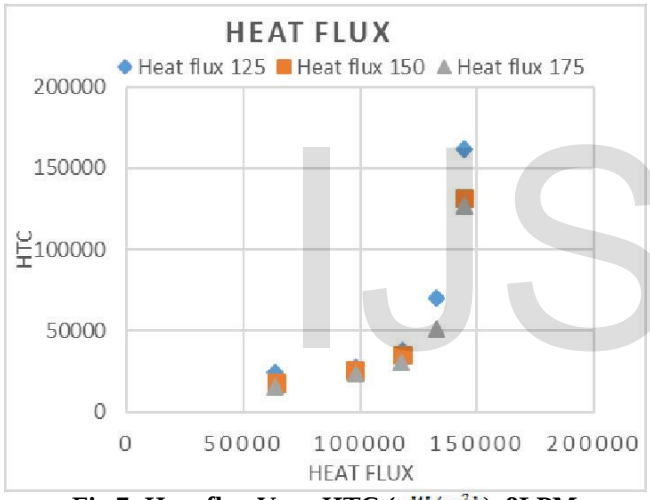

Fig.7: Heat flux Vs at HTC (W/m^2k) 8LPM.

The deviation of heat transfer coefficient due to heat flux of steam has shown in fig.7. at 8LPM. The heat transfer coefficient increases with increase in heat flux of steam. Also the heat transfer coefficient higher for smaller coil diameter and lower for bigger coil diameter.

C) Effect of mass flux of steam on heat transfer coefficient.

In this section the effect of mass flux of steam on heat transfer coefficient has studied.

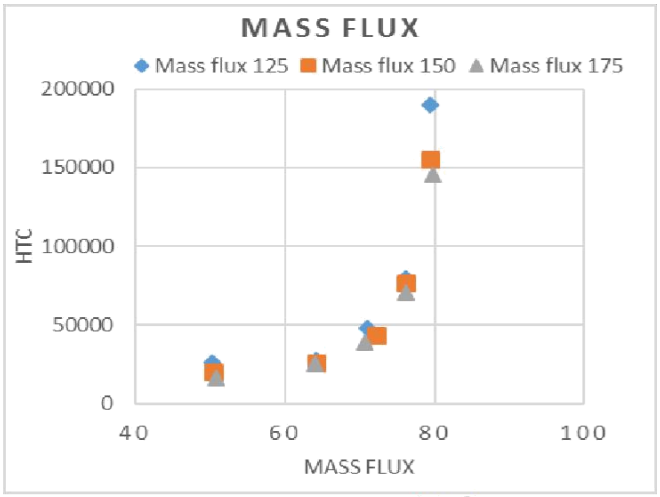

Fig.8: Mass flux Vs at HTC (W/m^2k) 3LPM.

The deviation of heat transfer coefficient due to mass flux of steam has shown in fig.8. at 3LPM. The heat transfer coefficient increases with increase in mass flux of steam. Also the heat transfer coefficient higher for smaller coil diameter and lower for bigger coil diameter.

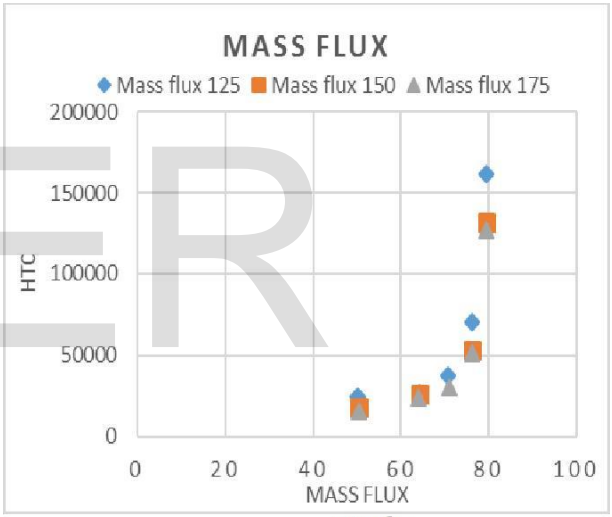

Fig.9: Mass flux Vs HTC (W/m^2k) at 8LPM.

The deviation of heat transfer coefficient due to mass flux of steam has shown in fig.9. at 8LPM. The heat transfer coefficient increases with increase in mass flux of steam. Also the heat transfer coefficient higher for smaller coil diameter and lower for bigger coil diameter.

CONCLUSION :

From the experimental study it has been shows that there are significance effect on heat transfer coeficient of various coil diameter. Hence the helical coil heat exchange more superior then straight tube heat exchanger.

1) The experimental results show that condensation heat transfer coefficient increases with increases in saturation temperature of steam.
2) The heat flux higher in smaller coil diameter and lower in bigger coil diameter. The condensation HTC increase with increase in heat flux. The condensation HTC higher in smaller coil diameter and lower in bigger diameter.

3) The condensation heat transfer increases with increase in mass flux of steam.
4) The coil curvature ratio has significance impact on heat transfer coefficient.
5) The condensation heat transfer coefficient higher in 3LPM cooling water flow rate and lower in 8LPM cooling water flow rate.

ABBREVIATION:

HTC- heat transfer coefficient **(** W/m^2k).

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