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An experimental investigation for the rate of heat transfer in double pipe heat exchanger inside helically coiled tube

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ABSTRACT

The effect on heat transfer and pressure drop is characterized by arranging tubes in helical shape with a different pitch, the experiment is conducted. During conducting experiment the tubular region is maintained by varying the mass flow rate of fluid with the same temperature. After the experiment, the calculated results are obtained, for the same working condition. The average heat transfer rate is increased by 18% by making a tube in helical coil shape over a straight tube. At the same time, the overall heat transfer coefficient also increased by 18% by providing a helical coil shape over a straight tube. Also, the helically coiled tube plays an important rule to improve the heat transfer rate and overall heat transfer coefficient, also raise in pressure drop across the flow. The number of turns and diameter of the coil is important to create turbulence inside the coil. The increase in heat transfer rate with an increase in pressure drop. By comparing with present work we can increase the heat transfer rate by inserting the spring inside the helically coiled tube and also increases by a change in fluid properties. As compared with previous work on the same experiment the helically coiled tube with the minimum pitch we can achieve the high thermal performance

Keywords— *Helical Coil, Heat Transfer coefficient, Reynolds number, Nusselt number, Pressure drop, Heat transfer rate, Thermal performance*

1. INTRODUCTION

Heat exchangers are device use to transfer the heat from one fluid to another fluid, which is having different temperature without direct contact between the two fluids which are separated by solid surface along with liquid medium. The fluid may be a single combination or multiple combinations and involved in dissimilar application like evaporation or condensation in different pass either may be single pass or multi – pass and heating or cooling application. Heat exchanger usually maximizes the transfer of heat by maximizing the contact surface area between fluids. Heat exchangers are used in industrialized application such as oil and gas industry, power generation, chemical processing industry, diameter in automobiles and air conditioning devices.

The drawing of heat exchanger is somewhat difficult. Some of parameters plays very important rule in design of heat exchanger like rate of heat transfer, pressure fall, friction factor and size of the exchanger. Selection of material, energy, cost and economic aspects are produce extra operational in designing of exchangers. To increase the heat transfer rate with increase the overall heat transfer coefficient, the weight and size of heat exchanger enable to reduce. B. K. Hardik[3],experiment are conducted to study the effect of the curvature of helical coil, Reynolds number and iPrandtl number on friction factor and local Nusselt number with water as working medium. They carried a test by selecting a tube to coil having diameter 13.1 to 67mm and having pitch of coil is 50mm. The Reynolds number is varied between 300 and 19000 by this experiment they got the drop of pressure depends on curvature of the coil for both laminar and turbulent regions. The Nusselt number decreases in outer side (from 100% to 20%) with decrease curvature ratio and inner side Nusseltinumber increase (from 25% to 35%) with increase coil to tube diameter ratio (D/d). Anand kumar solanki, Ravi kumar [5], to study condensation heat transfer coefficient and frictional pressure drop of R-135a inside a dimpled helically coiled tube. The test is carried out by taking three different tube, they are dimpled helical coil, smooth helical coil, and smooth straight tube.

The measurements are taken at saturation temperature (40^0C and 50^0C) with mass flux of 70, 110, 150, 190 kg/m^2s. The quality of used vapors is in the range of 0.1-0.8. For this experimental set the tube to coil diameter is 10-100mm and having 25mm pitch, length of helically coiled is 200mm. The rate of heat transfer coefficient in dimple helically coiled tube (20-35%) is higher than smooth helical coil and (50-60%) higher than smooth straight tube. As compare to smooth helical and straight tube the rate of heat transfer coefficient in helical coil (35-45%) is higher than straight tube. S.V. Prabhu [4] to study the effect of curvature on local boiling heat transfer coefficient and two phase pressure drop in helically coiled tube by using water as a working fluid. The secondary flow which may effect on heat transfer distribution and pressure drop because of vary in curvature by the geometrical properties like pump diameter, coil diameter etc., The length of helically coiled tube also effect on two phase pressure drop.

The experiment is carried out by selecting six helically coiled tube of stainless steel having inner diameter is of 6-10mm and the ratio of tube to coil diameter is 14-58mm and the pitch of coil is 50mm. They analyzed drop of pressure, heat transfer coefficient and heat flux based on coil and tube diameter. The rate of heat transfer higher in helically coiled tube (12% to 18%) compare with straight tube.

2. DESCRIPTION OF THE EXPERIMENTAL SET UP

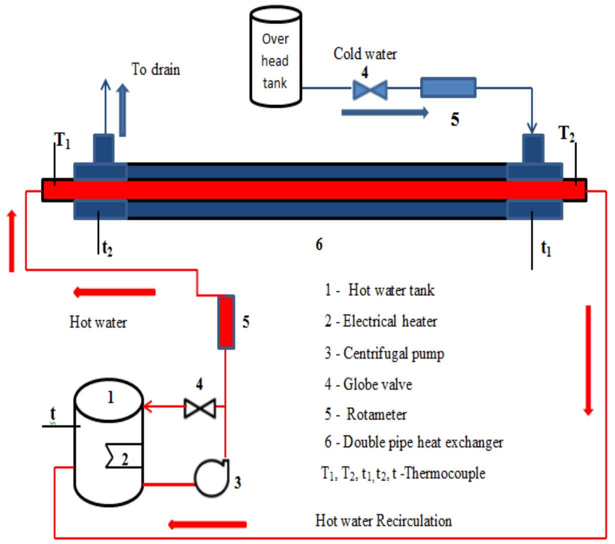

Fig. 1: Schematic layout of Experimental Arrangement

Figure 1 shows a schematic diameter gram of the experimental facility. The experimental section is the one of part of experimental setup arranged in counter flow pattern in heat exchanger with double pipe with piping system. The connection piping arrangement in the text section such that can be easily replaced. The setup consists of two circular tubes in which the inner material having high thermal conductivity and outer material has a low thermal conductivity and having low cost than the inner tube material. So copper material are used for inner tube having a coil diameter of 58mm and length is 1m, in which the hot water is allow to flow in tube side and outer tube made by PVC an cold water allow to flow in annulus side of 1m long and 75 mm outer diameter meter of a pipe [5].The main reason to use PVC material in annulus side, its possess less thermal conductivity.

The experiment is conducted over three tubes, one is straight and other two are helically coiled tube with different pitch, but all the tubes are fixed in same test section. The straight tube is taken as reference tube to compare with two different helically coiled tubes. The working fluid is selected as water because the water is easily available in our environment. The water from the over tank is directly feed to annuls side due to gravitational force and centrifugal pump is used in hot water side or tube side to flow water inside the tube with different flow rate. The water is heated by using heater in a storage tank. To measure the flow rate of working fluid we are using calibrated flow meter i,e. Rotameter, which is placed at both the cold and hot inlet of the fluid side. The flow may control by rotameter by operating manually and flow controls with the help of glove valve placed inlet side of both hot and cold fluid. The hot water is produced by placing water heater in a storage tank and with help of centrifugal pump it feed to tube side.

The calibrated-type thermocouples are used to measure the temperature were placed in five different places, namely; two were placed at hot water inlet and ioutletiside, another two were placed at cold water inlet and ioutletiside and one placed at hot water bath for hot water measurement[6]. The pressure tapping of upstream and downstream for pressure drop measurement at hot waterside, the U-tube manometers are used to measure pressure drop along tube side. The U-tube manometer is connected to both inlet and outlet of hot water with mercury used as a manometrici fluid.

3. DATA REDUCTION

(a) Surface area of helical coil tube can be calculated by;

$$A_s = N*\pi^2*D*d\sqrt{\left(1+\left(\frac{p}{\pi D}\right)\right)2} \qquad \text{in } m^2$$

Where
A_s=Surface area of helical coil tube in m^2
D= Diameter meter of helical coil in m.
d= Diameter meter of tube in m.
P= Pitch of the coil in m.
N= Number of turns.

(b) Heat transferred of fluid, Q can calculate by using

$$Q = m*Cp*(t_2-t_1)$$

Where
m = Mass flow rate of fluid in kg/s.
Cp=Specific heat of fluid at stable pressure in J/kg ^{0}C.i
$t_1$and t_2 = Inlet and outlet temperature of fluid respectively ^{0}C.

(c) The Reynolds number on hot fluid side can be calculated by:

$$Re = \frac{4m}{d\mu\pi}$$

Where m= Mass flow rate of hot liquid in kg/s.

(d) Nusselt number in turbulent region is calculated by using;

$$Nu = 0.00619*Re^{0.92}*Pr^{n}*(1+3.456(d/D))$$

Where, n = 0.4 for hot fluid
n = 0.3 for cold fluids
Pr = Prandtl number.

(e) Friction factor calculation:

$$f = [1+0.11Re_m^{0.23}(d/D)^{0.14}](0.316/Re_m^{0.25})$$

Convective heat transfer coefficient:
Heat transfer coefficient based on inner tube side calculated using Nusselt number equation:

$$Nu = \frac{h*d}{K}$$

Where, K = Thermal conductivity of working fluid, W/m-K

4. RESULTS AND DISCUSSION

4.1 Heat Transfer Rate

The figure 2 consists of three set of average heat transfer rate for straight tube (Q_t), helically coiled tube with 30mm pitch (Q_{c1}) and coil with 25mm pitch (Qc_2). For straight tube, the average heat transfer rate increases from 0.2kW to 2kW for the range of Reynolds number 8472 to 13932 along the hot fluid side. The average heat transfer rate increases with increase in Reynolds number correspondingly the Nusselt number also increases. The main advantage of increase in Nusselt number in tube side also increase in convective heat transfer coefficient which helps the higher the overall heat transfer coefficient. The helically coiled tube with 30mm pitch is also shows that the increase in average heat transfer rate from 0.26kW to 3.57kW for a same Reynolds number. Similarly in helical coil with 25mm pitch there may be increase the heat transfer rate from 0.26kW to 4.6kW. Comparing with straight tube and coil with 30mm pitch the better average heat transmission take place in a coil with 25mm pitch. The increase in average heat transfer coefficient in straight tube and helical coil with 30mm and 25mm pitch are 1.8kW, 3.3kW and 4.34kW respectively.

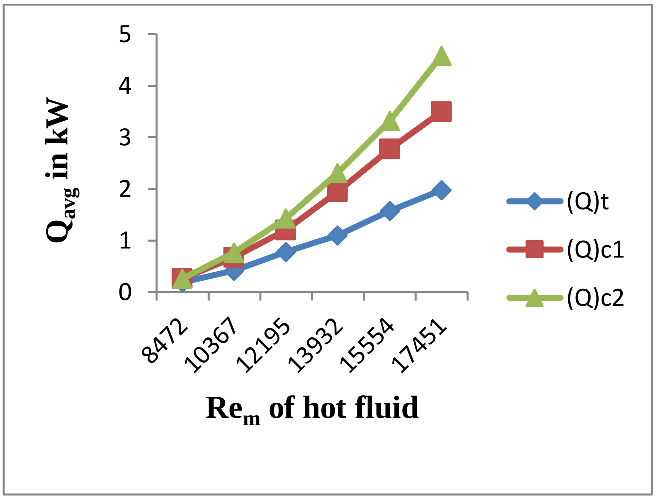

Fig. 2: Effect of Average heat transfer rate over Reynolds

4.2 Nusselt Number Results

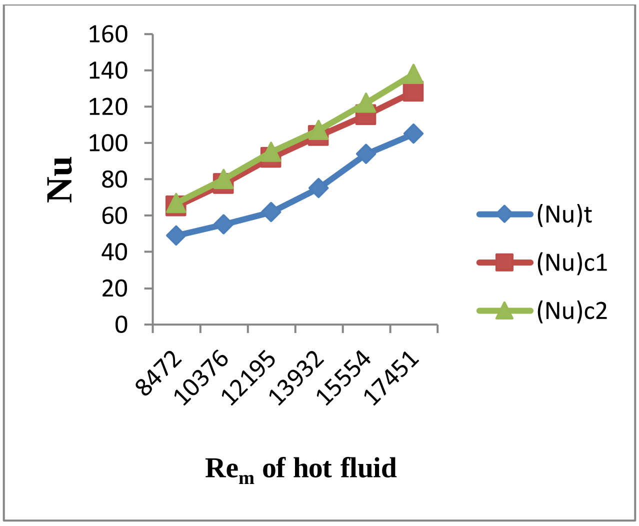

Fig. 3: Effect of Nusselt Number over Reynolds Number

From the figure 3 we can say that the Nusselt number is increases with increase in Reynolds number of hot fluid. In straight tube the range of Nusselt number is increase from 20% to 45% of the nominal value. This improvement in Nusselt number because due to promote in turbulent intensity sensibly by with thermal boundary layer thickness. Than we used two different helical coils having different pitch for a heat exchanger. The increment of Nusselt number in a coil having pitch 30mm is in the range of 27% to 70% and in 25mm pitch 30% to 75%. In a coil the turbulence are generated due to that the better heat transformation take place between the fluid and wall surface, hence the variation in heat transfer coefficient results cause reduce the boundary layer thickness on internal tube surface.

4.3 Convective Heat Transfer Coefficient

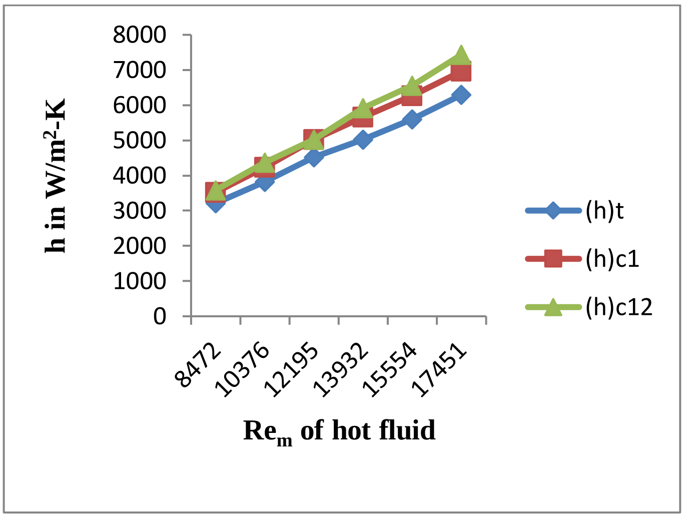

Fig. 4: Effect of Convective heat transfer coefficient over Reynolds number of hot fluid

By making the exchanger in a helical coil shape, it leads to enhance the heat transfer coefficient and also convective heat transfer coefficient along the coil side. For the straight tube, the heat transfer coefficient increase from 25% to 60% for a Reynolds number 8476 to 17451. The figure 4 shows that in the helical coil having pitch 30mm, the heat transfer coefficient increases from 35% to 85%, with increase in Reynolds number. Higher heat transfer coefficient is achieved at high Reynolds number. For the second helical coil having pitch 25mm the increment of heat transfer rate from 40% to 90%.

4.4 Pressure Drop results

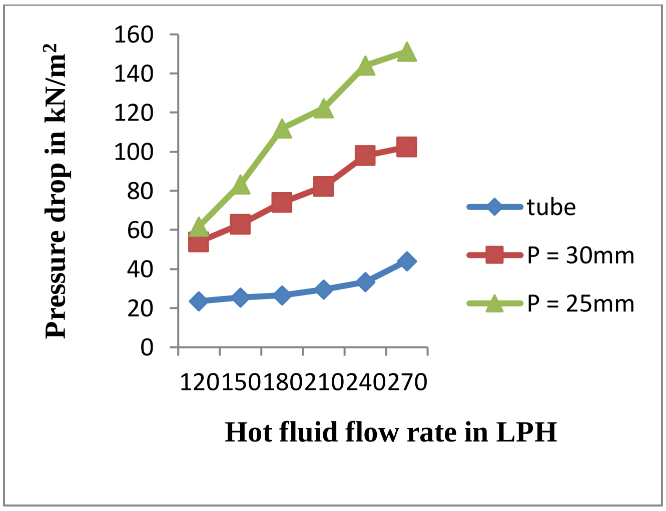

Fig. 5: Effect of Pressure drop over Flow rate of hot fluid

The drop of pressure in straight tube and a helical coil is study under different flow rate of hot fluid on tube side. The pressure drop can be measured on both the inlet and outlet end of heat exchanger, by using u-tube manometer. The range of pressure drop in a straight tube along tube side is from 23.54 to 44.14 kN/m^2 for a flow rate of hot fluid from 120 to 270 LPH. Where the drop of pressure in helical coil having pitch 30mm from 53.5 to 102.35 kN/m^2 under same flow condition as that of straight tube. And also the pressure drop in helical coil with 25mm is from 61.8 to 151.2 kN/m^2 for same flow condition that of a both the above tubes.

4.5 Overall Heat Transfer coefficient

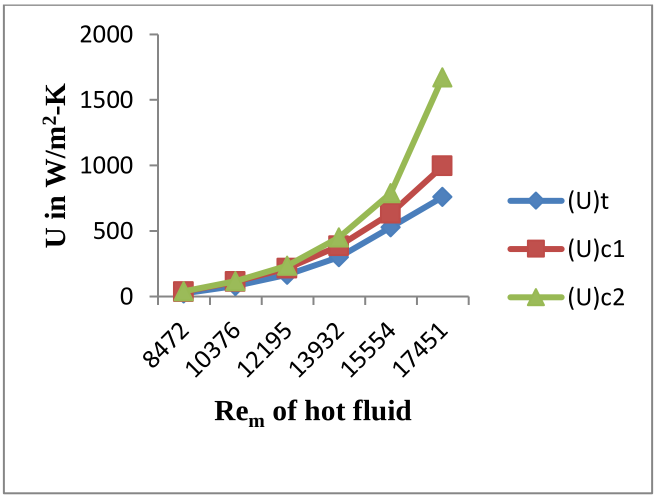

Fig. 6: Effect of Overall heat transfer coefficient over Reynolds number of hot fluid

Above figure 6 shows that the overall heat transfer coefficient is increases with increase in Reynolds number of hot fluid on tube side. As compare the outcome results we can say that the overall heat transfer coefficient is less in straight than the coil, which also influenced by the Reynolds number of hot fluid. The forced convection are in inside the coil which indicate that heat rate is little attach on overall heat transfer coefficient. It is apply for only some stable situations with little amount of latent heat sensible heat transfer between the two solid wall surfaces.

5. CONCLUSION

The investigational work is conducted for together straight and two different helically coiled copper tubes by using water as a working fluid. The main aim of this experimental work is impact on curvature surface over a length of tube to transfer rate on double pipe heat exchanger. The experiment is conducted in turbulence flow circumstance for different Reynolds number from 8475 to 17451 by using centrifugal pump. The parameters like pressure drop, overall heat transfer coefficient, friction factor, thermal performance factor are calculated used for both the helical coil and compare the results with the reference straight tube.

- The size and dimensions of heat exchanger is reduces by increase in Nusselt number, so that the cost of heat exchanger also become less.
- For the straight tube the average heat transfer rate increase from 0.19kW toi1.98 kW and for the helically coiled tube with 30mm and 25mm pitch the average heat transfer rate increases from 0.26kW to 3.57kW and 0.26kW to 4.6kW respectively for the range of iReynolds number 8342 to 17451 on hot fluid side
- The convective heat transfer coefficient for straight tube is increase from 25% to 60% and coil by 30mm and 25mm pitch are in the range of 30% to 85% and 35% to 90% in that order for a given iReynolds number in a turbulence region.
- From experimental investigation it is clearly seen that the any heat transfer application both in industry or domestic purpose the helically coiled tube heat exchanger gives better heat transfer rate than the straight tube.
- For helically coiled tube with 30mm pitch is from 0.06 to 0.048 and for coil with 25mm pitch is from 0.65 to 0.05. It is clear that the friction factor may decrease with increase in flow rate and Reynolds number on hot fluid side.
- The thermal performance ratio of helically coiled tube which having 30mm pitch is increases with increase in iReynolds number in the range of from 0.527 to 0.85 for different flow rate of hot fluid, and for the coil with pitch 25mm has the thermal performance ratio is from 0.57 to 0.941.
- The drop of pressure in straight tube and two helically coiled tubes is noted under the different flow rate of hot fluid on tube side. For a straight tube the pressure drop take place in the range of 23.54kN/m^2 to 44.14kN/m^2 for a flow rate of hot fluid is from 120LPH to 270LPH. For coil with 30mm pitch has pressure drop from 53.95kN/m^2 to 10235kN/m^2 and for 25mmm pitch the range of pressure drop is from 61.8kN/m^2-151.2 kN/m^2 for different flow rate condition on hot fluid side.

6. REFFERENCES

[1] Liyao xie, Yongqi Xie, Hongwei Wu, Jianzu Yu: Highigravity influence on boilingiheat transfer in helicalicoils. International Journal of Heat andiMass transfer 73, 706-715, 2014.

[2] Junli, Haifu Ma, Zijiang Yang,and Jianqiang Shan: An assesment of heat transfer modelsiof water flow in helicallyicoiled tube based on selected experimentalidatasets. Annals ofiNuclear Energy 110, 648-667, 2017.

[3] B.K. Hardik, P.K.iBaburajan, and S.V. Prabhu: Local heat transfericoefficient in helical coil withisingle phase flow. 89, 522-538, 2015.

[4] Shuo Chen, Zhenxiao Hu, Yao Xiao, Hanyang GU: Experimental investigation of subcooled flow boiling heat transfer in helical coils. NucleariEngieering and Design 327, 187-197, 2018.

[5] B.K. Hardik, S.V. Prabhu: Boilingipressure drop and local heat transfer distribution of helical coils with water atilow pressure. International Journal of Thermal Science.114, 44-63, 2017.

[6] Anand Kumar Solanki, Ravi Kumar: Condensation of R-134a insideidimpleed helically coiled tube –in –shell typeiheat exchanger. Applied Thermal Engineering 129, 535-548, 2018.

[7] Zhang Cancan, Wang Dingbiao, Xian SA, PengXu: Numericaliinvestigation of heat transfer and pressure drop in helicallyicoiled tube with spherical corrugation 133, 332-341, 2017.

[8] Patnala Sankarra Rao, K Kiran Kumar: Numerical andiExperimental Investigation of heat transferiaugmentation in double pipe heat exchanger withihelical and twisted tape inserts. Internaltionali Journal of Engineering Technology and Advance Engineering.2250-2459, 2014.

[9] Davood Panahi, KamiariZamzamiam: Heat transfer enhancement of shelliand coiled tube heat exchanger utilizing helicaliwire tubulator. 376-398, 2016.

[10] Sreejith K, T.R. Sreesatha Ram, Sushmith S: Experimental investigation of a helical coil heat exchanger, 2278-4721, 2015.

BIBLIOGRAPHY

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