ENHANCEMENT OF HEAT TRANSFER COEFFICIENT THROUGH HELICAL COIL

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ABSTRACT

Helical coil tube are used to enhanced the heat transfer coefficient and also accommodate a large heat exchange surface in a given volume. Heat transfer in coiled tube is more compared to that in straight tube due to the contribution of secondary vortices formed as a result of centrifugal force. Helical coil configuration is very effective for heat exchange and chemical reactors because of their large heat transfer area in a small space with high heat transfer coefficient. Recently developments of helical coil type heat exchangers are being used because the helical coil configuration has the advantages of more heat transfer area and better flow. Temperature drop for helical coil tube is higher than straight tube.This is due to the curvature effect of the helical coil. Fluid stream in the outer layer of pipe moves faster than the fluid streams in the inner layer. This difference in the velocity will set in secondary flow by which heat transfer will be increased. It can be seen that for the helical tube the average temperature drop was increased by 36.56% as compared to the straight coil when the mass flow rate varied from 0.00909kg/s to 0.01136kg/s..

Keywords:- Convection, Heat transfer coefficient, curvature ratio ,Reynold number, Nusselt number, Prandtl number, centrifugal force, mass flow rate

1.INTRODUCTION

Helical coils are used widely in processing industries for cooling and heating application since the centrifugal forces experienced by the fluid acts to promote contact with the channel wall, thereby tending to insure good contact with the wall and enhanced heat transfer.Helical coil tubes are used in heat exchange equipment to obtain a large heat transfer area per unit volume and to enhance the heat transfer coefficient on the inside surface fig.(1).As a result of centrifugal force a secondary flow pattern consists of two vortices perpendicular to the axial flow direction is set up and heat transfer occurs not only by diffusion in the radial direction but also by convection. The contribution of this secondary convective transfer dominates the overall process and enhances the rate of heat transfer per unit length of tube compared to a straight tube of equal length. The flow and heat transfer in coiled tube are governed by Dean number, $Dn=R_{ed}\ [D/dc]^{0.5}$ where D is the tube diameter and *dc* is the coil diameter

Three region are distinguished

1) The region of small dean number

Dn< 20 where inertial force due to secondary flow are negligible.

$N_{\acute{u}}=1.7\ (Dn^2\ Pr)^{1/6}$ if $(Dn^2\ Pr) > 10{,}000)$

2) The region of intermediate Dean number

20<Dn<100, in which the inertial force due to secondary flow balance the viscous force

$N_{\acute{u}}=0.9\ (Re^2\ Pr)^{1/6}$ if $(Dn^2\ Pr) > 10{,}000)$

3) The region of large Dean number Dn> 100 where the viscous force are significant only in the boundary near the wall.

$N_{\acute{u}}=0.7\ (R_{ed}^{0.43}\ Pr^{1/6}\ (D/dc)^{0.07}$

Theseequation are valid both for a uniformheat flux and a uniform wall

dc] **0.5** where D is the tube diameter and *dc* is the coil diameter. . In laminar flow the friction factor in a coiled tube is

$f= 64/\ R_{ed}\quad 21.5Dn\ /\ (1.56+\log_{10} Dn)^{5.73}$

Transition to turbulent flow occur at

$(R_{ed})_{critical} = 2\ (D/dc)^{0.32}\ x\ 10^4$ for (15 (D/dc) <860

For value of (D/dc) > 860 critical Reynolds number for a curved pipe is the same as that for a straight pipe.For turbulent flow in forced convection in helically coiled tube, Hausen has proposed the following correlation

$$\frac{N_{uaHelical}}{N_{uaStraig\ \ ht}} = 1+ (\frac{21}{\Re^{0.14}} (D/dc)$$

Here LHS is the ratio of average Nusselt Number for Helical and Straight tube D is the diameter for Helical and Straight tube , D is the

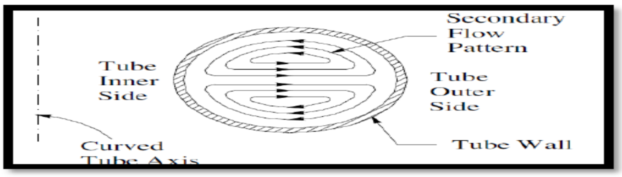


Figure 1: Fluid flow in curved pipes

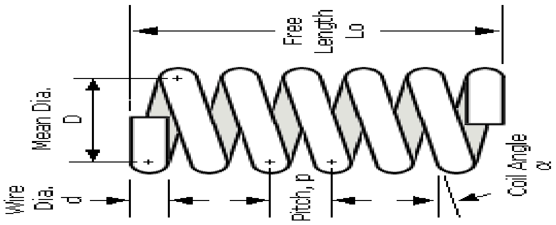


Fig. 1Helical Coil

diameter of the tube and dc is the diameter of the coil.

As the mass flow rate increases the temperature drop decreases in both cases. At higher mass flow rate due to the increased velocity resident time for the fluid decrease thus reducing the temperature drop. The difference in temperature drop between straight and helical coil increases with the mass flow rate and helical coil show the better performance than straight tube. Several option are available for enhancing heat transfer associated with internal flow. Enhancement may be achieved by increasing convection coefficient and or by increasing the convection surface area.By coiling tube heat transfer may be enhanced without inducing turbulanc or additional heat transfer surface area.In this case centrifugal force accelerate the secondary flow consisting of a pair of longitudinal vortices that increase the heat transfer coefficient

2.Application of Helical Coil

Helical coils are extensively employed for heat transfer application in the process and power industries. Some of the application are listed as.

1] Helical coils are used for transferring heat in a chemical reactor and agitated vessel because heat transfer coefficient are higher in helical coil. This is especially important when chemical reactor having high heat of reaction are carried out and the heat generated (or consumed) has to be transferred rapidly to maintain the temperature of the reaction. Also because of helical coils have a compact configuration more heat heat transfer surface can be provided per units of space than by use of straight tube.

2] Due to compactness it is used for steam generation in marine and industrial application.

3] The existence of self induced acceleration field in helical coils makes helical coil most desirable for

heat transfer and fluid flow application in the absence of a gravity field, such as for spaceship in outer space.

4]Helical coils have recently being studied for possible application in bio-engineering . Weissman and Mocker"s recently studied the use of helical coils to augment mass transfer in membrane blood-oxygennerators.Thier study demonstrated both theoretically and experimently that by coiling a membrane tube into a helical coil, they could substantially increase the mass transfer rate of oxygen and carbon dioxide to and from blood flowing inside the tube.

5] Helical coils hyave been extensively used in the cryogenic industry for the liquefaction of gases.

2.1 Experimental Result

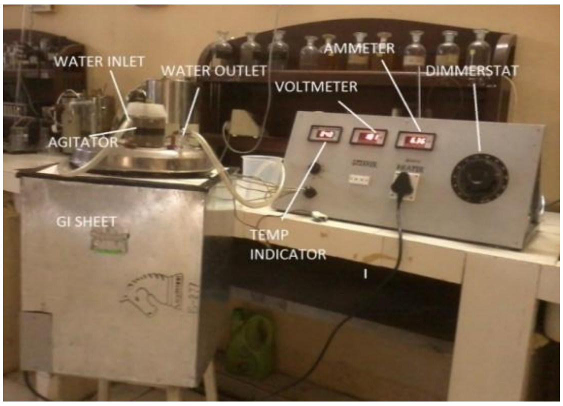


Fig.2

Following are the important properties which play a vital role to enhance the heat ransfer coefficient.

2.2 Curvature Ratio

The ratio of the tube radius to coil radius is the curvature ratio ($\delta \frac{r}{R}$)

$De=Re(d/D)^{0.5}$ For flow through Inner tube d=di

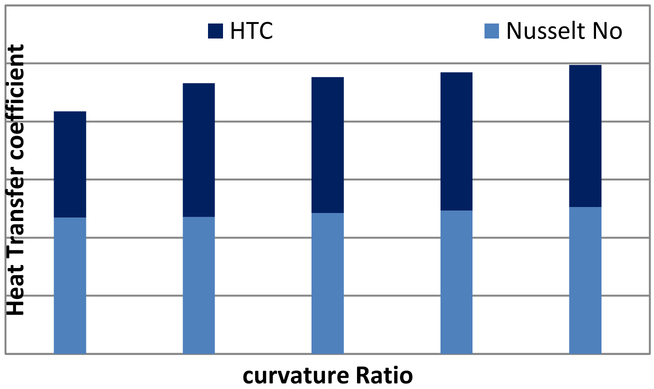
For flow through Annular space $d= d_h$

In this experimental work curvature ratio is changed in three ways

a. Change in inner tube diameter while keeping outer tube diameter and coil diameter constant.
b. Change in outer tube diameter while keeping inner tube diameter and coil diameter constant.
c. Change in coil diameter while keeping inner and outer tube diameter constant.
Following graph shows that heat transfer coefficient is directly proportional to curvature ratio.As we increase the value of curvature ratio value of heat transfer coefficient also increase.Curvature ratio play a vital role to enhance the heat transfer coefficient in helical coil.Result show the relation between curvature ratio and heat transfer coefficient in helical coil.As per experimental and analytical result selection of proper curvature ratio is essential to enhance the rate of heat transfer coefficient.Precaution should be taken while selecting the curvature for extra curvature ratio increase the sharpness of the helical coil.Hence proper curvature ration play a vital role to enhance rate of heat transfer coefficient in helical coil.

Here also as per result value of increased curvature ratio also increased the value of Nusselt number. And increased value of nusselt number increase the value of heat transfer coefficient. Graph shows the increased value of curvature ratio also increased the value of Nusselt number in helical coil. And increased the value of Nusselt number increased the value of heat transfer coefficient in helical coil

Fig.3



2.3 Secondary flow development

In helically coiled tube flow is modified due to curvature effect. When fluid flow through straight tube the velocity of the fluidat centre of tube is maximum, zero at tube wall and symmetrically distributed about the tube axis. In helically coiled tube arrangement due to curvature effect, velocity is highest at the centre .The fluid at the centre is subjected to maximum centrifugal action and pushes the fluid towards the outer wall .The fluid at the outer wall moves inwards along the tube wall to replace the fluid ejected outward.Resultantly two vertices symmetrical about horizontal plane through the centre of tube are formed.Thus Secondary flow is characterized by centrifugal action and acts in plane perpendicular to primary flow . Secondary flow development plays an important role in heat transfer coefficient in helical coil heat exchanger.

2.4 Mass flow rate

Again from the analytical analysis it is shown by the graph that heat transfer coefficient is directly proportional mass flow rate. Apart from experimental and analytical analysis result show expected value of heat transfer coefficient for helical coil is more as compared to straight pipe. As value of mass flow rate increases the value of heat transfer coefficient also increases.Result show the

variation of mass flow rate and variation of coefficient of heat transfer for helical as well as straight pipe.
Result show the helical coil have more advantageous than straight pipe to enhance the rate of heat transfer coefficient.

2.5 Friction Factor

In addition to depend on Reynolds number, the friction factor is a function of the tube surface condition. It is minimum for smooth surface and increase with increasing surface roughness. For turbulent flow the heat transfer coefficient increase with wall roughness. However although the general trend is one of the increasing heat transfer coefficient with increasing friction factor ,the increase in friction factor is proportionately larger when friction factor is approximately four times larger than the corresponding value for a smooth surface, heat transfer coefficient no longer change with additional increases in friction factor.

2.6Comparison of HTC between straight pipe and helical pipe

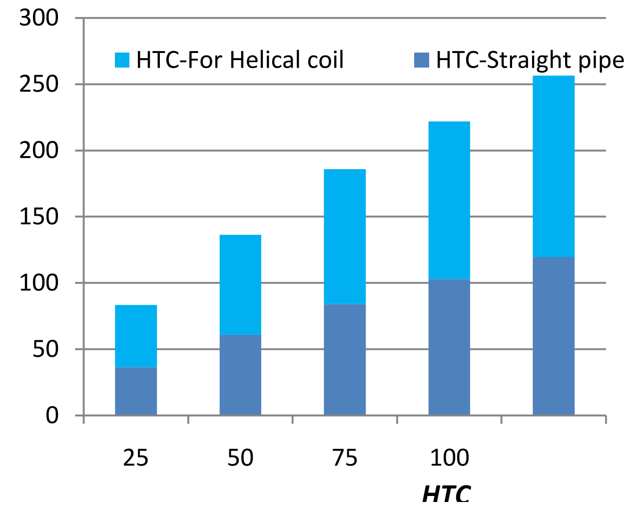


Fig.4

2.7Result:-

Experimental and analytical result show that heat transfer coefficient for helical coil is more as compared to straight pipe Only because of helical coil following result are obtained

Result	Helical Coil	Straight ipe
HTC	More	Less
Nusselt Number	More	Less
Curvature Ratio	-	-
Reynolld no	More	Less

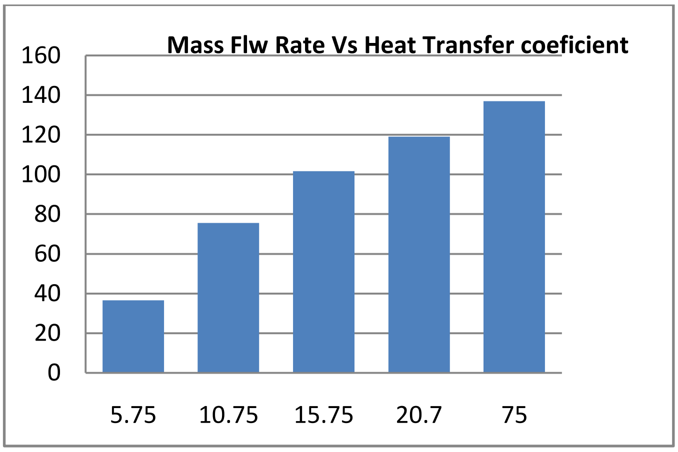


Fig.5

2.8 2.6 Scope for future work

The experimental work carried out for the convective heat transfer coefficient analysis in a helical coil, can be further studied by emphasing on the effect of

1]Number of turn of coils. 2] Curvature ratio.
3] Circulating the surrounding fluid inside the coil.
4] Mass flow rate. 5] Critical Reynold Number.
6] Friction Factor

2.9 Number of Figure

1] Fig.1 for image of Helical coil
2] Fig.2 for Experimental arrangement.
3] Fig.3 Graph Curvature ratio and HTC
4] Fig.4 Graph for mass flow rate and HTC
5]Fig.5 Graph for copmarision of HTC between straight pipe and Helical coil

3.Conclusion

1] As curvature ratio increase, the transition of fluid from laminar to turbulent regims gets delayed.This results in higher value of critical Reynold Number for helically coiled tube heat exchanger.

2] With helical coil tube heat exchangers it is possible to accommodate large heat transfer surface area within small space when compared with straight tube arrangement. Name:- Rahul G.Karmankar
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3] As curvature ratio increase the heat transfer coefficient also increase.This increase in heat transfer coefficient for fluid flowing through inner tube remains higher than that of fluid flowing through annular space.

4] Increase in coil pitch weakens the secondary flows with the same Reynolds number and ultimately approaches to straight tube characteristics.Therefore when coil pitch is increased heat transfer coefficient of the fluid decrease.

5] The helical coil effect is negligible in low Re of laminar and Turbulent region.

3.1Reference

1] Abo Elazm M.M. Ragheb A.M. Teamah M.A.” Experimental and Numerical comparision between the performance of Helical cone coil and ordinary helical coil used as dehumidifier for humidification in desalination units” International Journal of Applied Engineering Research Vol. 2 No.1 2011

2] Bibin Prasad Sujith V. Mohammed Shaban K.Saju Haneef. Sandeep N, Vishnu Raj Comparision of Heat Transfer between a helical and straight tube heat exchanger. International Journal of Engineering Research and Technology, Volume 6 , Number 1, 2013.

3] J.S. Jayakumar Helically coiled Heat exchanger –Basic design application Dr. Jovan mitrovic (Ed) March 2012