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Enhancement of Heat transfer rate by using Helix tube and Friction Factor

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Abstract - Tube with rough surface has much higher heat transfer coefficient than tubes with smooth surface. Therefore tube surface are often intentionally roughed, corrugated or finned in order to enhance the convection heat transfer coefficient and thus the convection heat transfer rate. Heat transfer in turbulent flow in a tube has been increased by as much as 400 percent by roughing the surface. Roughing the surface of course also increase the friction factor and thus the power requirement for the pump or the the fan. The convection heat transfer coefficient can also be increase by inducing pulsating flow by pulse generators, by inducing swirl by inserting a twist tape into the tube or by inducing secondary flows by coiling the tube. Helix tube are used to enhanced the heat transfer rate 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

Key Words:- Convection, Heat transfer coefficient, ,Reynold number, Nusselt number, Prandtl number, centrifugal force, Friction Factor

1.INTRODUCTION

Friction Factor is dimensionless quantity. Friction factor is also called as Darcy friction factor after after French engineer Henry Darcy. -1803-1858 who first studied experimentally the effects of roughness on tube resistance. Liquid or gas flow through pipes or ducts in commonly used in heating and cooling application. The fluid in such application is forced to flow by fan or pump through a tube that is sufficiently long to accomplish the desired heat transfer rate. In this paper we will pay particular attention to the determination of the friction factor and convection coefficient. Since they are directly related to the pressure drop and heat transfer rate respectively. These quantities are then used to determine the pumping power requirement and required tube length. The friction factor is related to the shear stress of the surface which is related to the slope of the velocity profile of the surface. Noting that the velocity profile remains unchanged in the hydro dynamically fully developed region, the friction factor also remain constant in that region. Friction factor f can be determined from an appropriate relation as the first Petukhor equation. Gnielinski's equation should be preferred in Calculation. Again properties should be evaluated at the bulk mean fluid temperature. Any irregularity or roughness on the surface disturb the laminar sub layer and affects the flow. Therefore unlike laminar flow the friction factor and the convection coefficient in turbulent flow are strong function of surface roughness. The friction factor in fully developed turbulent floe depends on the Reynold no. and relative roughness. In 1939 C.F. Colebrook combined all the friction factor data for transition and turbulent flow in smooth as well as rough pipes into the following implicit relation known as Colebrook equation

$1/\sqrt{F}$ =-2.0 log (€lD/3.7 +2.51/Re$\sqrt{F}$---Turbulent Flow

Friction factor for circular tube of diameter D with mean velocity Um is

$F = 64\mu / {}_{\varrho}UmD = 64/Re$

Then the pressure drop $\Delta P = P1-P2 = f.L/D.Um^2/2$

Pumping power required

P= V(ΔP) Watts
when V is the Volume flow rate in m^3/s

The Nusselt Number Nu= hD/k
The heat transfer coefficient ho =48 k/11D

Numbers of correlation between friction factor and Reynolds number are suggested by different engineers and few of them are listed below.

1] Blasius Formula $f = 0.3164/(Re)^{0.25}$ for Re ‹ 10^5

2] Less formula $f = 0.0072 + 0.611/Re^{0.35}$ for 400 ‹ Re ‹ 4 x 10^5

3] Formann Formula $f= 0.0054 + 0.396/Re^{0.3}$ for 400 ‹ Re ‹ 20 x 10^5

4] Prandtl Formulation $1/\sqrt{F} = 2.0 \log Re\sqrt{F} -0.8$
Re 10^5

The flow Reynold number is
$Re = \rho d v/\mu$

Friction factor $f= 0.184 / (Re)^{0.2}$
Again from the Reynold analogy

$St = f/8$

$Nu/ RePr = f/8$
In the absence of data for Pr we presume it to be unity
$Nu = f/8 \times Re$
$h= Nu \times K/d$
$Q= hA \Delta T$

Forced convection gives greater heat transfer rate than natural convection for both gases and liquids
Thus by using the mention formulae we can calculated the value of friction factor and heat transfer rate.

2. PARAMETRES

A] TURBULENT FLOW :-

The motion of fluid particles is irregular and it proceeds along erratic and unpredictable paths. The stream lines are interwined and they change in position from instant to instant. Fluctuating transverse velocity components are superimposed on the main flow and the velocity of individuals fluid elements fluctuate both along the direction of flow and perpendicular to it. Obviously a turbulent flow is eddying and sinuous rather than rectilinear in character. A nature of fluid flow is governed by the following parameters

1. Mean flow velocity
2. Dynamic viscosity
3. Density of fluid
4. Characteristic dimension of the flow passage

B] REYNOLD NUMBER :-

Re is the ratio of inertia force to the viscous force. Reynold number is indicative of the relative importance of inertial and viscous effects in a fluid motion. At low Reynold number the viscous effects d0ominate and the fluid motionnis laminar. At high Reynolda number the inertial effects leads turbulent flow and the associated turbulence level dominats the momentum and energy flux. bReynold number constitutes an important criterion of kinematic and dynamic similarity in forced convection heat transfer velocity within the given field would be similar in magnitude, direction and turbulence pattern when their Reynold number are same.

C] NUSSETL NUMBER:-

Nu – Establish the relation between convective film coefficient h thermal conductivity of the fluid k and significant length parameter *l* of the physical system
Nu= hl/k

Apparantly the Nusselt number hl/k may be interpreted as the ratio of temperature gradient at the surface to an overall reference temperature gradient.The Nusselt number is a convenient measure of the convective heat transfer coefficient for a given value of the Nusselt number the convective heat transfer coefficient is directly proportional to the thermal conductivity of the fluid and inversely proportional to the significant length parameter.
PRANDTL NUMBER;_ Ratio between fluid ability to store heat and to transfer heat through conduction.

$Pr = \mu Cp/k$

D] HELIX TUBE:-

Helix tube are compact in size and provides distinct benefit like higher film coefficient, more effective utilization pressure drop which results in efficient and less expensive design. Helix coil permits handling of high temperature and extreme temperature difference without high induced stress or costly expansion joints. Helix coils offer advantages over straight tube due to their compactness and increase heat transfer coefficient. The increased heat transfer coefficient is a consequence of the curvature of the coil which induce centrifugal force to act on the moving fluid resulting in secondary flow. When a fluid flows through a straight tube the velocity is maximum at the tube center, zero at the tube wall and symmetrically distributed about the axis. However when fluid flows through a helix coil the primary velocity profile shown in fig. is distorted by the addition of secondary flow pattern. The secondary flow is governed by the centrifugal action and acts in the pipe perpendicular to the primary flow. Since the velocity is maximum at the centre the fluid at the centre is subjected to maximum centrifugal action which pushes the fluid towards the wall. The Fluid at the outer wall moves inwards along the tube wall to replace the fluid ejected outwards. This result in the formation of two vortices symmetrically about horizontal plane through the tube Centre. Thus by coiling tube heat transfer may be enhanced without inducing turbulence or additional heat transfer surface area. In this case, centrifugal force induce a secondary vortices that increase the heat transfer rate.

E] NUSSELT NUMBER FOR HELICAL COIL

Nu- Helix/ Nu-Straight = $1 + (21/Re^{0.14})(D/dc)$
Nu-helix = Nu $[1+ (21/ Re^{0.14})(D/dc)$
D- diameter of the tube and dc is the diameter of the coil

Fig.1-Diagram for Helix tube

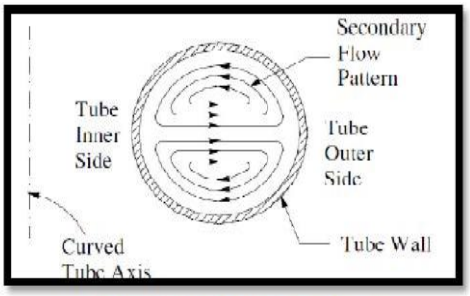
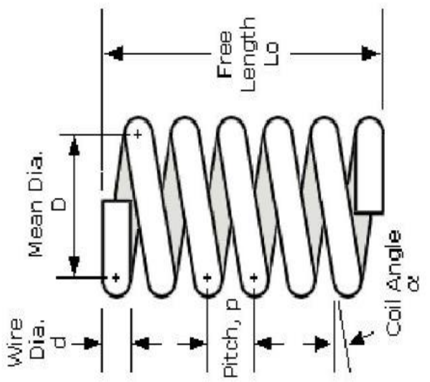


Figure 1: Fluid flow in curved pipes



3. IMPORTANCE OF HELIX TUBE

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

1] Helical coils are used for transferring heat in a chemicalreactor 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 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. Weismann 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.

4. EXPERIMENTAL ARRANGEMET AND RESULT

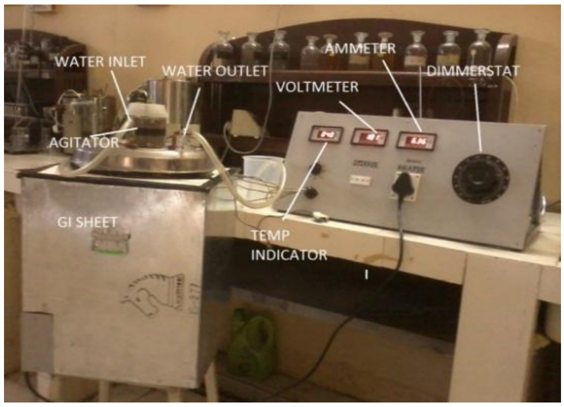


Fig.2

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

5. CURVATURE RATIO

The ratio of the tube radius to coil radius is the curvature ratio ( )–
$De=Re(d/D)^{0.5}$ 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.

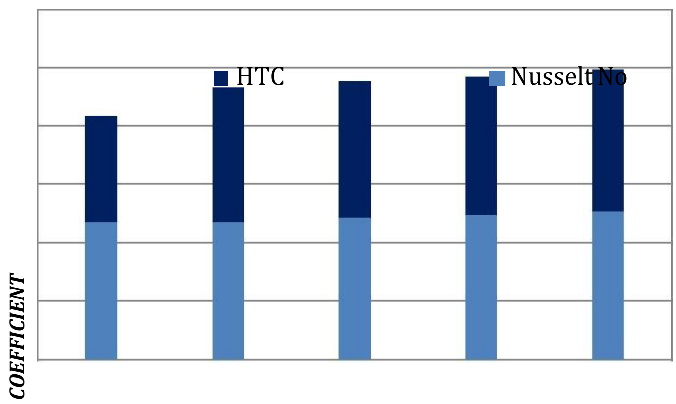
b. Change in outer tube diameter while keeping inner tube diameter and coil diameter constant.

c. Change in coil diameter while keeping inner 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



6. 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.

7. 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.

8. 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.

FRITION FATOR AND HEAT TRANSFER RATE

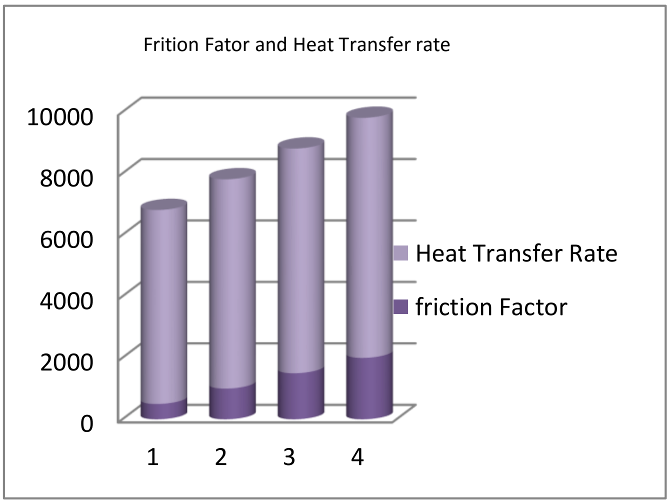


Fig.4

From the above graph it can be infer that as the value of friction factor increases upto certain limit the value of heat transfer rate can also be enhanced. And heat transfer rate is more in turbulent flow than laminar flow

9. COMPARISON OF HTC BETWEEN STRAIGHT PIPE AND HELICAL PIPE

From the above graph it can be infer that heat transfer coefficient for helix tube is more as compared to heat transfer rate for straight tube.

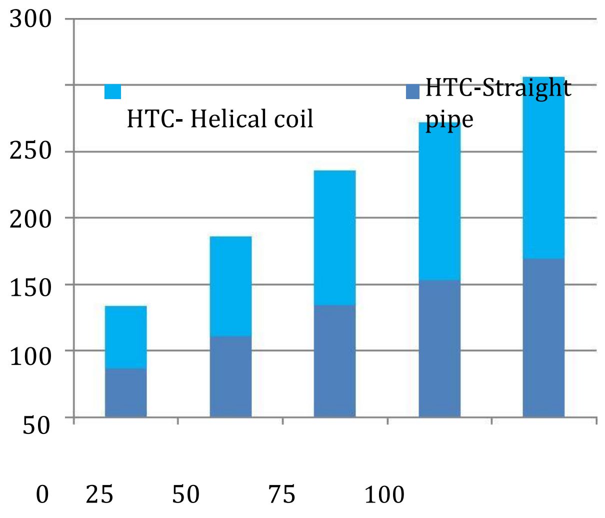


Fig.5

10. 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 emplacing on the effect of

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

11. 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 Friction factor and HTC
5] Fig.5 Graph for copmarision of HTC between straight pipe and Helical coil
6] Table-1-Result for HTC

12. RESULT:-

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

Table-1

RESULT	HELICAL COIL	STRAIGHT COIL
HTC	More	Less
Nusselt Number	More	Less
Curvature Ratio	-	Less
Reynolld no	More	Less
Friction Factor	More	Less

13. CONCLUSION

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

1] 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.
2] 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

3] 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

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

5] 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

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