NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
ISSN: 2394-3696
VOLUME 2, ISSUE 2 FEB.-2015

A Review on Comparison between Shell And Tube Heat Exchanger And Helical Coil Heat Exchanger

Namrata D. Ranaware
P.G. Student, M.E. Heat Power, J.S.C.O.E, Hadapsar, Pune (M.S.) India
Krishnat N. Molawade
B. Tech Student, Walchand College of Engineering, Sangli (M.S.) India
Prof. L. N. Mane
Professor, Department of Mechanical Engineering, J.S.C.O.E, Hadapsar, Pune (M.S.) India

Abstract
The curved shape of the tube causes the flowing fluid to experience centrifugal force. The extent of centrifugal force experienced depends on the local axial velocity of the fluid particle and radius of curvature of the coil. The fluid particles flowing at the core of the pipe have higher velocities than those flowing near to the pipe wall. Thus the fluid particles flowing close to the tube wall experience a lower centrifugal force than the fluid particles flowing in the tube core. This causes the fluid from the core region to be pushed towards the outer wall. This stream bifurcates at the wall and drives the fluid towards the inner wall along the tube periphery, causing generation of counter-rotating vortices called secondary flows which produce additional transport of the fluid over the cross section of the pipe. This additional convective transport increases heat transfer and the pressure drop when compared to that in a straight tube.
Keywords-Shell and tube heat exchanger, helical coil heat exchanger, heat transfer, secondary flow.

INTRODUCTION
Several techniques are used to improve the thermal performance of heat transfer devices. Active technique, passive technique and compound technique are used for enhancement of heat transfer. The active techniques require external forces like fluid vibration, electric field, and surface vibration. The passive techniques require special surface geometries or fluid additives like various tube inserts and the compound technique is the combination of any two or more methods of used for improving the performance of heat exchanger. The passive techniques includes Treated Surfaces, Rough surfaces, Extended surfaces, Displaced enhancement devices, Swirl flow devices, Coiled tubes, Surface tension devices, Additives for liquids and additives for gases [1]. Helical coiled tubes are superior to straight tube due to their compactness and increased heat transfer coefficients. The use of helical coils adds efficiency to the heat exchanger performance because of their high heat transfer and smaller space requirement. Helical coils are widely used in piping systems, heat exchangers, storage tanks, chemical reactors and many other engineering applications.

LITERATURE REVIEW

W. Witchayanuwat, S. Kheawhom presented a detailed investigation on heat transfer from exhaust particulate air of detergent spray drying tower to water by helical coiled heat exchanger. The result shows that the increasing of the coiled tube pitch decreases the inside Nusselt number [9].

Salimpour investigated three heat exchangers with different coil pitches and found that the shell-side heat transfer coefficient of coils with larger pitches is higher than those with smaller pitches for the counter-flow configuration [10].
Prabhanjan et al. experimentally investigated the natural convection heat transfer from helically coiled tubes in water. They reported that different lengths were used to correlate the outside Nusselt number to the Rayleigh number. The published result shows effect of curvature ratio, pitch and centrifugal forces on a flowing fluid [11].
Shokonhmand et al. carried out an experimental study of shell-and-coil heat exchangers using Wilson plots, where Wilson plot is a technique to estimate the heat transfer coefficients. They tested three heat exchangers for both parallel-flow and counter-flow configuration. These heat exchangers have different coil pitches and curvature ratios, and Wilson's plot was used to calculate the overall heat transfer coefficients of the heat exchangers [12].

STRAIGHT TUBE HEAT EXCHANGER

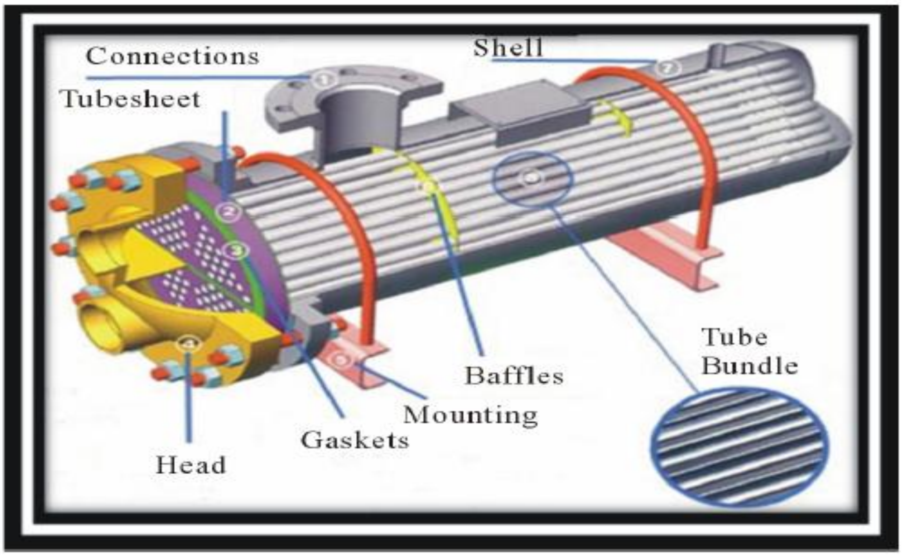


Fig.1 Fixed tube-sheet shell and tube heat exchanger [3]

When the medium containing heat is a liquid or a vapour which heats another liquid, then the shell and tube heat exchanger must be used since both paths must be sealed to contain the pressures of their respective fluid. The shell contains the tube bundle, and usually internal baffles, to direct the fluid in the shell over the tubes in multiple passes. The shell is inherently weaker than the tubes so that the higher-pressure fluid is circulated in the tubes while the lower pressure fluid flows through the shell. When a vapour contains the waste heat, it usually condenses, giving up its latent heat to the liquid being heated. In this application, the vapour is almost invariably contained within the shell. If the reverse is attempted, the condensation of vapours within small diameter parallel tubes causes flow instabilities. Tube and shell heat exchangers are available in a wide range of standard sizes with many combinations of materials for the tubes and shells [4].

Heat transfer in straight tubes is governed by Reynolds and Prandtl Numbers, under both laminar and turbulent flow conditions, and is usually presented in a form such as:

$$N_{Nu} = c\, N_{Re}^{a}\, N_{Pr}^{b} \text{ ....(1)}$$

ISSN: 2394-3696
VOLUME 2, ISSUE 2 FEB.-2015

Where, N_{Nu} is the Nusselt number, with the a, b, and c being constants. A commonly used correlation for turbulent flow is the one derived by Dittus and Boelter (1930) and cited by Kern (1955), which uses the following values in equation 1: c = 0.023, a = 0.8 , and two values of b depending on the kind of heat transfer performed. When the fluid is being heated, b = 0.4 and when the fluid is being cooled, b = 0.3.

Heat transfer rate of shell and tube heat exchanger depends on some of following parameters such as length of tube, number of baffles, baffle cut:

The fig.2 shows the effect of baffle cut on heat transfer, rate of heat transfer decreased with increase in the baffle cut. The fig.3 shows the effect of number of baffles and length of tube on heat transfer coefficient.

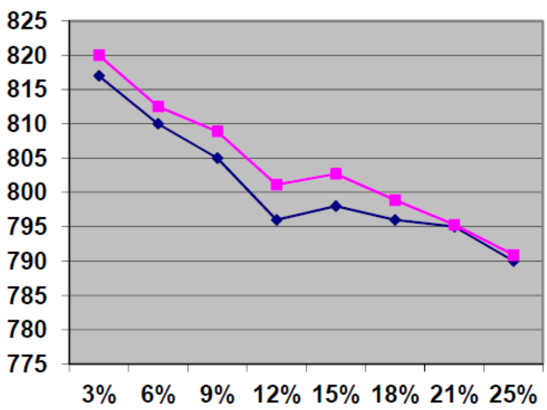


Fig.2 Baffle Cut v/s Heat Transfer [5]

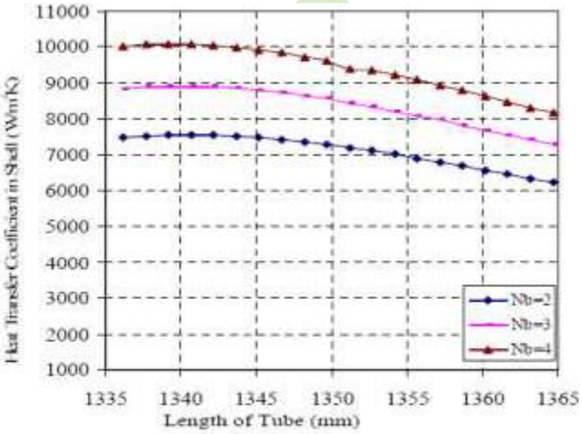


Fig.3 Heat Transfer Coefficient on Number of baffles and length of tube [6]

HELICAL COIL HEAT EXCHANGER

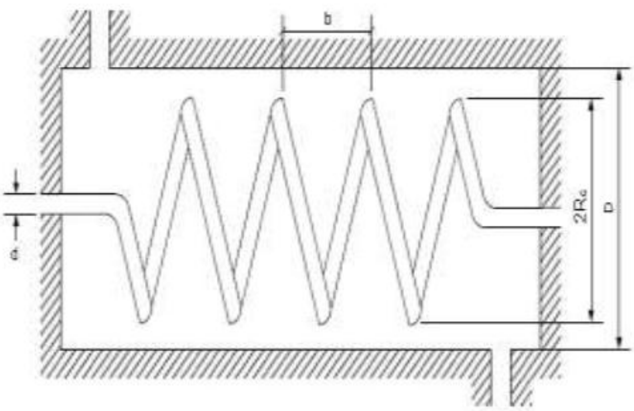


Fig.4 Schematic view of a typical shell and Coiled tube heat exchanger [8]

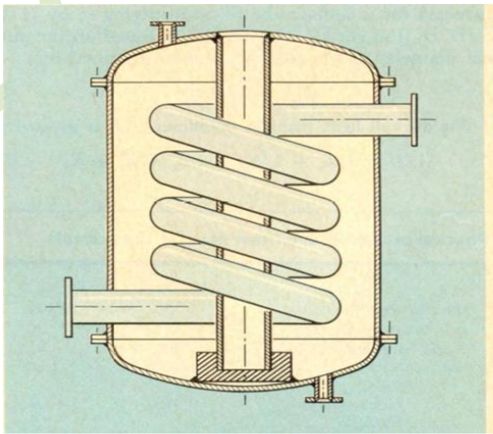


Fig. 5 Helical coil heat exchanger [13]

Helically coiled exchangers have compact size provides a distinct benefit. Helical geometry permits handling of high temperatures and extreme temperature differentials without high induced stresses or costly expansion joints. High-pressure capability and the ability to fully clean the service fluid flow area add to the exchanger's advantages, Although various configurations of coil are available

A typical shell and coiled tube heat exchanger is shown in Fig.4 in this figure, d is the diameter of the coiled tube, Rc is the curvature radius of the coil, D is the inner diameter of shell, and b is the coil pitch. The curvature ratio, d, is defined as the coil-to-tube diameter ratio, d/2Rc, and the non dimensional pitch, c, is defined as b/2(π)Rc.

In coiled tubes, the heat transfer coefficients are higher due to the presence of secondary flow, which increases the extent of mixing. The difference between the heat transfer coefficient (h) in coiled tubes and straight tubes is significant, as demonstrated by Jeschke (1925), who proposed the use of a factor based on curvature ratio as follows:

$$N_{Nuc} = N_{Nus}\,[1 + 3.5\,(r / R)] \quad \text{................................ (2)}$$

Heat transfer rate of helical coil heat exchanger depends on some of following parameters such as coil pitch, Pitch circle diameter, pipe diameter:

The fig.6 shows the effect of coil pitch on heat transfer. J S Kumar [2] analyse different. Coil with pitch of zero, 15 mm, 30 mm, 45 mm and 60 mm were analysed, the result is represented in fig.6.

The coils with PCD 100 mm, 200 mm, 300 mm and 400 mm were analysed. In all these cases, the coil pitch and pipe diameter were kept at 30 mm and 20 mm respectively and the coils consisted of two turns (J. S. Kumar). The effect of PCD is to influence the centrifugal force on the moving fluid. This will in turn affect the secondary flows along the pipe cross section. As the PCD is increased, the effect of coil curvature on flow decreases and hence centrifugal forces play a lesser role in flow characteristics. The fig.7 shows the effect of PCD and length of tube on heat transfer coefficient.

Fig. 8 shows, the effect of pipe diameter on heat transfer in a helical coil is considered. The J. S. Kumar [2] considered pipe diameters for analysis were, 10 mm, 20 mm, 30 mm and 40 mm. For all these cases, coil has a pitch of 45 mm and PCD of 300 mm and the coil consists of two turns.

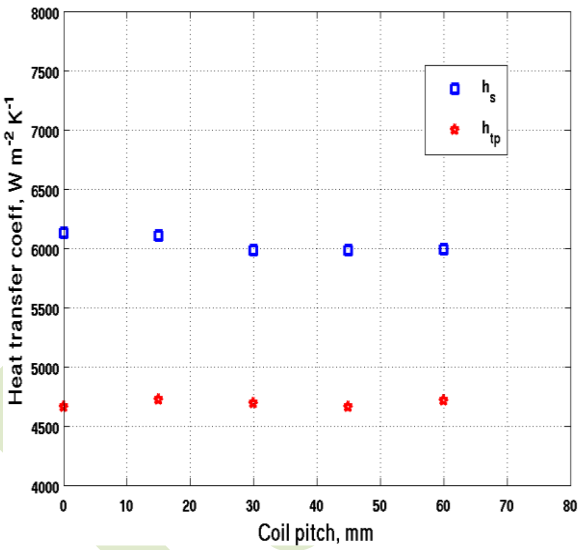


Fig.6 effect of coil pitch on heat transfer Coefficient [2]

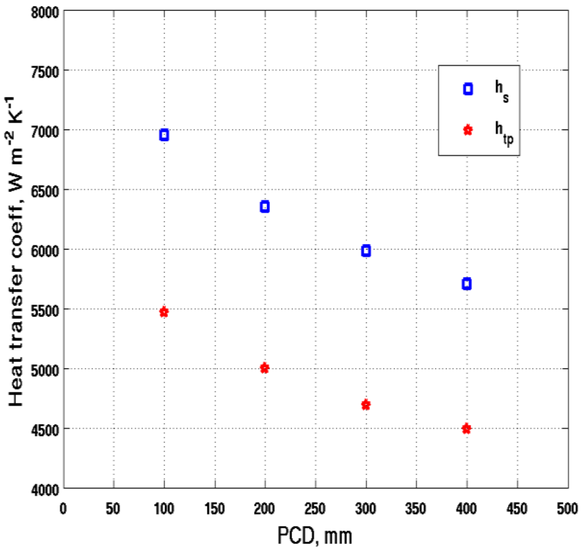


Fig.7 effect of PCD on heat transfer coefficient [2]

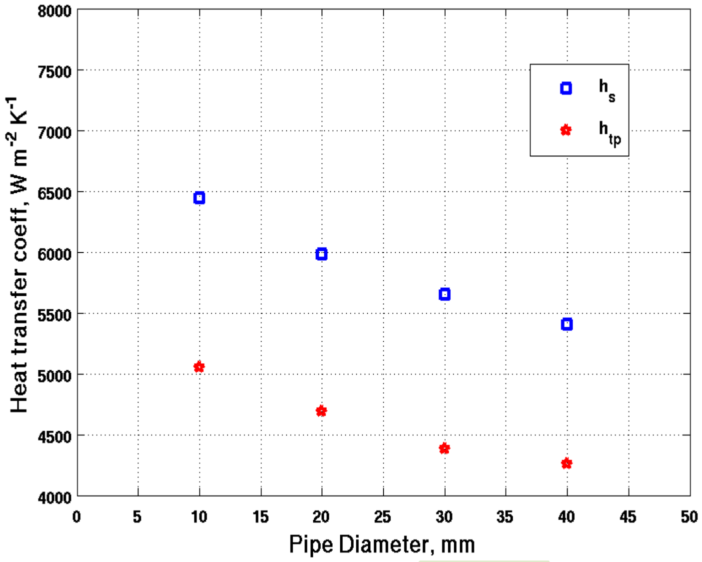
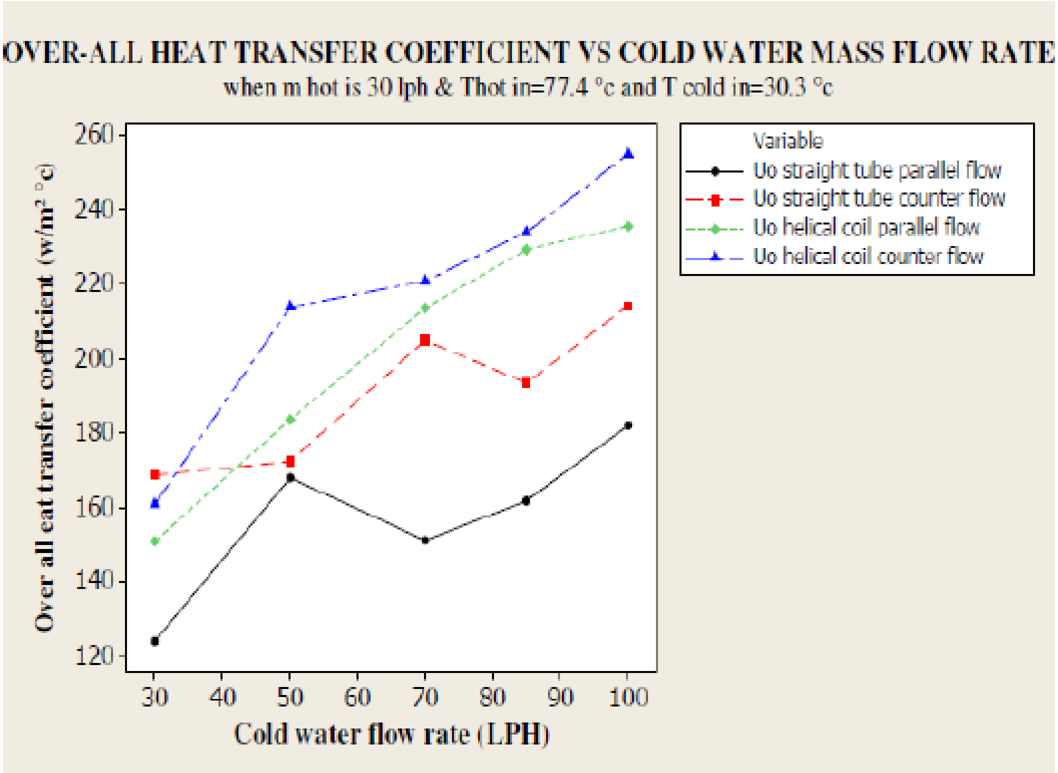


Fig.8 effect of pipe diameter on heat transfer coefficient [2]

COMPARISION BETWEEN STRAIGHT TUBE HEAT EXCHANGER AND HELICAL COIL HEAT EXCHANGER

Fig 9 shows the variation of overall heat transfer coefficient for straight tube parallel flow, straight tube counter flow, helical coil parallel flow and helical coil counter flow, when hot water mass flow rate is constant and cold water mass flow rate varied. As the mass flow rate through the shell increases the overall heat transfer coefficient increases, and it is observed that hot mass flow rate inside tube increases the overall heat transfer coefficient also increases. Overall heat transfer coefficient of counter flow heat exchanger is high compared to corresponding exchanger parallel flow. Helical coil counter flow has max. Overall heat transfer coefficient and straight tube parallel flow has lowest overall heat transfer coefficient for corresponding readings.



ig.9 variation of overall heat transfer coefficient when mass flow rate inside the tube is 30 LPH.[7]

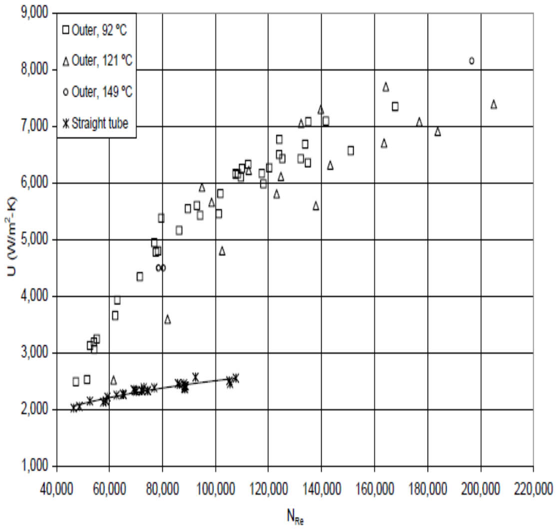


Fig.10 U in straight and helical heat exchangers function of flow rate

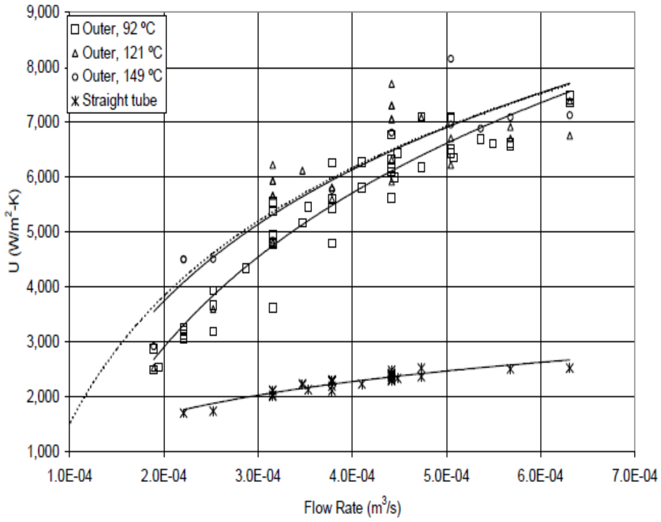


Fig.11 U in straight and helical heat exchangers function of NRe

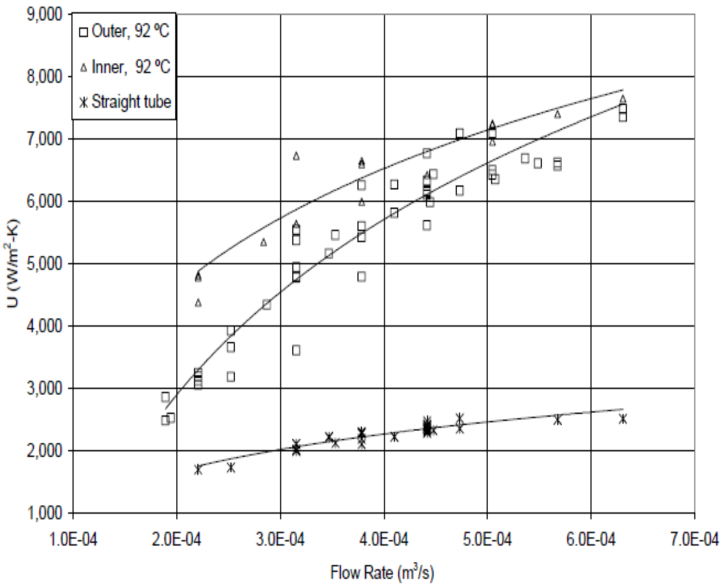


Fig.12 U in helical heat exchangers of different coil diameters as a function of flow rate

Pablo Coronel and K.P. Sandeep [8] studied the determination of convective heat transfer coefficient in both helical and straight tubular heat exchangers under turbulent flow conditions. The results show that the overall heat transfer coefficient (U) in the helical heat exchanger is much higher than that in straight tubular heat exchangers.
The results of the experiments with different flow rates in the inner and outer coils are summarized in figures 10, 11, 12. For all values of Reynolds numbers, the overall heat transfer coefficient in the helical coils was larger than that in the straight tubes. The overall heat transfer coefficient (U) in the helical heat exchanger increased with flow rate and approached a maximum value at higher flow rates [8].

CONCLUSION

From study it is clear that, Helical coil counter flow is most effective in all these conditions and straight tube parallel flow heat exchanger is least effective. Overall heat transfer coefficient increases with increase in hot water mass flow rate and cold water mass flow rate. The coil pitch is found to have significance only in the developing section of heat transfer. The torsional forces induced by the pitch causes oscillations in the Nusselt number. However, the average Nusselt number is not affected by the coil pitch. Unlike the flow through a straight pipe, the centrifugal force caused due to the curvature of the pipe causes heavier fluid (water-phase) to flow along the outer side of the pipe. High velocity and high temperature are also observed along the outer side. The torsion caused by pitch of the coil makes the flow unsymmetrical about the horizontal plane of coil. As the pitch is increased, higher velocity and higher temperature regions are on the bottom half of the pipe. Increase in pipe diameter, keeping the inlet velocity constant, causes higher heat transfer coefficient and lower pressure drop. This effect is due to the influence of secondary flows. As the PCD is increased, the centrifugal forces decreases and this causes reduction of heat transfer coefficient and pressure drop. The coil parameters, viz., PCD and pipe diameter and void fraction at inlet have significant effect on the heat transfer.

REFERENCES

[1]Swapnil Ahire, Purushottam Shelke, Bhalchandra Shinde, Nilesh Totala, *"Fabrication and Analysis of Counter Flow Helical Coil Heat Exchanger", International Journal of Engineering Trends and Technology (IJETT) (2014)*

[2] J. S. Jayakumar, "*Helically Coiled Heat Exchangers", Heat Exchangers - Basics Design Applications, 2012*

[3] Shravan H. Gawande, Sunil D. Wankhede1, Rahul N. Yerrawar, Vaishali J. Sonawane, Umesh B. Ubarhande, "*Design and Development of Shell & Tube Heat Exchanger for Beverage", Modern Mechanical Engineering, (2012)*

[4] D. A. Reay, E & F. N. Span , "*Heat Recovery Systems", 1979.*

[5] Vijaykumar Chalwa1, Nishal Kadli, "*Study Of Variation For Pressure Drop And Temperature Distribution In A Shell And Tube Heat Exchanger In Case Of Vertical Baffle", 2013*

[6] Sandeep K. Patel, Professor Alkesh M. Mavani, *"Shell & Tube Heat Exchanger Thermal Design With Optimization Of Mass Flow Rate And Baffle Spacing", International Journal of Advanced Engineering Research and Studies, 2013.*

[7] N. D. Shirgire1, P. Vishwanath Kumar, *"Review on Comparative Study between Helical Coil and Straight Tube Heat Exchanger", IOSR Journal of Mechanical and Civil Engineering, 2013.*

[8]K.P. Sandeep, "*Heat Transfer Coefficient in Helical Heat Exchangers under Turbulent Flow Conditions", International Journal of Food Engineering, 2008*

[9] Witchayanuwat W, Kheawhom S. , "*Heat Transfer Coefficient for Particulate Air flow in Shell and Coiled Tube Heat Exchangers", International Journal of Chemical and biological Engineering 2010*

[10] Salimpour, "*Heat transfer Coefficients of shell and coiled tube heat exchangers", Experimental Thermal and Fluid science 2009*

[11]Prabhanjan DG, Ragbavan GSV, Kennic TJ., *“Comparison of heat transfer rates between a straight tube heat exchanger and a helically coiled heat exchanger”, Heat and mass transfer,2002*

[12] H. Shokouhmand, M. R. Salimpour and M. A. Akhava,. *“Experimental investigation of shell and coiled tube heat exchangers using wilson plots”, Int. Commun. Heat Mass Transfer 2008.*

[13] W. Witchayanuwat and S. Kheawhom, *“Heat Transfer Coefficients for Particulate Airflow in Shell and Coiled Tube Heat Exchangers”, International Journal of Chemical and Biological Engineering (2010)*

NOMENCLATURE

N_{Nu} =Nusselt number
N_{Pr} =Prandtl number
N_{Re} =Reynolds number
r Radius of tube (m)
R Radius of coil (m)
a, b, c =Correlation constants
PCD= Pitch circle diameter
U Overall heat transfer coefficient (W/m^2-K)