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A Basic Review on CFD Analysis of a Tube in Tube Helically Coiled Heat Exchangers

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ABSTRACT

Helically coiled heat exchangers are very compact type of heat exchangers and they require very less space for their installation. Heat from one fluid to another is transmitted mainly through conduction. The two working fluids are separated through a thin metallic wall. Because of their compact design and high thermal efficiency, these types of heat exchangers are gaining popularity. Recently a lot of research is being carried out in this field. In this paper, a review has been made to study the advances in the design of helical coil heat exchangers. From literature it is found that, Computational Fluid Dynamics is a promising tool to evaluate the performance of heat exchangers in design phase only.

KEYWORDS: Helical coil heat exchanger, Multi tubes in tube heat exchanger, CFD simulation, energy savings, and heat transfer rate.

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INTRODUCTION

Helically coiled heat exchanger is very promising kind of heat exchanger for various engineering processes because of its accommodation of large heat transfers area in a small space with high heat transfer coefficients. Helically coiled heat exchangers can be can be used for wide range of engineering applications which include food processing, nuclear reactors, heat recovery systems, chemical processing, refrigeration and air conditioning systems and medical equipment. Related to design tube curvature in helically coiled heat exchangers induces a secondary flow pattern which leads to enhancement of heat transfer between tube wall and flowing fluid[1]. The two major advantages of helical coiled heat exchangers include high heat transfer surface area per occupied size and high heat transfer rate due to the induced secondary flow which is absent in straight tube heat exchangers[2.] A tube in tube helical coil heat exchanger has been shown in Fig. 1.

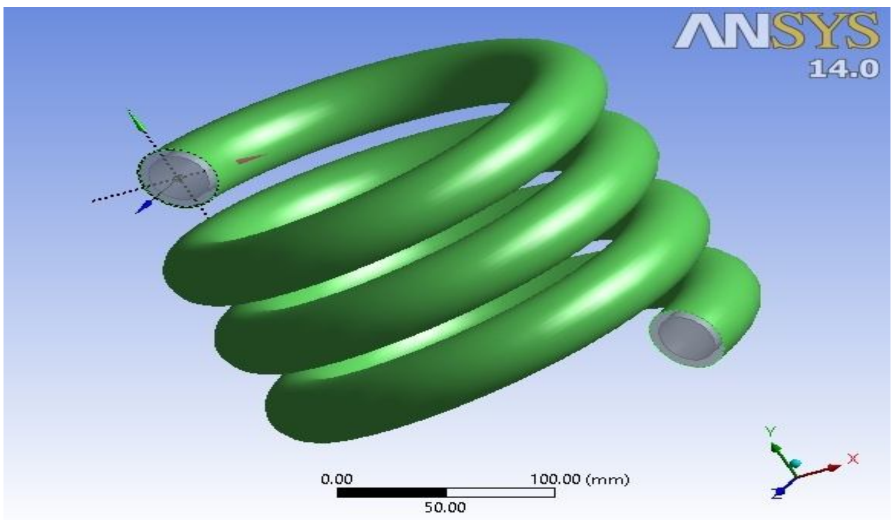

Fig.1 A schematic diagram of multi tubes in tube helical heat exchanger

REVIEW

Vijaya Kumar Reddy et al.[3] have studied the tube in tube helical coil heat exchanger and its compact structure, larger heat transfer area and higher heat transfer capability etc. Helical coils are extensively used as heat exchangers and reactors due to higher heat and mass transfer coefficients and compact structure. The authors modeled tube in tube helically coiled heat exchanger and studied its heat transfer characteristics for different fluid flow rates by using Computational Fluid Dynamics (CFD). The authors found out that as inner tube flow rate increased from 400 to 600lph with constant outer tube flow rate of 700LPH, the LMTD increased by 1.33%.

H.F. Elattar et al.[4] studied about the multi tube helical coil heat exchangers, their compactness with high performance and about the challenges in engineering applications. The authors found out effects of the operating and geometrical parameters. The authors simulated and found out performance of multi tube in tube heat exchangers using ansys fluent 14.5 for turbulent flow. The study was done to study the Nusselt numbers, heat transfer coefficients, pumping power, effectiveness, and thermal hydraulic index.

Anas El Maakoul el al.5 investigated the thermo-hydraulic performance of a double pipe heat exchanger with helical baffles using CFD. The simulation was done for different values of Reynolds number and baffles spacing. The results were compared with those of simple double pipe heat exchangers. The authors found enhancement in heat transfer without significant enhancement in its size and weight.

Hamed Sadighi Dizaji et al.[6] investigated tube in tube helical coil heat exchangers experimentally the authors studied about flow where exergy loss was more, and it was found that maximum augmentation of exergy loss occurred in parallel flow configuration. It was also concluded that exergy loss increased with the increase of hot or cold water flow rates and the curve behavior was also held responsible for exergy loss.

M. Farzaneh-Gord et al.[7] investigated geometrical parameters and operational conditions of helically coiled heat exchangers for optimizing flow characteristics based on entropy generation minimization approach using the second law of thermodynamics. The authors found that geometry of heat exchanger affects its performance.

Rennie, T. J. et al.[8] investigated overall heat transfer coefficients and effectiveness of shell and helically coiled tube heat exchangers. The authors worked on the recovery of waste heat which can lead to operation more environment friendly, also leading to cut costs. The helical coil heat exchanger has been experimented and analyzed on the basic of log-mean temperature difference method. Helical coil heat exchangers are framed out to be efficient and it is concluded that their overall heat transfer coefficient increases with mass flow rate.

Sahu, N. K. et al.[9] worked for enhancement in heat transfer in helical coils using ANSYS CFX. They considered parameters include pitch length of helical coil and mass flow rate of fluids. The results were compared with experimental results. It was found that on decreasing the pitch length and relative velocity of fluids in helical coil heat exchanger, heat transfer rate increased.

Huminic, G. et al.[10] investigated heat transfer and entropy generation inside a helically coiled tube-in-tube heat exchanger in laminar flow regime using two different types of nanofluids. It was found the numerically that the use of nanofluids in helically coiled tube-in-tube heat exchanger improve the heat transfer performances. Also, the increase of nanoparticles volume concentration leads to the increase in Nusselt number and the reduction of the entropy generation.

Hashemian, M. et al.[11] studied the effect of hydraulic, geometrical and thermodynamic characteristics in heat exchanger. The authors investigated various conical tube arrangements with different flow directions. The authors found that on increase of cold water mass flow rate, entropy generation and entropy generation number increases.

Misurati, K. A. et al.[12] studied helically coiled tube under uniform heating and one-side heating which are generally applied in various industrial applications such as the water cooled wall in power plant boilers. To investigate the flow and heat transfer characteristics in this case, numerical simulation of the flow in a helically coiled tube is performed under uniform and non-uniform (heating on the inner coil side wall) heat flux boundary conditions for both laminar and turbulent flows. It was found that the secondary flow distributions are hardly affected by changing heating method. However, a larger temperature gradient can be found for one-side heating condition.

Reddy, K. V. K. et al.[13] studied about importance of helical coil heat exchanger in industrial application due to its compact structure. The authors studied fluid flow behavior and heat transfer characteristics for different fluid flow rates in both tubes with the help of CFD. It was found that if inner tube flow rate increases with constant outer tube flow rate, LMTD increased but as the outer tube rate increase with constant inner tube flow rate, LMTD is decreased. It was concluded that when flow velocity and Reynolds number increases, the overall heat transfer coefficient increases.

Jayachandraiah, D. et al.[14] analyzed heat transfer characteristics of helical coil heat exchanger using CFD. The geometry had Coil tube and Shell having an inner diameter of 8.41 mm and 260 mm respectively with shell height if 250 mm. CFD analysis is performed for different volume flow rates of 40, 60, 80, 100 and 140 LPH at Coil side and constant rate of 200 LPH at Shell under steady state conditions. Better heat transfer characteristics at the flow rate of 80 LPH are found out. It was concluded that heat transfer rate. Dean number and overall heat transfer to efficient increases with increase in flow rate at Coil side.

Palve, V. M. et al.[15] studied about flow and heat transfer phenomena related to helically coil-tube heat exchanger, the authors investigated effect of tube diameter mean flow rate and pressure drop characteristics in a helical coil heat exchanger. It was found that temperature drop is maximum for lower flow rate and goes on reducing as the flow rate increases. The result showed that the temperature drop and pressure drop were affected by geometry of helical coil heat exchanger.

Mhaske, G. B., et al.[16] investigated the heat transfer characteristics with the help of an experimental setup in which a wire was wound over the inner tube to increase the turbulence in the flow. Heat transfer rate, LMTD, overall heat transfer coefficient, efficiency, Reynolds number, Nusselt number and Friction factor were calculated. Also by changing the working fluid heat transfer relation were found.

Imran, M., et al.[17] did analysis for a tube-in-tube helical coil heat exchanger with constant heat transfer coefficient for turbulent flow. The authors numerically modeled helical coil tube-in-tube heat exchanger for different boundary conditions and optimized condition of heat transfer for different D/d ratio. The effect of D/d ratio on heat transfer rate and pumping power has been found out for different boundary conditions. It was found that with increase in D/d ratio the Nusselt number decreases; for a particular value of Reynolds number. LMTD increases at a steady rate with increase in Reynolds number.

G.B. Mhaske., et al.[18] experimented a counter flow tube in tube helical coil heat exchanger. The results have been compared with numerically obtained value. The numerical work dealt with the pitch variation of the internal wound wire and its effect on the heat transfer rate. From Experiment heat transfer rate, LMTD, overall heat transfer coefficient, efficiency, Reynolds number, Nusselt number, and friction factor are calculated. The numerical and experimental result bears a close agreement.

Kuvadiya, M. N., et al.[19] numerically simulated tube in tube helical coil heat exchanger. The heat exchanger has been checked for different boundary condition. Nusselt numbers, Darcy friction factor, Log mean temperature difference variation with respect to Reynolds number for different D/d ratio has been plotted. It is found that with increase in the Reynolds number, the Nusselt number for the inner tube increases. On increasing in flow rate, turbulence between the fluid elements increases the Nusselt number. Also the heat transfer rate increases.

Nada, S. A., et al.[20] experimentally investigated tube in tube helically coiled heat exchanger for variation in is geometrical parameters and fluid flow parameters as like number of inner tube, hydraulic diameter of annulus, Reynolds numbers and input heat flux. The authors tested different coils with different number of inner tubes, like 1, 3, 4, and 5. It was found that coils with 3 inner tubes had higher values of heat transfer coefficient and compactness parameter. It was concluded that pressure drop increased with increase. In Reynolds number and number of inner tubes.

Pawar, S. S., et al.21 experimented for heat transfer through vertical helical coils using water as working fluid. Correlations between Nusselt number for Newtonian and non-Newtonian fluids, and two correlations for friction non-Newtonian fluids have been proposed. The experimental results have been compared with the CFD results and are found to be in close agreement.

Kshirsagar, M. P., et al.[22] experimented of a wire wound tube-in-tube helical coiled heat exchanger. The variations in flow rate in the inner tube and in the annulus were varied for counter-current flow configurations. They found the efficiency of the tube-in-tube helical coil heat exchanger increased as compared to the convention heat exchanger. The experimentally calculated efficiency was found to be 93.33%.

Amol, A., et al.[23] experimentally investigated the convective heat transfer coefficients of a helical coil heat exchanger. Three helical coils of different curvature ratio and pitch have been arranged horizontally in a shell and tested for counter flow arrangements. The authors studied heat transfer coefficients by considering pitch ratio and curvature ratio of a helical coil heat exchanger. It was found that the shell side heat transfer coefficients are larger than the tube side heat transfer coefficients by considering the pitch ratio and curvature ratio.

Karanth, V. K., et al.[24] did CFD analysis for a helical coil tubular heat exchanger and compared the results with the straight coil under similar geometrical and operating conditions. CFD simulation of helical coiled tubular heat exchanger under constant wall temperature conditions have been carried out. It is found that the helical heat exchanger showed 11% increase heat transfer rate as compared to straight tube, and it is also found that Pressure drop for helical coil is more when compared with the straight tube for identical conditions.

Mirgolbabaei, H., et al.[25] numerically investigated vertical helically coiled tube in shell heat exchanger. The authors investigated the effect of dimensionless coil pitch and tube diameter on the effectiveness of the heat exchangers. It is observed that the increase of the shell-side fluid mass velocity decreases the effectiveness of the heat exchanger.

Nada, S. A., et al.[26] numerically found out the characteristics of heat transfer for multi tubes in tube helically coiled heat exchanger. The authors investigated the influences of the design and operation parameters such as heat flux, Reynolds numbers and annulus geometry on the heat transfer characteristics. The testing was done for different numbers of inner tubes specifically 1, 2, 3, 4, and 5 tubes, and it was observed that the annulus formed by using five inner tubes showed the best heat transfer performance and compactness parameter. A correlation for predicting Nusselt number as function of Reynolds number and the inner tubes number has been presented from the numerical results.

CONCLUSION

Following points can be calculated for the literature;

1) Helically coiled tube in tube heat exchanger with counter flow configuration is highly effective.
2) Helical heat exchanger has higher heat transfer rate as compared to straight tube.
3) For helically coiled tube-in-tube heat exchanger, heat transfer performances are improved by using nanofluids.
4) CFD is an effective tool for performance prediction of heat exchangers in design phase only.

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