A review on design and development of spiral coil heat exchangers

Manoj Kumar[1], Vishal Gupta[2], Samarjeet Bagri[3]

[1]M.Tech. Scholar, Department of Mechanical Engineering, Radharaman Institute of Research and Technology, Bhopal, India
[2]Principal, Diploma, Radharaman Engineering College, Bhopal, India
[3]Assistant Professor, Radharaman Group of Institutes, Bhopal, India

---***---

ABSTRACT: -*Spiral coil heat exchangers are excellent heat exchangers because of the compact design and high heat transfer rate. There are a lot of research which are going on the design of heat exchangers for enhancement in heat transfer rate. In the present paper, research done by many researchers to increase the effectiveness of heat exchangers has been discussed. Through detailed study, it has been found that spiral coil heat exchangers have the higher rate of heat transfer as compared to straight tube heat exchangers.*

KEYWORDS: -*spiral coil heat exchanger, CFD Analysis, Heat transfer rate, effectiveness, mass flow rate***.**

INTRODUCTION

A heat exchanger is a device which is used to transfer heat between two fluids separated by a solid wall or through direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum industries, natural-gas processing, and sewage treatment. Among all heat exchangers Spiral coil heat exchangers, occupy the least space. They give high heat transfer performance. The design of spiral coil heat exchangers is of a uniform cross- section which creates "swirling" motion within the fluid to give better heat transfer performance. The fluid flow is fully turbulent at a much lower velocity than in straight tube heat exchanger and fluid travels at constant velocity throughout the whole unit. So, the boundary layer problem is also eliminated.

Conventionally, spiral tube heat coupling mechanism is attributed to many factors such as geometrical configurations, compact size, bigger thermal conduction space, the number of loops, etc. A lot of researches have been conducted to investigate and determine what configuration and geometry of spiral coil heat exchanger to further could enhance the heat transfer rate. The outcome results of both experimental and analytical studies end up to the same conclusion that Spiral coil heat exchangers have better heat transfer rate. Applications of such type heat exchangers include their usage in geothermal heat pumps, extracting oil and gas, and other solid-fluid interaction applications. Parameters such as the number of loops per unit tube length, mass flow rate, coil orientation, and coil pitch are some of many factors that influence the heat transfer efficiency and yet their effects on coil performance and heat rate are needed to be further emphasized. The main objectives of this paper include studying the design and the behavior of spiral coil heat exchangers and their performance.

LITERATURE REVIEW

Naphon and Wongwises investigated the performance characteristics of heat transfer in spiral coil heat exchanger under cooling and dehumidification condition. The spiral coil unit contained six strips of concentric spirally coiled tubes, the diameter of a straight copper tube was taken 9.27 mm into a spiral coil had five numbers of turns. Water and air as working fluids were used. In this analysis, the cooled water flows from outer coil to inner coil and hot air flow from center of the shell and then across spiral tubes to the periphery. For this analysis, a mathematical model based on mass and energy conservation has been developed. In this mathematical model, the authors applied Newton-Raphson iterative method to determine heat transfer characteristics. It was conducted that model results were more beneficial as compared to experimental data.[1]

Nguyen and San showed the heat transfer effectiveness of a counter-current spiral heat exchanger as a function of the number of transfer unit, ratio of flow capacity rates, number of spiral turns and dimensionless start point angle of spiral. Effectiveness of heat transfer depends upon dimensionless start point angle. If the number of spiral turns is greater than 20, the heat transfer effectiveness of the spiral heat exchanger is equivalent to counter flow heat exchanger. The number of spiral turns increases the heat transfer effectiveness is also increases. But, the ratio of flow capacity rates decreases. For gain of maximum heat transfer rate the spiral heat exchanger required large no. of transfer units for balanced flow conditions. But this working condition needs extra mechanical power.*[2]*

P. Bharadwaj and A.D. Khondge analyzed pressure drop and heat transfer characteristic of flow is a spirally grooved tube with twisted tape. The experiment was conducted for laminar to full turbulent ranges with considerations of Reynolds no. It was noted that the heat transfer rate increases in spiral grooved tube as compared to the smooth tube. Again, it is shown that if twisted tape is inserting in spiral grooved tubes, the heat transfer rate increases with these twist ratio. Finally, the results show that the heat transfer rate increases in a spirally grooved tube with and without twisted tape in laminar to turbulence range of Reynolds numbers.[3]

Paisarn Naphon compared numerical and experimental results of heat transfer and flow characteristics of horizontal spiral coil tube. The spiral coil had five turns and tube diameter 8 mm and was made of copper. Water was used as a working fluid. For numerical simulation, k-ε turbulence method was used. It was concluded that Nusselt nunber and pressure drop for a spiral coil is higher than the straight tube.[4]

Duc-Khuyen Nguyen and Jung-Yang San applied the 3-D printing technique for manufacturing a counter-current spiral heat exchanger. The performance of heat exchanger is a function of the thickness of the wall. Numerically and Graphically it is presented that material selection plays important role in heat exchanger.[5]

Young-seok son amd jee- young shin used CFX to conduct three-dimensional numerical analyses of the shell-and-tube heat exchangers with spiral baffle plates. Obtained results have been compared with the results of conventional shell and tube heat exchanger. Baffle results were found to be for shell and tube heat exchanger with baffle plates.[6]

Xia et. al. studied the method to enhances heat transfer for the smooth helical tube. It was shown that the spiral corrugation enhances heat transfer due to swirling motion. It was concluded that helical tube cooperating with spiral corrugation increases heat transfer but increases flow resistance also.[7]

Air side performance of spiral fin and tube heat exchangers has been analyzed by Pongsoi and Pikulkajorn. Experimental, numerical & simulation results have been found out and compared.[8]

Bhavsar et.al. made an arrangement for a flow of hot and cold fluids through axial and spiral path respectively. The model has been designed and fabricated for experimental works. Analysis has been done for spiral tube and shell & tube heat exchangers.[9]

Jayachandriah et.al proposed a new correlation for predicting pressure drop in horizontal spiral coil using experimental data and work done. Outermost and innermost diameter of shell, outer and inner diameter of tube, coil pitch & no. of coils & material have been kept fixed. Firstly, mass flow rate of hot and then cold water have been varied to find effectiveness.[10]

Omid Seyadashraf studied the flow characteristics of spirally coiled tubes in terms of secondary flow and pressure drop. Four spiral shape tubes with different curvature ratios were numerically simulated under constant wall temperature. The flow of water was from innermost turn to outermost turn. k–ε turbulence model has been used to handle boundary layer and mass flow rate has been varied to study pressure drop in the spiral coils. The results have been compared with the experimental data reported in the literature. [11].

Duc-khuyen Nguyen and Jung-yangsan studied the counter current spiral heat exchanger. As the number of spiral turns increases the optimum number of transfer unit at maximum heat transfer effectiveness increases. Using second law, an optimum hot flow to cold flow capacity rate ratio has been found out. It is concluded that large energy can be recovered if spiral heat exchanger possesses large no. of transfer units. For large no. of transfer units, small mechanical power, in addition, is required.[12]

Babak Dehghan B. Has worked for the thermal performance of vertical spiral ground heat exchangers using experimentation & numerically techniques. Nine ground heat exchanger and two boreholes with U-Tube ground heat exchangers have been used for obtaining experiments results. Numerical results have been validated with the experimental data All the nine ground heat exchangers have been examined for most critical working conditions using the obtained long-term heat transfer rate.[13].

Kwanchanok Srisawad and Somchai Wongwises experimented on the heat transfer characteristics of a helically coiled finned tube heat exchanger. Corrugated edge at inner diameter has been made. In shell side, atmospheric air and for tube side, hot water have been used as a working fluid. The mass flow rate for both air and water has been varied along with hot water temperature. Effect of inlet boundary condition of both the fluids has also been discussed. [14]

Nunez et.al presented design approach for sizing of a spiral heat exchanger. The smallest dimensions were obtained using heat transfer coefficient which was directly related to pressure due to friction. It was concluded that continuous change in the direction of flow of fluids leads to higher values of heat transfer coefficient.[15]

Zekeriya Altac and Ozge Altun numerically investigated heat transfer and flow in spiral tube coil. Commercially available CFD code fluent has been used for analysis. The effects of the spiral tube pitch, curvature ratio, the Prandtl and the Dean number on the friction factor and the heat transfer has been numerically investigated. Heat transfer enhances on increasing Reynolds number along with friction losses.[16].

Ke et.al numerically simulated heat transfer characteristics for conical spiral tubes. Numerical data has been validated using experimental data and it has been found to be within a tolerance limit of 5%. It has been found out that cone angle and cross section have a significant effect on tube heat transfer.[17]

Kiatpachai et.al stated that the heat exchanger is a basic component used in thermal processes such as industrial fluid heating, household appliances, waste heat recovery units etc. Presently, the spiral fin-and-tube heat exchanger is used as a favored type of heat exchanger for the waste heat recovery unit system, i.e., the economizer heat exchanger. The experimental results reveal that the fin pitch has a significant effect on the air-side performance. It is confirmed that the fin pitch of 3.6–6.2 mm has the same trend in heat transfer coefficient at the tested condition. The study investigates the effect of fin pitches on the air-side performance of serrated welded spiral fin-and-tube heat exchangers having Z-shape flow arrangement and the number of tube rows in the range of high Reynolds numbers. For f-friction factor, a detectable rise of the friction factor is found when the fin pitches increase to 6.2 mm. Moreover, the air-side performance correlations of serrated welded spiral finned tube heat exchangers are proposed for the practical industrial application.[18].

Lee et. al. investigated the heat transfer characteristics of spirally coiled circular fin-tube heat exchanger. Parameters such as frost thickness, pressure drop, frost thickness, heat transfer rate and Nusselt number were measured and analyzed. The Nusselt no. of spirally coiled circular finned tube has been compared with flat plate fin tube heat exchangers. Reynolds number, fin pitch normalized by hydraulic diameter, Fourier no. & no. of tube rows have been used to develop correlation with Nusselt no.[19].

CONCLUSION

There are many kind of research that have been done for enhancing the heat transfer rate of heat exchangers. Experimental methods (model analysis) give accurate results but are expensive and time-consuming. CFD has emerged as a boon for researchers. Using numerical techniques, parameters such as heat transfer rates, temperature, and effectiveness can be found out in detail easily. Among heat exchangers, spiral tube heat exchangers give better heat transfer rate and occupy less space. CFD can be used for detailed analysis of spiral tube heat exchanges efficiently also.

REFERENCE:-

1. Naphon. P & Wongwises. S – A study of the heat transfer characteristics of a compact spiral coil heat exchanger under wet surface conditions. 29 (2005) Pp- 511–521.
2. Nguyen. K.D San. Y. J - Heat Transfer and Energy Analysis of a Spiral Heat Exchanger. 37 (2016) Pp-1013-1026.
3. P. Bhardwaj & A.D. Khondge- A.W. Heat transfer and pressure drop in a spirally grooved tube with twisted tape insert.International journal of heat and mass transfer 52 (2009) Pp- 1938-1944
4. Naphon. P - Study on the heat transfer and flow characteristics in a spiral coil tube.38 (2011) Pp- 69-74.
5. Nguyen. K D -Decrement in heat transfer effectiveness due to solid heat conduction for a counter-current spiral heat exchanger.(2016) Pp-821-831
6. Son. S. Y & J. Y Shin*ksme - International Journal* Performance of a Shell-and-Tube Heat Exchanger with Spiral Baffle Plates .15 (*2001)* Pp-1555-1562
7. Xia. L .Y, Hua W. J, Hang. W, Li-Ping. K, Hang. T- Fluid Flow and Heat Transfer Characteristics in Helical Tubes Cooperating with Spiral Corrugation.17 (2012) Pp- 791-800.
8. Pongsoi. P & Pikulkajorn.S- Heat transfer and flow characteristics of spiral fin-and-tube heat exchangers.79 (2014) Pp- 417-431.
9. BHAVSAR. J. J, MATAWALA, K.V, DIXIT- Design and experimental analysis of spiral tube heat exchanger. 1 (2013) Pp-2320-2392.
10. Jayachandriah, B.Kumar, U.M.Jagesh, R.Krishna, V.M.T- Fabrication and design of spiral tube heat exchanger.(2014)
11. Seyedashraf. O- Numerical study of pressure drop in the horizontally spirally coil tube. ISSN 2147–0308 (2015) Pp- 55-60.
12. Nguyen. D. K And San. J Y - Heat Transfer and Energy Analysis of a Spiral Heat Exchanger.(2016) Pp-1013-1026.
13. Babakdeghan B.- Experimental and computational investigation of the spiral ground heat exchangers for ground source heat pump applications 121 (2017) Pp-908-921.
14. Srisawad. K & I. Wongwises.S - Heat transfer characteristics of a new helically coiled crimped spiral finned tube heat exchanger(2009) Pp- 381–391.
15. Nunez. M.P, Davalos.L.C, And Fuentes. A.M- Alternative design approach for spiral plate heat exchangers. 2003
16. Altac.Z & Altun. O -Hydrodynamically and thermally developing laminar flow in spiral coil tubes.77 (2014) Pp-96-107.
17. Ke.Y, Qi.G.P, Cai.S.Y, Tao. M. H - Numerical simulation on heat transfer characteristic of conical spiral tube bundle 31 (2011) Pp- 284-292.
18. Kiatpachai.P, Pikulkajorn.S, Wongwises.S - Air-side performance of serrated welded spiral fin-and-tube heat exchangers 89 (2015) Pp-724-732
19. Lee.M, Kang.T, Joo.Y, Kim.Y- Heat transfer characteristics of spirally-coiled circular fin-tube heat exchangers operating under frosting conditions 34 (2011) Pp- 328-336.