A REVIEW ON DEVELOPMENTS IN TECHNOLOGIES OF HEAT EXCHANGERS WORLDWIDE

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Abstract - *In industrial applications such as chemical, food processing, power production, space heating, refrigeration and air conditioning industries, heat exchangers are widely used. In order to obtain a large heat transfer per unit volume and to enhance the heat transfer rate helical coil heat exchangers are widely used. In this paper, research work done in the field of helical coil heat exchangers by various researchers has been discussed.)*

Key Words*: Heat exchanger, helical coil, CFD, Heat transfer*

1. INTRODUCTION

A device which is used to transfer heat from one fluid to other with direct or indirect contact is called heat exchanger. A heat exchanger works as a medium of heat transfer between two fluids one hot & other cold. The heat exchanger must have high rate of heat transfer and low cost. Among three modes of heat transfer, the heat transfer by radiation is negligible in a heat exchanger; therefore, it is not taken into account. [1]. For getting the high rate of heat transfer helical coiled heat exchangers are mostly used. To obtain huge amount of heat transfer per unit volume and to increase the rate of heat transfer on the inside surface helical coil heat exchanger are more efficient ones. [2]. The curvature of the tube in helical coil heat exchanger helps to provide the centrifugal force which further leads to obtain secondary flow which makes mixing of fluid and results in enhancement of heat transfer. There are various industrial applications of heat exchanger such as food industries, power production, manufacturing plants, air conditioning etc. [3]

Literature review

Prabhanjan et al. (2004) determined the advantages of using a helically coiled heat exchanger and compared it with straight tube heat exchanger for liquids. The particular difference was in the boundary conditions for the helical coil heat exchanger by considering fluid-to-fluid heat exchanger. It was shown that the heat transfer coefficient was affected by the geometry of the heat exchanger and the temperature of the water surrounding the heat exchanger. [4]

Xia et al. experimented on spiral corrugation on the inner wall of smooth helical tube heat exchanger and found that there was a passive heat transfer enhancement method. Numerical simulation was performed to give the turbulent flow and temperature fields in helical tubes cooperating with spiral corrugation. The effects of the spiral corrugation parameters and Reynolds number on the flow along with heat transfer were studied. The results showed that due to additional swirling motion the spiral corrugation can enhance heat transfer of the smooth helical tube. An increase in heat transfer can also be obtained by the decrease of the pitch of spiral corrugation. It was concluded that helical tubes cooperating with spiral corrugation show 50%-80% increase of heat transfer. [5]

Olasiman et al. designed and simulated a heat exchanger. Numerically obtained results were compared with experimental test data. The test was done 5 times to measure values of different variables. It was found that the values had different relationship among them. Correlation between exit temperature, pitch size, heat gases & mass flow rate was shown. The effectiveness of the heat exchanger was found to be directly proportional to the diesel fuel temperature. [6]

The effect of operational and geometrical parameters on the thermal effectiveness of shell and helically coiled tube heat exchangers was investigated by Alimoradi. Study state analysis was performed by considering water as working fluid. The viscosity and thermal conductivity of fluid were assumed to be dependent on temperature. Two correlations were developed to predict the thermal effectiveness using wide ranges of mass flow rates, dimensionless geometrical parameters and Reynolds numbers. It was concluded that for same values of NTU and Cr, the electiveness was averagely 12.6% less than the effectiveness of parallel flow heat exchangers and this difference was nearly constant. [7]

Jayakumar et al. suggested that helically coiled heat exchangers are used in various process industries due to better heat transfer characteristics and compact layout. Few experimental results on hydrodynamics of air–water flow through helical pipes have been reported but numerical investigation can give much deeper insight into the physics of the problem. Pitch circle diameter, pitch of the coil, diameter of the pipe have been varied to study the influence on thermal hydraulic characteristics of the two-phase flow. Analysis has also been carried out by changing the inlet void fraction for a given value of the flow velocity. From these analyses, it has been concluded that correlations for heat transfer and pressure drop gets effected by pitch circle diameter, pipe diameter and void fraction at the inlet. [8]

Chaves et al. have compared performance of two different helically coiled heat exchangers with two and three helical coils using (CFD).Simulations were performed for various temperatures and the inlet cold fluid temperature. Results indicated that the performance of both heat exchangers for the hot fluid inlet temperature 25°C was quite similar, but for 40°C hot fluid inlet, the heat exchanger with three turns was more efficient than the other one. It was shown that the performance of both two & three helical coil heat exchanger could be increased by increasing the hot fluid inlet temperature. [9]

Kharat et al. developed a Correlation for heat transfer coefficient for flow between concentric helical coils. Existing Correlation was found to result in large discrepancies. Experimental data has been used to validate CFD simulations to develop improved heat transfer coefficient correlation for the flue gas side of heat exchanger. For studying the efficiency of various parameters, mathematical model has been developed using data obtained from numerical and experimental. New correlation using numerical technique has been found out and it is found to have better fit with experimental results.[10]

Kumar et al have numerically modeled tube in tube helically coil heat exchanger for different fluid flow rate. The three-dimensional governing equations have been solved using control volume finite difference method Ƙ-ε model has been used to take care of turbulence. Reynolds number has been varied from 20,000 to 70,000. The overall heat transfer coefficients are calculated for both parallel and counter flow configurations. The Nusselt number and friction factor values in the inner and outer tubes are compared with the experimental data reported in the literature. New empirical correlations are developed for hydrodynamic and heat transfer predictions in the outer tube of the tube-in-tube helically coiled. [11]

Jayakumar et al. explained the heat transfer characteristics of double pipe helical heat exchangers and considered fluid-to-fluid heat transfer. The methodology of CFD analysis of heat exchanger has been validated. The characteristics of heat transfer inside a helical coil for various boundary conditions are compared. It is found out that the specification of a constant temperature boundary condition for an actual heat exchanger does not give appropriate modeling. Hence, conjugate heat transfer and temperature dependent properties have been considered on analysis of heat exchanger of heat transport media. The experimental setup has been developed and results are compared with the CFD calculation results. Based on the experimental results a correlation has been developed to calculate the inner heat transfer coefficient of the helical coil. [12]

Pawarand and Sunnapawar carried out experiments on isothermal steady state and non-isothermal unsteady state conditions in helical coils for Newtonian and non-Newtonian fluids. Water and glycerol–water mixture were used as Newtonian, and dilute aqueous polymer solutions of Sodium Carboxyl Methyl Cellulose and Sodium Alginate as non-Newtonian fluids have been considered in this study. These experiments were performed for various coil curvature ratios as in laminar and turbulent flow regimes for numerical analysis has been used. The CFD results have been compared with the experimental results. The results are found to be in good agreement with each other correlation between Nusselt number to Prandtl number and coil curvature ratio using least-squares power law fit has been presented in this paper other calculations for finding the Nusselt number in Newtonian and non-Newtonian fluids are also proposed. The obtained correlations are found to be in good agreement with previous investigations. [13]

Prabhanjan et al. carried out experimental investigated on the natural convection heat transfer from helical coiled tubes in water correlation between outside Nusselt number and the Rayleigh number using different characteristic lengths has been given using the relationship based on a power law equation. The best correlation was found out using the total height of the coil. The outlet temperature of a fluid flowing through a helically coiled heat exchanger has been predicted using developed model obtained values have been compared with experimental results and both values have been found to be very close. [14]

Piazza and Ciofalo obtained numerical result for turbulent flow and heat transfer in curved pipes which represent helically coiled heat exchangers carried refinement study, turbulent model study have been compared with experimental results. Using SST and RSM result were in close agreement with literature data. RSM model has been further used to compute friction coefficient and Nusselt number. [15]

Deshmukh et.al. found that helical coil tube type heat exchanger give highest heat transfer result among all counter flow analysis of helical coil heat exchanger using Fluent has been done. Temperature contours have been plotted. Copper has been chosen as the material for heat exchanger and working fluid has been taken as water. It is concluded that first law of thermodynamics plays an important role in helical coil heat exchanger. [16]

Pakdaman et. al. experimentally investigated pressure drop characteristics of nanofluid flow inside vertical helically coiled tubes for the laminar flow. The temperature has been maintained constant at the temperature of 95 c and given isothermal boundary. Pitch to tube diameter ratio has been varied along with coil to tube diameter rough correlation have been proposed. It is concluded that nanofluid flows show higher rate of pressure drop compared to that of the base fluid flow. [17]

Kalb and Seader Studied heat transfer in curved tubes of circular cross section axially uniform wall heat flux with peripherally uniform wall temperature has been considered as the boundary condition. The fully developed velocity profiles utilized have been calculated. The thermal energy solutions have been found out for low dean numbers, Prandtl-number and curvature ratio parameters have been varied. Nusselt numbers have been also correlated as and function of Dean number and Prandtl numbers only.[18]

Rogers and Mayhew Experimentally found out forced convection heat transfer and friction factors for water flowing through steam heated coils and the results have been compared with available data for smooth coils, existing equations are found to give satisfactory results.[19]

Conclusion

The efficiency of helical coil heat exchangers is higher than that of straight coil heat exchanger. A lot of research has been done for enhancing the heat transfer rate of helical coil heat exchanger by varying parameters such as diameter, mass flow rate, pitch diameter. Using CFD one can easily predict the detailed flow behaviour and heat transfer in the heat exchanger. It is found out that CFD is a good tool to analyses the performance of heat exchangers and it gives satisfactory results.

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