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Review on Heat Transfer in Spiral Heat Exchanger

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Abstract- Energy saving is major matter in our global world, and heat exchanger is very useful for energy saving. Of course heat exchanger is most significant component for chemical reaction, distillation, dissolution, crystallization, fermentation etc. So the correct selection of heat exchanger is important in these process industries. Spiral Heat Exchangers are known as excellent heat exchanger because of compact structure and high heat transfer efficiency. The flow of the two fluids is counter-current, which makes it possible to have a close temperature approach between the two medias being treated in the heat exchanger.A large variety of fluids can be suitable for a spiral heat exchanger solution e.g. fouling liquids containing solids and fibres, waste water, slurries, mixtures with inert gases, cooling and heat recovery, vapour/liquid condenser and vacuum condenser with inert gases.

Index Terms- Heat transfer coefficient, Foulingfactor, Overall heat transfer coefficient, Reynold's Number, Prandtl Number

I. Introduction

A heat exchanger is equipment built for efficient heat transfer from one medium to another. The media are separated by a solid wall to prevent mixing. They are widely used in chemical and petrochemical plants, refineries and sewage treatment. A basic heat exchanger involves a wall separating the flow paths of a hot fluid and a cold fluid. The amount of heat transferred depends upon various factors like type of fluid flow, area of heat transfer, thermal conductivity of the separating wall etc. There are three primary classifications of heat exchangers according to their flow arrangement.Co-current or parallel flow heat exchangers heat exchangers, the two fluids flow in the same direction.Counter-current or counter-flow heat exchangers the two fluids flow in oppositedirections.Cross-currentorcross-flow heat exchangersuch heat exchangers, the two fluids flow roughly perpendicular to one another.

II. BASIC TYPES OF HEAT EXCHANGERS

Over the years, numerous models have been suggested for heat exchangers, with changes being made in the conventional designs to achieve higher heat transfer areas, higher heat transfer coefficients, and also to design economically viable models. Some of the conventional models are:
i) Shell and Tube Heat Exchanger: This comprises of a shell that contains a number of tubes held together between two tube sheets at either end. It is mainly used for the cooling of hydraulic fluids, reboilers etc.
ii) Plate Heat Exchanger: This consists of alternate square plates and frames which hold the plates together. There are holes at the four corners which form four continuous channels for the fluids to flow. It is widely used in chemical, pharmaceutical and food industries.
iii) Double Pipe Heat Exchanger: It is a relatively primitive model consisting of two concentric pipes. One fluid flows through the inner pipe and the other flows through the annulus formed by the two pipes. It can be used instead of plate heat exchangers but is rarely an option as it occupies more space.
The type of Heat Exchanger that is to be used depends upon which type of fluid is to be handled, operating temperature range, floor spacing, and type of flow required. In general, Heat Exchangers are designed with the sole aim of achieving maximum heat transfer area and heat transfer coefficients within the specified temperature range. In order to increase the area of heat transfer, fins or corrugated plates may be used. To increase the heat transfer coefficient, baffles are placed to introduce turbulence. Ultimately, all these factors are taken into consideration for developing a Heat Exchanger required for particular operation.Spiral heat exchanger maintenance is easy. Each side of the closed spirals can be accessed by opening the side frame of the heat exchanger without any special tools. When opening the side frame there will be full access to the heat transmission area on one side, which can be cleaned without getting in contact with the other side of the heat exchanger. The side frame is designed with hinges which make lifting equipment unnecessary. The spiral heat exchanger is a compact solution. The design only requires a small space for installation compared to traditional heat exchanger solutions. This saves valuable production space and costs.

III. Literature survey

The research was done by Kondhalkar and Kapatkat on performance analysis of spiral tube heat exchanger used in oil extraction system [1]. They discussed about the effective use of spiral tube heat exchanger in oil extraction process. They carried out research on the performance analysis of spiral tube heat exchanger over the shell and tube type heat exchanger. They studied the Performance of spiral tube heat exchanger and shell and tube heat exchanger for sugandh mantri oil emulsion.They found that the relation between mass flow rate and effectiveness and found out that for the same mass flow rate effectiveness increases for the spiral tube heat exchanger.Also it was observed that the heat transfer coefficient increased with increase in Reynolds number. Also they investigated the relation between Reynolds numbers and Nusselt number and concluded that Nusselt number increases with increase in Reynolds number. They finally compared the spiral heat exchanger with the shell and tube heat exchanger and found out that effectiveness of shell and tube heat exchanger for lemon grass oil and sugandh mantra oil averages between 0.3 to 0.4 against for spiral 0.4 to 0.5 which shows increase in the effectiveness. They found out that heat transfer coefficient for shell and tube type heat exchanger was 350 – 600 W/m^2K against for spiral tube heat exchanger is 450 to 650 W/m^2K. It shows increase in the heat transfer rate with use of spiral tube heat exchanger. The research work was carried out by Thirumarimurugan et. al on experimental and simulation studies on spiral heat exchanger for miscible system using matlab[2].They have done an experimental investigation on comparative heat transfer study on a solvent and solution using spiral heat exchanger. They used steam as the hot fluid and water and acetic acid -water miscible solution as cold fluid. They carried out series of runs between steam and water, steam and acetic acid solution.The flow rate of the cold fluid was varied from 120 to 720 lph and the volumefraction of Acetic acid was varied from 10-50%. Experimental results such as exchanger effectiveness, overall heat transfercoefficients were calculated. Generalized regression model was used for artificial neural network simulation using matlab and the data obtained was compared with experimental findings and found to be valid.The research was carried out by Naphon and Wongwises on study of the heat transfer characteristics of a compact spiral coil heat exchanger under wet-surface conditions [3]. The objective of their work was to find the heat transfer characteristics and the performance of a spiral coil heat exchanger under cooling and humidifying conditions. Air and water were used as working fluids. A mathematical model based on mass and energy conservation is developed and solved by using the Newton–Raphson iterative method to determine the heat transfer characteristics. They found that enthalpy, effectiveness and the humidity effectiveness decreased with increasing air mass flow rate for a given inlet-water temperature, inlet-air humidity ratio and water mass flow rate. The increase in the outlet enthalpy and outlet humidity ratio of air was larger than those of the enthalpy of saturated air and humidity ratio of saturated air. Therefore, the enthalpy effectiveness and humidity effectiveness tend to decrease with increasing air mass flow rate. They also observed that the effect of inlet-air temperature on the tube surface temperature. At a specific inlet-air temperature, the tube surface temperature generally increases with increasing air mass flow rate; however, the increase of the tube surface temperature at higher inlet-air temperatures was higher than at lower ones for the same range of air mass flow rates. They found that at a specific air mass flow rate, the tube surface temperature decreases as water mass flow increases. Finally the results obtained from the developed model are validated by comparing with the measured data.The research was carried out by Hossain et. al.on comprehensive study on heat transfer co-efficient and effectiveness for water using spiral coil heat exchanger [4].They have done experimental study to investigate the overall heat transfer co-efficient and effectiveness for water using spiral coil heat exchanger. They designed and fabricated a physical model of the spiral coil heat exchanger. They varied the mass flow rate of hot fluid from 0.049 kg/sec to 0.298 kg/sec and the mass flow rate of cold fluid from 0.029 kg/sec to 0.225 kg/sec.They found the effects of heat transfer rate on Reynolds number for three different cold water flow rate. They have observed that the heat transfer rate increases almost linearly with increasing Reynolds number, which is acceptable for the spiral coil heat exchanger. The heat transfer rate was maximum in case of medium cold water flow rate (0.129kg/sec).They have found that overall heat transfer co-efficient is maximum for the highest cold water flow rate (0.225kg/sec) and minimum for the lowest cold water flow rate (0.029kg/sec). They have also observed that Nusselt number increased linearly with increasing Reynolds Number for all three cold water flow rate. At 0.129kg/sec cold water flow rate Nu was maximum with respect to Reynolds Number. They have observed that effectiveness decreases with the increase of Reynolds Number and the value is maximum for the medium cold water flow. The research was carried out by Bhavsar et al. on design and experimental analysis of spiral tube heat exchanger [5].Their objective was to develop new design methodology for flow of hot and cold fluids, where hot fluid flows in axial path while the cold fluid flows in a spiral path. They suitably designed and fabricated the spiral tube heat exchanger to measure the experimental tests. The objective of their work was to streamline design methodology of spiral tube heat exchanger. They have designed methodology for spiral tube heat exchanger and experiments performed on it to analyses pressure drop and temperature change in hot and cold fluid on shell side and tube side.The research was carried out by Baghel and Upadhyaya on effect of coil diameter on pressure drop in Archimedean spiral coils [6]. The main objective of this investigation was to study the effect of the coil diameter on the pressure drop in the Archimedean spiral tube coils. They developed a relation between the pressure drop and the feed flow rate for the steady state Newtonian fluid into the Archimedean spiral tubes. They constructed two spiral tubes with different inside tube diameter using the thick walled polyethylene tubing and the pressure drop versus flow rate data were taken for the both configuration for the wide range of maximum and minimum radius of the curvature, pitch and the inside diameter of the tube. They collected data for feed flow rate versus pressure drop data for the two configurations of the spiral tube coils using the carbon tetrachloride and mercury as the manometerfluid for the isothermal Newtonian fluid such as water. They studied various effects of feed flow rate and the coil diameter. They observed that the effect on the pressure drop was for the wide range of feed flow rate from 1 to 5 lpm for the 6 mm coil geometry.They concluded that on increasing the feed flow rate the pressure drop increases and vice versa. Due to the presence of the secondary flow inside the coil and centrifugal flow due to curvature ratio increases the pressure drop inside the Archimedean spiral coils.They also concluded that on increasing the inside diameter of the coil, the pressure drop decreases while the feed flow rate was same for all the configurations because the velocity of the fluid into the spiral coil decreases due to increase of the diameter of the coil.The research was carried out by Rajavel and Saravanan on an experimental study of spiral plate heat exchanger for electrolytes[7].The main objective of their study was to investigate convective heat transfer coefficient for electrolytes using spiral heat exchanger.They performed experiments by varing the mass flowrate,temperature and pressure of the cold fluid,keeping the mass flowrate of hot fluid constant.They investigated that heat transfer coefficient increases with increase in reynolds number of electrolytes which increases the Nusselt number.They concluded that data obtained from the experimental study compared with the therotical data.They have also developed a new correlation based on experimental data for practical application.The research was carried out by Ramachandran etl. on heat transfer studies in a spiral plate heat exchanger for water- palm oil two phase system [8].They conducted experiment by using spiral plate heat exchanger with hot water as the service fluid and the two-phase system of water - palm oil in different mass fractions and flow rates as the coldprocess fluid.They investigated heat transfer coefficients.The research was carried out by Kaliannan Saravanan etl. on Spiral plate heat exchangers play a vital role in cooling high density and high viscous fluids[9]. They investigated convective heat transfer co-efficient for electrolytes using spiral plate heat exchanger. Their methodology shows a test section consists of a Plate of width 0.3150 m, thickness 0.001 m and mean hydraulic diameter of 0.01 m. They have varied massflow rate of hot fluid is varying from 0.4 to 0.8 kg/ sec and the mass flow rate of cold fluid varies from 0.3 to 0.8 kg/sec.They performed experiments by varying the mass flow rate, temperature and pressure of coldfluid, keeping the mass flow rate of hot fluid constant.They concluded that data obtained from the experimental study are compared with the theoretical data. They have proposed a newcorrelation for the nusselt number that can be used for practical applications.The research was carried out by Shabiulla and Sivaprakasam on experimental investigation and neural modeling of water-butanol system in a spiral plate heat exchanger [10].They have conducted experiments by varying the mass flow rate of cold fluid (Butanol) and inlet temperature of the hot fluid(Water), by keeping the mass flow rate of hot fluid constant. They studied the effects of relevant parameters on the performance of spiral plate heat exchanger.They have proposed Artificial Neural Network (ANN) models for the analysis of spiral heat exchanger. They investigated that prediction of the parameters can be obtained without using charts and complicated equations.They compared the data obtained from ANN and polynomial models for overall heat transfer coefficient and Nusselt number with those of experimental data. They concluded that the accuracy between the NN's predictions, polynomial model's predictions and experimental values are achieved with minimum mean absolute relative error less than or equal to ± 7 % for the training and testing data sets respectively. They suggested the reliability of the Neural Networks as a Modeling Tool for Engineers in preliminary design and analysis of Spiral plate Heat Exchangers.An analytic model for spiral coil type ground heat exchanger was developed by Jaywan Chung and others [11]. Here they used green's function method to consider the 3 dimensional shape effects of a spiral coil heat exchanger. The spiral coil source model was transformed into the formula of error function to improve and simplify computation for the engineering application. To analyze the characteristics of the analytical model, the analytical model's prediction results were compared with test measurements by thermal response test conducted in a model chamber and the parametric study was performed. The spiral coil source model was transformed into the formula of error function to improve and simplify computation for the engineering application. To analyze the characteristics of the analytical model, the analytical model's prediction results were compared with test measurements by thermal response test conducted in a model chamber and the parametric study was performed. Rakesh and Sushant studied the effect of coil diameter on pressure drop in Archimedean Spiral Coils [12]. The aim of this investigation was to study the effect of the coil diameter on the pressure drop in the Archimedean spiral tube coils. The relation between the pressure drop and the feed flow rate has been obtained for the steady state Newtonian fluid into the Archimedean spiral tubes. The two spiral tubes were constructed with different inside tube diameter using the thick walled polyethylene tubing and the pressure drop versus flow rate data were taken for the both configuration for the wide range of maximum and minimum radius of the curvature, pitch and the inside diameter of the tube. The pressure drop in the spiral tube coils depend on the geometrical parameter of the different coils. The pressure drop in the spiral tube was represented by using the dimensionless Reynolds number and the Euler number. Rangasamy made an experimental and numerical study of a spiral plate heat exchanger [13]. The effects of geometrical aspects of the spiral plate heat exchanger and fluid properties on the heat transfer characteristics were also studied. Water was taken as test fluid. The effect of mass flow rate and Reynolds number on heat transfer coefficient has been studied. Correlation has been developed to predict Nusselt numbers. Numerical models have been simulated using CFD software package FLUENT 6.3.26. The numerical Nusselt number have been calculated and compared with that of experimental Nusselt number.Fouling of the heat transfer surfaces in a steam assisted gravity drainage (SAGD) in SITU facility for he recovery of the oil sands bitumen as studied by Pugale and others [14]. Fouling of heat ransfer surfaces presents an ongoing challenge to SAGD plants. SAGD produced water contains significant concentrations of dissolved solids as well as suspended clays, fee oil, and dissolved organics. Under certain conditions of temperature, pressure and velocity, these components will cause fouling in heat exchanger and steam generator tubes. This led to the need for complex water treatment in conjunction with frequent down time for the cleaning and the maintenance. Hence fouling of these surfaces leads to additional operating cost and lost production for the SAGD sector.Yanuar and others conducted an experimental investigation of convective heat transfer coefficient for nanofluids using spiral pipe heat exchanger [15]. The aim of this study was to investigate experimentally flow and convective heat transfer characteristics of water-based nanofluids flowing through a spiral pipe. Analysis was carried out by Students of Shree Satya Saya Institute of Science and Technology in parallel and counter flow with inward and outward direction for achieving maximum possible heat transfer [16]. In this problem of heat transfer involved the condition where Reynolds number again and again varies as the fluid traverses inside the section of flow from inlet to exit, mass flow rate of working fluid is been modified with time. More and more analysis and experimentation and systematic data degradation led to the conclusion that the maximum heat transfer rates is obtained in case of the inward parallel flow configuration compared to all other counterparts, which observed to vary with small difference in each section. Furthermore, for the increase heat transfer rate in spiral plate heat exchanger was obtained by cascading system. Haque investigated the cause of calcium oxalate fouling in spiral heatexchangers. Calcium oxalate solubility decreased with lowering temperature [17].The predicted precipitation rate due to temperature difference was consistent with the observed fouling rate. This observation suggested that the effluent supersaturates and forms precipitate (scale) upon contact with the cold heat exchanger surface. Suspended particles then accumulate and cause rapid fouling. He used physical separation methods and did a partial replacement of NaOH with $Mg(OH)_2$ during alkaline bleaching to reduce calcium oxalate content and minimize fouling.

IV. CONCLUSION

The research was carried out by various scientists on spiral plate heat exchangers and the results obtained were found valid and satisfactory. The research was carried out by Núñez resulted in maximizing pressure drop and so minimizing the size. The research done by Kondhalkar and Kapatkat concluded that heat transfer coefficient increases with increase in Reynolds number. It was observed that the heat transfer rate increases almost linearly with increasing Reynolds number. Study on the various effects of feed flow rate and the coil diameter was done and concluded that on increasing the feed flow rate the pressure drop increases and vice versa. A relation between the pressure drop and the feed flow rate for the steady state Newtonian fluid into the Archimedean spiral tubes was developed.

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