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Experimental Analysis of Spiral Heat Exchanger: Evaluation of Reynolds Number and Nusselt Number for Acetic Acid – Water System

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ABSTRACT

In this paper an experimental analysis has been conducted to investigate effect of Reynolds number on Nusselt number for different concentration acetic acid- water miscible system in the spiral heat exchanger (SHE). 5 % to 30% Acetic acid in water is cold fluid while hot fluid is water. Mass flow rate of cold fluid is varied and keeping the hot fluid flow rate constant then the values of Nusselt number are calculated.
Keywords : Spiral Heat Exchanger; Reynolds number; Nusselt Number

I. INTRODUCTION

Heat exchanger selection is very important in industry. As energy saving plays an important role in industry. Heat exchanger is an important component for various unit operations like distillation, crystallization, fermentation etc. Spiral heat exchanger is used in industry where energy saving is the major concern. Its design consists of spiral plate rolled to form a concentric shape. The concentric shape of the flow passage yields turbulence at low Reynolds number which results in increase of heat transfer and reduces the fouling in the spiral heat exchanger. This yields a compact and space saving construction that can be readily integrated in any plant and reduces installation cost.

II. LITERATURE SURVEY

The research was carried out by Jay J. Bhavsar et. al on design and experimental analysis of spiral tube heat exchanger[1].They designed and fabricated spiral tube heat exchanger for which they employed new arrangement for flow of hot and cold fluids. They concluded that design method available in literature is scattered so they developed a design procedure for spiral heat exchanger. The research was carried out by J.C. Kurnia and A.P. Sasmito on Heat transfer performance of non-circular coiled tubes [2]. They developed an essential summary of numerical studies main focus was to provide a general overview of the advantage and disadvantages of non-circular coiled tubes in thermal engineering applications. They tried to discuss the challenges and directions of their research work. They finally concluded that heat transfer improves in the coiled tube by increasing pumping power. They also concluded that if the geometry of coil is complex than the processes of manufacturing the tube and creating the computational domain will become major issues in non-circular coiled tube studies. The research was carried out by Ryohei Fujii,Mingcong Deng and Shin Wakitani on non linear remote temperature control of a spiral plate heat exchanger[3].They investigated that time delay is considered when process equipment controlled by wireless network. They designed a time delay compensation controller. They also designed spiral heat exchanger model. Finally they established a control system for effectiveness of spiral heat exchanger. The research was carried by Jamshid Khorshidi, Salman Heidari on Design and construction of spiral heat exchanger [4].They discussed governing equation for this and designed lab sized model and constructed. They used two galvanized iron sheet as heat transfer surface. The predesigned simulation of heat exchanger using Fluent software to see the performance of heat exchanger. They designed heat exchanger using gambit software. They come to conclusion that Nusselt number is more at the entrance and decreases as the fluid go forward through the heat exchanger. They finally concluded that optimization of heat exchanger can be done by simulation. The research was carried out by Skhan Park, Seung-Rae Lee, Seok Yoon And Gyu-Hyun Go on an analytical model for a spiral coil type ground heat exchanger [5]. They developed spiral coil source model and its analytical solution to consider 3 dimensional shape effects of spiral coil heat exchanger. They finally concluded that satisfied results are obtained by analytical solution. The research was done by Kondahkar, G.E. and Kapatkat on Performance Analysis of Spiral Tube Heat Exchanger Used in Oil Extraction System [6].They discussed the effective use of spiral heat exchanger in oil extraction process. They studied analysis of spiral heat exchanger over shell and tube heat exchanger. They concluded that due to the continuous curved flow section overall heat transfer coefficient is more as compared to shell and tube heat exchanger. They finally concluded that concurrent flow increases heat exchanger effectiveness from 0.3 to 0.5 for spiral heat exchanger. The research was carried out by Yoo Geun jong et. al on fluid flow and heat transfer characteristic of spiral coiled tube: effects of Reynolds number and curvature ratio[7].They studied that by increasing the radius of curvature of spiral coiled tube the total rotating angle reach 12ð.They performed three dimensional flow analysis with different Reynolds number as constant wall heat flux condition was set in thermal field. They noticed that centrifugal force due to the curvature effect plays important role in increasing heat transfer and pressure drop as compared to the straight tube. They concluded that similar trends observed for main flow and secondary flow. They also concluded that Nusselt number and friction factor increases with same proportion with Reynolds number and square root of dean number. They finally concluded that Reynolds is found to have stronger effect compared to curvature ratio.The research was carried done by R. W. Tapre and Dr. J. P. Kaware on heat transfer characteristic of spiral heat exchanger: effect of reynolds number on heat transfer coefficient for acetic acid - water system. Experimentation was conducted to investigate heat transfer coefficients and Reynolds number for acetic acid- water miscible system in the spiral heat exchanger. They used cold fluid as Acetic acid – water solution while hot fluid as water. They varied the mass flow rate of cold fluid from 0.0833 Kg/sec to 0.133 Kg/sec and varying the concentration of cold fluid from 5 % to 30% Acetic acid in water. They established a new correlation for Nusselt number calculation which fitted for experimental data. The hot fluid flow rate was kept constant then the values of Reynolds number and heat transfer coefficient were calculated. They concluded that heat transfer coefficient increases linearly with Reynolds number for four different cold water flow rate which was satisfactory for spiral heat exchanger.

III. METODOLOGY

The experimental setup of spiral heat exchanger consists of hot and cold fluid storage tanks. It consists of two pumps for hot and cold fluid of 0.5 hp each are connected to the tanks. Valves are attached to the pipes to adjust the flow rate as per the requirement. Drain is provided at the bottom of shell which can be opened or closed with a valve when required. Two rotameters are attached adjacent to the hot and cold water tanks to measure the flow rates. To measure the accurate inlet and outlet temperature of hot and cold fluids digital temperature indicator is used.

IV. PROCEDURE

Two third of its capacity two tanks are filled with respective fluids. The fluid is heated by switching on the heater in the hot fluid tank. Heating is continued till the required temperature is attained. The fluids are pumped through the pipe with the help of the pumps and flow rate is adjusted with the help of valves fitted to the pipes. Care must be taken of drain valve as it should be closed before starting of the experiment. Both the shell and tube side fluids are allowed to fill completely. Heat exchange takes place between fluids and temperature readings are noted. Reynolds number, Nusselt number are calculated.

V. CALCULATION METHODOLOG[8]

The rate of heat released or absorbed is calculated as,

$$Q = M\,Cp\,\Delta t \qquad (i)$$

Where, M is hot or cold fluid flow rate,

Cp is specific heat capacity of hot or cold fluid,

ΔT is Temperature difference of hot and cold fluid.

To calculate theoretically the Nusselt number for cold fluid shell side [8]

$$Nu = 1.7\,(Re)^{0.4}\,(Pr)^{0.4} \qquad (ii)$$

For hot fluid theoretically Nusselt number is calculated[8],

$$Nu = 1.7\,(De)^{0.4}\,(Pr)^{0.4} \qquad (iii)$$

Where,

Nu= Nusselt Number,

D_e= Dean Number of hot fluid,

Pr =Prandtl Number of cold fluid

To calculate Hydraulic diameter (D_H) tube side,

$$D_H = \frac{2HW}{(H+W)} \qquad (iv)$$

H is plate height in (m)

W is plate width in (m)

Tube side fluid Reynolds number,

$$R_e = \frac{M_h D_H}{HW\mu_h} \qquad (v)$$

To Calculate Dean number (D_e) for hot fluid

$$D_e = R_e\sqrt{\frac{D_H}{2R_c}} \qquad (vi)$$

Where,

R_c is radius of curvature of the path channel,

R_e is reynolds number of hot fluid

To calculate Nusselt number experimentaly (N_u) for cold and hot fluid,

$$N_u = \frac{h\,de}{k} \qquad (vii)$$

VI. RESULTS AND DISCUSSION

Figure 1 shows the plot of the Nusselt number (Nu) with Reynolds number (Re) for four different cold water flow rate. From the experimental result it is shown that the Nusselt number increases linearly with increasing Reynolds Number for all four cold water flow rate.The effects of Nusselt number with respect to reynolds number is studied for both co-current and counter flow arrangements as shown in figure 1.

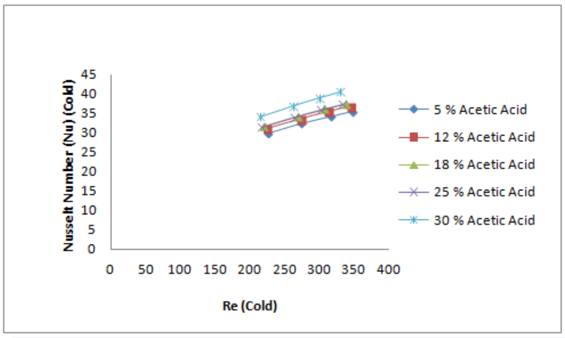

Fig. 1: Nusselt Number (Cold) Vs Reynolds Number (Cold) for Acetc Acid-Water System

VII. CONCLUSION

Experiments were performed by varyng the cold water flowrates for different concentration of cold fluid in spiral heat exchanger in parallel and counter current flow arrangements.The result shows that

Nusselt number increases linearly with Reynolds number for four different cold water flow rate.

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