Experimental Investigation on Effectiveness of Spiral Heat Exchanger for Acetic Acid- Water System

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Abstract— **This paper presents an experimental investigation for effectiveness of a spiral heat exchanger for acetic acid – water and water system. Spiral heat exchanger model was designed and fabricated. The heat exchanger consists of steel shell and spiral tubes. The cold fluid flows through shell and hot fluid flows through tubes which reduces heat loss. The hot fluid is water while cold fluid is acetic acid water solution. The fluid concentration is varied from 5% to 30%. The flow rate of hot fluid was kept constant while the flow rate of cold fluid was varied from 300 LPH to 480 LPH. The effect of effectiveness for different cold fluid flow rate was studied.**

Keywords— Spiral Heat Exchanger, Effectiveness, Reynolds Number

I. INTRODUCTION

Heat exchange is an important process in engineering where the transfer of thermal energy between fluids takes place at different temperatures. The fluids are separated by heat transfer surface which separates both fluids. Common examples of day to day life use are automobile, reboilers, condenser etc.Spiral heat exchanger consists of spirally wound coils in circular pattern. This spirally wound coils are placed in the shell where as the fluid surrounded to tubes forms the shell side fluid. Heat transfer rate is more in spiral tubes as compared to straight tubes. In spiral heat exchanger thermal expansion of spiral tube is not occurring and self cleaning is done due to spiral flow path in tubes and shell side due to centrifugal force and secondary flow which show more heat transfer.

II. LITERATURE SURVEY

The research was carried out by V. Vijayan et al. They used rectangular and Archimedean spiral. They compared performance of two geometries using CFD simulation software RANS. They used hot and cold fluid as air by keeping the heat transfer area for both geometries same. They kept channel width, depth and channel wall thickness same for both geometries. They performed experiments for three different Reynolds number, five external heat loss coefficients. They observed that rectangular spiral heat exchanger has more advantage over Archimedean spiral heat exchanger. They concluded that outer wall thermal conductivity is important parameter under non adiabatic conditions [1].The research was done by M.D.Kathir Kaman et al. They designed spiral heat exchanger for 7 KW. They found out that smaller spacing, large width of plate is used which can handle heat and pressure duty. They finally concluded that plate width of 301.92mm to handle heat and pressure duty for 7 KW of spiral heat exchanger [2]. The research was carried out by Thomas D. Traubert et al.They fabricated spiral heat exchanger of grade 316L stainless steel. They noticed that a leak was developed after using spiral heat exchanger as condenser on distillation column. The leak was identified on cooling water side.Examination method detected the presence of transgranular cracks. They finally concluded that cracks and leak were due to chloride stress corrosion cracking [3].The research was carried out by H. Dhaou et al. They have carried out experimentation for geometric and operating parameters of finned spiral heat exchanger to know the performance of charging process of MHV. They concluded that experimentally reactor charge time is reduced and choice of parameter is important [4]. The research was done by S. Maruyama et al. They studied that while producing electricity carbon dioxide is produced on large amount. They designed compact radiation converter using a spiral heat exchanger to recover heat energy from exhaust gas. They measured surface temperature on radiant tube by thermo viewer and then calculated radiant energy. They concluded that high effectiveness was obtained and heat loss from exhaust gas was minimized [5].The research was carried out by Duc-Khuyen Nguyen et al. They prepared spiral heat exchanger model in which solid heat conduction was carried out radially and steam wise. They found out effectiveness is increased with increase in NTU. Biot number decreases due to spiral direction heat conduction which results in decrease in effectiveness but they noticed that effectiveness is increased by radial direction heat conduction. They finally concluded that solid heat conduction effect is small on effectiveness [6]. The research was done by Mohan Vishal Verma et al. They carried review study of spiral heat exchanger. They studied performance and uses of spiral heat exchanger. They discussed for designed lab scaled model construction. They came to know stainless steel was used as material of construction for plates [7]. The research was carried out by S. S. Pawar et al. They performed experiment on helical, spiral and U tube coil. They performed experiments for same length for three different geometries for turbulent flow. They varied Reynolds number from 200 to 12000. They finally concluded spiral coil gives higher overall heat transfer coefficient than U tube and helical coil [8]. The research was carried by R.W. Tapre et al. They carried out experimentation to study the effect of Reynolds number on heat transfer coefficient for two phase system. They varied mass flow rate of cold fluid flow rate keeping hot water flow rate constant. They finally concluded that heat transfer coefficient increases as Reynolds number increases for cold fluid flow rate [9]. The research was carried by R.W. Tapre et al. They carried out experimentation for evaluation of Reynolds number and Nusselt number for acetic acid water system. They used cold fluid as acetic acid water miscible fluid while hot fluid as water. They varied the concentration of acetic acid in water from 5 to 30 %. They carried experimentation for parallel and counter current flow arrangement. They finally concluded that Nusselt number increases linearly with Reynolds number [10]. The research was carried by R.W. Tapre et al. They found out experimentally overall heat transfer coefficient for parallel and counter current flow in spiral heat exchanger. They varied the mass flow rate from 5 lpm to 8 lpm and keeping the hot fluid flowrate constant. They concluded that experimental overall heat transfer coefficient is more in counter current flow than in co-current flow.

III. EXPERIMENTAL SETUP

The experimental setup of spiral heat exchanger consists of hot and cold fluid tanks. Flow rate of hot and cold fluid is adjusted with the help of the valves provided and measured with the help of rotameters attached to both tanks. Both fluids are pumped with the help of two pumps each of 0.5 hp. To remove the shell side fluid a drain is provided at the bottom of the shell which can be operated with the help of valve. Inlet and outlet temperature of hot and cold fluid are indicated on digital temperature indicator [12].

IV. PROCEDURE

The two tanks are initially filled with the respective fluids up to approximately 75% of their capacity. The heating system is switched on. Heating commences and is continued till the required (predefined) temperatures are attained. The fluids are pumped with the help of pumps attached to the pipes at a specific flow rate and adjusted using the valves fitted to the pipes. Then flow rates are measured. The valve of the drain at the bottom is initially kept shut so that the fluid entering the channel is not allowed to escape. Both the channels are allowed to fill up completely. Since the fluid in the coil, i.e. the hot fluid is not linked to the drain directly; there will be some amount of residual fluid in the coil from the earlier runs. Hence, care should be taken to ensure that the temperature readings from the fluid in the coil are taken only after the residual fluid has been emptied. Heat exchange takes place and the temperature readings of the inlet and outlet of the hot fluid and those of the cold fluid are noted. Log Mean Temperature Difference (LMTD) is calculated using these readings. Reynolds number is calculated accordingly. The flow rates are varied and the procedure is repeated. The values of Reynolds number, effectiveness are obtained for parallel and counter current flow. [12].

V. RESULT AND DISCUSSION

Experiments have been performed to study the effects of effectiveness with respect to Reynolds number. Cold fluid concentration was varied from 5%, 12%, 18%, 25% and 30% of acetic acid in water. For each mass fraction of cold fluid experiment were performed in four set. In each set mass flow rate of hot fluid was kept constant (300 LPH to 480 LPH) and mass flow rate of cold fluid was varied from 300 LPH to 480 LPH.Calculations were done and graphs were plotted for effectiveness with respect to Reynolds number of the cold fluid are illustrated from Figures 1 to 5 for different mass fraction of cold fluid for co-current and from Figures 6 to 10 for different mass fraction of cold fluid for counter flow arrangement in spiral heat exchanger.

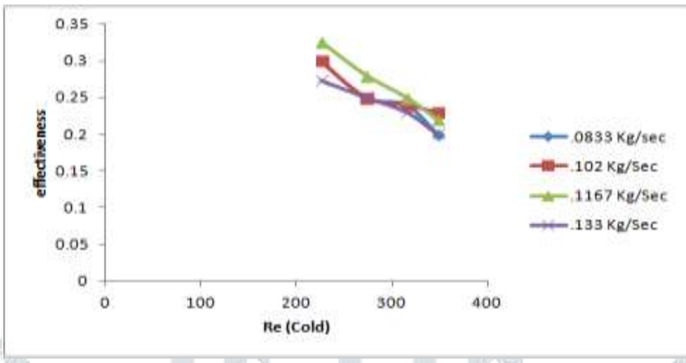

Fig. No.1: Variation of Effectiveness with Reynolds Number for different cold water flow rates for 5 % Acetic Acid-Water system (Co-Current Flow)

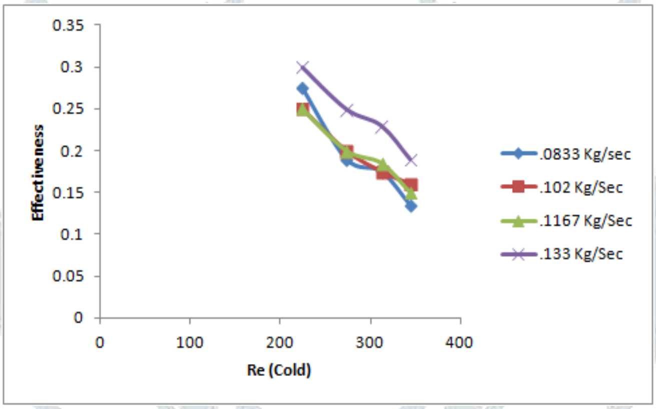

Fig. No.2: Variation of Effectiveness with Reynolds Number for different cold water flow rates for 12% Acetic Acid-Water system(Co- Current Flow)

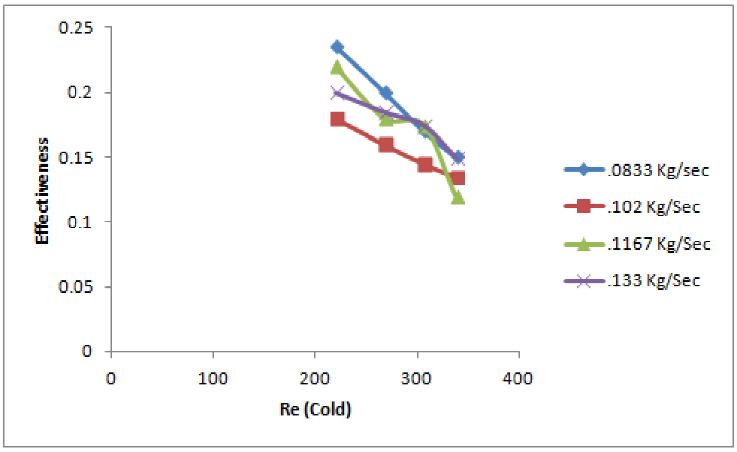

Fig. No.3: Variation of Effectiveness with Reynolds Number for different cold water flow rates for 18% Acetic Acid-Water system (Co- Current Flow)

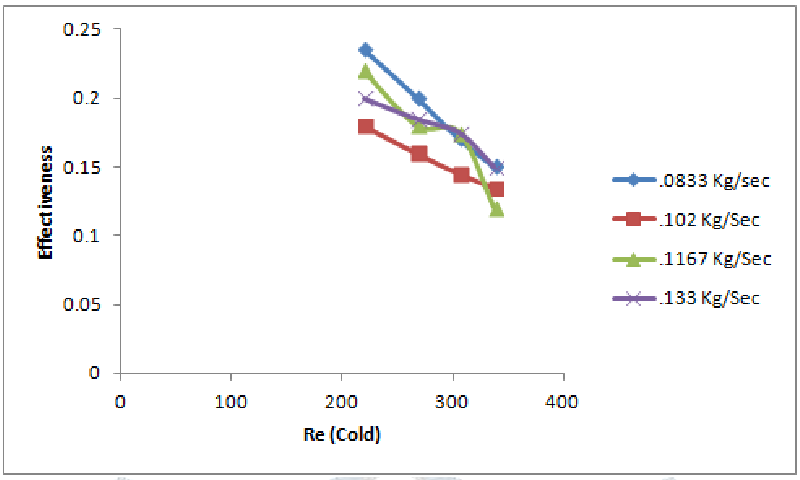

Fig. No.4: Variation of Effectiveness with Reynolds Number for different cold water flow rates for 25% Acetic Acid-Water system (Co- Current Flow)

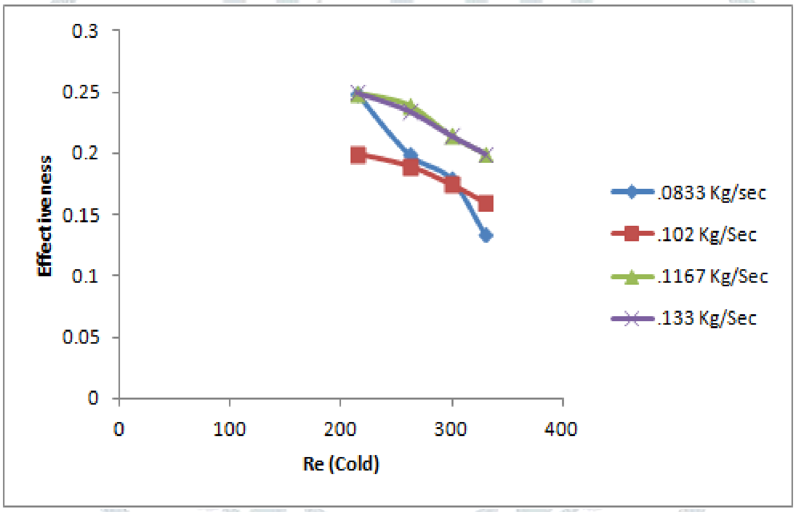

Fig. No.5: Variation of Effectiveness with Reynolds Number for different cold water flow rates for 30% Acetic Acid-Water system (Co- Current Flow)

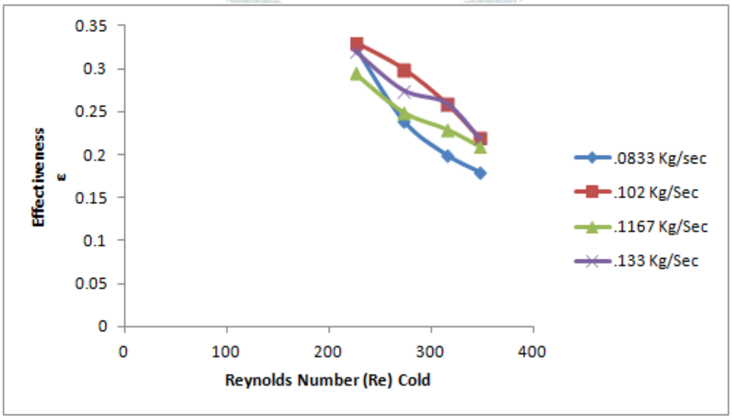

Fig. No.6: Variation of Effectiveness with Reynolds Number for different cold water flow rates for 5% Acetic Acid-Water system (Counter Current Flow)

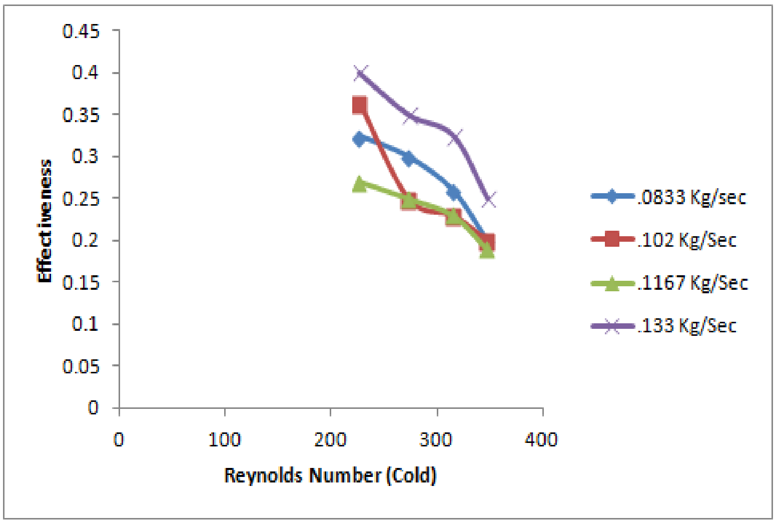

Fig. No.7: Variation of Effectiveness with Reynolds Number for different cold water flow rates for 12% Acetic Acid-Water system (Counter Current Flow)

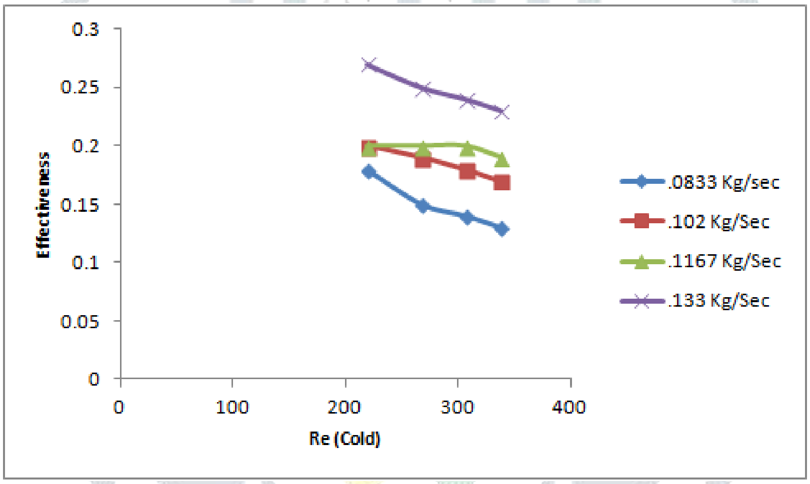

Fig. No.8: Variation of Effectiveness with Reynolds Number for different cold water flow rates for 18% Acetic Acid-Water system (Counter Current Flow)

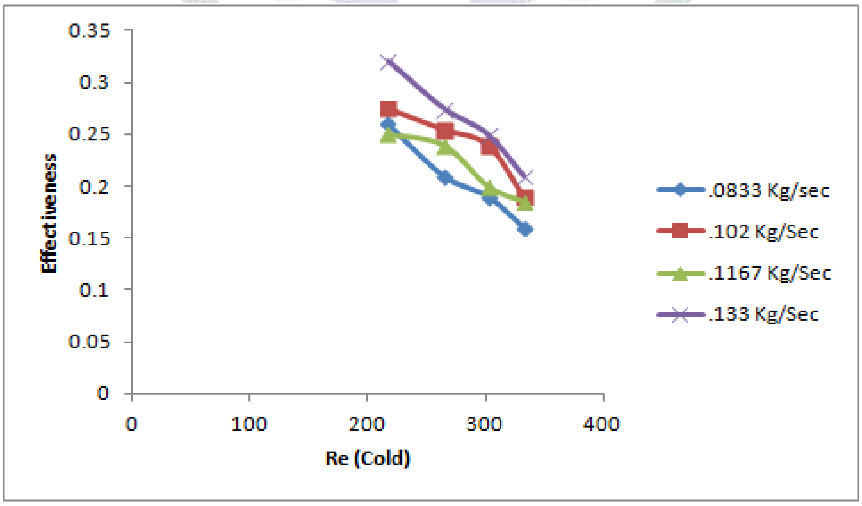

Fig. No.9: Variation of Effectiveness with Reynolds Number for different cold water flow rates for 25% Acetic Acid-Water system (Counter Current Flow)

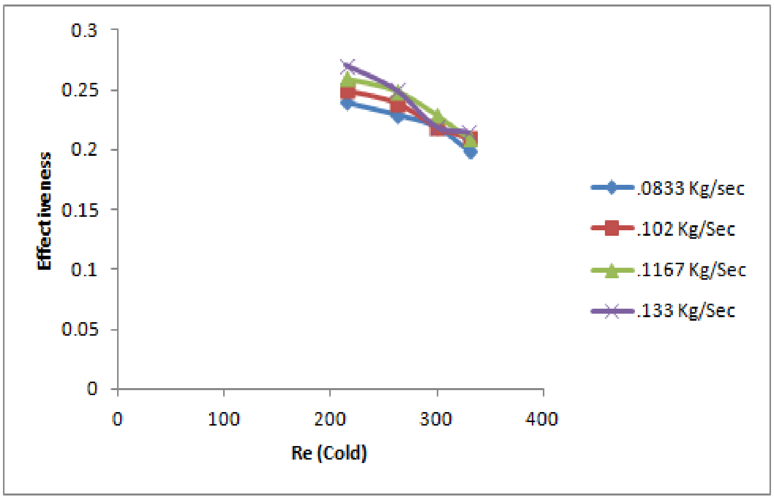

Fig. No.10: Variation of Effectiveness with Reynolds Number for different cold water flow rates for 30% Acetic Acid-Water system (Counter Current Flow)

V. CONCLUSION

Experiments were conducted in a spiral heat exchanger by keeping hot fluid flow rate constant and varying the cold side flow rates for different mass fraction of cold fluid in both co-current flow and counter current flow pattern. Heat transfer effectiveness (ε) with respect to Reynolds Number for four different cold water flow was studied. From the plots it is observed that, the effectiveness (ε) decreases with the increase of Reynolds Number (Re).This is due to higher Reynolds Number the hot and cold water get less time to exchange the heat between them. As a result effectiveness is lower for the heat exchanger.

VI. REFERENCES

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