Comparison of Theoretical and Experimental Overall Heat Transfer Coefficient for Acetic Acid –Water System in Spiral Heat Exchanger

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Abstract

In this paper detail study carried out by performing experiments for comparison of theoretical and experimental overall heat transfer coefficients. Initially designing of spiral heat exchanger was done and then fabricated. Cold fluid is acetic acid water miscible fluid is passed through shell side while hot fluid water is passed through tube side. Experiments were performed where hot fluid mass flow rate was kept constant and cold fluid mass flow rate was varied. From the result obtained comparison of overall heat transfer coefficient experimentally and theoretically.

Keywords — *Spiral heat exchanger, Theoretical overall heat transfer coefficient, Experimental overall heat transfer coefficient.*

I. INTRODUCTION

Heat exchanger is important equipment in chemical industry because of its wide application in process, petroleum, food, dairy industry and other industries. Spiral heat exchangers are widely used due to compact in size and high heat transfer rate. While designing a heat exchanger the most important factor is heat transfer area that decides the space requirement and size of heat exchanger. In spiral heat exchanger due to curvature of tubes centrifugal force is created which increases heat transfer rate. Thus due to less space required and more heat transfer coefficient spiral heat exchangers are preferred.

II. LITERATURE SURVEY

The research was done by Manoj V. et al. on heat transfer enhancement by using nanofluid in spiral plate heat exchanger. They studied heat transfer enhancement using aluminium oxide- water nanofluid in a spiral heat exchanger. They compared experimental results with conventional fluid. They also made numerical analysis with and without Brownian motion. They designed and fabricated and then tested spiral heat exchanger. They investigated heat transfer coefficient for water by varying mass flow rate. They also studied for nanofluid by varying mass flow rate [1]. The research was carried out by M. D. Kathir Kaman et al. on design and analysis of spiral plate heat exchanger for cooling applications. They designed spiral heat exchanger for 7 KW by using dimensions from Milton. They investigated that for spacing, larger width plate is used to satisfy heat and pressure load. Result showed that plate width of 301.92 mm satisfy heat and pressure load. They concluded that passive technique is used for enhancing heat exchanger efficiency, heat transfer coefficient, cost and size is reduced. Finally they concluded that plate width of 301.92mm is required for designing spiral heat exchanger. They also concluded that for smaller spacing large plate width required to satisfy heat and pressure load [2]. The research was carried out by G. N. Deshpande et al. on experimental investigation of performance of spiral coil in spiral tube heat exchanger. They used copper coils by blending straight copper tube of 10 mm inside diameter. They used spiral coils with four turns. Cold water is passed through spiral coil which enters from top and leaves from centre of heat exchanger. Hot water is used as hot fluid entering from the bottom and leaving from the top of the shell. They varied the mass flow rate of hot and cold fluid. They concluded that as the mass flow rate of cold fluid increases the overall heat transfer coefficient increases. They also concluded that Nusselt number and Reynolds number increases with increase in mass flow rate. Finally they concluded that effectiveness decreases with increase in mass flow rate of cold fluid [3]. The study was done by Susheel S. Pote et al. on review of experiment on spiral heat exchanger. They studied the application of spiral heat exchanger in industry due to compact and high heat transfer rate. They studied the experimental methods for comparing spiral heat exchanger with shell and tube heat exchanger. They finally concluded that spiral heat exchanger should be designed so that experiments can be performed to evaluate pressure drop and temperature changes in both fluids on shell side and tube side [4].The research was carried out by Ping Coi et al. on study on in homogeneity of heat transfer in tube side for spiral wound heat exchanger. They studied that due to different radii of spiral calculations done by traditional method does not consider the different radii. They studied that as the radii of spiral heat exchanger is different so traditional method does not give accurate result for these differences. They derived theoretical formula and developed correlation correction equation. They compared experimental results with CFD software. They concluded that median diameter is used to evaluate heat transfer coefficient. They also concluded that due to temperature difference in each layer the heat tansfer coefficient get affected [5]. The research was carried out by Petro Kapustenko et al. on plate and spiral heat exchangers for wet phosphoric acid production processes. They studied two major problems using spiral heat exchanger wet phosphoric acid production that aggressive nature of phosphoric acid and gypsum precipitate on heat exchanger surface. They concluded that effectiveness of heat exchanger can be increased by correct calculation and proper selection of heat transfer surface material and gasket. They also concluded that corrosion resistance and fouling factor should be considered [6]. The research was carried out by Nikhil Lokhande et al. on comparative analysis of spiral heat exchanger and gasketed plate type heat exchanger. They studied for gasketed plate effect of chevron angle of plate on thermal and hydraulic performance. They investigated for 65º and 30º chevron angle for two plates. They found that overall heat transfer coefficient is 86% more by gasketed plate heat exchanger than spiral heat exchanger. They also found that when chevron angle is increased from 65º and 30º pressure drop increases [7].The research was carried out by A.B. Jarzebski on dimensioning of spiral heat exchangers to give minimize the annual cost of heat surface and energy of pump required. They derived equation for exchanger with and absence of distance holder between plate strips for two input data. They finally concluded that properties of fluid affect the parameter of spiral heat exchanger [8]. The research was carried out by R. W. Tapre et al. on heat transfer characteristic of spiral heat exchanger effect of Reynolds number on heat transfer coefficient for acetic acid – water system. They performed experimental study by varying cold water flow rate and keeping the mass flow rate of hot water constant for counter current flow and co-current flow. They calculated values of Reynolds number and heat transfer coefficient. They concluded that heat transfer coefficient increases with increase in cold fluid flow rate [9].The research was done by R. W. Tapre et al. on experimental on experimental analysis of spiral heat exchanger and evaluation of Reynolds number and Nusselt number for acetic acid water system. They varied the concentration of cold fluid from 5% to 30% and mass flow rate from 5lpm to 8 lpm. They concluded that as Reynolds number increases Nusselt number increases linearly for four different cold water flow rates [10]. The research was carried out by R.W.Tapre et al. on experimental study of the effect of the Reynolds number on overall heat transfer coefficient in spiral heat exchanger for acetic acid water system. They performed experiment to calculate overall heat transfer coefficient for co-current and counter current flow in spiral heat exchanger. Cold fluid used as miscible acetic acid water solution. They varied the mass flow rate of shell side fluid while keeping the hot side fluid flow rate constant. They concluded that as the overall heat transfer coefficient increases with the increase in Reynolds of cold fluid. They also concluded that heat transfer is more in counter current flow than co-current flow [11].

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 [11].

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, overall heat transfer co-efficient are obtained [11].

V. RESULT AND DISCUSSION

Experiments have been performed to compare the results experimental and theoretically for overall heat transfer coefficient. Mass fraction of cold fluid 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 (0.0833 Kg/sec to 0.133 Kg/sec) and mass flow rate of cold fluid was varied from 0.0833 Kg/sec to 0.133 Kg/sec [11].Calculations were done and from the experimental and theoretical results graphs were plotted for overall heat transfer coefficient with respect to Reynolds number of the cold fluid are illustrated from Figures 1 to 10 for different mass fraction of cold fluid for co-current and counter flow arrangement in spiral heat exchanger.

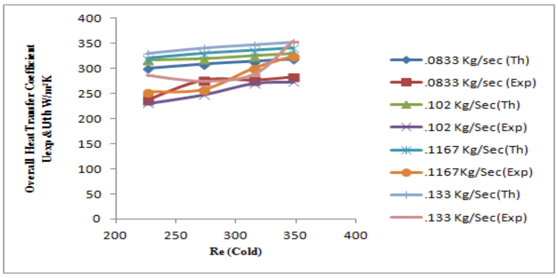

Fig. No.1: Variation of experimental Overall Heat Transfer Coefficient with Theoretical Overall Heat Transfer Coefficient for different cold water flow rates for 5 % Acetic Acid-Water system (Co-Current Flow)

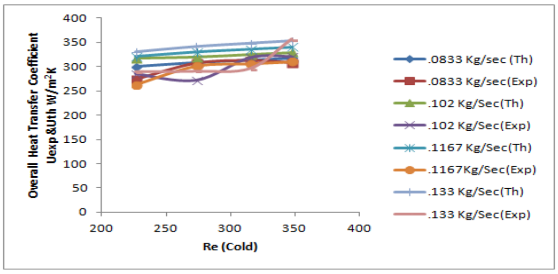

Fig. No.2: Variation of experimental Overall Heat Transfer Coefficient with Theoretical Overall Heat Transfer Coefficient for different cold water flow rates for 5 % Acetic Acid-Water system (Counter-Current Flow)

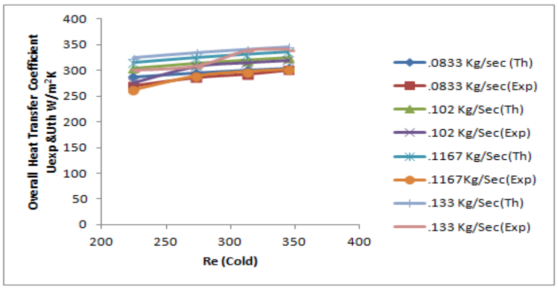

Fig. No.3: Variation of experimental Overall Heat Transfer Coefficient with Theoretical Overall Heat Transfer Coefficient for different cold water flow rates for 12 % Acetic Acid-Water system (Co-Current Flow)

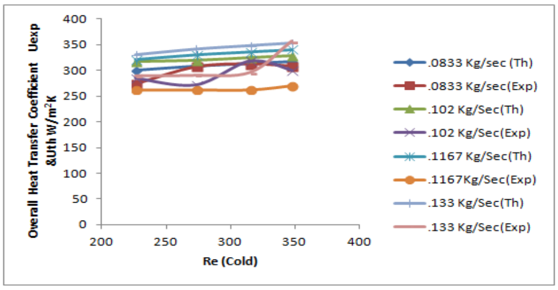

Fig. No.4: Variation of experimental Overall Heat Transfer Coefficient with Theoretical Overall Heat Transfer Coefficient for different cold water flow rates for 12 % Acetic Acid-Water system (Counter Current Flow)

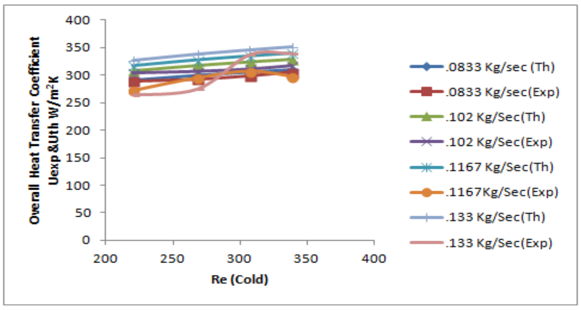

Fig. No.5: Variation of experimental Overall Heat Transfer Coefficient with Theoretical Overall Heat Transfer Coefficient for different cold water flow rates for 18 % Acetic Acid-Water system (Co-Current Flow)

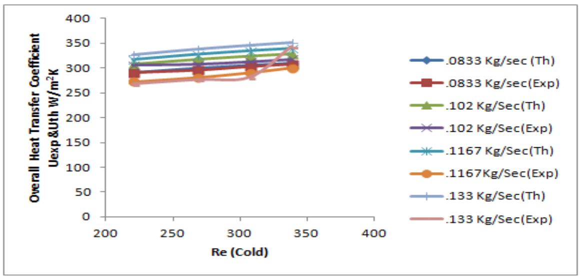

Fig. No.6: Variation of experimental Overall Heat Transfer Coefficient with Theoretical Overall Heat Transfer Coefficient for different cold water flow rates for 18 % Acetic Acid-Water system (Counter Current Flow)

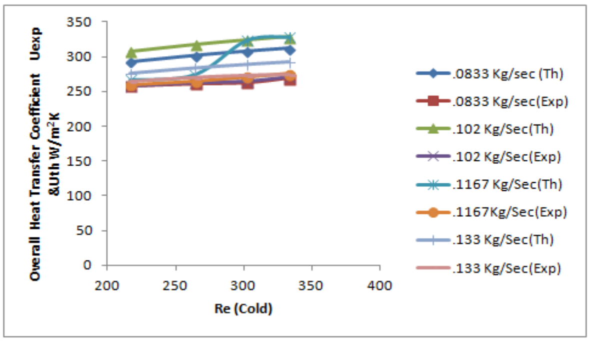

Fig. No.7: Variation of experimental Overall Heat Transfer. Coefficient with Theoretical Overall Heat Transfer Coefficient for different cold water flow rates for 25 % Acetic Acid-Water system (Co-Current Flow)

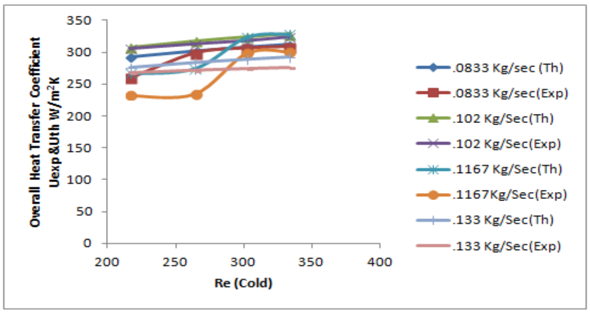

Fig. No.8: Variation of experimental Overall Heat Transfer Coefficient with Theoretical Overall Heat Transfer Coefficient for different cold water flow rates for 25 % Acetic Acid-Water system (Counter Current Flow)

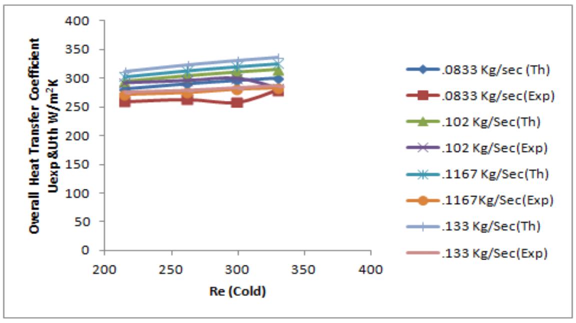

Fig. No.9: Variation of experimental Overall Heat Transfer Coefficient with Theoretical Overall Heat Transfer Coefficient for different cold water flow rates for 30 % Acetic Acid-Water system (Co-Current Flow)

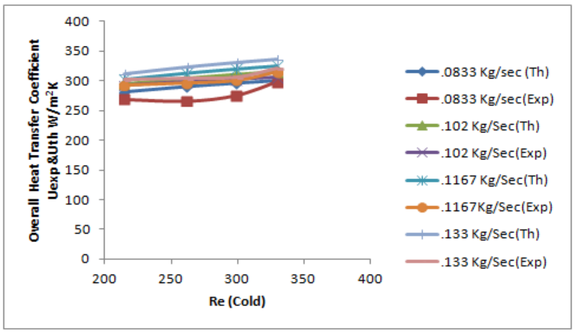

Fig. No.10: Variation of experimental Overall Heat Transfer Coefficient with Theoretical Overall Heat Transfer Coefficient for different cold water flow rates for 30 % Acetic Acid-Water system (Counter Current Flow)

VI. CONCLUSIONS

From the experimental and theoretical results it is concluded that experimental overall heat transfer coefficient less than the theoretical values within ± 20 %. A comparison of theoretical and experimental overall heat transfer coefficient with respect to Reynolds number of cold fluid was made between co-current flow and counter current flow in spiral heat exchanger. The effects of theoretical and experimental overall heat transfer rate on Reynolds number (Re) for four different cold water flow rate is studied. It is observed that the experimental overall heat transfer rate increases with increasing Reynolds number (Re), which is acceptable for the spiral coil heat exchanger. It is also observed that experimental overall heat transfer coefficient is more in counter current flow than co-current flow for the same operating conditions. Thus we conclude that rate of heat transfer is more in counter current flow in spiral heat exchanger.

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