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Simulation Studies on Plate Type Heat Exchanager using ANN

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Abstract :A plate type heat exchanger consists of plates instead of tubes to separate the hot and cold fluids. Because each of the plate has very large surface area, the plates provide each of the fluids with an extremely large heat transfer area. Due to the high heat transfer efficiency of the plates, plate type heat exchanger is very compact when compared to a shell and tube heat exchanger with the same heat transfer capacity. In this paper efforts have been made to study the performance of Plate type heat exchanger with miscible and immiscible systems. The experimental studies involved in the determination of outlet temperature of both cold and hot fluid for various flow rates. The water-water system, water-acetic acid system, water-ethylene glycol system, water-toluene system and water-kerosene system at 9%, 10%, 20% & 25% composition were used to determine the performance of plate type heat exchanger i.e. overall heat transfer coefficient(U), effectiveness(ε), cold side efficiency(η_c) and hot side efficiency(η_h). These experimental data were used to develop neural networks using general regression neural network (GRNN) Model. Further, these networks were tested with a set of testing data and then the simulated results were compared with the actual results of the testing data and found that the experimental data are very close to the simulated data.
Key words: Plate Type heat exchanger, Miscible and Immiscible Systems, Artificial Neural Network

Introduction

A Compact Heat Exchanger has been arbitrarily defined as having an area density greater than $700m^2/m^3$ for units operating in gas streams, and in excess of $300m^2/m^3$ when operating in liquid or two-phase streams[1]. A Plate Type Heat Exchanger consists of plates instead of tubes to separate the hot and cold fluids. Because each of the plate has very large surface area, the plates provide each of the fluids with an extremely large heat transfer area. Due to the high heat transfer efficiency of the plates, plate type heat exchanger is very compact when compared to a shell and tube heat exchanger with the same heat transfer capacity. In the 1930's PHEs were introduced to meet the hygienic demands of the diary industry. Today the PHE is universally used in many fields; heating and ventilating, breweries, dairy, food processing, pharmaceuticals and fine chemicals, petroleum and chemical industries, power generation, offshore oil and gas production, onboard ships, pulp and paper production etc. Plate heat exchanger also find applications in water to water closed circuit cooling water systems using a potentially corrosive primary cooling water drawn from sea, river, lake, or cooling tower, to cool, non-corrosive secondary liquid flowing in a closed circuit. Some of the research works on plate heat exchangers are heat transfer and pressure drop characteristics of an absorbent salt solution in a commercial plate heat exchanger investigated[2] . A Low-Cost Route was developed to Heat Recovery in the Plate Heat Exchangers[3] . A model was developed and described the performance analysis of a cross flow type plate heat exchanger for using as a liquid desiccant absorber (dehumidifier) and indirect evaporative cooler [4] . A method was proposed for calculation, charts and guidelines for selecting plate heat exchanger configurations[5]. An optimization method was developed for determining the best configuration(s) of gasket plate heat exchangers[6] . The Optimal Configuration Design for Plate Heat Exchangers was proposed[7] . The Combined Effects of Inlet Fluid Flow and Temperature Nonuniformity in Cross Flow Plate-Fin Compact Heat Exchanger Using Finite Element Method was proposed[8] .

A general calculation model was proposed for plate heat exchangers[9] . A New Approach for the Prediction of the Heat Transfer Rate of the Wire-on-Tube Type Heat Exchanger–Use of an Artificial Neural Network Model was proposed[10] . To the authors' knowledge and belief, no earlier works have been carried out to study the performance analysis of miscible and immiscible systems in the plate type heat exchanger. The proposed method provides an ideal platform to study the performance of plate type heat exchanger with miscible and immiscible systems.

Performance Analysis of Plate Type Heat Exchanger

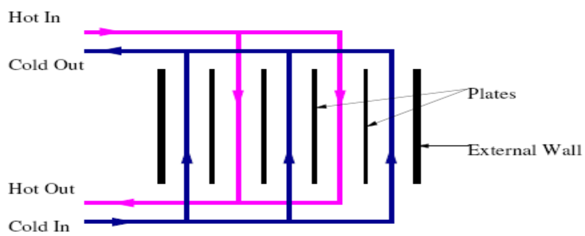


Fig.1. Schematic Diagram of Plate type Heat Exchanger

The schematic diagram of Plate Type Heat Exchanger is shown in the Fig.1. The experimental studies involved in the determination of outlet temperature of both cold and hot fluid for various flow rates. Both parallel flow pattern and counter flow patterns were studied. The Water-Water system, Water-Acetic acid system, Water-Ethylene

Fig.2. Nusselt Number(cold) versus Reynolds Number(cold)

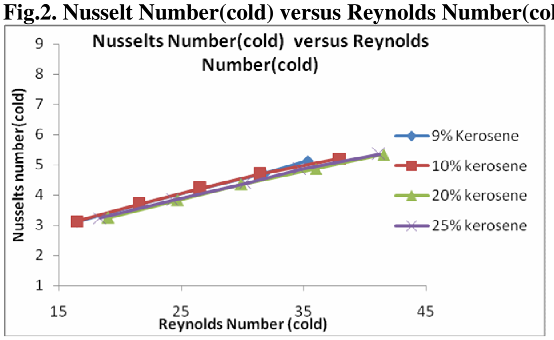
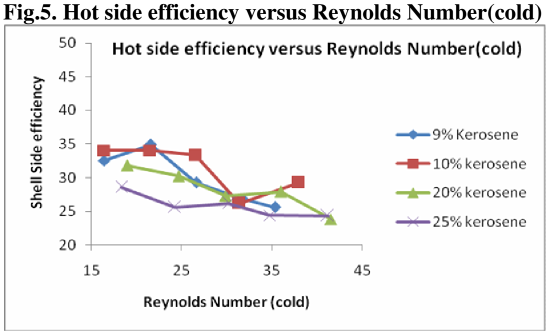


Fig.5. Hot side efficiency versus Reynolds Number(cold)



Glycol system, Water-Toluene system and Water-Kerosene system at various composition of 9%, 10%, 20% & 25% on volume % were used to determine the performance of Plate Type Heat Exchanger i.e. Overall heat transfer coefficient (U_0), Effectiveness(ε), Cold Side Efficiency(η_c) and Hot Side Efficiency(η_h). These experimental data were used to develop Neural Networks using general regression neural network(GRNN) model. Further, these networks were tested with a set of testing data and then the simulated results were compared with the actual results of the testing data. The experimental performance analysis of Kerosene – Water system for Plate Type Heat Exchanger for counter flow pattern is shown in the Fig.2 to Fig.6.

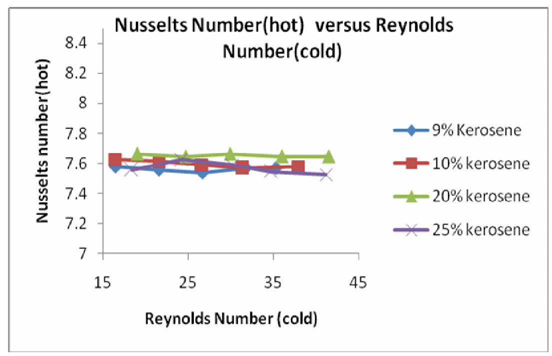


Fig.3. Nusselt Number(hot) versus Reynolds Number(cold

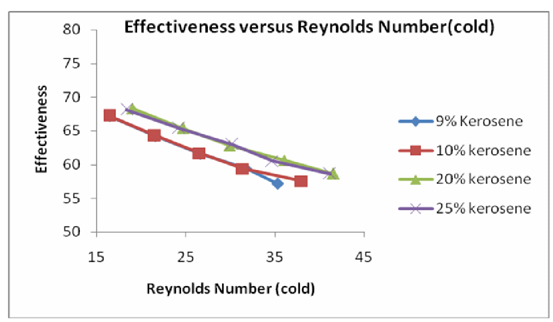


Fig.4. Effectiveness versus Reynolds Number(cold)

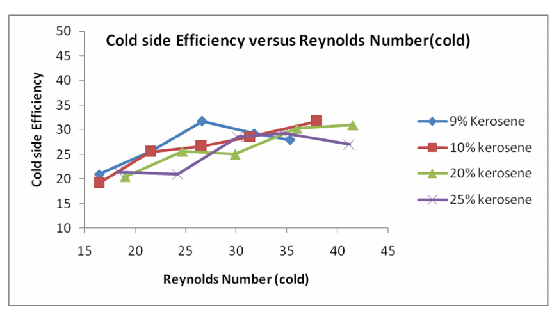


Fig.6. Cold side efficiency versus Reynolds Number(cold

Comparison of simulation output with the experimental data for plate type heat exchanger

The simulation is carried out using ANN[11,12] to predict Nusselt number of the cold fluid (N_{Nu}), Effectiveness (ε), Cold Side Efficiency (η_c) and Hot Side Efficiency (η_h) for the plate type heat exchanger. A comparison is made to show the performance characteristics of Plate type heat exchanger of the simulation output using ANN with the experimental data which is given in Table.1. The table indicates that the simulation results are very well agreed with the experimental data.

Table.1. Experimental and Simulated data for Parallel Flow Plate type Exchanger

EXPERIMENTAL				**SIMULATED**			
Over all heat transfer coefficient, U_o, W/m^2K	Effectiveness **ε** (%)	Hot side efficiency η_h (%)	Cold side efficiency η_c (%)	Over all heat transfer coefficient, U_o, W/m^2K	Effectiveness **ε** (%)	Hot side efficiency η_h (%)	Cold side efficiency η_c (%)
185.55	57.42	46.34	26.82	185.3779	57.4588	46.3415	26.8863
193.18	55.32	44.18	23.25	185.5276	57.4285	46.3418	26.8452
187.88	57.93	28.20	41.02	187.2436	58.0540	28.1242	40.9079
197.45	56.08	26.31	36.84	195.7051	58.3378	27.9299	40.6254
179.87	58.74	35.71	19.04	179.2585	58.8590	35.4333	19.3287
189.84	57.00	36.58	19.51	185.2585	58.8590	35.4333	19.3287
173.06	58.77	37.93	31.11	173.0632	58.7721	37.9333	31.1111
183.14	57.10	45.40	21.42	178.0632	58.7721	37.9333	31.1111
181.53	56.86	35.00	24.82	181.5345	56.8666	35.0000	24.8251
189.57	54.83	37.50	17.32	187.5346	56.8666	35.0000	24.8250
185.51	57.64	25.00	60.00	187.5127	61.1040	24.8502	60.1592
194.66	55.75	27.50	60.00	195.7099	61.4294	26.1158	58.8983
171.03	57.52	47.67	25.00	169.1115	57.9445	47.1695	25.5016
179.66	55.65	47.67	22.50	170.4723	57.6488	47.5263	25.1476
169.14	58.27	20.00	37.50	163.4363	59.4413	19.0811	38.3677
178.01	56.46	22.50	37.50	177.3817	58.6368	19.7140	37.7816
161.88	53.04	25.64	15.38	156.9850	54.1093	24.7363	16.2627
170.20	51.16	25.64	12.82	170.2401	53.4016	25.3388	15.6779
160.47	52.90	20.51	17.94	153.3362	54.6089	20.9901	18.6837
171.11	51.40	23.07	28.20	178.0110	55.7182	20.1226	20.6021
144.25	51.06	12.82	20.51	138.8663	52.2297	11.7126	20.8897
152.10	49.25	12.82	17.94	150.5595	51.8520	11.8968	20.6161
138.46	50.46	12.82	25.64	132.4003	51.7887	12.5269	25.9347
145.61	48.59	10.25	20.51	143.5753	51.5210	12.7422	25.7193
184.11	56.62	28.20	38.28	180.6881	57.3212	27.3501	38.2828
191.77	54.51	28.20	25.46	190.6906	57.3207	27.3504	38.2821
182.34	56.50	48.89	40.84	182.3367	56.5097	48.8899	40.8487
191.18	54.57	43.76	35.71	187.4365	56.9447	47.3589	41.3590
175.47	56.77	15.38	43.58	171.6012	57.5806	15.3065	44.5529
184.18	54.88	17.94	41.02	174.3594	57.0073	15.3833	43.8768
171.69	56.88	28.20	56.41	169.6400	57.2825	27.6916	55.8980
180.27	54.99	30.76	53.84	179.6418	57.2821	27.6923	55.8975

Graphical analysis

In this section the graphical analysis[13] has been carried out to validate the simulated outputs with the experimental data for plate type heat exchanger. The graphs shown below(Fig.7 to Fig.10) indicates the comparisons of the experimental data with the simulated values of overall heat transfer coefficient, effectivess, hot side efficiency and cold side efficiency for parallel flow plate type heat exchanger. It is shown that the simulation results are very well agreed with the experimental data.

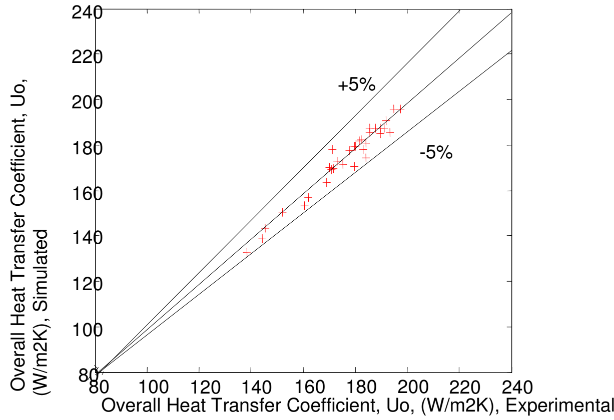


Fig.7. Overall Heat Transfer Coefficient(W/m^{2}K), Experimental Vs Overall Heat Transfer Coefficient(W/m^{2}K), Simulated

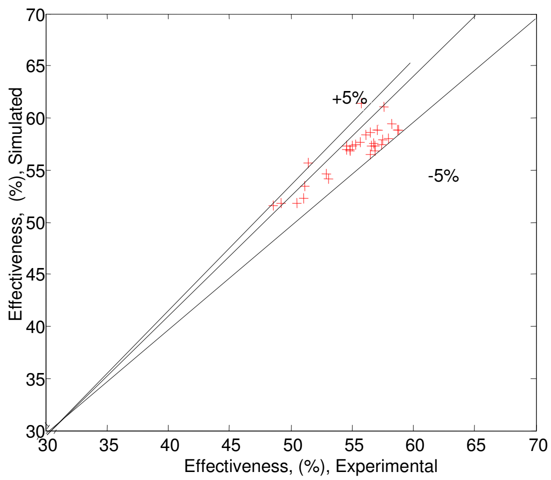


Fig.8.Effectiveness(%), Experimental Vs Effectiveness(%), Simulated

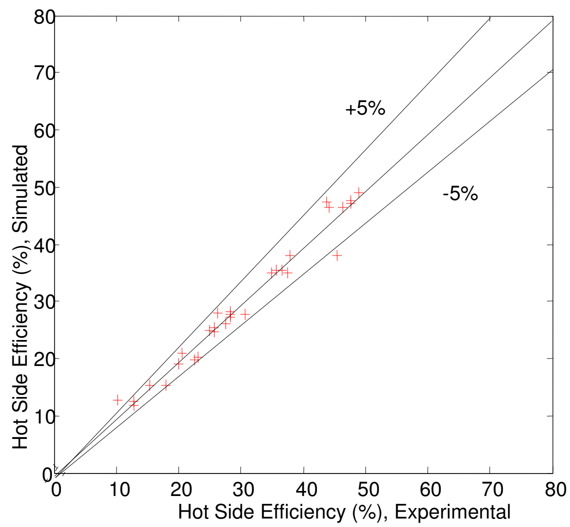


Fig.9.Hot side efficiency(%), Experimental Vs Hot side efficiency(%), Simulated

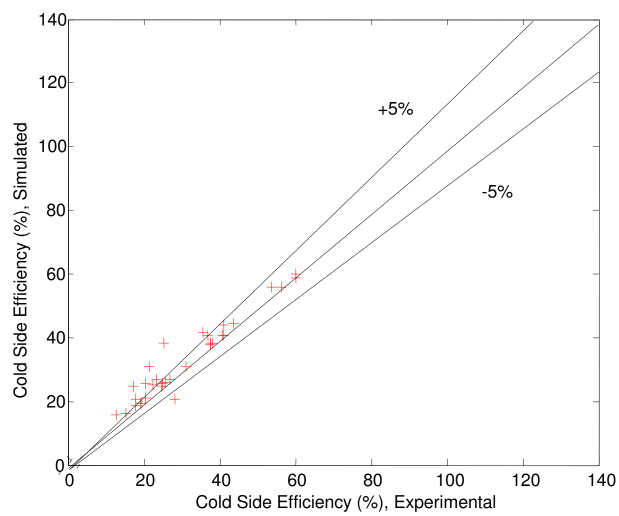


Fig.10.Cold side efficiency(%), Experimental Vs Cold side efficiency(%), Simulated

Comparison between parallel and counter current flow plate type heat exchanger

Comparison with respect to Heat Transfer Coefficient

When the individual heat transfer coefficient increases, the overall heat transfer coefficient increases which in turn increases the Nusselt number of cold fluid. As compared to parallel flow the heat transfer coefficient of counter flow is 10 to 90 % greater for both miscible and immiscible systems of various compositions.

Comparison with respect to Cold Fluid Side Efficiency

The Nusselt number of the cold fluid increases with increase in Reynolds number of the cold fluid for both the flow patterns. But Nusselt number of hot fluid decreases with increase in Reynolds number of the cold fluid. Thus as the Reynolds number increases the cold fluid side efficiency decreases. But when the parallel and counter flow patterns are compared the cold fluid side efficiency shows 2 to 5 % increase in counter flow than in parallel flow.

Comparison with respect to Hot Fluid Side Efficiency

The hot fluid side efficiency increases with increase in Reynolds number of cold fluid for both miscible and immiscible systems. The Nusselt number of cold fluid increases with increase in Reynolds number of cold fluid. The hot fluid side efficiency increases upto 17 % for a counter flow as compared to parallel flow for various compositions for both miscible and immiscible systems.

Comparison with respect to Effectiveness

Experimental results show that when the effectiveness of an heat exchanger is plotted against the Nusselt number of the cold fluid, the effectiveness increases as the mole fraction of the system increases at constant flow rate. This is because the Nusselt number of the cold fluid decreases with the mole fraction of the system. For a counter flow system the effectiveness is found to be higher than a parallel flow system for miscible and immiscible system at various compositions.

Conclusion

Experiments were conducted on a plate type heat exchanger with different mass flow rate of the cold fluid and different compositions (9%, 10%, 20% and 25% on volume basis) for parallel and counter current flow patterns. The effects of these parameters on the cold outlet temperature, hot outlet temperature, individual and overall heat transfer coefficients were studied. The comparison between parallel flow and counter current flow heat exchangers were made. The ANN was applied to predict Nusselts number of the cold fluid (N_{Nu}), Effectiveness (ε), Cold Side Efficiency (η_c) and Hot Side Efficiency (η_h) for the plate type heat exchanger. General regression was used to train and test the network since the target data was continuous. It is shown that the predicted results are close to experimental data by ANN approach.

1. Reay D.A. (2002), 'Compact Heat Exchangers, Enhancement and Heat Pumps', International Journal of Refrigeration, Vol. 25, pp. 460-470.
2. Warnakulasuriya,F.S.K. and Worek,W.M.(2008), 'Heat Transfer and Pressure Drop Properties of High Viscous Solutions in Plate Heat Exchangers', International Journal of Heat and Mass Transfer, Vol.51.. No.1-2., pp 52-67.
3. Lamb,B.R.(1982), 'Plate Heat Exchangers - A Low-Cost Route To Heat Recovery', Heat Recovery Systems, Vol. 2., No. 3., pp. 247-255.
4. Saman W.Y. and Alizadeh S. (2001), 'Modelling and Performance Analysis of a Cross-Flow Type Plate Heat Exchanger for Dehumidification/Cooling', Solar Energy, Vol. 70, No. 4, pp. 361-372.
5. Tadeusz Zaleski and Krystyna Klepacka(1992), 'Plate Heat Exchangers-Method of Calculation, Charts and Guidelines for Selecting Plate Heat Exchanger Configurations', Chemical Engineering and Processing, Vol. 31., pp 49-56.
6. Pinto J.M. and Gut J.A.W. (2004), 'Optimal Configuration Design for Plate Heat Exchangers', International Journal of Heat and Mass Transfer, Vol. 47, pp. 4833-4848.
7. Jorge A.W. Gut and Jose M. Pinto(2004), 'Optimal Configuration Design for Plate Heat Exchangers', International Journal of Heat and Mass Transfer, Vol.47., pp 4833–4848.
8. Ranganayakulu,Ch., and Seetharamu,K.N.(1997), 'The Combined Effects of Inlet Fluid Flow and Temperature Nonuniformity in Cross Flow Plate-Fin Compact Heat Exchanger Using Finite Element Method', Heat and Mass Transfer 32, pp 375–383.
9. Olaf Strelow (2000), 'A General Calculation Method for Plate Heat Exchangers', International Journal of Thermal Science, Vol. 39, pp. 645-658.
10. Yasar Islamoglu(2003), 'A New Approach for the Prediction of the Heat Transfer Rate of the Wire-on-Tube Type Heat Exchanger–Use of an Artificial Neural Network Model', Applied Thermal Engineering, Vol.23, pp 243-249.
11. Arturo Pacheco-Vega, Mihir Sen, Yang,K.T. and Rodney L. McClain(2001), 'Neural Network Analysis of Fin-Tube Refrigerating Heat Exchanger with Limited Experimental Data', Journal of Heat and Mass Transfer, Vol.44, pp 763-770.
12. Bittanti,S. and Piroddi,L.(1997), 'Nonlinear Identification and Control of a Heat Exchanger: A Neural Network Approach', Journal of the Franklin Institute, Vol.334, pp 135-153.
13. Gerardo Díaz, Mihir Sen, Yang,K.T. and Rodney L. McClain.(2001), 'Dynamic Prediction and Control of Heat Exchangers Using Artificial Neural Networks', International Journal of Heat and Mass Transfer, Vol. 44, pp 1671-1679.

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