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Experimental Investigation of Plate Heat Exchanger With Water/Oil Combination

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ABSTRACT— The present work includes development of an experimental setup to evaluate the performance of Plate Heat Exchanger with water/oil combination. Theoretical studies are carried out for the evaluation of heat transfer rate. The study includes experimental investigation of Plate Heat Exchanger with water-oil combination. The parameters that are considered for evaluation are overall heat transfer coefficient, and pressure drop. The plate heat exchanger selected for this study was CB30-34H (CB- Copper brazed, 30- series number, 34- No. of plates, H- high theta channels). The selection of plate heat exchanger was done for 20KW heat duty water/oil system. Studies and experimentation has been carried out for water/oil combination. The analytical and experimental values were compared.

Keywords— Plate Heat Exchanger (PHE), Corrugation, Water/oil combination.

I. INTRODUCTION

1920 (Seligman, 1963, Carlson, 1992). Some patents existed in 1870's in Germany (Clark, 1974). Nowadays PHE's are widely used in a broad range of heating and cooling applications in food processing, pharmaceutical, petrochemical, power, dairy, food & beverage industry, petroleum, pulp and paper, as well as in many water-chilling applications. High efficiency and compactness (i.e., high heat transfer capacity per unit volume compared to others, shell-and-tube heat exchangers), high flexibility for desired load and pressure drop, easy cleaning, and cost competitiveness are some of the basic features of PHE's. In recent times, PHE's are being more commonly used compared to other types of heat exchangers such as shell and tube type in heat transfer processes because of their compactness, ease of production, sensitivity, easy care after set-up and efficiency. Where shell and tube heat exchangers require temperature approach of about 5 °C or more. The temperature approach in PHE may be as low as 1 °C.

Although PHE's became popular for liquid-to-liquid heat transfer duties, their use in phase-changing applications was not common initially. Before the 1990's its applications were mostly in the fields of concentrating liquid food and drying of chemicals. Due to over refrigerant leakage, and also because of the pressure limits required, especially in condensation applications it application in refrigeration systems were rare. Due to the introduction of semi welded and brazed PHE's in the last two decades, it has been increasingly used in refrigeration systems.

The plate heat exchanger consists of a number of metal sheets (corrugated), the gaskets to separate the fluids. The metal sheets are stacked together to form channels for the passage of fluid. The hot fluid flows in one direction in alternating channels while the cold fluid flow in the other alternating channels in counter current manner. The selection of gasket material depends upon the operating condition and type of fluids. The plate heat exchanger basically is a series of individual plates fixed between heavy end cover. Tie bolt is used to tie the entire assembly. The number of plates, their perforation, the type and position of the gaskets and the location of the inlet and outlet connections at the covers characterize the PHE configuration, which further defines the flow distribution inside the plate pack. The flow distribution can be parallel, series or any of their various possible combinations.

II. LITERATURE SURVEY

Gut and Pinto [2003] has developed a mathematical model in algorithmic form for the steady-state simulation of gasketed plate heat exchangers with generalized configurations. The configurations of a plate heat exchanger (PHE) were characterized by a set of six parameters. Based on these parameters, they developed detailed mathematical model for the simulation of a PHE in steady-state with a general configuration in algorithmic form. The authors discuused a simulation example, where the effect of the assumptions on the overall heat transfer coefficient constant were analyzed. Only 0.7% deviation was observed in the two exchanger effectiveness of both the models.

Bhoi et al. [2013] presented an overview. The overview consisted of the recent investigations in the study of thermophysical characteristics of nanofluids and the role of nanofluids in heat transfer enhancement. They found that enhancement of heat transfer can be done by adding nanoparticles to the base fluid.

Javanjal and Parande [2013] carried out experiments to study the effects of different parameters on performance characteristics. The various parameters studies were properties of the fluid, flow rates, turbulence and temperature. Fluids used for experimentation were Ethylene glycol (100%) at 50°C having a constant lower mass flow rate (12 to 14gm / sec.) it was found that *hi* value obtained for 0.58 gasket thickness is 2.2 times that of *hi* value at 1.69 mm, and increase in pressure drop was found to be 7 times than that of at 1.69 mm gasket thickness. In similar way, *hi* improvement is 1.5 times for 0.96 mm gasket thickness and increase in pressure drop is 2.5 times than the values obtained at 1.69 mm gasket thickness. While for 1.06 mm gasket thickness improvement in *hi* is 1.3 times and the increase in pressure drop is 1.4 times.

B Sreedhara Rao et al. [2015] carried out heat transfer studies of corrugated plate heat exchangers (PHEs). Three different corrugation angles of 30^0, 40^0 and 50^0 were used for the study

Akturk et al. [2011] has designed an experimental set-up for determining the characteristics gasketed-plate heat exchanger with chevron plates. Experiments were performed on a plate heat exchanger with 30° chevron angle. Plate heat exchangers with 10 and 21 plates were used with a U type arrangement and one pass for each fluid. Experiments were conducted for different temperatures and flow rates for determining the characteristics change with the Reynolds number and Prandlt number. They found out new Nusselt and friction factor coefficient correlations were found as:

$$Nu = 0.3259 Re^{0.6125} Pr^{1/3} (\frac{\mu}{\mu_w})^{0.14}$$

$$f = 4291\, Re^{-1.278} + 0.3343$$

These correlations obtained can be used between a Reynolds number ranging between 450-5250.

Naik and Matawala [2013] performed experiments to investigate characteristics of chevron type heat exchanger. Different chevron angles and a number of range of Reynolds number were used for the experimentation. They obtained experimental heat transfer data for single phase flow (oil-to-water) configurations in a corrugated plate heat exchanger for different chevron angle plates. The effect of variation of chevron angles with other geometric parameter on the heat transfer coefficient was studied. It was found out that with change in the mass flow rate of oil and water keeping the temperature constant overall heat transfer coefficient changes. Increase in mass flow rate increases the heat transfer coefficient. From the results it was found that 60^{O} chevron plate has better heat transfer coefficient than 45^{O} and 30^{O} plates. The 60^{O} chevron plate has lower pressure drop at same mass flow rate as that of45^{O} and 30^{o} plates. Nusselt number was found to be increased with increasing Reynolds number.

Pinto and Gut [2002] has developed an optimization method. The optimization method was designed for determining the best configuration(s) of gasketed plate heat exchangers. The motive was to select the configuration(s) with the minimum heat transfer area that satisfies the various constraints that are on the number of channels, the pressure drop of both fluids, the channel flow velocities and the exchanger thermal effectiveness. In this work, an optimization method to select a detailed configuration that minimizes the heat transfer area of a PHE is presented. A number of simulation models were used for the exchanger evaluation. A screening procedure was proposed to solve the problem. An example of optimization was presented to find the efficiency of the proposed method. Examples that were discussed show that this algorithm can successfully select a group of optimal configurations for a given application using a very reduced number of simulations. It is also possible to use a variation of the screening method to optimize other objective functions other than the heat transfer area.

1. Design procedure

For designing the experimental set up, first we have to select the plate heat exchanger for a required heat load and temperatures. Once the PHE is select then according to the requirement the other equipments like pumps, rotameters, thermocouples can be selected.

The step by step design procedure is given below. The method used was LMTD method.

1) Calculate the unknown temperatures of the oil and water outlets using heat balance equation.
2) Calculate the LMTD value from the temperatures obtained.
3) From the obtained LMTD value calculate the number of transfer units (NTU).
4) Then calculate the heat transfer area required and the effective heat transfer area.
5) Using these areas the number of plates required can be calculated.
6) After the no of plates are obtained the overall heat transfer coefficient is calculated.
7) Using this heat transfer coefficient repeat the procedure from step 4 unless a constant value for number of plates is obtained.

Table 1 Input parameters

Load	Q	17.5 kW
Water inlet temperature	T_{wi}	30 ^{O}C
Oil (ISO VG 22) inlet temperature	T_{oi}	85 ^{O}C
Oil outlet temperature	T_{oo}	55 ^{O}C
Volumetric flow rate of water	V_w	4 m^3/h

Volumetric flow rate of oil	V_o	1 m^3/h
Specific heat of water	C_{pw}	4180 J/kgK
Specific heat of oil	C_{po}	2040 J/kgK
Thermal conductivity of water	k_w	0.618W/mK
Thermal conductivity of oil	k_o	0.129W/mK
Thermal conductivity of steel	k_{steel}	16 W/mK
Dynamic viscosity of water	μ_w	0.0008kg/ms
Dynamic viscosity of oil	μ_o	0.00803kg/ms

2. Experimental setup

The experimental set up consists of a test section consisting of Plate Heat Exchanger for study of heat transfer coefficient, two rotameters for measuring the flow rates of the fluids, a process fluid tank for heating and storage of process fluid, two centrifugal pump for circulation of process fluid through Plate Heat Exchanger at different flow rates, thermocouples for sensing the temperatures, heater and thermostat, digital indicators. The PHE selected is CB30-34H having 34 number of plates and corrugation angle as 60^O. The rotameters made up of acrylic having maximum discharge of 1800 LPH were used flow measurement of water and oil. A Centrifugal Regenerative pump (Self Priming and Mono Block) of 1 HP having maximum discharge of 1500 LPH was used for water. A gear pump of 1HP having maximum discharge of 1500 LPH was used for oil. A heater of 6KW was used for heating the oil. K type thermocouples were used for temperature measurement of the fluids. Two thermocouples were used for hot oil inlet and outlet temperatures, two for cold water inlet and outlet and one thermocouple was used in the hot oil tank. Digital indicators with 8 channels were used for direct display of temperature in ^{O}C form.

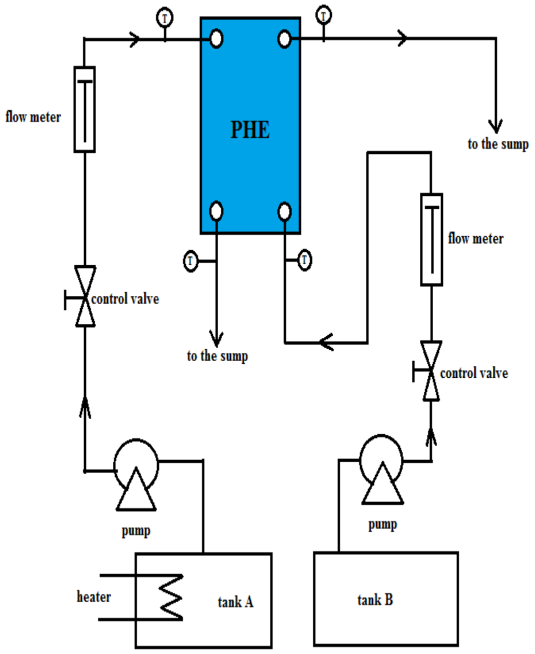

Fig.1 Experimental set up for PHE

3. Experimental procedure

The experimentation on PHE was carried out to study the performance of plate heat exchanger for different flow rates. The experimentation was carried out for water/oil combination at different flow rates. The flow rates of water were varied from 5 to 10 LPM and the flow rates for oil were varied from 5 to 25 LPM. The oil was heated in a tank till the required temperature and water was maintained at atmospheric temperature. The water and oil were passed through the PHE at different flow rates. The required flow rate was achieved using control valves. For different flow rates the inlet and outlet temperatures were obtained using thermocouples. The experimentation is carried out for counter flow arrangement.

Oil is passed through the port having diameter 0.0286m and water is passed through the port having diameter 0.0254m. Oil of grade iso VG22 is used. the heater used is of 6000 W to heat the oil. The experimentation readings for water/water combination were also obtained to study and compare the observations for water/water and water/oil combination.

4. Observations

The observations taken from the experimentation are shown below in the table 2 below. The observation includes the inlet and outlet temperatures of the hot and the cold fluid and the flow rates of the hot and the cold fluid.

Table 2: Inlet and Outlet temperatures (^{O}C) for water/oil combination

Flow rate of water LPM	Flow rate of oil LPM	Hot water temperatures (^{O}C)		Cold Water temperatures (^{O}C)	
		Toi	Too	Tci	Tco
15	8	43.7	34.5	30	30.9
15	12.5	46.2	34.9	30	31.4
15	18	54.2	39.6	30	33.8
15	20	55.9	40	30	34.1

Table 3: Inlet and Outlet temperatures (^{O}C) for water/water combination

Flow rate of cold water LPM	Flow rate of hot water LPM	Oil temperatures(^{O}C)		Water temperatures(^{O}C)	
		Toi	Too	Tci	Tco
15	5	46.5	44.7	42.7	43.8
15	10	47.3	46	42.1	43.4
15	15	46.6	43	41.1	43.4
15	20	46.3	43	41.1	43.7

5. Results and discussions

The experimental results obtained and the analytical values are compared in the table 3 below.

From the comparison it was found that the experimental results vary from the analytical calculations. The experimental values were found to be lower than the analytical calculations. These errors might be due to following:-

- Due to sensing errors of the themperature sensors.
- Due to heat losses to the surrounding.

In analytical calculations the above errors were not considered hence the experimental values were found to be varying from the analytical calculations. The above results show that the heat transfer coefficient increases as the flow rate is increased. And the error in the experimental values is reduced as the flow rate is increased. The error for 8 LPM flow rate is found to be 41% as we increase the flow rate the error is found to reduce. The error for 12.5, 18, and 20 LPM are 14.5%, 15%, 7.23% respectively.

From the fig 5 it can be seen that the heat transfer rate for water/water combination is much higher than that for water/oil combination for higher flow rates. As the flow rates increases the heat transfer rate increases. But for lower flow rates there is no much difference between the heat transfer rates for the water/oil and water/ water combination.

Table 4: Comparison of the experimental and calculated values for water/oil combination

Cold fluid flow rate LPM	Hot fluid flow rate LPM	Hot side			Cold side			U_{cal}	Q	U_{expt}
		Re	Nu	H	Re	Nu	H			
15	8	15	6.81	439	394	12	3807	378	2111	221

15	12.5	23	8.14	525	394	12	3807	440	4052	376
15	18	33	9.88	637	394	12	3807	515	7541	437
15	20	37	10.4	673	394	12	3807	539	9124	500

Table 5: Comparison of the experimental and calculated for water/water combination

Cold fluid flow rate LPM	Hot fluid flow rate LPM	Hot side			Cold side			U_{cal}	Q	U_{expt}
		Re	Nu	H	Re	Nu	H			
15	5	127	14	4478	355	29	9159	2283	620	225
15	10	254	22	7091	355	29	9159	2811	895	189
15	15	381	29	9278	355	29	9159	3101	3724	1265
15	20	508	35	11228	355	29	9159	3292	4552	1728

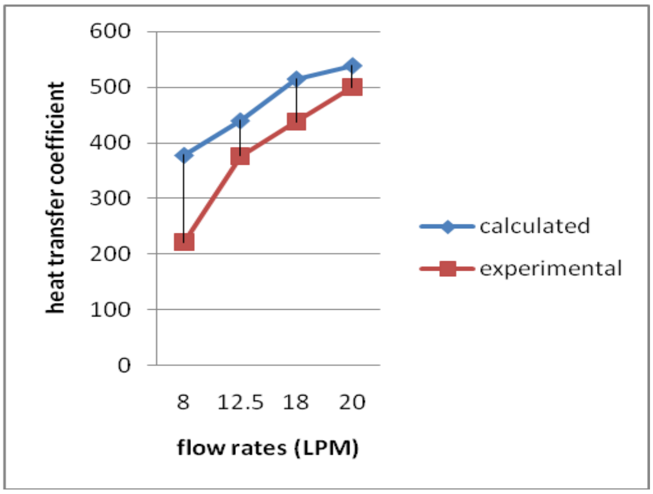

Fig 2 : comparison of experimental and theoretical heat transfer coefficient for water/oil combination

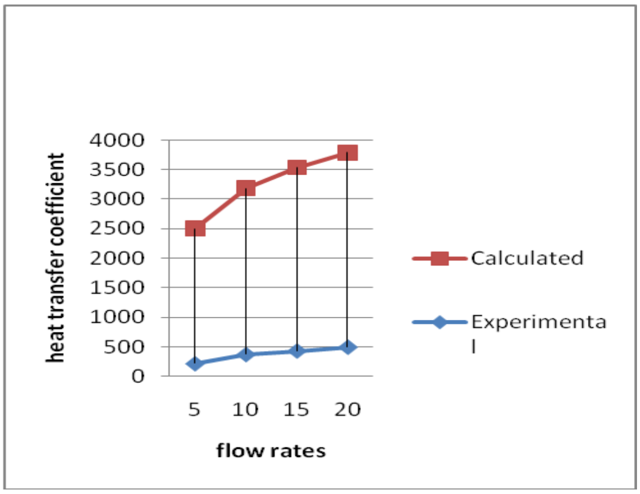

Fig 3 : comparison of experimental and theoretical heat transfer coefficient for water/water combination

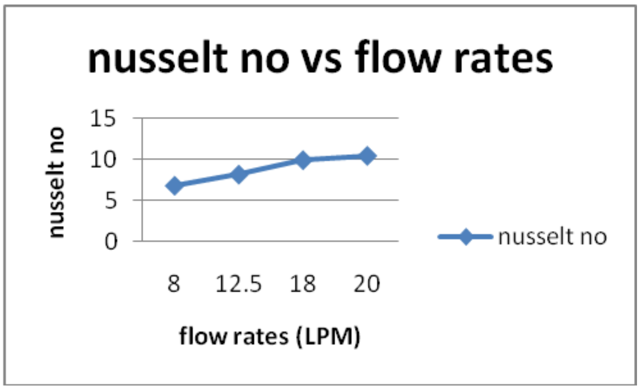

Fig 4: nusselt number variation for different flow rates for water/oil combination

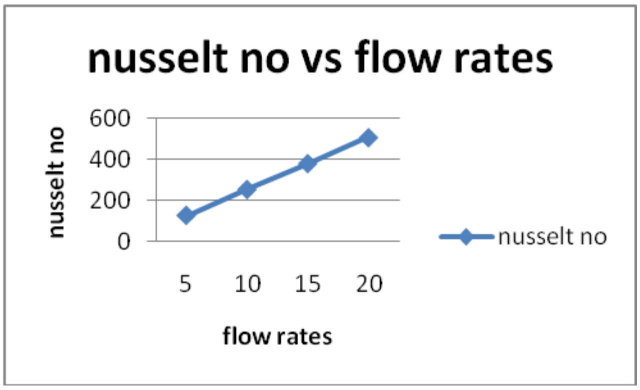

Fig 4: nusselt number variation for different flow rates for water/water combination

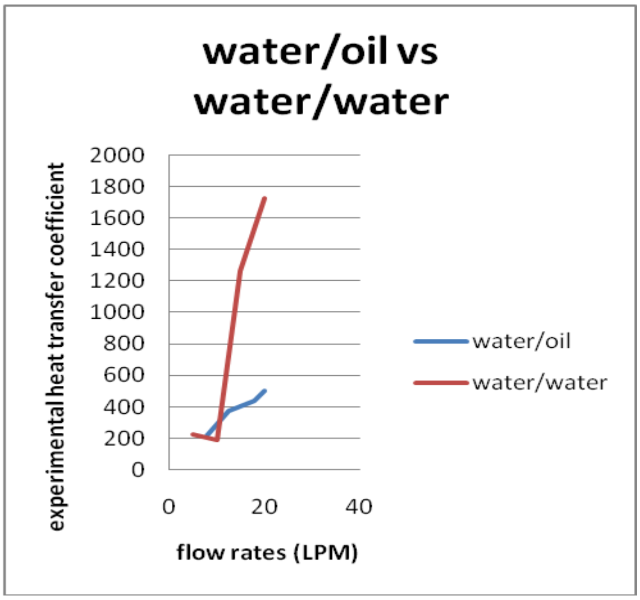

Fig 5 : comparison of experimental heat transfer coefficient for water/water and water/oil combination.

III. CONCLUSIONS

From the study it was found that the experimental results vary from the analytical calculation by about 15%. The main causes of errors are errors in sensing the temperatures, losses in heat due to the surroundings etc. These errors are tolerable. From the present study, we can conclude the Experimental results were very much in agreement with the analytical calculations and our design is a success.

IV. REFERENCES

Jorge A.W. Gut, Jose M. Pinto "*Modeling of plate heat exchangers with generalized configurations*" International Journal of Heat and Mass Transfer

Ramesh Bhoi , Dinesh Dabhi, Chetan Jaiswal "*Investigation on Enhancement of Heat Transfer Using Different Type of Nanofluids – Review"* International Journal of Applied Research & Studies

Jyoti K Javanjal, Madan Parande "*Experimental Studies on Heat Transfer Using Plate Heat Exchanger"* Journal of Chemical, Biological and Physical Sciences.

B Sreedhara Rao, Surywanshi Gajanan D, Varun S, MVS Murali Krishna, R C Sastry; "*Effect Of Corrugation Angle On Heat Transfer Studies Of Viscous Fluids In Corrugated Plate Heat Exchangers*" International Journal of Engineering and Technology Innovation.

F. Akturk, G. Gulben, S. Aradag, N. Sezer Uzol, S. Kakac "*Experimental Investigation of the Characteristics of a Chevron Type Gasketed PHE*" 6th International Advanced Technologies Symposium (IATS'11), 16-18 May 2011, Elazığ, Turkey.

Vishal R. Naik, V.K. Matawala "*Experimental Investigation of single phase Chevron Type Gasket Plate Heat Exchanger"*, International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-4, April 2013.

J.M.Pinto and J.A.W.Gut "*A Screening Method for the Optimal Selection of Plate Heat Exchanger Configurations"* Brazilian Journal of Chemical Engineering ISSN 0104-6632, Vol. 19, No. 04, pp. 433 - 439, October - December 2002

Jorge A.W. Gut, Jos M. Pinto "*Optimal configuration design for plate heat exchangers"* International Journal of Heat and Mass Transfer 47, 2004, 4833–4848

Jorge A.W. Gut, Renato Fernandesa, José M. Pintoa,b, Carmen C. Tadini "*Thermal model validation of plate heat exchangers with generalized configurations"* Chemical Engineering Science 59, 2004, 4591 – 4600

Edris Ebrahimzadeh, Paul Wilding, David Frankman, Farhad, "*Theoretical and experimental analysis of dynamic plate heat exchanger: non-retrofit configuration"* Applied Thermal Engineering 1359-4311, October 2015

A. Lozano, F. Barreras, N. Fueyo, S. Santodomingo, "*The flow in an oil/water plate heat exchanger for the automotive industry"* Applied Thermal Engineering 28 (2008) 1109–1117.

S. Kakac, H. Liu (1998), Heat Exchangers, Selection, Rating, and Thermal Design, *CRC Press, New York*, pp. 283-328.

Richard H. Pletcher, John C. Tannehill, Dale A. Anderson, (2013), Computational Fluid Mechanics and Heat Transfer, *CRC Press*, Third Edition.

F.P. Incropera, D.P. DeWitt, Fundamentals of Heat and Mass Transfer, third ed., Wiley, New York, 1990, pp. 183-213.