International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 4 Issue 5, August 2020 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Experimental and Numerical Investigation of the Influence of the Flow Rate on Heat Transfer Characteristic on the Plate Heat Exchanger

Zaw Htet Win, Mi Sandar Mon

Mechanical Engineering Department, Yangon Technological University, Yangon, Myanmar

ABSTRACT

The paper proposes an experimental and numerical approach of analyzing on the influence of working fluid and mass flow rate on the heat transfer characteristic in plate heat exchanger by performing the experiment on an industrial counter flow plate heat exchanger with 59˚ chevron angle. In this study, numerical results obtained from Aspen HYSYS V10 Exchanger Design and Rating (EDR) were compared with experimental data and showed good arrangement. The effective heat transfer area is 4.2 m^2. Water is used as cold fluid and oil is used as hot fluid with the counter flow arrangement. Cold water flow rate is controlled at different flow rate of 2 m^3/hr, 4 m^3/hr and 6 m^3/hr. Hot oil flow rate is varied from 3.6 m^3/hr to 5.2 m^3/hr. The inlet temperature of cold water and hot oil to heat exchanger were kept constant at 50˚C and 32˚C respectively. The experimental and numerical results show significant effect of flow rate on heat transfer rate, overall heat transfer coefficient, and effectiveness. It is shown that the Aspen HYSYS V10 EDR is a reliable tool for investigation of heat transfer characteristic in the plate heat exchangers at various flow rate.

KEYWORDS: *Aspen HYSYS V10 EDR, Flow Rate, Heat Transfer Rate, Working Fluid, Plate Heat Exchanger*

How to cite this paper: Zaw Htet Win | Mi Sandar Mon "Experimental and Numerical Investigation of the Influence of the Flow Rate on Heat Transfer Characteristic on the Plate Heat Exchanger" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-4 | Issue-5, August 2020, pp.435-439, URL: www.ijtsrd.com/papers/ijtsrd31870.pdf

IJTSRD31870

INTRODUCTION

Energy Saving has been put under high priority around the world and one of the most efficient ways is to recover the heat which is already generated in the process as efficiently and economically as possible. Use of heat exchanger with better thermal efficiency saves on primary energy and also reduce the emissions to environment.

Heat exchangers are equipment that transfer heat from one medium to another. Heat exchanger uses metal plates to transfer thermal energy (enthalpy) between two fluids at different temperature and in thermal contact. The proper design, operation and maintenance of heat exchangers will make the process energy efficient and minimize energy losses.

In literature, there are many researches available on plate heat exchanger. Kanaris et al. [1], studied experimentally and numerically the flow and heat transfer in a two-channel plate heat exchanger (PHE), to predict flow characteristics, pressure losses and heat transfer in two-channel PHE. Iulian Gherasim et al. [2], studied an experimental investigation for heat transfer and fluid flow in a plate heat exchanger. This paper described an experimental investigation on the thermal field in a two channel chevron-type plate heat exchanger for laminar and turbulent flow conditions.

N. Manigandan et al. [3] studied a numerical investigation of a chevron type brazed plate heat exchanger. This paper provides a numerical simulation of brazed plate heat exchanger at an element by element along to a length of a plate. N. Manigandan et al. [4] studied an experimental investigation of a chevron type brazed plate heat exchanger, this paper provides a thermal characteristics of the fluid by using various no of plates, several fluid flow rate and inlet and outlet temperature values.

U. K. Nayak et al [5] studied the experimental investigation of brazed plate heat exchanger (corrugated plate). This paper described the average heat transfer between two liquid increases with the increase in hot water flow rate. The overall heat transfer coefficient U, the temperature difference between two stream at outlet are also present.

In the present work, the effect of mass flow rate on heat transfer rate, heat transfer coefficient in the hot channel of industrial heat exchanger have been investigated.

Sharifi et al. [9] numerically analysed a plate heat exchanger with counter-flow arrangement in steady state and transient conditions. They used different numerical methods to predict the temperature distribution in steady state condition as well as fluid temperatures at exit of flow channels in transient condition. They also validated their numerical results by comparing them to experimental results in a test rig using specially designed flat plates.

Galeazzeo et al. [11] studied heat transfer in plate heat exchanger experimentally and numerically. Computational fluid dynamics tool was used to build the virtual prototype of the plate heat exchanger with four channels and flat plates. Temperature and velocity distribution for the channels were presented and compared with experimental data.

EXPERIMENTAL SETUP AND PROCEDURE

A. Experimental Setup

The experimental work has been performed in the Safe-Life Process Plant which is situated in Uniteam Training, No-85, Pan Haling Street, Sanchaung Township, Yangon.

The schematic diagram of experimental setup is shown in Fig. 1. The experimental facilities in this study include (1) cold water storage tank, (2) hot oil storage tank with immersion heater, (3) centrifugal pumps, (4) flow control valve, (5) flowmeters, (6) temperature transmitters, (7) real time data logger. Experimental setup is carried out by using a commercial Alfa Laval M6-FG plate heat exchanger with chevron angle 58° stainless steel plates. Cold water and hot oil exchange the heat through heat exchanger with the counter flow arrangement as shown in Figure 1.

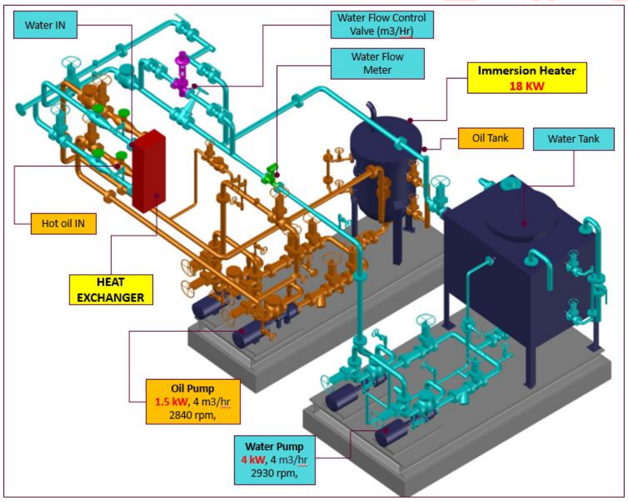

Fig.1 Graphical 3D model of experimental setup

The process flow diagram of the heat exchange between cold water and the hot oil through plate heat exchanger is shown in Figure 2. Photographic view of the experimental setup is shown in Figure 3.

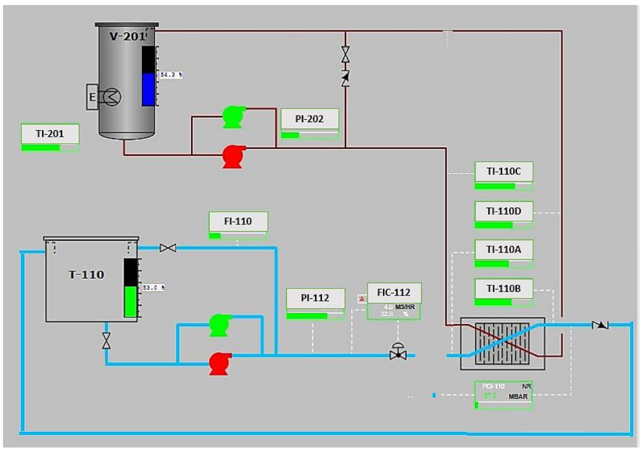

Fig.2 Process flow diagram of experimental setup

The capacity of the cold water tank is 1.4 m^3 and the capacity of the hot oil tank which is fitted with 18 kW heater as heat source is 0.37 m^3. Hydraulic oil 32 is used as hot oil and the temperature of the hot oil is controlled at 50°C by the thermostat. The centrifugal pump with the capacity of 4 KW is circulated the cold water from the water tank and hot oil re-circulation is done by 1.5 KW centrifugal pump. Four YOKOGAWA temperature transmitters are installed at the inlets and the outlets of the plate heat exchanger and one YOKOGAWA temperature transmitter is installed at the oil tank to monitor the temperatures at these locations. The two YOKOGAWA pressure differential transmitters are installed at the heat exchanger inlet and outlet of cold water and hot oil to monitor the pressure drop.

The flow velocity of cold water to the heat exchanger is controlled by using Flowserve automatic flow control valve installed at the inlet line of heat exchanger. The YOKOGAWA electromagnetic flow meter is installed at the cold water inlet of the heat exchanger to monitor the flow rate. The flow velocity of hot oil in the heat exchanger is controlled by using the manual valves and YOKOGAWA vortex flow meter is installed at the hot oil outlet line of heat exchanger to monitor the flow rate. The temperature variations of the heat exchanger at different flow rate are monitored and collected using a real time data logger.

Fig.3 Photographic view of the experimental setup

B. Experimental Procedure

The 1.5 kW oil pump is switched on to start the oil closed loop circulation. Then 18 kW immersion heater in the oil tank is switched on to heat up the circulated oil. The oil temperature in the oil tank is controlled at 50°C by using a thermostat. Sufficient time is given to the system in order to achieve the desire set temperature. The hot oil flow rate is adjusted at desired flow rate by adjusting the manual flow control valve and flow rate is monitored by Vortex flow meter installed at the downstream of the heat exchanger. Two oil pumps are run in parallel in order to increase the flow rate from 3.6 m^3/hr to 5.2 m^3/hr.

Then cold water pump is started and desired flow rate of cold water is controlled at 2 m^3/hr, 4 m^3/hr and 6 m^3/hr respectively by Flowserve automatic flow control valve and monitored by electromagnetic flow meter. The inlet and the outlet of the plate heat exchanger are monitored by YOKOGAWA temperature transmitters installed at inlet and outlet lines of heat exchanger and also at the oil tank. Pressure drop of the cold and hot fluid channels is monitored by the YOKOGAWA pressure differential transmitters. The different flow rate of hot and cold fluid and temperature at the inlet and outlet of the plate heat exchanger are monitored and recorded in the real time data logger.

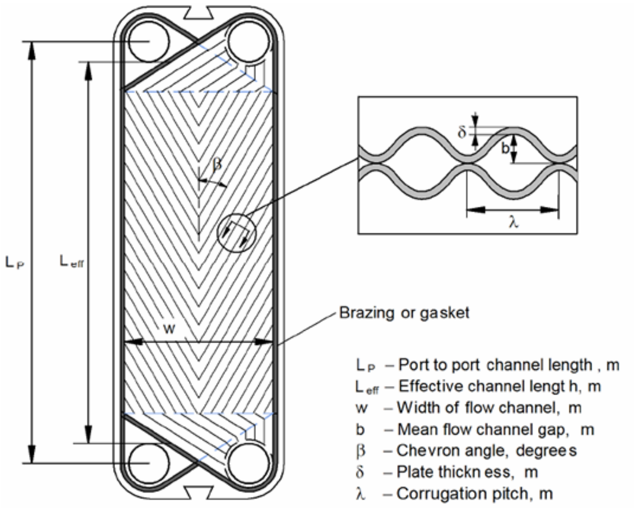

Fig.4 Geometry and parameter of Alfa Laval M6-FG Plate

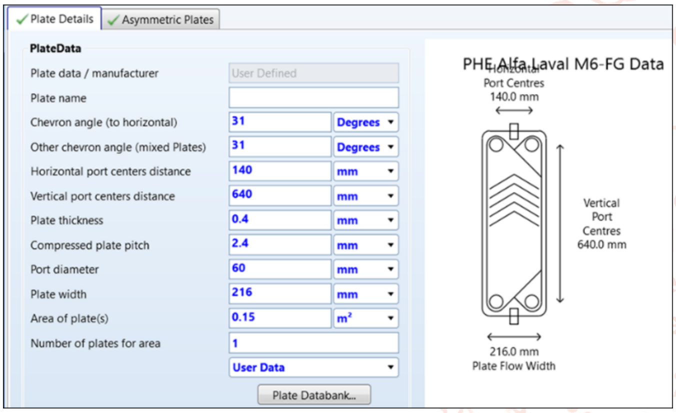

Fig.5 Input parameter of plate heat exchanger to Aspen Software

The heat absorbed by cold water Qc and the heat removed from the hot oil Q_h are calculated by equations (1) and (2).

$Q_c = m^{\circ} C_{p,\, water}\, \Delta T_c$ Equitation (1)

$Q_h = m^{\circ} C_{p,oil}\, \Delta T_h$ Equitation (2)

Where m° is the fluid mass flow rate, C_p is a specific heat at constant pressure and ΔT is the difference in fluid temperature between inlet and outlet of heat exchanger.

The overall heat transfer coefficient is defined as

$U = \frac{Q}{A.LMTD}$ Equitation (3)

Where A is the effective heat transfer surface area and LMTD is the log-mean temperature difference for counter flow arrangement.

Results and Discussion

Experiment are run with six case as per below table 1.1. In each experimental run, the temperature distribution of the fluid outlet of the heat exchanger at different flow rates of cold water (2 m^3/hr, 4 m^3/hr and 6 m^3/hr) are recorded with the respective hot oil flow rate of 3.6 m^3/hr and 5.2 m^3/hr. The inlet temperature of cold water and hot oil to heat exchanger are maintained for constant temperature of 32 ° C and 50° C at different flow rates.

Table 1.1 Parameter for the Cases

CASE	Th,in	Th,out	Tc,in	Tc,out	Qh	Qc
Oil - Water	˚C	˚C	˚C	˚C	m³/hr	m³/hr
1	50	40.4	32	38.5	3.6	2
2	50	38.3	32	36.2	3.6	4
3	50	37.7	32	34.3	3.6	6
4	50	41.8	32	40.2	5.2	2
5	50	39.7	32	37.1	5.2	4
6	50	39.2	32	35.2	5.2	6

A. Effect of flow rate to fluid outlet temperature and ΔT

It is observed from the figure 6 that the cold water outlet temperature is decreased as increasing flow rate of cold water for both oil flow rate of 3.6 m^3/hr and 5.2 m^3/hr. The outlet temperature of cold water is higher in higher flow rate of hot oil. Maximum cold water outlet temperature difference between experimental results and numerical result is 1.5˚ C.

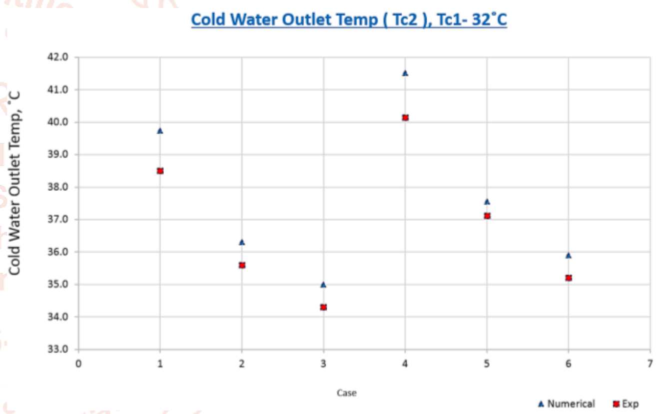

Fig. 6 Cold water outlet temperature vs flow rate

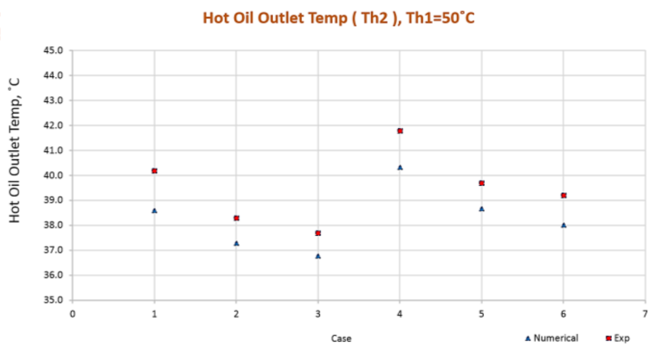

Fig. 7 Hot oil outlet temperature vs flow rate

Figure 7 shows the effect of variation of flow rate of water on outlet temperature of hot oil for different flow rate of oil. It is found that the outlet temperature of hot oil is decreased as increasing in flow rate of cold water for both oil flow rate of 3.6 m^3/hr and 5.2 m^3/hr. The outlet temperature of hot oil is higher in lower flow rate of hot oil. Maximum hot oil outlet temperature difference between experimental results and numerical result is 1.5˚ C.

Figure 8 shows the effect of variation of flow rate of water on temperature difference between outlet and inlet of cold water. It is found that the temperature difference between outlet and inlet of cold water is decreased as increasing in flow rate of cold water for both oil flow rate of 3.6 m^3/hr and 5.2 m^3/hr. The temperature difference between outlet and inlet of cold water is higher in higher flow rate of hot oil. Experimental and numerical results show similar.

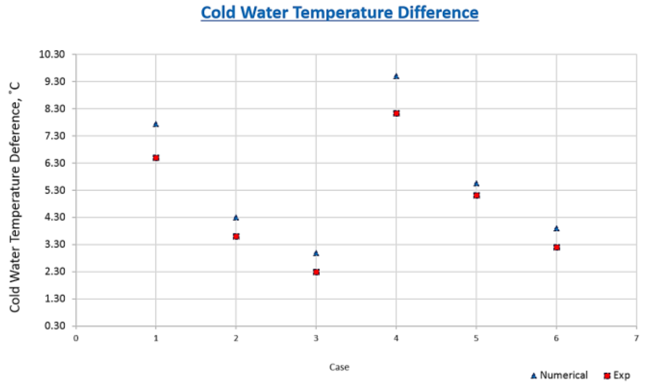

Fig. 8 Effect of flow rate on ΔT cold water

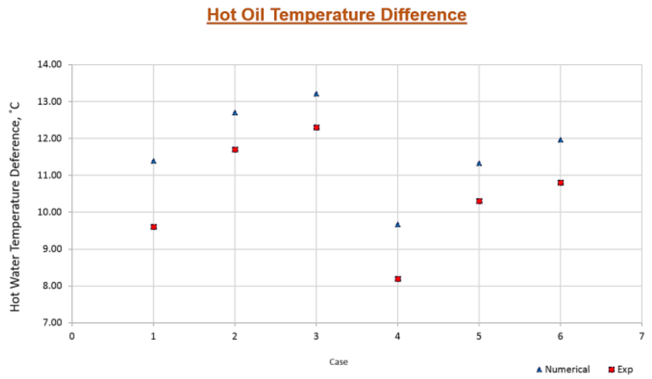

Fig. 9 Effect of flow rate on ΔT hot oil

Figure 9 shows the effect of variation of flow rate of water on temperature difference between outlet and inlet of hot oil. It is found that the temperature difference between outlet and inlet of hot oil is increased as increasing in flow rate of cold water for both oil flow rate of 3.6 m^3/hr and 5.2 m^3/hr. The temperature difference between outlet and inlet of hot oil is higher in higher flow rate of hot oil.

B. Effect of fluid flow rate on overall heat transfer coefficient and heat transfer rate

Figure 10 shows the effect of variation of flow rate of water on the overall heat transfer coefficient of heat exchanger. It is found that the overall heat transfer coefficient of plate heat exchanger is increased as increasing in flow rate of cold water for both oil flow rate of 3.6 m^3/hr and 5.2 m^3/hr. The overall heat transfer coefficient is higher in higher flow rate of both fluids.

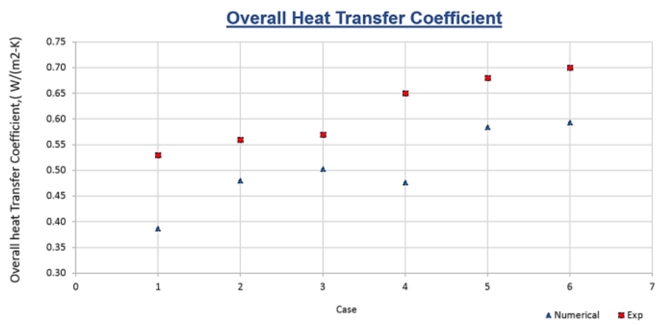

Fig.10 Overall heat transfer coefficient vs flow rate

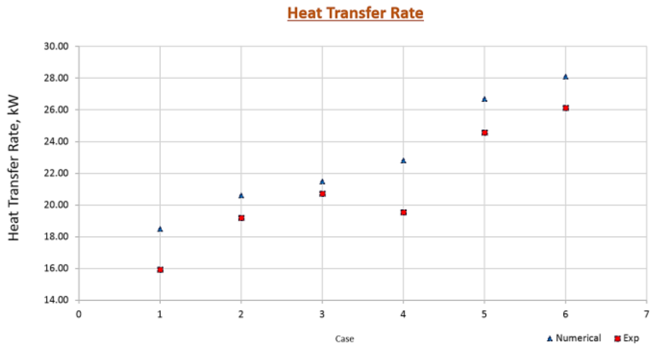

Fig. 11 Heat transfer rate vs flow rate

Figure 11 shows the effect of variation of flow rate of water on the heat transfer rate of hot oil. It is found that the heat transfer rate of is increased as increasing in flow rate of cold water for both oil flow rate of 3.6 m^3/hr and 5.2 m^3/hr. The heat transfer rate is higher in higher flow rate of both fluids.

Effectiveness of plate heat exchanger

Figure 12 shows the effect of variation of flow rate of water on effectiveness of plate heat exchanger. It is found that the effectiveness of plate heat exchanger is increased as increasing in flow rate of cold water for both oil flow rate of 3.6 m^3/hr and 5.2 m^3/hr. The effectiveness of plate heat exchanger is higher in higher flow rate of hot oil.

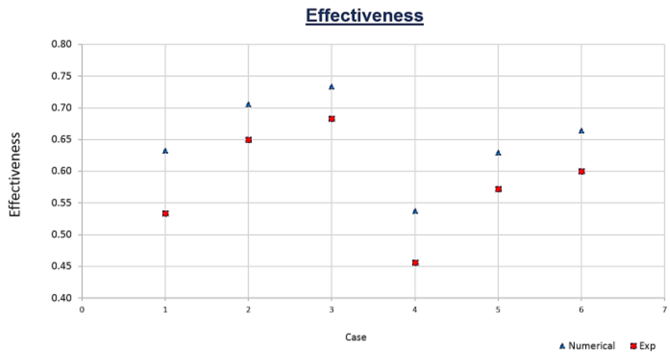

Fig. 12 Effectiveness of plate heat exchanger

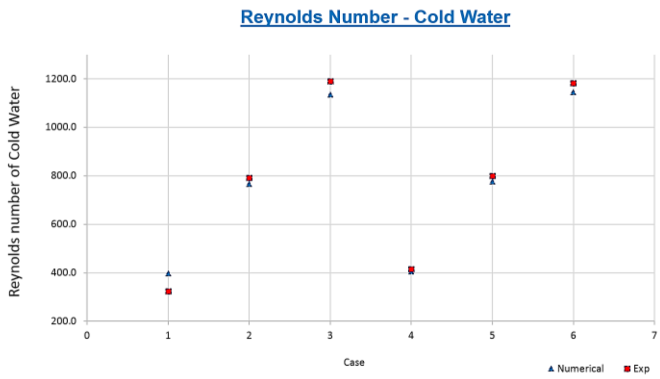

Fig. 13 Effect of flow rate on Reynolds number of cold water

Figure 13 shows the effect of variation of flow rate of water on Reynolds number of cold water. It is found that the Reynolds number of cold water is increased due to viscosity of water is decrease as increasing in flow rate of hot oil.

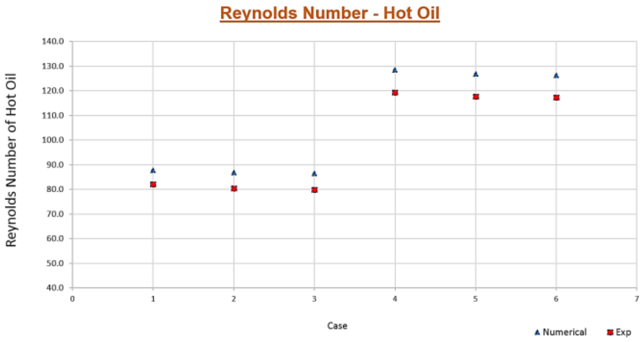

Fig. 14 Effect of flow rate on Reynolds number of hot oil

Figure 14 shows the effect of variation of flow rate of cold water on the Reynolds number of hot oil. It is found that the Reynolds number of hot oil is decreased due to viscosity is increasing as increasing in flow rate of cold water.

Conclusion

In the present work, the influence of the fluid flow rate on heat transfer and pressure drop on industrial plate heat exchanger have been studied by experimentally. It is concluded that the flow rate has a significance effect on heat transfer rate of the heat exchanger for hot and cold side. When the flow rate of hot oil is increased, the heat transfers co-efficient of hot side is also increased by keeping the flow rate of water constant. Overall heat transfers co-efficient is increased with the increasing in flow rate of both fluids. The highest cold water outlet temperature is received by the lowest the flow rate of cold water and the higher the flow rate of hot oil. The pressure drop through heat exchanger is increased as the flow rate is increased. Numerical results are found to be in good agreement with experimental results with the maximum and minimum deviation of ±10% and ±1% respectively in temperature.

Acknowledgment

The author acknowledges with honour to his supervisor, Professor and Head of Mechanical Engineering Department, YTU for her valuable guidance and encouragement to perform this paper. A special thanks is also due to Mr. Paul Van Empel, MD of Uniteam Training for all his supports and suggestions to this experiment.

References

[1] A. G. Kanaris, A. A. Mouza, S. V. Paras, Flow and Heat Transfer in a Corrugated Plate Heat Exchanger using a CFD code, Chem. Engg. Tech. 29(8) (2006) 923-930.

[2] Iulian Gherasim, Matthew Taws, Nicolas Galanis, Cong Tam Nguyen, Experimental investigation for Heat transfer and fluid flow in a plate heat exchanger, International Journal of Thermal Sciences. 50 (2011) 1492-1498.

[3] N. Manigandan, M. Suresh, Numerical Investigation of a Chevron Type Brazed Plate Heat Exchanger, Applied mechanics and materials journal, ISSN No: 16609336

[4] N. Manigandan, V. NaveenPrabhu, Experimental Investigation of a Brazed Chevron Type Plate Heat Exchanger, International Journal of Research in Science and Engineering, ISSN No: 2349784X

[5] U. K. Nayak, Sumit Kumar, Chandan Kumar Experimental Investigation of Brazed Plate Heat Exchanger, International Journal of Research in Science and Engineering, Volume No.07, Special issue No.07, March 2018. ISSN No.2319-8354

[6] Sharifi, F., Narandji, M. R. G., and Mehravaran, K. 1995. "Dynamic Simulation of Plate Heat Exchangers." *International Communications in Heat and Mass Transfer* 22 (2): 213-25.

[7] Dwivedi, A. K., and Das, S. K. 2007. "Dynamics of Plate Heat Exchangers Subject to Flow Variations." *International Journal of Heat and Mass Transfer* 50 (13): 2733-43.