

Analysis of effectiveness of heat exchanger shell and tube type one shell two tube pass as cooling oil

Farel H. Napitupulu*, Romulus Situmorang and H V Sihombing

Mechanical Engineering Department, Faculty of Engineering, Universitas Sumatera Utara, Jl. Almamater, Kampus USU, Medan, 20155, Indonesia

*farelnapitupulu@yahoo.com

Abstract. Heat exchanger is a device that produces heat transfer from a fluid to another fluid, which can be applied as a cooling oil to maintain the oil temperature at the operating standard. This study was conducted to determine whether the oil temperature exit the shell and tube heat exchanger one shell and two tube pass, by calculating the effectiveness of the cooling oil on the tube (tube) using water as cooling fluid flowing through the shell (shell) using NTU- ϵ and experimental studies. Shell and tube heat exchanger one shell and two tubes pass effective used to cooling oil, because it can reduce oil temperature up to 32 %.

1. Introduction

In modern times the application of knowledge about heat transfer has developed rapidly because it is needed in everyday life. In this case the heat exchanger is one of the most widely used applications, where a heat exchanger is a device that produces heat transfer from a fluid to another fluid. Because of its very important function, shell-and-tube heat exchangers are widely used in the power plant and chemical engineering [1-2], refrigeration [3], heat pump[4], solar drying [5]and waste heat recovery due to their robust geometry construction, reliable operation, easy maintenance and possible upgrades.

Knowledge of the characteristic of heat exchanger is important before it applied. Aman Singh Rajpoot et al, optimized of finned tube oil cooler for turbin guide bearing application by effective utilization of area so as to extract and deliver more heat as compared to the existing system [6]. Srinivasa Rao and Kalyani, analys shell and tube heat exchanger with different fluid flow. The research overall performance of shell and tube heat exchanger operated with hot water-cold water, hot kerosene-cold water and hot oil transformes-cold water, from the research result that hot oil transformer-cold water was the best combination with heat transfer coefficient 5875.35 W [7]. Sumit S Mukadam et al, analysis using shell and tube heat exchanger with various parameters such as pitch layout and baffle spacing on the oil cooling. In the study, comparing the results obtained from experimental prosedure and simulation approach. Heat exchanger can decrease hot oil temperature 26°C [8]. Yuxin and Zhihua Wang studied on the heat transfer characteristics of a shell and tube phase change energy storage heat exchanger. In this study, heat transfer characteristic of shell and tube heat exchanger by using a comercial code computational fluid dynamic (CFD). Using shell and tube heat exchanger can reduce 30%-40% of temperature [9]. M Zebua and Ambarita simulated the efect of baffle spacing to the effectiveness of a shell and tube heat exchanger. Baffle spacing having higer impact to increase effectiveness of shell and tube heat exchanger [10]. Yan Li et al.investigated the flow filed and the heat transfer characteristics ofa shell and tube heat exchanger for syngas cooling. The result show that the higher operation pressure can improve the heat transfer and space between baffles can decrease the resistance effectively

[11]. Observed heat transfer and effectiveness-number of transfer units for different volume concentrations of Fe_3O_4 nanofluids flow in inner tube of a double pipe U-bend heat exchanger with different pitch ratios of wire coil with core-rod (WCCR) inserts. The double pipe U-tube heat exchanger has an inner tube diameter of 0.019 m and an annulus tube diameter of 0.05 m with a length of 5 m [12].

Study mainly focused on the oil cooler is basically shell and tube heat exchanger type one shell and two tube pass. Water is used as cooling agent because of its higher specific heat capacity, density and thermal conductivity. In this research variation rate flow of water 180 l/hour, 300 l/hour, 420 l/hour, 540 l/hour. The temperature inlet and temperature outlet of oil and water will measure. Temperature of oil and effectiveness of shell and tube heat exchanger type one shell and two tube pass are proposed based on the experimental data.

2. Solution Method

In this study the design used in the process is an experimental method and is a qualitative research that clearly describes the experimental results from the laboratory against previously determined variables, with the aim of analyzing the effectiveness of shell and tube type heat exchanger with one shell and two tube passes as oil cooling. Figure 2.1 below shows schematic of the experimental setup of the shell and tube exchanger.

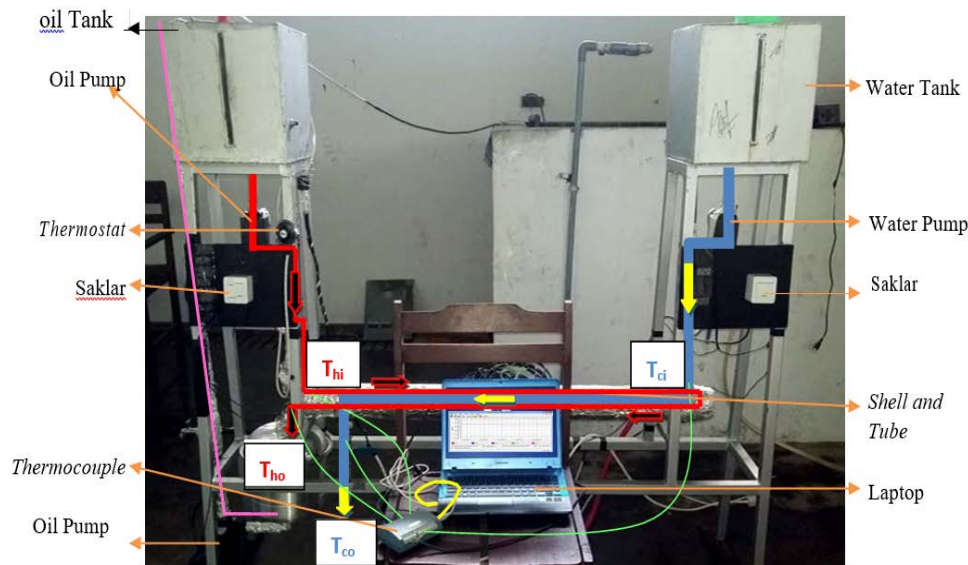


Figure 2.1 Schematic diagram of heat transfer test

Performance of a heat exchanger, it is necessary to relate the total heat transfer rate to the temperature of the incoming and outgoing fluid, the overall heat transfer coefficient, and the total surface area for the heat transfer rate. The heat transfer equation between hot fluid and cold fluid is equilibrium. Figure 2.3 showed the fluid flow of heat exchanger one shell and two tube pass. Temperature oil inlet is 60°C and temperature water inlet is 27°C .

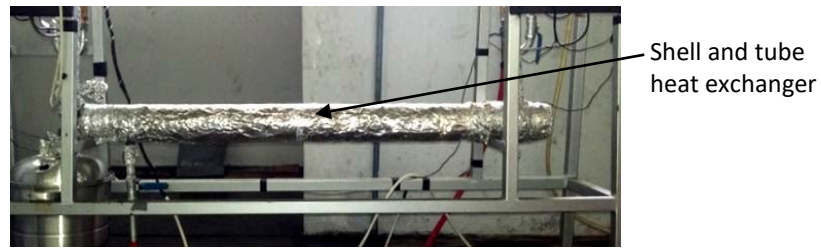


Figure 2.2 Photo of shell and tube heat exchanger

Tabel 1.Geometric parameter of testing shell and tube heat exchanger type one shell and two tube pass

No	Parameter	Shell	Tube
1	Inner diameter (mm)	66	12
2	Outer diameter (mm)	70	13
3	Material	steel	cooper

Figure 2.3 shown the oil with high temperature flow from tube inlet heat exchanger and water counter flow from inlet shell heat exchanger. Operational temperature and variation debit of oil and water has shown in table 1.

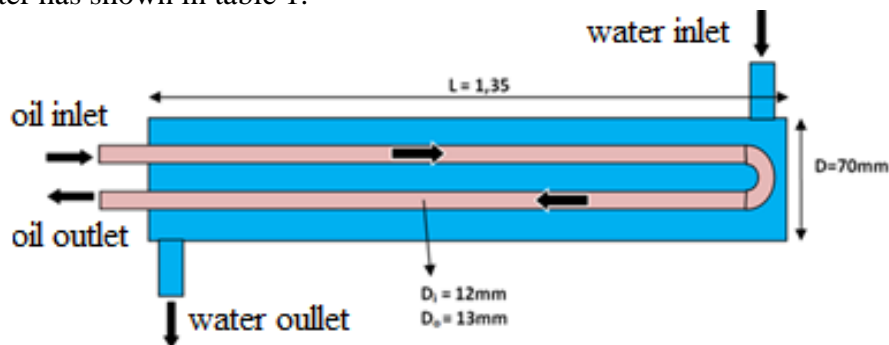


Figure 2.3 fluid flows of shell and tube heat exchanger one shell and two tube pass

The different parameters of shell and tube heat exchanger type one shell and two tube pas installed are shown with in table 2, detailed rate flow and temperatureoperating of oil and temperature operating of water.

Tabel 2.Temperature specifications

No	Parameter	Unit	Shell side inlet	Tube side inlet
1	Fluid		Oil	Water
2	Operating Temperature	°C	60	27
3	Rate flow	Litre/hour	60	180
				300
				420
				540

The effectiveness of a heat exchanger, it is the total heat transfer rate to the temperature of the inlet and outlet fluid, the overall heat transfer coefficient, and the total surface area for the heat transfer rate. The heat transfer equation between hot fluid and cold fluid is equilibrium. The rate of heat transfer between hot fluids and cold fluids and by ignoring the heat transfer that occurs in heat exchangers on the environment, ignoring changes in potential energy and kinetic energy, and by applying steady energy equations, and in the case of this fluid does not under a phase change and assumed the condition of constant specific heat, then the equation,

$$q = \dot{m}_h c_{p_h} (T_{h,i} - T_{h,o}) \quad (1)$$

$$q = \dot{m}_c c_{p_c} (T_{c,o} - T_{c,i}) \quad (2)$$

If the direction of flow of the two fluids inside the heat exchanger is parallel. This means that both fluids enter on one side and exit from the other side flowing in the same direction. If the flow graph is parallel equation will be obtained,

$$q = \dot{m}_h c_{p_h} (T_{h,i} - T_{h,o}) = \dot{m}_c c_{p_c} (T_{c,i} - T_{c,o}) \quad (3)$$

If the assumption of the value of specific heat capacity (C_p) is cold and hot fluid is constant, there is no loss of heat to the environment and the steady state, then the heat transferred,

$$q = U A \Delta T_{RL} \quad (4)$$

$$\Delta T_{RL} = \frac{\Delta T_1 - \Delta T_2}{\ln (\Delta T_1 / \Delta T_2)} \quad (5)$$

Counter flow, that is if both fluids flow in opposite directions and exit on the opposite side. If the flow graph is parallel equation will be obtained,

$$q = \dot{m}_h c_{p_h} (T_{h,i} - T_{h,o}) = \dot{m}_c c_{p_c} (T_{c,o} - T_{c,i}) \quad (6)$$

Cross Flow, This means that the direction of the second flow of fluid intersects. The NTU-effectiveness method is a method based on the effectiveness of heat exchangers in removing certain amounts of heat. Where the effectiveness of the method has several advantages for analyzing the problems which we have to compare different types of heat exchanger in order to choose the best kind to carry out a specific task for heat. The effectiveness of heat exchangers with the following equation [13]

$$\text{Effectiveness} = \varepsilon = \frac{\text{The actual heat transfer rate}}{\text{The rate of heat transfer possible}} = \frac{Q_{\text{actual}}}{Q_{\text{maximum}}} \quad (7)$$

Fouling factor in the heat exchanger is the formation of a layer of deposit on the surface of heat transfer from unwanted materials or compounds. For a shell tube type heat exchanger that has no fins, the equation becomes,

$$\frac{1}{UA_s} = R = \frac{1}{h_i A_i} + \frac{R_{f,i}}{A_i} + \frac{\ln(D_o/D_i)}{2\pi k L} + \frac{R_{f,o}}{A_o} + \frac{1}{h_o A_o} \quad (8)$$

3. Results and Discussion

Experimental data of the fluid outlet has been obtained from the results of record the measuring instruments, so that calculation of the effectiveness of heat exchanger is carried

out. Calculation effectiveness of heat exchanger can calculate by ratio using data fluid temperature inlet and outlet.

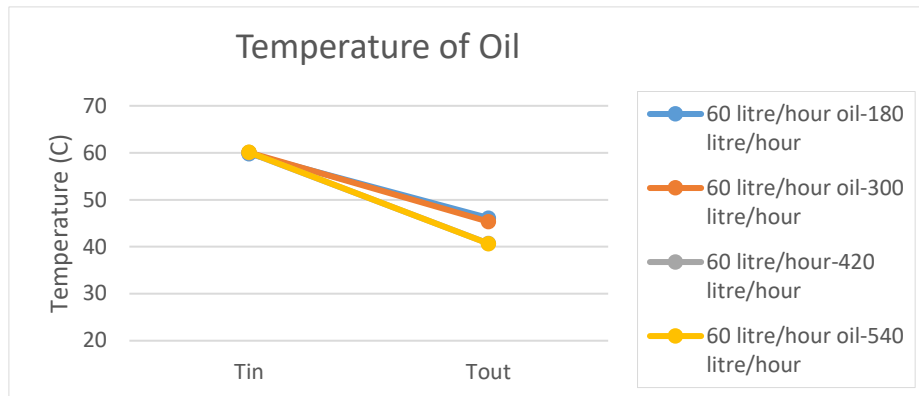


Figure 3.1 Graph temperature of oil inlet and outlet heat exchanger

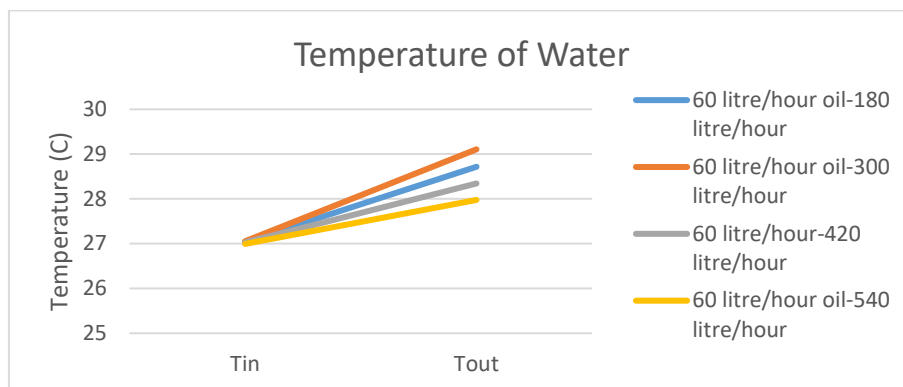


Figure 3.2 Graph temperature of water inlet and outlet heat exchanger

Figure 3.1 and figure 3.2 shown graph of temperature inlet and outlet. Temperature of water inlet was constant 27 °C. The water flow with rate flow of water 540 litre/hour can reduce oil temperature from 60.10 °C to 40.67 °C

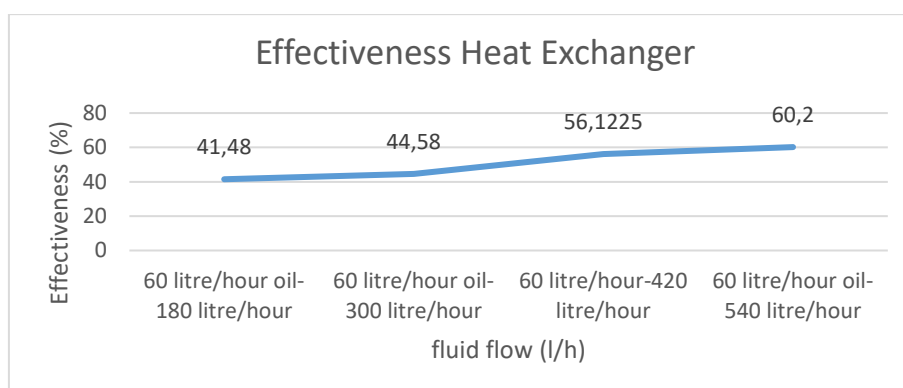


Figure 3.3 Effectiveness of shell and heat exchanger type one shell and two tube pass

From the calculation data, it can be seen that the effectiveness of the heat exchanger is increase by the incoming fluid discharge of the heat exchanger both oil and water. Maximum of effectiveness heat exchanger is 60.2% and minimum 41.48 %. The effectiveness increase directly according to the debit of water.

4. Conclusion

An experimental test was showed that shell and tube heat exchanger one shell and two tube pass effective used for oil cooling. It can reduce oil temperature up to 32.3 %. The rate flow of fluid has high impact to increase the effectiveness of shell and tube heat exchanger type one shell and two tube pass.

References

- [1] Bonilla J, Rodriguez-Garcia M.M, Roca L, and Valenzuela L. 2015. *IFAC-Papers OnLine***48-11** 097-102.
- [2] Hsieh J.C, Lee Y.R, Guo T.R, Liu L.W, Cheng P.Y, Wang C.C. 2014. *Energy Procedia***61** 874-877.
- [3] Napitupulu F.H, Sabri M, Sihombing F, and Sihombing H.V. 2018. *IOP Conf. Series: Material Science and Engineering***420** 012014.
- [4] Napitupulu F. H, Sitepu T, Kusuma J and Wijaya A. 2018. *Talenta Conference Series***01** 115-134.
- [5] Siagian P, napitupulu F.H, Setyawan E.Y, Siagian L, Napitupulu R.A.M, and Ambarita H. 2018. *IOP Conf. Series: Material Science and Engineering***420** 012035.
- [6] Rajpoot A.S, Sahu H.S, Saxena N.V, Kumar P. 2017. *International Journal of Science Technology and Engineering* **Vol.3** (8), 2349-784X.
- [7] Rao S. K and Kalyani P. 2018. *International Conference on Recent Innovation in Science, Engineering and Management*. ISBN: 978-93-87793-01-9.
- [8] Mukadam S.S, Naik O.V, Naik P.S, Naik P.P, Yekane A.S. 2018. *International Research Journal of Engineering and Technology* Vol. 05 (4). E-ISSN: 2395-0056.
- [9] Zheng Y and Wang Z. 2019. *Energy Procedia***158** 4402-4409.
- [10] Zebua M.A and Ambarita H.2018. *IOP Conf. Series: Materail Science and Engineering***420** 012036.
- [11] Li Y, Jiang X, huang X, Jia J, and tong J. 2010. *International Journal of Heat and Mass Transfer***53** 4543-4551.
- [12] Sundar L.S, Kumar N.T.R, Addis B.M, Bhramara P, and Singh M.K. 2019. *International Journal of Heat and Mass transfer***14** 405-419.
- [13] Holman J P 1997 *Heat Transfer* Jakarta :Erlangga
- [14] Incropera Frank P 2011 *Fundamentals of Heat and Mass Transfer*, Seventh Edition. United States of America
- [15] Kuppan T 2000 *Heat Exchanger Design Handbook*, Second edition. New York: Marcel Dekker. Inc