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ANALYSIS OF THE EFFECT AMOUNT OF PLATE, DIAMETER PORT, AND WIDTH OF COMPRESSION ON INTERCOOLER PERFORMANCE IN PT. INDONESIA POWER

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ABSTARCT

This analysis to determine the performance of the intercooler based on actual data, and the intercooler's performance against design specifications changes using the NTU method. Variable design specifications in the study are the number of plates, compressed area, and port diameter values from intercooler specifications provided by the company. The results of the inter-device performance analysis of compatibility with the specifications required by the company amounted to 99.40%. The results of the first trial of the tool specifications point the compatibility value to increase to 99.98% by increasing the number of plates from 79 to 150 plates, reducing the compressed area value from 0.47 to 0.2 m and increasing the port diameter value from 0.2 to 0,5 m. The results of the trial 2 tool specification showed a decrease to 86.51% due to changes in variable variables, by the number of plates to 25, raising the compressed plate width to 0.5 meters and increasing the port diameter to 0.6 m. The highest overall heat transfer value on May 23-24 is 346.225,37 $\frac{W}{m^2.K}$ based on actual data calculation of Intercooler effectiveness. The lowest overall heat transfer value is 346.213,29 $\frac{W}{m^2.K}$ based on data calculation it occurred on 22 May 2019.

Keyword: Effectiveness, Intercooled, Design, Primary, Secondary

I. INTRODUCTION

The intercooler recovery system is a type of direct contact system with a closed system that has a primary and secondary cooling system. The choice of heat exchanger as intercoller cooling media is due to two main things, namely its concise geometry and enlarged heat transfer area. The advantage in the exchanger plate is in the plate, which can be released on the plate, and gasket using fluid flow. with the correlation also expected turbulence of the greater fluid flow in the end the more heat that occurs. The effectiveness and overall heat transfer coefficient become several important parameters in determining the performance of the intercooler. Intercooler has several compartments that can be arranged as needed, some divided by the number of plates, port diameter, and area of compressed area. Changes in the design specifications of the heat exchanger can affect the performance of the intercooler.

To fulfill further analysis in determining the optimal design of the main intercooler on the type of fluid flow owned, an approval parameter is needed. The required parameter is the specification intercooler, heat transfer that occurs which is calculated based on the actual data using the NTU method. The main objectives in this analysis are the requirements agreed between registrants, removal of the overall fulfillment coefficient, and heat machining required by the appropriate data collector. With a more in-depth analysis of these parameters, use an optimal design and assessment of various intercooler designs in terms of evaluation, the overall heat transfer coefficient, and the heat required by the intercooler will be much easier and can be used for further studies that are compatible with intercoolers.

II. LITERATURE REVIEW

Heat is a form of energy that can be transferred from one place to another, but cannot be created or destroyed at all. In the process, heat can cause an increase in the temperature of a substance or changes in pressure, chemical reactions and electricity. The process of heat transfer can be done directly, and indirectly. The difference temperature and pressure in the fluid will affect the speed of heat transfer, heat transfer coefficient, and efficiency of the heat exchanger.

Heat transfer is the process of heat transfer which occurs between hot objects and cold objects, each of which is called the source and receiver (source and receiver). There are 3 types of transitions Hot that is conduction, convection and radiation.

Conduction heat transfer is a mechanism heat transfer that occurs with a flow or the process propagation of an object which higher temperature to that object lower temperature or from an object to other objects with direct contact. In other words the process of molecular heat transfer by means of moving molecules. Conduction heat transfer can take place at solids, liquids and gases.

Convection heat transfer is a mechanism heat transfer that occurs from one object to other objects by means of the objects themselves. There are 2 kinds of convection heat transfer namely forced convection and free convection. Natural convection is molecular displacement - molecules in substances that are heated due to their presence difference in density. Forced convection is convection heat transfer which took place with the help of other workers, for example is the air exhaled on a plate by the fan. Radiation heat transfer is heat transfer from one object to another with help electromagnetic waves, where this power will be converted to heat if the energy is absorbed by another thing.

Indirect heat transfer is found in various types of heat exchangers such as plate, shell and tube, spiral and others. In most cases, plate type heat exchangers should help with better heat dissolution of other types of heat exchangers.

The heat exchanger is a device used to transfer heat from the flow of the substance to another substance without mixed flow. Indirect heat exchange is found in various types of heat exchangers such as the type of plate, shell and tube, spiral and others. In most cases the plate type heat exchanger has a heat transfer effectiveness

Plate heat exchangers is a heat exchanger consisting of a plate and frame. In plate heat exchangers, plate arranged with a certain arrangement, thus forming two lines is called the hot side and a cold side. Hot side fluid drained with relatively hotter temperatures and a cold side fluid flowed with relatively cooler temperatures. Liquid fluid that is used as a medium can be of the same type or another, such as water - water, water – oil.

A. Advantages Plate Heat Exchanger

The advantage of the heat exchanger plate type start with the design. Heat exchanger plate type, namely:

1. Greater efficiency
2. The costs are more economical
3. maintenance and cleaning easier
4. the closer the temperature approach compared to other technologies.

B. Losses Plate Heat Exchanger

Losses Plate Heat Exchanger The weakness or loss contained in Plate Heat Exchangers are as follows:

1. Plates are less good shape to withstand the pressure.
2. Plate Heat Exchanger is not suitable for more than 30 bar pressure

III. METHODOLOGY

This analysis is composed of several stages. The first stage is to conduct a literature study both directly and indirectly. Then, after conducting a literature study, it was continued with data collection which included intercooler design specifications, and intercooler operating conditions for 5 days, then the next process to do is the validation process. The validation process is carried out on experimental results and numerical results through the NTU method. Based on these experimental and numerical results, the comparison and analysis process will then be carried out and conclusions will be drawn.

There are three intercooler performance parameters discussed in this study, namely the overall heat transfer coefficient, the effectiveness of the intercooler, and the heat needed by the intercooler.

A. Heat Transfer Coefficient

$$Hc = \frac{Nu \times k}{de} \quad \{1\}$$

Keterangan :
Nu = Nusselt number
Hc = convection heat transfer
K = heat conductivity of water
De = diameter equivalent
(Source: Willey, 2003: 638)

B. Overal Heat Transfer Coefficient

$$U = \frac{1}{\frac{1}{h_{hot}} + \frac{t}{K_p} + \frac{1}{h_{cold}}} \quad \{2\}$$

Information :
U = overall heat transfer coefficient
H= displacement of heat transfer
t = plate thickness
kp = heat conductivity of water
(Source: Holpman, 1986: 34)

C. Plate Area

$$A = (W - Dp).(L.Dp) \quad \{3\}$$

Information :
A = area of the plates
W = width of the plate
L= length of plate
Dp = diameter port
(Source: Naryono (...): 18)

D. Δ LMTD

$$LMTD = \frac{\Delta T1 - \Delta T2}{Ln[\frac{\Delta T1}{\Delta T2}]} \quad \{4\}$$

ΔT1 = Thin - Tcout
ΔT2 = thout - Tcin
(Source: Harini, 2017: 54)

E. Heat Requid on Operating Conditions

$$Q = U.A.\Delta T_{LMTD} \quad \{5\}$$

Information :
Q = heat requid
U = overall heat transfer
A = area of the plates
(Source: Holpman, 1986: 34)

$$Cc = \dot{m}.C_p \quad \{6\}$$

Information :
Cc = minimum heat capacity
M = mass flow rate
(Source: Handoyono, 2000: 2)

F. Ratio of Operating Thermal Liquid Flow Rate

$$R = \frac{Cmin}{Cmax} \quad \{7\}$$

Information :
R = ratio of operating liquid
(Source: Willey, 2003: 641)

G. Number of Transfer Unit

$$NTU_{min} = \frac{U \times Atp}{C_{min}} \quad \ldots\ldots\ldots\ldots \{8\}$$

Information :
Ntu = Number of transfer unit
A = area of the projection
(Source: Willey, 2003: 641)

H. Effectiveness Intercooler

$$\varepsilon = \frac{1-\exp[-(1-R)NTU_{min}]}{1-R.\exp[-(1-R)NTU_{min}]} \quad \ldots\ldots\ldots \{9\}$$

(Source: Willey, 2003: 642)

IV. RESULT AND DISCUSSION

Intercooler uses two direct contact cooling principles, namely primary and secondary systems. Intercooler primary system, i.e. fluid coming from the cooling tower is pumped using a primary intercooler pump (PIP) to the intercooler as a cooling medium in the secondary system. The secondary intercooler system, i.e. fluid from the storage tank pumped to the header tank is used as a secondary fluid intercooler which will then be cooled by fluid from the primary system. The data needed to calculate effectiveness is the intercooler specification which can be seen in **Table 4.1**, the intercooler trial I specification which can be seen in **Table 4.2**, the intercooler trial II specification which can be seen in **Table 4.3**. Following are the intercooler design specifications.

Table 4.1. Spesifiction Intercooler PT Indonesia Power

No	Plate Properties	Symbol	Value	Unit
1	Plate material	-	Titanium	-
2	Plate Thickness	t	0,8	MM
3	Chevron angle	B	30	O
4	Total number plate	Nt	79	-
5	Number of passes	Np	1	Pass
6	One chanel flow area	Ach	0,00012	M^2
7	All port diameter	D	0,2	M^2
8	Enlargement factor	Ø	0,2227	-
9	Total effective area	Ac	0,7018	M^2
10	Thermal conductivity of plate	Kp	247	$W/m^2.K$
11	Vertical port distance	Lv	1,450	M
12	Effective channel width	Lw	0,675	M
13	Horizontal port distance	Lh	0,4610	M
14	Compressed plate pack length	Lc	0,474	M

Table 4.2. Spesification Intercooler Trial I

No	Plate Properties	Symbol	Value	Unit
1	Plate material	-	Titanium	-
2	Plate Thickness	t	0,8	MM
3	Chevron angle	B	30	O
4	Total number plate	Nt	150	-
5	Number of passes	Np	1	Pass
6	One chanel flow area	Ach	0,00012	M^2
7	All port diameter	D	0,5	M^2
8	Enlargement factor	Ø	0,2227	-
9	Total effective area	Ac	0,7018	M^2
10	Thermal conductivity of plate	Kp	247	$W/m^2.K$
11	Vertical port distance	Lv	1,450	M
12	Effective channel width	Lw	0,675	M
13	Horizontal port distance	Lh	0,4610	M
14	Compressed plate pack length	Lc	0,2	M

Table 4.3. Spesification Intercooler Trial II

No	Plate Properties	Symbol	Value	Unit
1	Plate material	-	Titanium	-
2	Plate Thickness	t	0,8	MM
3	Chevron angle	B	30	O
4	Total number plate	Nt	25	-
5	Number of passes	Np	1	Pass
6	One chanel flow area	Ach	0,00012	M^2
7	All port diameter	D	0,6	M^2
8	Enlargement factor	Ø	0,2227	-
9	Total effective area	Ac	0,7018	M^2
10	Thermal conductivity of plate	Kp	247	$W/m^2.K$
11	Vertical port distance	Lv	1,450	M
12	Effective channel width	Lw	0,675	M
13	Horizontal port distance	Lh	0,4610	M
14	Compressed plate pack length	Lc	0,5	M

Supporting data needed in this experiment are temperature, pressure, and flow rate collected for 5 days on May 19, 2019 - May 23, 2019 shown below.

Table 4.4 Intercooler Operation Condition

Date	Hot Fluida		Cold Fluida		Pressure (bar)	flowrate (m^3/h)	
	Thin (°C)	Thout (°C)	Tcin (°C)	Tcout (°C)		hot	cold
19	39	37,11	31,82	34,14	2,4	428	496
20	39,22	37,2	32,13	34,24	2,39	428	496
21	39	36,85	32,45	34,68	2,42	428	496
22	38,5	36,5	32,68	34,86	2,53	428	496
23	38,56	36,72	32,72	34,91	2,54	428	496

Effectiveness, heat required, and the overall heat transfer coefficient of the intercooler are the main parameters in this analysis. The other supporting parameters are the heat needed, and the value of NTU to support the main parameters of intercooler performance. The results of data processing for 5 days using the initial intercooler design data can be seen in **Table 4.5.**

Table 4.5. Intercooler Performance Calculation

Date	U (W/m^2.K)	Q (W)	NTU	ε (%)
19	346,217.25	1,279,489.12	23.0317	99.39174
20	346,225.37	1,279,519.14	23.0323	99.39148
21	346,225.37	1,279,519.14	23.0323	99.39148
22	346,213.29	1.279.474,50	23.0306	99.39039
23	346,215.46	1.279.482,50	23.0309	99.39040

The results of calculations using the NTU method with the initial design data intercooler and actual data for 5 days, then analyzed using the graph shown below.

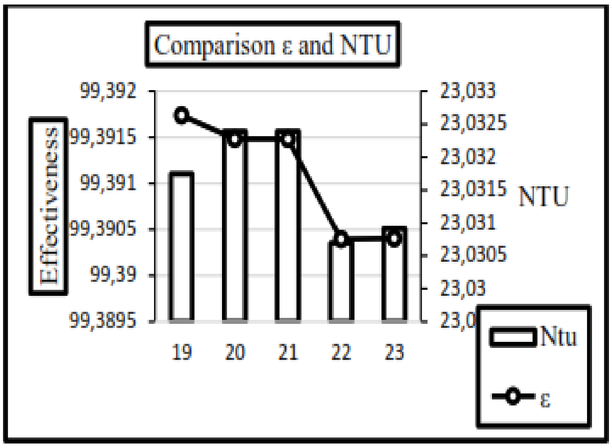

Figure 4.1. Comparison of Effectiveness and NTU

Figure 4.1 shows the comparison of the effectiveness and NTU values using actual data for 5 days, starting May 19-23 2019. The overall effectiveness and NTU values are fluctuating and directly proportional. The effectiveness value and the fluctuating NTU intercooler correlate with the operating conditions (temperature, pressure, and flow rate) taken for 5 days. The highest value of effectiveness and NTU occurred on May 21, 2019 with a value of 99.3915% and 23.032. The overall value of effectiveness and NTU does not differ greatly with an average value of effectiveness above 99% and an average NTU value above 23.00. This indicates that in the operation of the intercooler temperature, pressure, and flow rate are maintained so that the required parameters can be met. The effectiveness value which is directly proportional to NTU indicates that when the NTU value rises, the overall heat transfer coefficient also follows. The overall heat transfer value that rises will affect the effectiveness of the intercooler. The effectiveness value and NTU obtained are then compared with the required heat value (Q) and the overall heat transfer coefficient (U) shown in the graph below.

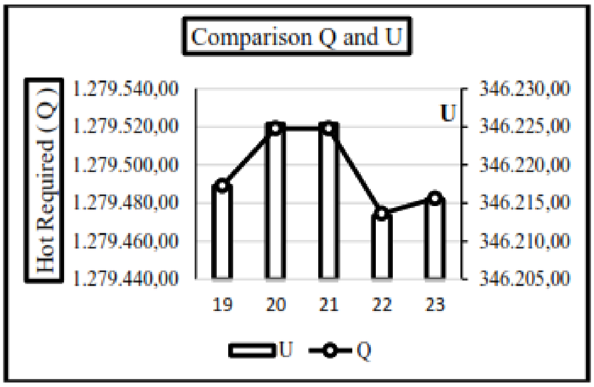

Figure 4.2. Comparison of the Heat Required With the Overall Heat Transfer Coefficient

From the data of operating conditions for 5 days and the initial design data of the intercooler, the values of Q and U were overall proportional and straightforward. These fluctuating Q and U values correspond to the operating conditions (temperature, pressure and flow rate) obtained for 5 days. The fluctuating Q and U values overall do not differ much from the highest values occurred on the 21st and 22nd with Q values of 1,279,519 Watt and U of 346,225.37 W / m^2.K. Q value rises indicating that the coefficient of heat transfer, surface area, and high temperature differences. This is in accordance with the mathematical equation shown in equation 5. The values of Q and U are directly proportional to the value of effectiveness, when effectiveness rises, the value of the overall heat transfer coefficient is higher according to **Figure 4.1** and has a type of counter current fluid flow.

The effectiveness value, the heat required, overall heat transfer coefficient from the initial intercooler design data are then compared with trial design data I, and trial II intercooler shown in the graph below.

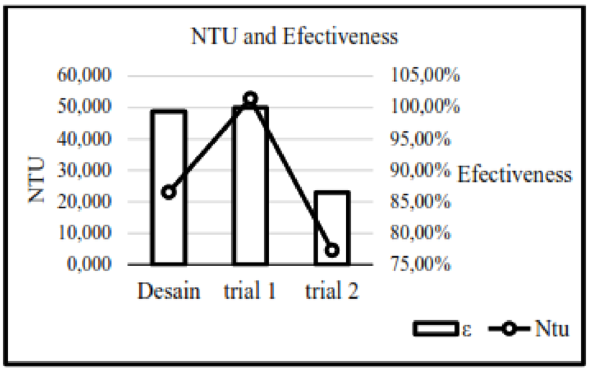

Figure 4.3. Comparison Effectiveness and NTU

Figure 4.3. shows a comparison between NTU design values with trials I, and II under the same

operating conditions. The effectiveness value and NTU are taken from the average value of actual data for 5 days. The experimental results show that increasing the value of intercooler plates from 79 to 150 significantly increases NTU values, but does not significantly affect the value of intercooler effectiveness. This is in accordance with equations 3 and 8 which explain the more plates, the value of the area of the projection plate increases and has implications for NTU values, but does not affect the Cmin value. Cmin value is influenced by changes in flow rate and intercooler temperature in accordance with equation 6. Intercooler effectiveness value did not change significantly, from 99.39 to 99.98%. Fluid with a maximum temperature difference value is cold fluid with a minimum flow rate.

Energy balance requirement that the energy received by one fluid must be the same as the energy released by the other fluid. If the value of the flow rate of the surrounding fluid is greater, the fluid experiences a temperature difference that is greater than the maximum, and this is not possible, so it is not possible to achieve 100% effectiveness. The effectiveness value and NTU trial II decreased to 86.51% by reducing the number of plates to 25, increasing the port diameter to 0.6, and compressed plates to 0.5. The increase in port diameter and plate compression influence the value of the fluid Reynold number which then affects the value of the heat transfer coefficient and the effectiveness of the intercooler. The larger the port diameter and the compression diameter, the smaller the Reynold number with the same operating conditions. This is then compared to the value of the plate compression area and the overall heat transfer coefficient which can be seen in the figure below.

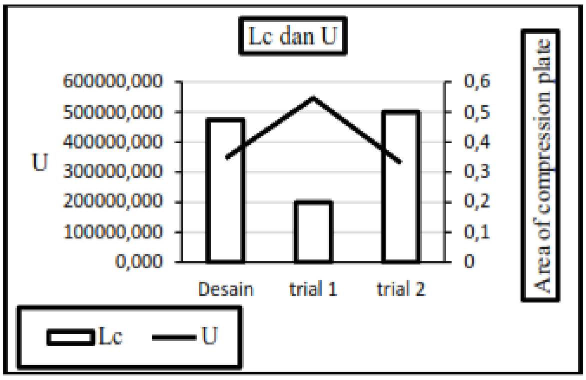

Figure 4.4. Size Compression Area and NTU

Figure 4.4 shows the comparison of the value of the compressed area (Lc) with the overall heat transfer coefficient (U) inversely proportional. The results of trial I showed a U value of 520,610 W / m2.K by reducing the value of the plate compression area to 0.2. The results of trial II show the value of U decreased to 310.0552 W / m2.K by increasing the value of the plate compression area to 0.5. This is correlated with Figure 3.3 which shows that the overall heat transfer coefficient has the same trend as effectiveness when the diameter of the port, and the area of the compressed area is enlarged.

V. CONCLUSION & RECOMENDATION

From the results of the analysis of intercooler performance from design data and actual data of operating conditions at PT Indonesia Power Kamojang, it can be concluded:

1. The highest effectiveness value using intercooler design data and actual data obtained 99.40% with an overall heat transfer coefficient value of 346,225.37 W / m2.K and the heat required is 1,279,519 Watt.
2. increasing the number of plates and compressed diameter can be increasing the performance of intercooler that are offset by decreasing the area of compressed area.

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