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ANALYSIS OF CONDENSER HEAT TRANSFER RATE BY LMTD METHOD AT POWER PLANT

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Abstract

Condenser is a heat exchanger that functions to convert steam into water, in the field of power generation industry condenser functions to convert low pressure steam from turbines into deaerator filling water. Like all equipment, condensers require maintenance to ensure optimal performance, condenser maintenance at Cilegon combine cycle power plant refers to routine maintenance of steam turbines not based on a decrease in condenser performance, this causes the maintenance carried out to be ineffective. Routine maintenance carried out on the condenser in the form of cleaning the condenser water box and condenser tube from garbage and crust on the condenser tube wall, crust on the tube wall causes the difference in temperature in and out of the condenser cooling water and the difference in temperature in and out of the hot fluid from the turbine is not too far away, from these parameters with the Log Mean Temperature Difference (LMTD) method, the heat transfer rate that occurs in the condenser can be calculated to determine the condenser's performance. The heat transfer rate value of the condenser Cilegon combine cycle power plant before maintenance in June 2023 was 51362294.48 kcal/h with an LMTD value of 0.76 and after overhaul in July was 127246219.7 kcal/h with an LMTD value of 1.86. From the calculations that have been carried out for the maintenance of the condenser in Cilegon combine cycle power plant condenser, it is recommended that it be carried out when the heat transfer rate value is below 110000000 kcal/h.

Keywords: *condenser, heat transfer rate, LMTD*

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1. Introduction

In the recent period of globalisation, the development of the industrial sector has progressed at an accelerated pace. This has led to a surge in demand for electricity, which is now a basic necessity in both the household and everyday life sectors. The use of electricity for household purposes is a case in point. This demand is met by a number of power plants, combined cycle power plant is one of the type power plant in Indonesia. Cilegon combined cycle powet plant has 2 units of gas turbines, designated GT 1.1 and GT 1.2, with 240 MW capacity single steam turbine, with 260 MW capacity. One of the main components of the steam turbine is condenser. A condenser is a heat exchanger that serves to convert the output steam from the steam turbine into filling water, which is then used to make steam in the steam turbine. In operation, a condenser, like any heat exchanger, requires maintenance to ensure optimal performance. Maintenance of the condenser at PLTGU Cilegon includes patrol checks and annual routine maintenance, which is carried out in accordance with the routine maintenance of the steam turbines not based on a decrease in condenser performance, this causes the maintenance carried out to be ineffective. The annual condenser maintenance procedure involves the cleaning of the condenser water box and condenser tube from blockages of garbage and scale on the condenser tube wall. This is carried out in order to prevent the accumulation of fouling in the condenser pipes (tubes) caused by garbage carried by sea water, which would otherwise result in a decrease in the heat transfer process in the condenser [1]. This will result in a difference in temperature between the condenser cooling water and the hot fluid from the turbine. The difference in temperature can be calculated using the Log Mean Temperature Difference (LMTD) method, which

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enables the heat transfer rate in the condenser to be determined [2]. As previously stated, the annual routine maintenance of the condenser is contingent upon the maintenance of the steam turbine. Maintenance is not based on changes in the parameters that occur in the condenser. To determine the effectiveness of maintenance carried out on the condenser Cilegon combined cycle power plant , it is necessary to analyse the heat transfer rate in the condenser with the LMTD method before and after maintenance of Cilegon combined cycle power plant. Here is the process diagrams of combine cycle power plant.

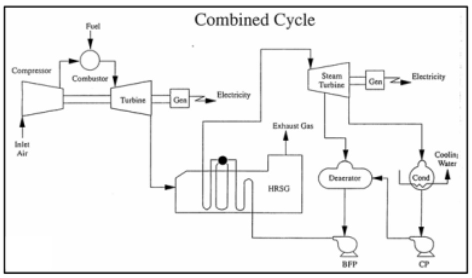

Figure 1. schematic diagrams combine cycle power plant

2. Experimental and Procedures

2.1 Research Stages

The analysis of this condenser involves several steps. The first is a literature study, which involves identifying existing research and references. The second is field observation and problem identification. This is followed by a field review by take the photos and parameter in power plant and then interview with technician and operator, which identifies potential research topics. condenser maintenance at Cilegon combine cycle power plant refers to routine maintenance of steam turbines not based on a decrease in condenser performance.

The subsequent stage is the collection of data, which includes the temperature of the cold fluid entering and exiting the condenser, the temperature of the steam fluid entering the condenser from the low-pressure turbine, the temperature of the hot fluid exiting the condenser. Once all the data has been collected by log sheet operator period June – July 2023, it is processed using LMTD calculations to obtain the heat transfer rate value. Following this, the results of the calculations are analysed to determine the change in the heat transfer rate before and after maintenance. Finally, a report is compiled.

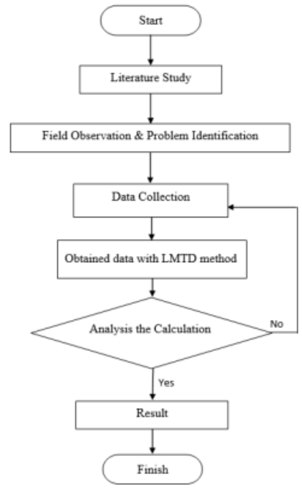

Figure 2. Research flow chart

2.2 Condenser Specification

Based on the results of data collection in the field, condenser built in November 2005, the cooling surface condenser is as follows 23070 m^2 and the material of condenser is titanium and then that will be full described in Table 1, as follows:

Table 1. Specification Condenser

No	Description	Specification
1	Built Year	2005. 11
2	Cooling Surface	23070 m^2
3	Condenser Vacuum	0,074 Bar Abs
4	Weight	420 Ton
5	Velocity inTube	2,0 m/s
6	Material	Titanium
7	Outside Diameter Tube	22,23 mm
8	Tube Number	21796
9	Tube thickness Average	0,5115 mm

2.3 LMTD (Log Mean Temperature Difference

This method is used to find the average temperature of the inlet and outlet fluid temperatures in the heat exchanger so that the heat transfer rate can be calculated, by comparing the fluid temperature at the end of the heat transfer. The use of this LMTD method can also be used when the value of fluid temperature at entry and fluid temperature at exit is known. the formula taken in the manual book is as follows :

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$$LMTD = \frac{(Thout - Tcin)-(Thout-Tcout)}{ln\frac{(Thout-Tcin)}{(Thout-Tcout)}}$$

Description :
LMTD = The LMTD value
Thout = Hot fluid temperature enter the condenser
Tcin = Cold fluid temperature enter the condenser
Tcout = Cold fluid temperature left the condenser

2.4 Overall Heat Transfer Coefficient (U)

The overall heat transfer coefficient is the total amount of thermal resistance between two fluids that occur heat transfer or can also be defined as a combination of heat transfer coefficients and includes all existing coefficients The calculation equation taken from the manual book is as follows:

$$U = U_1 \times F_w \times F_m \times F_c \times 4{,}882$$

Description :
U = Overall Heat Transfer Coefficient
U1 = Uncorrected heat transfer coefficients .
Fw = Inlet water temperature correction factor .
Fm = Tube material and gauge correction factor.
Fc = Cleanliness factor (°C).
4,882 = Conversion factor (Kcal/m3h°C)

2.5 Heat Transfer Surface Area

The heat transfer surface area referred to here is the actual area that heat transfer occurs in the condenser, the equation used to calculate the actual heat transfer surface area is as follows:

$$A_{act} = \pi \times do \times N \times L$$

Descripction :
do = outer diameter of condenser tube (mm).
N = Number of condenser tubes.
L = Effective length of condenser tube (mm).

2.6 Heat Trasnfer Rate

Heat transfer rate is the amount of heat energy that is conducted or transferred between two objects or systems in a unit of time. This can happen through conduction (heat transfer through direct contact between objects), convection (heat transfer through the movement of a fluid such as air or water), or radiation (heat transfer through electromagnetic waves). The rate of heat transfer can be measured in various units such as watts (W) or calories per second. The heat transfer rate can be calculated using formula :

$$Q = U . A . LMTD$$

Description :
Q = Heat transfer rate (W).
U = Overall heat transfer coefficient.
Aact = Actual heat transfer surface area (m^2).
LMTD = LMTD value

3. Results and Discussion

3.1 LMTD value and Heat Transfer Rate Before Maintenance

Data Collection and calculation are carried out in Juny 2023. The following are the results of observations and data collection of LMTD value and Heat Transfer Rate.

Table 2. LMTD value and Heat Transfer Rate Before Maintenance

No	Tcin (°C).	Tcout (°C)	Thout (°C)	LMTD	Q (kcal/h)
1	31.4	33.9	34.5	1.52	104868250.79
2	31.4	33.9	34.5	1.52	104868250.79
3	31.3	33.9	34.5	1.55	106994488.34
4	31.9	33.7	34.3	1.30	89444665.92
5	31	33.5	34.1	1.52	104868250.79
6	30.8	33.4	33.9	1.43	98164655.12
7	30.7	33.3	33.8	1.43	98164655.12
8	30.8	33.3	33.9	1.52	104868250.79
9	30.9	33.5	34	1.43	98164655.12
10	31	33.6	34.2	1.55	106994488.34
11	31.4	33.7	34.2	1.34	91968433.92
12	31.3	34.2	34.8	1.64	113276054.79
13	31.5	34.2	34.8	1.58	109104069.30
14	31	33.8	34.5	1.74	119845353.78
15	31.1	33.7	34.2	1.43	98164655.12
16	30.5	33.1	33.7	1.55	106994488.34
17	30.5	33	33.7	1.64	113314009.57
18	30.7	33.2	33.9	1.64	113314009.57
19	30.6	33	33.7	1.61	111102343.39

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The table above is the result of calculation from heat transfer rate before maintenance.

3.2 LMTD value and Heat Transfer Rate After Maintenance

Data Collection and calculation are carried out in July 2023. The following are the results of observations and data collection of LMTD value and Heat Transfer Rate.

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Table 3. LMTD value and Heat Transfer Rate After Maintenance

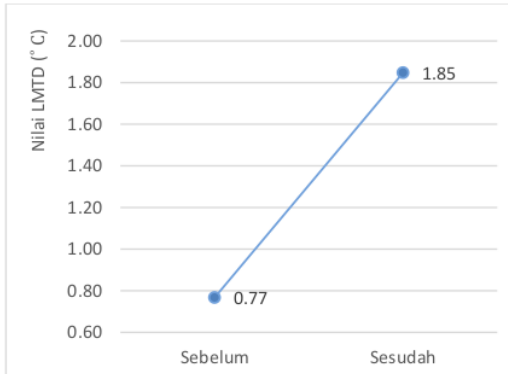
No	Tcin (°C).	Tcout (°C)	Thout (°C)	LMTD	Q (kcal/h)
1	30.5	33.2	33.5	1.17	80776582.18
2	30.6	33.1	33.2	0.77	52858332.46
3	30.7	33.6	34.2	1.64	113276054.79
4	30.6	33	33.9	1.85	127246219.66
5	30.4	32.8	33.3	1.37	94051314.59
6	30.4	32.9	33.2	1.12	77103397.99
7	30.4	32.9	33.2	1.12	77103397.99
8	30.7	33.1	33.2	0.75	51362294.48
9	30.3	32.8	33.5	1.64	113314009.57
10	30.2	32.7	33.1	1.26	86934589.76
11	30.2	32.7	33.2	1.40	96116444.73
12	30.4	32.9	33	0.77	52858332.46
13	30.5	33	33.2	0.96	66169067.70
14	30.5	32.8	33.4	1.46	100562671.83
15	30.3	32.5	33.1	1.43	98381597.51
16	32.3	34.8	35.2	1.26	86934589.76
17	31.6	34.2	34.5	1.15	78947217.07
18	31.3	33.9	34.3	1.29	88890755.62
19	31.3	34.6	35.2	1.76	121448285.94
20	31.5	34.2	34.6	1.32	90831471.43
21	31.4	34	34.5	1.43	98164655.12
22	31.5	34.1	34.5	1.29	88890755.62

The table above is the result of calculation from heat transfer rate after maintenance.

3.3 Comparing the LMTD values and heat transfer rate before and after maintenance.

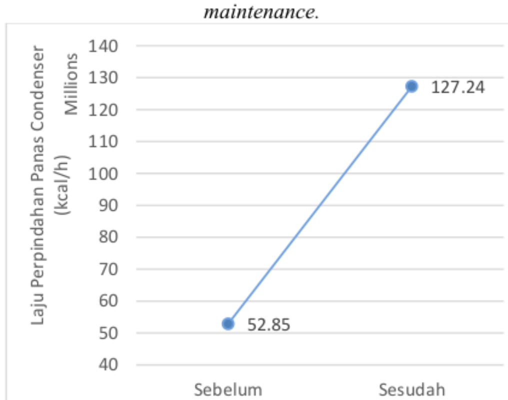
Based on the table 3 and table 4, it can also be noted that there are changes in several parameter values that occur after maintenance is carried out on the condenser Cilegon combine cycle power plant, but it is still necessary to calculate the heat transfer rate that occurs in the condenser between before and after maintenance in order to become a stronger basis for maintenance planning, from the calculation results obtained for the LMTD value before the maintenance activities of cleaning the water box and condenser tube is 0.77 ˚C then for the LMTD value after maintenance activities is 1.85 ˚C this can be seen in Figure 2. which shows a graph of LMTD values before and after maintenance of cleaning water boxes and condenser tubes in Cilegon combine cycle power plant.

Figure 2. LMTD graph before and after maintenance.



After seeing the results of the calculation and graph of the LMTD value above, continued with the results of the calculation of the heat transfer rate value that occurs before and after maintenance, before the maintenance activities of cleaning the water box and tube condenser the value of the heat transfer rate that occurs is 51362294,48 kcal / h while the value of the heat transfer rate that occurs after the maintenance activities of cleaning the water box and tube condenser is 127246219,7 kcal / h for trending the heat transfer rate graph can be seen in Figure 3.

Figure 3. Trending of heat transfer rate before and after maintenance.



Looking at the LMTD and heat transfer rate graphs in Figure 2 and Figure 3 the LMTD value that occurs in the condenser is directly proportional to the heat transfer rate value, then there is a considerable difference in heat transfer rate value between before and after maintenance, this shows that there is a change in LMTD value and heat transfer rate which is influenced by condenser maintenance activities in the form of cleaning water boxes and condenser tubes in

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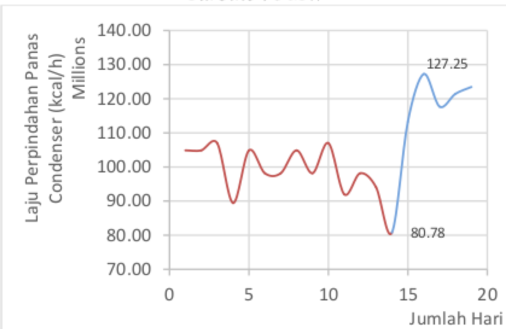
the Cilegon PLTGU unit, the values displayed in Figure 2 and Figure 3 are the lowest heat transfer rate value before maintenance and the highest heat transfer rate value data after maintenance without seeing variations in how much steam turbine load is operating. Then for the trending graph of the condenser heat transfer rate taken from the period June - July 2023. Load variations that occur due to limited gas supply from third parties and requests from network needs from the Cilegon area, based on the current operation of the Cilegon PLTGU tends to be asked to operate up to a steam turbine load of 70 MW, so data is taken when the steam turbine operates at a load of 70 MW. The heat transfer rate graph is shown in Figure 4 as follows:

Figure 4. Trending Heat Transfer Rate at Load Steam Turbine 70 MW



Looking at the heat transfer rate graph of the Cilegon PLTGU condenser unit calculated using the LMTD method at a load of 70 MW above, it can be seen that the orange graph is a graph of the heat transfer rate value that occurs before maintenance and for the blue graph is a graph of the heat transfer rate value after maintenance, the heat transfer rate value that occurs before maintenance is on average in the range of 90000000-110000000 kcal/h but more often below 110000000 kcal/h, then after maintenance the average value of the heat transfer rate is in the range of 110000000-125000000 kcal/h, and even had a value of 127246219.7 kcal/h. According to the existing commissioning data at a load of 70 MW, the value of the heat transfer rate is at a value of 110000000 kcal/h, meaning that periodic condenser maintenance in the form of cleaning the water box and condenser tube will be more effective if when the value of the heat transfer rate that occurs in the condenser is below 110000000 kcal/h, condenser maintenance is immediately carried out, no need to follow the steam turbine maintenance cycle so that the condenser performance is maintained at its best performance.

4. Conclusions

Routine maintenance of the Cilegon PLTGU condenser unit is quite effective, but it will be much more effective if the condenser maintenance is carried out when the heat transfer rate value that occurs in the condenser is below 110000000 kcal/h.

Calculation of the LTMD value of the Cilegon PLTGU condenser unit before maintenance in June 2023 of 0.76 and after maintenance in July 2023 of 1.86.

Based on the LMTD calculation carried out, the heat transfer rate value of the Cilegon PLTGU condenser unit before maintenance in June 2023 was 51362294.48 kcal/h and after overhaul in July it was 127246219.7 kcal/h.

The heat transfer rate of Cilegon PLTGU unit condenser at 70 MW load before maintenance in June 2023 in the range of 90000000-110000000 kcal/h and after maintenance in July 2023 the heat transfer rate of Cilegon PLTGU unit condenser increased in the range of 110000000-125000000 kcal/h, even the highest value reached 127246219.7 kcal/h.

5. Suggestions

The calculation of the heat transfer rate of the Cilegon PLTGU condenser unit using the LMTD method is far from perfect. This is because the pressure drop, plugging factor and other parameters are not included in the calculation, then the limitations of data collection due to the operating pattern of the Cilegon PLTGU which follows the demands of the network and the limited primary energy so as to make the data analysis using certain assumptions this causes reduced data accuracy.

Maintenance of the Cilegon PLTGU condenser unit should be carried out when the heat transfer rate is at a value below 110000000 kcal/h so that in operation it can be in its best condenser performance,. The author hopes that the next Cilegon PLTGU condenser unit research can provide sharper and more accurate results. Then this final project is expected to be a reference for other researchers to examine condenser performance, and provide benefits to the Cilegon PLTGU to determine the effectiveness of condenser maintenance in improving the performance of condenser equipment.

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