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ANALYSIS OF THE EFFECT OF CHANGES IN VACUUM PRESSURE ON CONDENSER EFFECTIVENESS BEFORE AND AFTER OVERHAUL IN BLOK 1 PLTGU UP GRESIK

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ABSTRACT

The condenser in the operation of PLTGU serves to condense the residual steam of the low pressure turbine. The purpose of this study is to determine the effect of changes in vacuum pressure on condenser performance and determine the effect of overhaul on condenser performance. The variation in vacuum pressure on the condenser will be seen the effect of vacuum pressure on condenser performance. The results obtained the effectiveness score after overhaul was better than before overhaul by an average of 42.032% to 47.022%. The highest effectiveness at vacuum pressure of 679.5 mmHg was 46.103% before overhaul and 49.66% after overhaul. Meanwhile, the lowest effectiveness at vacuum pressure of 669.5 mmHg with effectiveness values before overhaul 39.45% and 45.94% after overhaul. The effectiveness of the condenser increases by an average of 4.99% after the overhaul. The level of vacuum in the condenser affects the effectiveness value of the condenser, the higher the value of vacuum pressure will increase the value of the heat transfer rate so that the effectiveness will increase. Factors that affect condenser performance are the level of tube cleanliness, the number of pluggings, vacuum pressure, and the operation of condenser supporting components.

Keywords: Vacuum pressure, Condenser, Effectiveness

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1. INTRODUCTION

The condenser has an important role in the operation of the combined cycle, so the condenser performance needs to be considered. Condenser performance can be measured based on the effectiveness value of a condenser. The condenser is a heat exchanger so that the heat transfer rate in the condenser is a reference for the performance of a condenser, because the heat transfer rate value is a parameter of the condenser's ability to transfer heat from high temperature steam to cooling water. Condenser effectiveness is a measure of the thermal efficiency of the condenser. So, to optimize condenser performance, you need to pay attention to the effectiveness value of the condenser.

The performance of the condenser can also be influenced by the vacuum pressure in the condenser. When operating conditions, the condenser is in a vacuum state. The condenser vacuum level has an important role in maintaining optimal condenser performance. The condenser pressure is set below atmospheric pressure (<1atm). The condenser is made under vacuum pressure to make it easier for the steam in the system to condensate and to protect the condenser so that there are no gases that can damage the condenser. If the condenser pressure does not operate at sufficient vacuum, the boiling point processed by the condenser will increase, causing cooling efficiency to decrease, and can even cause damage to the system. Thus, the vacuum pressure in the condenser must be maintained to produce optimal condenser performance.

The Condenser Block 1 of PLTGU UP Gresik has been operating for years and has certainly experienced a decline in performance. The decrease in condenser performance is caused by several things, such as leaks which cause many tubes to be installed with plugs, causing less than optimal heat absorption or heat transfer between steam and cooling water. Therefore, to maintain condenser performance, an overhaul is carried out to carry out comprehensive maintenance on the condenser components.

2. RESEARCH METHODS/DESIGN

2.1 Condenser

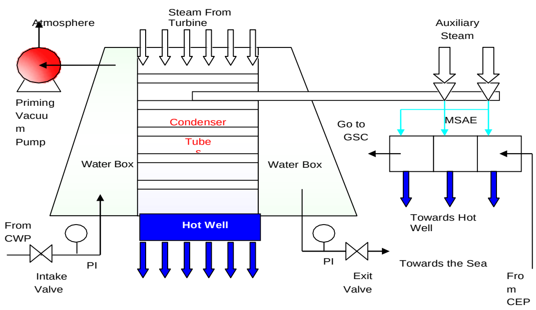

Figure 1. Condenser Working System

The cycle in this condenser begins with saturated steam coming out of the LP turbine flowing into the condenser on the shell side. On the side of the condenser tube, cooling water will be supplied in the form of water from the Circulating Water Pump (CWP). With the presence of hot steam on the shell side and water/coolant on the tube, heat transfer or heat transfer will occur condensation. The steam will condense so that it changes phase to a liquid phase. This condensate water will be collected in the hotwell at the bottom of the condenser. After that, the water in the hotwell will be pumped by the Condensate Extraction Pump (CEP) to flow to the HRSG.

In the condenser to create vacuum pressure there is a Starting Air Ejector (SAE) which is used when initially starting the unit. SAE functions to draw in air and residual steam contained in the condenser shell until it reaches a certain vacuum pressure in the condenser shell. SAE gets energy from auxiliary steam. Meanwhile, when the unit is operating normally, the SAE is turned off and replaced by the Main Steam Ejector (MSAE) to maintain vacuum in the condenser shell. MSAE is the main ejector to maintain vacuum pressure in the condenser shell during operation so that steam from the turbine can enter the condenser shell.

2.2 Condenser Vacuum

In a condenser working system, the vacuum level is very important. The vacuum pressure in the condenser is below atmospheric pressure (<1 atm). The vacuum in the condenser is carried out by an air ejector to create vacuum pressure and maintain vacuum in the condenser. Vacuum pressure can be an indicator of condenser performance. If there is an abnormal vacuum pressure in the condenser, it will hinder the condensation process. If the condensation process is hampered, it will also affect the performance of the condenser. Having a good vacuum will increase the working efficiency of the condenser, because it will speed up. Therefore, a vacuum level must be maintained in the condenser so that the generator can work optimally.

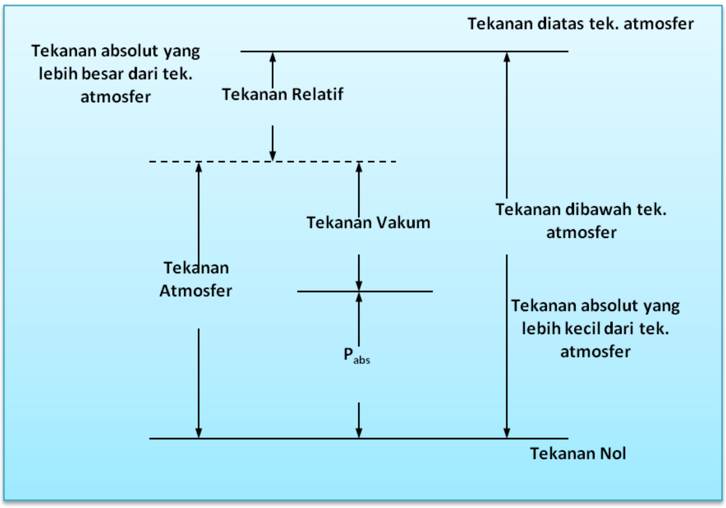

Figure 2. Graph of the Relationship Between Abs Pressure, Gauge and Vacuum

2.3 Condenser Effectiveness Calculation

By using the Rankine cycle as the working cycle, the remaining steam from the LP turbine will enter the condenser for condensation by the condenser so that you can determine the effectiveness of the condenser using the following equation:

- Determining Absolute Pressure

  Pabs = Patm – Pvakum (1)

  By using absolute pressure, the vapor enthalpy value will be obtained using the steam table application

- Determining Heat Capacity

  $$Tfh = \frac{Thin + Thout}{2} \quad (2)$$

  $$Tfc = \frac{Tcin + Tcout}{2} \quad (3)$$

  By obtaining Tfh and Tfc you can determine the heat capacity using the steam table application

- Determine the value of the coolant mass flow rate

  $$\dot{m}c = \frac{\dot{m}h \times hg}{Cpc \times} \quad (4)$$

- Determine the value of the heat transfer rate

  $$Q_C = \dot{m}h \times hg \quad (5)$$

- Determining the LMTD Value

  $$\Delta LMTD \quad \frac{T - Tco}{}$$

$$= \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln\left(\frac{T_{hi} - T_{co}}{T_{ho} - T_{ci}}\right)} \quad (6)$$

- Determining the Area of Heat Transfer

$$A = \pi \times L \times do \times \sum Tube \quad (7)$$

- Determining the Overall Heat Transfer Coefficient

$$U = \frac{Q}{A \times \Delta LMTD} \quad (8)$$

- Determine the maximum heat transfer rate value

$$Qmax = Cmin \times (Thin - Tcin) \quad (9)$$

- Determining Condenser Effectiveness

$$\varepsilon = \frac{Q}{Qmax} \quad (10)$$

3. RESULTS AND DISCUSSION

Based on the operational data of PLTGU UP Gresik Block 1 before and after the overhaul, the effectiveness calculation results for the condenser are obtained which are presented in the following table:

Table 1. Effectiveness Calculation Results Before and After Overhaul

Before Overhaul						
Parameters and Units	**Vacuum Pressure Variation (mmHg)**					
	666.8	667	668	669	670	672.4
Pabs (Bars)	0.1207	0.1203	0.12004	0.11977	0.115369	0.107370
hg (kJ/kg)	2590.47	2590.35	2590.27	2590.19	2588.87	2586.34
Cpc (kJ/kg.C)	4.17953	4.17952	4.18043	4.17953	4.17953	4.17954
Cph (kJ/kg.C)	1.94019	1.94019	1.94011	1.94019	1.94011	1.93988
$\dot{m}\,c$ (kg/s)	6411,717	6226,414	6079,585	6038,838	5902,986	5447,268
Qactual (kJ/s)	155428.2	156140.5	157574.7	159008.8	160366.1	161646.2
$\dot{m}\,h$ (kg/s)	60	60,277	60,833	61,388	61,944	62.5
LMTD (℃)	11,301	11,285	11,242	11,226	11,183	11,071
A (□2)	14460.49717					
U (W/□2℃)	874,931	880,276	891,822	901,306	913,636	932,516
Cc (kJ/s℃)	24652.34	23942.61	23384.86	23224.88	22731.25	21027.19
Ch (kJ/s℃)	2768226	26880987	17497521	19552173	13892786	14088488
C	0.000968	0.000968	0.001452	0.001290	0.0017758	0.0016160
Qmax (kJ/s)	393930	385146.6	381229.2	378592.5	375009.9	350612.9
Effectiveness	0.394557	0.405405	0.413333	0.42	0.4276315	0.461038
Effectiveness (%)	39.45	40.54	41.33	42	42.76	46.10
After Overhaul						
Parameters and Units	**Vacuum Pressure Variation (mmHg)**					
	666.8	667	668	669	670	672.4
hg (kJ/kg)	2590.47	2590.35	2590.27	2590.19	2588.87	2586.34
Cpc (kJ/kg.C)	4.17954	4.17954	4.17954	4.17954	4.17954	4.17954
Cph (kJ/kg.C)	1.93949	1.93949	1.93926	1.93934	1.93919	1.93911
$\dot{m}\,c$ (kg/s)	5519.44	5439.19	5738.42	5459.53	5303.21	5202.58
Qactual (kJ/s)	156867.3	156860.08	158294.2	159728.3	161804.37	163083.1
$\dot{m}\,h$ (kg/s)	60,555	60,555	61,111	61,666	62.5	63,055
LMTD (℃)	10,846	10,805	10,805	10,743	10,702	10,599
A (□2)	14553,10362					
U (W/□2℃)	914,182	917,768	926,229	940,020	957,149	976,441

Cc (kJ/s°C)	21221.6	20915.60	22067.9	20996.98	20421.67	20082,6
Ch (kJ/s°C)	2859589	20127752	3716018	2020175	12481203	16819568
C	0.000806	0.0011294	0.000645	0.001129	0.0017758	0.001292
Qmax (kJ/s)	341417.1	338726.8	350166.1	339993.2	336907.73	328340.6
Effectiveness	0.481707	0.48366	0.48366	0.487013	0.45751634	0.510791
Effectiveness (%)	45.94594	46.308724	45.20547	46.97986	48.02631	49.66887

3.1 LMTD Before and After Overhaul

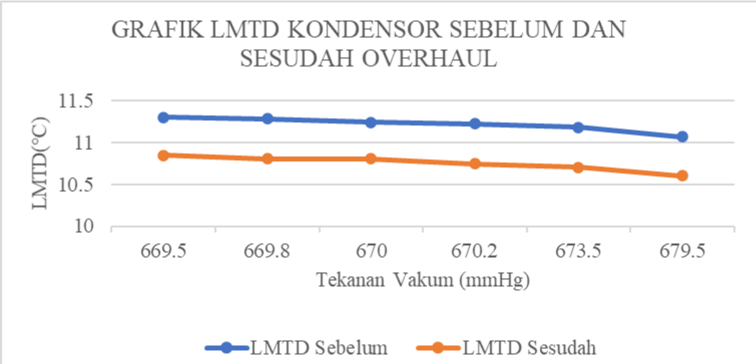

Figure 3.LMTD before and after Overhaul

It was obtained that the LMTD valueafter overhaul it is better. Basically, overhaul activities are carried out to clean fouling in the condenser tubes, so that the LMTD value will decrease and increase the heat transfer coefficient. The LMTD value is influenced by the temperature of the cooling water entering the system, before the overhaul the average incoming coolant temperature is 31.25°C, while after the overhaul the average coolant temperature is 30.76°C. So, the LMTD value can be seen from the difference in inlet and outlet coolant temperatures in the condenser system. The greater the difference in inlet and outlet coolant temperatures, the better the LMTD value. The average difference in inlet and outlet coolant temperatures (ΔTfc) before the overhaul was 6.31°C and after the overhaul was 7.01°C. This caused an insignificant change in LMTD before and after the overhaul with the average LMTD value from 11,218°C to 10,750°C, so that there was only a decrease in LMTD of 0.468°C. The decrease in the LMTD value occurs because the heat transfer process carried out by the cooling water to condense the residual steam from the turbine output is getting better, which is getting closer to the temperature value of the used turbine steam. By carrying out an overhaul, the tubes in the condenser are in a clean condition, so the heat absorption in the tubes is better.

3.2 Heat Transfer Rate

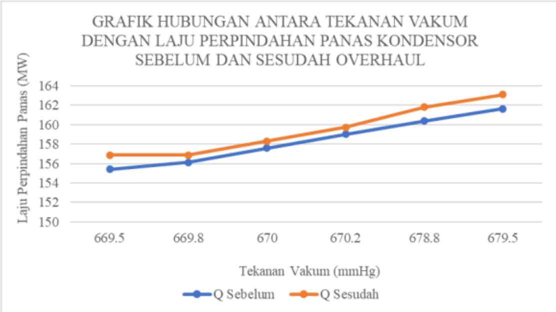

Figure 4. Heat Transfer Rate Before and After Overhaul

Vacuum pressure affects the value of the heat transfer rate in the condenser. In the graph, a vacuum pressure of 679.5 mmHg produces a high heat transfer rate value, namely before the overhaul, 149,293 MW and after 150.62 MW, while at the lowest vacuum pressure of 669.5 mmHg, the heat transfer rate value is 142,983 MW before the overhaul, which becomes 144,307 MW. after overhaul. The value of the heat transfer rate which is followed by an increase in vacuum pressure in the condenser is influenced by the mass flow rate of steam entering the condenser. The greater the vacuum pressure in the condenser will increase the mass flow rate of steam entering the condenser. The increase in the heat transfer rate in the condenser is also influenced by the clean condition of the condenser tube, thereby increasing the value of the heat transfer rate in the condenser.

The level of heat transfer in the condenser depends on the coolant flow, cleanliness of the condenser tube and temperature differences. The increase in vacuum pressure occurs due to the lower temperature of the coolant in the form of sea water which will affect the steam condensation rate and the LP turbine steam mass flow rate. With a lower steam mass flow rate, less steam will condense, thereby reducing the heat transfer rate value.

3.3 Overall Heat Transfer Coefficient

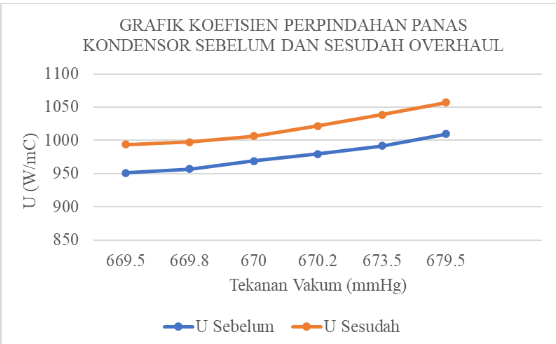

Figure 5. Overall Heat Transfer Coefficient Before and After Overhaul

The overall displacement coefficient value increased on average by 976.318 W/m°C to 1019.2683 W/m°C after the overhaul. The increase in the overall transfer coefficient value of 42.95 W/m °C after the overhaul shows that the condenser system transfers heat better. The heat transfer coefficient value itself is influenced by the heat transfer rate and LMTD value. Figure 4.7 shows that the LMTD value after overhaul decreases, this affects the heat transfer coefficient value. The lower the LMTD value, the higher it will be the heat transfer coefficient value, while in Figure 4.9 it can be seen that the heat transfer rate value increases, therefore indicating that the heat transfer coefficient value is directly proportional to the heat transfer rate. The heat transfer coefficient is also influenced by the heat transfer surface area of the codensor, with plugging, it will reduce the heat transfer area so that it will reduce the heat transfer coefficient value. With a better heat transfer coefficient value, it will also affect the efficiency value of the condenser.

3.4 Effect of Vacuum Pressure on Condenser Effectiveness

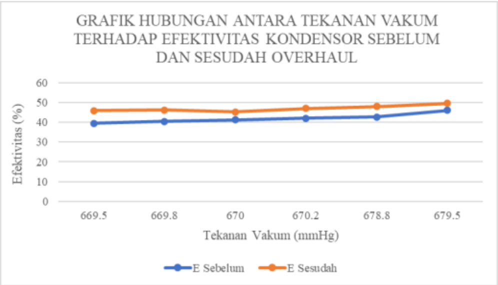

Figure 6.

Relationship between Vacuum Pressure and Condenser Effectiveness Shows that the vacuum pressure value influences the effectiveness value of the condenser both after and before an overhaul is carried out. The increase in the vacuum pressure value in the condenser is followed by an increase in the effectiveness value in the condenser. The highest effectiveness value before the overhaul was when the vacuum pressure was 679.5mmHg with an effectiveness of 46.1%, while after the overhaul the effectiveness was 49.66%. It can be proven that vacuum pressure affects condenser performance, the higher the vacuum pressure value, the faster the condensation process of residual LP turbine steam that enters the condenser system. A fast condensation process will increase the efficiency or effectiveness value of a condenser. The increase in the effectiveness value of the condenser is due to the fact that during overhaul activities, damaged tubes are retubed, thereby increasing the condensation process in the condenser after the overhaul is carried out. Therefore, it is necessary to maintain a sufficient condenser vacuum level to maintain optimal condenser performance.

4. CONCLUSIONS AND RECOMMENDATIONS

With the results of calculations and analysis based on the objectives and problem formulation, the following conclusions can be obtained:

1. Vacuum pressure affects the condenser effectiveness value before and after overhaul. The lowest vacuum pressure of 669.5 mmHg obtained effectiveness before overhaul of 39.45% and 45.9% after overhaul. At the highest vacuum pressure of 679.5 mmHg, the effectiveness before overhaul was 46.103% and 49.66% after overhaul. The greater the vacuum pressure value, the greater the effectiveness and heat transfer rate of the condenser.
2. Overhaul activities affect the performance of the condenser because retubing of the condenser increases its effectiveness with an average of 42.032% before the overhaul to 47.022% after the overhaul. The heat transfer rate increased from an average of 145,831 MW to 146,825 MW and the heat transfer coefficient increased by 899.08 W/m°C to 938.63 W/m°C, while the LMTD decreased from before the overhaul with an average of 11. 21°C to 10.75°C.

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