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Effect of Load Cooling on the Performance of Steam Power Plant Condensers

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Abstract

This study analyzes the impact of cooling load on condenser performance in the Steam Power Plant. The condenser, as a heat exchanger, plays a critical role in condensing steam from the turbine back into liquid form, thus maintaining the continuous cycle of the steam power system. Survey-based research was conducted, with data collected on steam and cooling water temperatures at various stages. The steam inlet and outlet temperatures were recorded at 514°C and 465°C, respectively, with cooling water entering at 32.9°C and exiting at 38.9°C at a flow rate of 100 m³/h. Using the Log Mean Temperature Difference method, initial and final temperature differences were calculated at 453°C and 465°C. Results suggest that tube fouling or leakage contributes to declining condenser efficiency, which can significantly reduce power plant performance. This study highlights the importance of regular maintenance and monitoring of condenser units to optimize thermal efficiency and power generation output.

INTRODUCTION

Energy needs in Indonesia are currently increasing. Indonesia is a country with a relatively large area, and along with economic and national development, it is experiencing an overall electrical energy crisis (Rasyid, 2010; Rustam, 2016; Sidabutar, 2018). This can be observed from the total power installed by the State Electricity Company, which has reached 26,000 MW, with a peak load of 24,000 MW, while the effective power available is only around 25,000 MW. This means that if the electricity load increases further, the State Electricity Company will no longer have electricity reserves (Adistia et al., 2020; Rosadi & Amar, 2019).

According to Mulyadi et al., (2023); Setiawan et al., (2017), since 2006, coal-fired power plants have been the most common, accounting for 37.88% of all power plants. Coal is fully utilized as fuel for Steam Power Plants, which initially used oil as fuel. Consequently, electrical energy is crucial for all aspects of daily life, and people recognize its importance. Steam Power Plants generate electrical power using prime movers and generators (Ifvournamasari et al., 2023).

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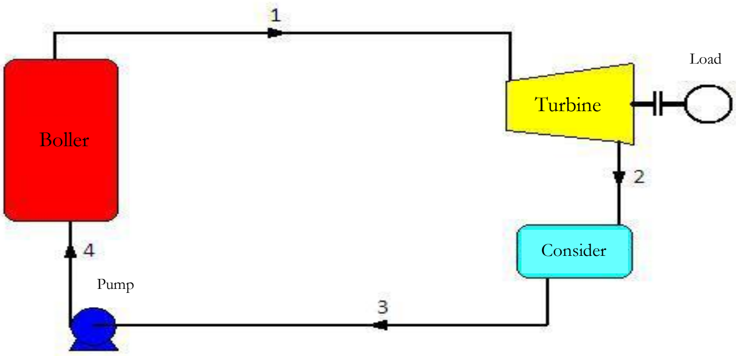

Fig 1. Steam power generation cycle

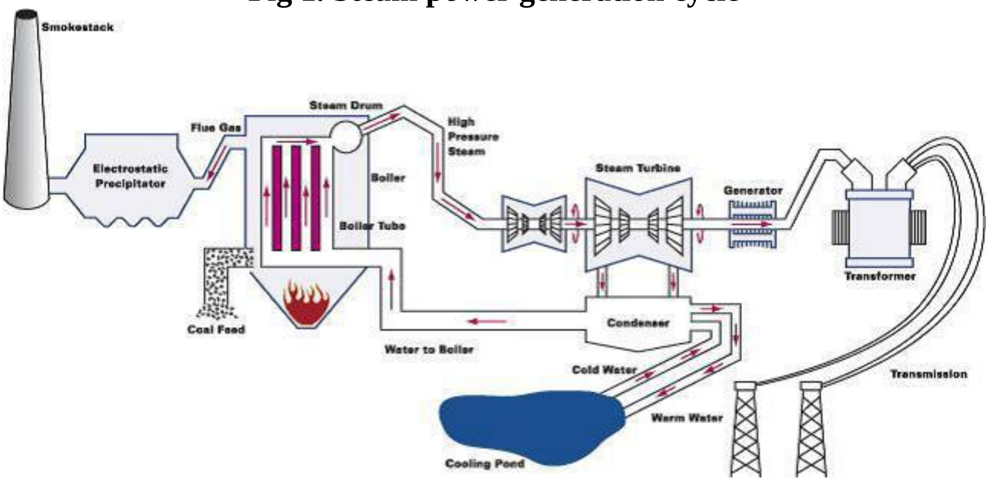

Fig 2. The working process of a steam power plant

One of the Steam Power Plants located in West Sumatra has a capacity of 2 x 100 MW. The condenser, a type of heat exchanger, functions to condense the working fluid (Likadja et al., 2019). In a steam power system, the main role of the condenser is to convert steam into liquid so that it can be pumped back to the boiler (Ashfania et al., 2021). Steam from the turbine flows outside the pipes, while cooling water flows inside the pipes.

One common issue in condensers in steam power plants that affects performance is condenser tube leaks. These leaks are generally caused by damage or erosion to the roll tube or pores penetrating the thickness of the pipe (Ali & Choi, 2019; Dave & Juneja, 2023; Khalid et al., 2020). The vacuum in the condenser is influenced by the amount of steam entering it, and leaks in the condenser tube can cause seawater and condensate water to mix, leading to corrosion on the condenser walls (Mazed et al., 2018). If this problem occurs, it can reduce the generator's efficiency, which is undesirable, as Steam Power Plants operate continuously every day.

METHODS

This research employs a descriptive method to examine the cogeneration system at the Ombilin Sijantang Sawahlunto Steam Power Plant. The data collected includes initial and final data obtained through direct observation and interviews with technical personnel at the plant (Putra & Melkias, 2022; Teguh et al., 2022). Observations were conducted to record operational conditions and technical parameters, while interviews were used to gather in-depth information regarding procedures and maintenance of the condensation system. Data from observations and interviews were then analyzed to evaluate and recalculate the cooling load on the condenser. This analysis considered various factors that influence condenser performance, such as temperature and cooling water flow

(Attia, 2015; Hassan et al., 2020; Wang et al., 2015). The results of this analysis are expected to provide insights into the condenser's efficiency and identify necessary improvements in the cooling system at the steam power plant.

RESULT AND DISCUSSION

Research was conducted by collecting initial and final data on objects in the Steam Power Plant, focusing on a component known as the condenser. The study began with field observations, identification of each tool that was part of the research object, and a review of relevant literature to provide foundational knowledge for conducting the research. This process enabled the collection of final data on the studied objects, which is presented in the table below:

Table 1. Condenser data of steam power plant

No	Collection type Data	Steam comes in Condenser	Steam exits the condenser	Cooling water enters the condenser	Cooling water comes out of the condenser
1.	Initial temperature conditions	514 ℃	465 ℃	32,4℃	38,9 ℃
2.	Final condition temperature	515℃	490℃	32,9℃	41,4℃

In data processing, the final calculation results were obtained by applying the formula for calculating the average temperature difference, known as the Log Mean Temperature Difference (LMTD). This calculation involves subtracting the temperature at one end of the heat exchanger from the temperature at the other end and then dividing by the natural logarithm of the temperature ratio.

Log average temperature difference (LMTD) calculation formula:

$$\Delta T_M = \frac{(T_{h2} - T_{c2}) - (T_{h1} - T_{c1})}{\ln \frac{(Th2 - Tc2)}{(Th1 - Tc1)}}$$

Information : Δ TM: Average temperature difference

Th1: Condenser inlet steam temperature °C

Th2: Condenser exit steam temperature °C

Tc1: Cooling water temperature entering the condenser °C

Tc2: Cooling water temperature leaving the condenser °C

Survey results from the Steam Power Plant showed that the initial temperature of the steam entering the condenser was 514°C, while the steam exit temperature was 465°C (Aliabadi et al., 2020; Li et al., 2019; Liu et al., 2016). The cooling water entering the condenser was at 32.4°C, and the exit temperature of the cooling water was 38.9°C. The final data revealed an entry temperature of 515°C, an exit temperature of 490°C, and a cooling water entry temperature of 32.9°C, with an exit temperature of 41.4°C. The overall heat transfer area was 320 m², the water flow rate was 180 kg/second, and the heat transfer coefficient was 320°C. Using these values, the average temperature difference (LMTD) and the displacement in the double pipe were determined (Mahdi et al., 2019).

Calculations for initial data

Known:

T_{h1} = 514 ℃ T_{h2} = 465 ℃

T_{c1} = 32,4 ℃ T_{c2} = 38,9

Calculation of average temperature difference (LMTD)

$$\Delta T_M = \frac{(T_{h2} - T_{c2}) - (T_{h1} - T_{c1})}{\ln \frac{(Th2 - Tc2)}{(Th1 - Tc1)}}$$

$$\Delta T_M = \frac{(465°C - 38{,}9°C) - (514°C - 32{,}4°C)}{\text{In}\frac{(465°C-38{,}9°C)}{(514°C-32{,}4°C)}}$$

$$= \frac{426{,}1\ °C - 481{,}6}{\text{In}\frac{(426{,}1°C)}{(481{,}6°C)}}$$

$$= \frac{-55{,}5}{\text{In}\ (0{,}8847)}$$

$$= \frac{-55{,}5}{-0{,}1225}$$

$$= 453\ °C$$

So, the average temperature difference at the initial condition is 453 W

Calculations for final data

Known :

T_{h1} = 515 °C T_{h2} = 490 °C

T_{c1} = 32,9 °C T_{c2} = 41,4 °C

Calculation of average temperature difference (LMTD)

$$\Delta T_M = \frac{(T_{h2} - T_{c2}) - (T_{h1} - T_{c1})}{\text{In}\frac{(Th2-Tc2)}{(Th1-Tc1)}}$$

$$\Delta T_M = \frac{(490 - 41{,}4) - (515 - 32{,}9)}{\text{In}\frac{(490-41{,}4)}{(515-32{,}9)}}$$

$$= \frac{448{,}6 - 482{,}1}{\text{In}\frac{(490-41{,}4)}{(515-32{,}9)}}$$

$$= \frac{-33{,}5}{\text{In}\frac{(448{,}6)}{(482{,}1)}}$$

$$= \frac{-33{,}5}{\text{In}\ (0{,}9305)}$$

$$= \frac{-33{,}5}{0{,}0720}$$

$$= 465\ °C$$

So, the difference in average temperature from the final data is 465 W

Initial Data Double Pipe Calculation

$q = UA.\ \Delta T_M$,maka

$A = (33{,}70 \times 10^5) / (320)\ (453) = 234\ m^2$

Double Pipe Calculation Final Data

$q = UA.\ \Delta T_M$, maka

$A = (33{,}70 \times 10^5) / (320)\ (465) = 241\ m^2$

Based on the analysis of the recalculated cooling load on the Steam Power Plant condenser unit, the coolant temperature load entering the condenser varied. Calculations using the LMTD formula showed that the initial temperature entering the condenser was 453°C, while the final temperature was 465°C, with the double pipe calculations ranging from 234°C to 241°C. This data indicates a reduction in water supply and blockages in the condenser pipes.

CONCLUSION

Based on the findings presented in the discussion section, it can be concluded that decreases in pressure or temperature within the condenser, turbine, and connecting channels between components significantly impact condenser performance. The actual performance of the condenser and the initial and final heat outputs differed. Calculations on the coolant temperature difference in a Steam Power Plant revealed that the initial temperature entering the condenser was 453°C, while the final entry temperature was 465°C. Data analysis indicated blockages in the tube lines, fouling in the cooling water, and a reduced cooling water supply.

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