

Failure Analysis of Condenser Tube in Unit 1 of the Tenayan Steam Power Plant 2 X 110 MW

Nur Rohman Aziz
Mechanical Engineering
 Universitas Muhammadiyah Riau
 Indonesia
 nur.rohman.aziz@gmail.com

Ahmad Kafrawi Nasution*
Mechanical Engineering
 Universitas Muhammadiyah Riau
 Indonesia
 ahmadkafrawi@umri.ac.id

Ridwan Abdurrahman
Mechanical Engineering
 Universitas Muhammadiyah Riau
 Indonesia
 ridwanabdurrahman@umri.ac.id

*Corresponding author

Abstract—This study conducted a failure analysis of the condenser tube in unit 1 of the Tenayan Steam Power Plant. It started from the inspection in the first year after the commercial off date (COD) where there is a leaky tube, so there is further suspicion. Various tests and analysis are carried out such as tube vacuum testing, Eddy current testing, condenser tube material analysis, condenser water quality analysis, effectiveness and heat transfer on a condenser to the determination of root cause failure analysis to ensure condenser performance. From the results obtained, the cause of the failure of the condenser tube in unit 1 is the thinning of the condenser tube wall. The failure mechanism is erosion corrosion caused by the use of water in condensers that contain high turbidity.

Keywords— *Condenser, Erosion Corrosion, RCFA, turbidity, dent*

I. INTRODUCTION

Failure of a component in a plant can cause a decrease in performance and at the same time losses at a plant. The operational reliability of the power plant depends on the quality of the condenser pipe, corrosion resistance and anti-fouling performance [1]. Wang, Y. (2007) also said the condenser pipe's lifetime directly affects the operational status of the power plant unit [2, 3].

The condenser is one of the important equipments in the process of a special powerplant on the PLTU system. The main function of the condenser is as a device used to condense steam from the extraction of turbines into air points (condensate air) and condense steam into the air that is accommodated at Hotwell. Furthermore, the water is circulated again to be turned back into steam [4].

The condenser is a component that works to convert steam into water and be reused [5]. The change process is carried out by flowing current into the room that contains the pipe. Steam flows outside the pipe while water as coolant flows through the inside of the pipe as the scheme shown in Figure 1 (a). Water requirements for cooling in the condenser are very large, so planning is usually taken into account. Cooling water is taken from sources that have enough water, such as lakes or the sea.

II. BRIEF HISTORY

The Tenayan steam power plant has a capacity of 2 X 110 MW which was built in 2012 and completed in 2017. Unit 1 of the Tenayan steam power plant was commissioned from March 2016 to March 2017, and in October 2017 the commercial off date (COD) was carried out. After one year of operation, the Tenayan steam power plant is held at the first year inspection (FYI) to see the condition of the equipment after 1 year of operation. When inspections were carried out on the condenser, 23 tubes were leaked and a blockage was made.

The vacuum tightness test was then performed on the unit 1 tube condenser in the same year and a vacuum time of the vacuum tightness test on condenser unit 1 on September 9, 2016, May 23, 2017, and August 14, 2017. The value of the vacuum drop was 708.6 Pa/min. This value exceeds the standard of 400 Pa/min. This test serves to determine the performance of the condenser when the vacuum pump is turned off. When overhauling, the condenser is checked to confirm the leakage point by using the water filling method on the side of the shell. The results of checking found 23 tubes that have leaks.

III. ANALYTICAL TECHNIQUES

A. Condenser Tube Vacuum Testing

Checking the condenser tube leak by a vacuum testing was carried out. The implementation of this leak test follows the ASME Section V Leak Test standard article 10 [6].

B. Eddy Current Testing

Eddy Current Testing (ECT) is one of the main techniques in the Nondestructive Testing (NDT) method used in object testing to detect defects, cracks, and holes in various conductive materials [7]. The principle of Eddy Current Testing is based on the interaction between the source of the magnetic field and the object being tested, which is called the eddy current. The principle of Eddy Current Testing is based on the interaction between the magnetic field source and the test object [8]. The inspection of eddy current tests on condenser tubes follows the ASME BPVC standard Part V Article 8, App.II Eddy Current Test for Nonferro magnetic Pipes [9].

Before conducting the ECT test, plotting and marking of the sheet were performed as a reference for the X-Y tube

coordinates, Row number and Tube number following the tube sheet configuration. Furthermore, plotting the X-Y coordinates is adjusted to the segmentation as shown in Figure 1 (c).

C. Condenser Tube Material Analysis

The analysis used is to use the In Situ XRF (X-ray fluorescence) tool for the material composition of the condenser pipe and metallography test to see the structure of the microtube.

D. Effectiveness of a Condenser

Effectiveness is a quantity that can explain how effective the work of a heat exchanger is. The equation used to calculate the effectiveness is [10].

$$\varepsilon = Qc / Q_{Cmax}$$

Q_{Cmax} = Maximum heat transfer that may be achieved by the condenser

C_c = Heat capacity of the cooling fluid

C_h = Fluid heat capacity

C_{min} = Minimum heat capacity

E. Heat transfer on a Condenser

The equation of heat transfer in a thermodynamic condenser is as follows:

$$Q = (m_{h\ in} \times I_{in}) - (m_{h\ out} \times I_{out})$$

$$Q = U \times A \times F \times \Delta T_{lm,CF}$$

Where :

Q = Heat transfer inside the condenser

$m_{h\ in}$ = Mass flow rate of steam entering the condenser

I_{in} = Enthalpy steam entering the condenser

$m_{h\ out}$ = Mass flow rate out of the condenser

I_{out} = Enthalpy condenser water comes out

U = Overall convection coefficient

A = Cooling Surface

F = Correction Factor for shell and tube type heat exchangers

$LmTlm$

CF = Log Mean Temperature Difference

F. Root Cause Failure Analysis

Root cause failure analysis (RCFA) is a series of logical steps that guide observers through a process that separates facts that include an activity or failure. When a problem is defined, this analysis will systematically determine the most appropriate thing to do that will solve a problem and ensure that the problem will not be repeated [11].

The research method used in this study is the RCFA (root cause failure analysis) method. This method is used to find the roots of problems that occur with the help of a fishbone diagram tool that is supported by material analysis and NDT.

IV. RESULTS & DISCUSSION

A. Condenser Vacuum Test tube

Leakage tests conducted during routine maintenance did not find leaks.

B. Eddy Current Condenser Test

The results of the examination using ECT of 10,716 tubes are summarized in Table 1, where there are 437 tubes that have been damaged, with details of 218 tubes that can not be tested because there is a blocked tube. This block tube occurs due to uneven welding results on the surface of the condenser tube or a blockage in the middle of the tube position so that the eddy current probe cannot enter. From the results of further inspection, the damage that often occurs is dent and thinning thick diameter of the condenser tube.

TABLE I. SUMMARY OF EDDY CURRENT TEST RESULTS

UNIT	INSIDE DEFECT			OUTSIDE DEFECT		
	<20%	21% - <60%	61% - <100%	<20%	21% - <60%	61% - <100%
	ID1	ID2	ID3	OD1	OD2	OD3
Condenser 1 Side A Upper	4	5	3	10	9	0
Condenser 1 Side B Upper	1	4	8	3	0	0
Condenser 1 Side A Lower	5	3	3	5	0	1
Condenser 1 Side B Lower	0	0	1	1	2	0
TOTAL	10	12	15	19	11	1
UNIT	BLOCKED TUBE	OLD PLUG	LOST PLUG	DENT	TOTAL	
	BT	OP	LP	D		
Condenser 1 Side A Upper	21	6	3	27	88	
Condenser 1 Side B Upper	134	1	2	72	225	
Condenser 1 Side A Lower	54	10	1	40	122	
Condenser 1 Side B Lower	9	6	0	10	29	
TOTAL	218	23	6	149		

Based on Eddy current test data, there are 147 dent tubes. From the identification of the causes, the dent of the condenser tube was caused by the fabrication process during installation. This proved to be no flashlight between the condenser tube and the tube sheet. Due to the dent of the condenser tube, the fluid flow in the tube is no longer laminar flow, so turbulent flow that occurs can trigger erosion in the tube wall. The same thing was also pointed out by Volkan Cicek (2014) where the main cause of erosion-corrosion is turbulent flow in a fluid which is also called turbulence corrosion [12].

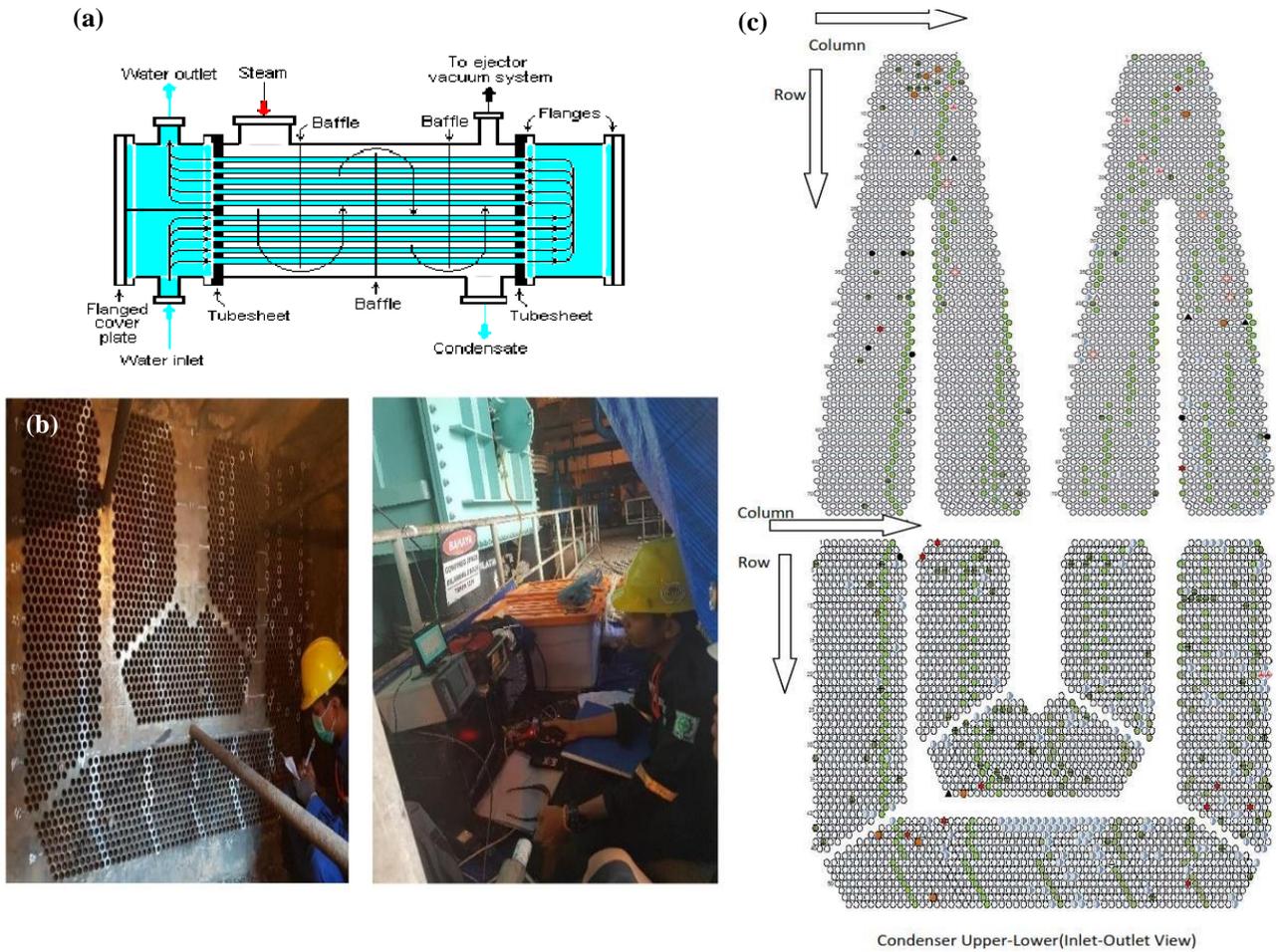


Fig. 1. (a) condenser scheme, (b) arrangement of condenser tubes, (c) plotting and marking condenser tubes

C. Condenser Tube Material Analysis

Test results of the chemical composition of the tube material are shown in Table II. When viewed from the composition test results based on the alloy elements contained in the material is almost the same as the SS304 material [13]. The microstructure analysis of the tube material was then performed as shown in Figure 2. The microstructure image of the tube material is matched with the microstructure of the SS304 material using ASM Handbook Metallography and Microstructures [13]. The microstructure image obtained is a condenser tube material that has been used for 3 years with a maximum working temperature of 80 °C.

TABLE II. RESULTS OF IN SITU XRF (X-RAY FLUORESCENCE) TUBE CONDENSER

Material	Alloy element (%)				
	Fe	C	Si	Mn	Cr
Tube	71.760		0.083	1.087	17.770
SS 304[13]	Bal.	0.080	0.080	2.000	18-20

Material	Alloy element (%)			
	Ni	Mo	S.	P.
Tube	8.850	0.045	0.014	0.016
SS 304[13]	8 - 10.5	-	0.035 max	0.045 max

This is the same as the statement of J. Paul Guyer (2013) that the tube material used for the specification of water cooling freshwater with a specific conductance of 2000 - 9000 Ms/cm and chlorine content of 250 - 1500 Mg/L is SS 304.



Fig. 2. The microstructure results from the condenser tube, 400X magnification.

D. Condenser Water Quality Analysis

The measurement data of the pH value of the Siak river water shows the value of 5.32 - 6.48. From the measurement of turbidity value from raw water, it is obtained 200 - 300

NTU, where this value exceeds the standard that is <15 NTU. Tests were also carried out on cooling water and turbidity values obtained 227.86 NTU and Total Suspended Solid (TSS) 236 mg/L. The application of chemicals in the water treatment system has not been maximized and solid particles from the Siak river water are still carried away, which can be seen in Figure 3.



Fig. 3. Condition of Air Cooling Tower

To ensure the particles dissolve in water from the cooling tower, a composition test of the particles is carried out. From the results of testing the composition of particles as shown in Table III and the highest is silica and iron.

The Electric Power Research Institute (EPRI) states that all condenser tube materials will quickly experience corrosion - corrosion if there is mud or sand in the water (turbidity and TSS) originating from cooling water. [14].

TABLE III. COMPOSITION OF WATER COOLING TOWER DEPOSITS

PARAMETER	UNIT	RESULT
Iron	% Fe ₂ O ₃	3.57
Sodium	% Na ₂ O	0.58
Potassium	% K ₂ O	0.35
Zinc	% ZnO	0.22
Copper	% CuO	0.01
Manganese	% MnO	0.14
Nikel	% NiO	<0.01
Magnesium	% MgO	0.20
Loss Of Ignition	%	82.51
Silica	% SiO ₂	4.42

E. Effectiveness and Heat transfer on a Condenser

Based on the calculation of heat transfer, it can be concluded that each one plugging condenser can reduce heat transfer by 0.016 MW or equivalent to 16,000 Watts. The maximum allowable plugging is 5892 plugs because the minimum allowable heat transfer to the condenser so that it can be used to change the phase is 71.28 MW. Therefore, if the plug has reached 5.892 tubes, the condenser needs to be retubing to replace the tube that has been plugging.

F. Root Cause Failure Analysis

From the above data, several causes of condensing tube depletion in unit 1 can be taken which is poured into the fishbone diagram shown in Figure 4. The results of this discussion will be the basis for determining the root cause of the problem so that failure defense tasks can be obtained to minimize condenser tube failures.

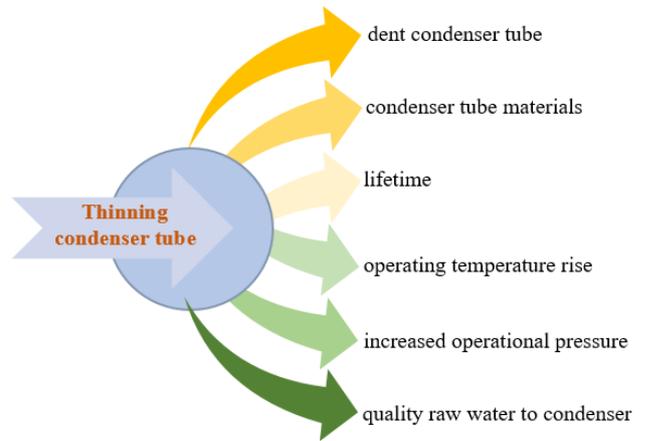


Fig. 4. Fish Bone Diagram

Based on the results of the study, matrices were made for a number of causes which could result in depletion of the condenser tubes as shown in table IV.

TABLE IV. CAUSES OF CONDENSER DEPLETION PROBLEMS

No	Cause of Problem	Confirmation Step	Results
1	Condenser tube is not straight (dent)	The results of eddy current tester found 149 dent tubes.	Cause
2	Tube condenser material is not suitable	Results from XRF SS 304 tube material, according to the standard	Not a Cause
3	Age / Lifetime	The new condenser is installed and operated for 3 years. The results of the metallographic tube condenser are still good.	Not a Cause
4	Increase the operating temperature of the condenser	From the operating data, there was no significant increase in temperature.	Not a Cause
5	Condenser operating pressure increase	From the operating data, there was no significant increase in pressure.	Not a Cause
6	Condenser raw water exceeds quality standards	From the operation data, it is known that the NTU value exceeds 200-300 NTU standards (standard < 50 NTU)	Cause

From some of the causes above, there are 2 causes of problems that can be a way for condensation depletion, namely: Condenser dent tube and Condenser raw water exceeds quality standards.

The thinning of the Unit 1 condenser tube begins with the amount of dent and high turbidity in the condenser cooling water. When ECT was done, there was a lot of damage in the form of a dent in the tube and there were several tubes that had been plugged. Therefore, it can be concluded that the dent occurred due to fabrication at the time of installation so that the cooling water flow in the condenser tube experienced turbulent flow. Such conditions are exacerbated by the high content of sludge and TSS in cooling water. These two things that cause erosion corrosion to occur and cause thinning of the condenser tube.

V. CONCLUSION AND RECOMMENDATIONS

Based on research on "Failure Analysis of Condenser Tube in Unit 1", there are several conclusions that can be drawn. Analysis of the condenser tube material is SS 304. While the mechanism of condenser tube failure is in the form of tube wall thinning, condenser tube bender and use of raw water contain turbidity of sand.

It is recommended to use water for condensers using a closed cycle where the water used comes from the water treatment system and not from the river anymore.

ACKNOWLEDGMENT

The authors would like to thank PT PJB UBJOM PLTU Tenayan and Universitas Muhammadiyah Riau, Indonesia for their cooperation in completing this article.

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