Preliminary Study of Failure Analysis on Tube Material Boiler Based on Pressure Aspect

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Abstract. Tube boiler has an important function to change water from liquid to vapor phase. However, it needs a material selection which has a role to find the best material properties, mainly at steam power plant. One of the properties is to receive a pressure when a boiler is being operated. Several literatures suggested that material characteristics affected the life of a material after receiving pressure repeatedly which lead to failure. The aim of this study is to find the best formula in anticipating the occurrence of repeated failures of a tube based on pressure aspect, mainly in steam power plant. Results show that Analysis of various papers mentions failure caused by several interrelated factors. Factors that causes a failure was discussed due to corrosion and overheating, while the pressure factor is not a main factor causing a failure. The best formula for determining the failure analysis in terms of stress are material selection, visual observation of the failure form, knowing the location of the failure, measuring the thickness and using the Von Mises and API calculations to determine pressure acceptable to the material. This study suggests to use these findings as a pressure maximum which can be accepted material. In further studies related to find the remaining life of the material in terms of stress and thickness on tube boiler operation.

1. Introduction

Human life today cannot be separated with energy. In the process of energy conversion in Indonesia, there are several generations (energy) that generate electrical energy, one example is steam power plant. Steam power plant using a boiler as a place to change the water by using heat from the combustion of fuel, the heat of combustion then the heat of the combustion products flowed into the water to produce steam (water vapor that has a high temperature). We can conclude that the boiler serves to produce steam that can be used for the process or subsequent needs. Steam can be used to keep the temperature in the petroleum distillation column and evaporator process in the evaporator. Generally, combustion used in boilers are coal, gas, and fuel oil. One such generation is the steam power plant. In steam power plants, boilers have an important role. A boiler is a place for changing water from a liquid phase to a vapor phase [1,2]. Inside the boiler, there are tubes as a fluid place. In the event of failure of the tubes in the boiler, it will cause the process of transfer of electrical energy to the consumer can be stopped [1]. If the transfer
process is not occurring, it will result in economic losses from the steam power plant. In order for the process of phase change to take place properly, the tubes used must be in accordance with the criteria when the tube is operated. The choice of material from mechanical properties can be seen from the material's ability to accept loading without causing damage when the tube is being operated, thus extending the useful life of the material [1,3]. Analysis to find the best properties of materials has been done by performing various solutions to cases of tube failure. From the various solutions to these cases, more about the failure caused by corrosion factors, so the review of the causes of failure of various factors need to be discussed mainly from the voltage factor. In this paper will be reviewed on the analysis that has been done then determine the best formula to determine the failure of the boiler tube seen from various aspects, especially those involving pressure factor. Recommendations from the results of this study analysis can serve as a reference in conducting failure analysis in similar cases.

2. Processing scheme
This paper discusses the analysis of various papers on the failure analysis of the boiler tubes in boilers. From the various papers are analyzed then taken the best conclusions and methods in conducting analysis on the failure of the boiler tube. The methodology of the research paper can be shown as follows:

1. Study literature
2. Find Paper (failure on tube boiler)
3. Paper analysis
4. Find best method
5. Conclusion

The method used in analyzing paper is by:

1. Separation of papers relating to the analysis of the failure of the published steam-powered boiler tube.
2. Sorting results are studied and then analyzed on the causes of failure in terms of several aspects.
3. Making conclusions from the results of research papers that have been studied and analyzed on the conclusion of the cause of failure of any factor.
4. Provide input and find the best formula to determine the cause of the failure factor especially in terms of the effect of the tension on the tube when operated so that no similar damage will occur.

3. Discussion
The failure analysis of the super heater tube boiler [1]. The boiler uses coal fuel. The presence of local heating can affect the uneven distribution of temperature so that it will affect the stress concentration in the material. The failed investigation was found on the tube located on the super heater. Super heater tube is using the material Cr-Mo Low Alloy Steel. Visually, failure looks like a fish's mouth. To determine the factors causing the damage, observation is made on the material. These observations can be visual macro observations. Microscopic observations were performed using an electron microscope, in this case observations using SEM. From the results of micro-observation, found a creep indication (a failure that is often experienced in materials used for high temperatures). The presence of elliptical and globular crystalline grains indicates that overheating of the area. The existence of bright area indicates that the area occurs periodization. Test results using chemical composition show that the material has been suitable and there is no significant change. The analysis using X-Ray rays shows that Fe-Oxide and Hydroxide are referred to as corrosion products. The result of the stress calculation is found that due to the decreasing of thickness, in sample A and sample B it is found that the material has passed its yield strength when operated at a voltage in accordance with the standard of operation. From the various analyzes that have been done, it can be concluded that the failure is caused by overheating of the tube and in that part there is a thick crust so that the crust is moistening the corrosion that can reduce the thickness. In that part also creep.
The Root cause analysis and economic implications on the Thermal Power plant with a power of 210MW [4]. Failures are analyzed on the parts that exist in the boiler. The analysis begins by grouping the kinds of damage that can occur in the main boiler tube, including: stress rupture, erosion, water side corrosion, fatigue, fire side corrosion, and lack of quality control. The case study lasted for ten years beginning in 2004 until 2014 located in Maharastra area, India. From the results of the investigation for ten years the damage occurred in the water wall tube, economizer, reheated, final super heater, low temperature superheat. The most failure is in the economizer part of 30%. Factors that contribute to the failure of the Economizer include stress rupture, fatigue, erosion, water side corrosion, fire side corrosion and lack of material quality. Of the six factors that have the most influence is the erosion corrosion. The economic impact caused by the failure analyzed in ten years was water wall tube of 340.97 million per unit, at economizer of 465.73 millions of units. The economic impact of the reheated failure was 285.09 millions of units, the final part of the super heater was 263.16 millions of units, and at the super heater low temperature of 263.16 millions of units. At the end of the conclusion provides an explanation that preventive action is needed to prevent the occurrence of more serious failures such as indications of causes of failure and take action in minimizing similar events in the future.

The material analyzed is BS35 carbon steel with diameter 63.5 mm with 3.5mm thickness [2]. The frequent failures of the tube in the paper are stress-corrosion cracking, pitting, water-side corrosion, fire-
side corrosion, fatigue failure, overheating, dissimilar metal weld fatigue, mechanical fatigue and erosion. Failure is in the form of a crack at the end of the tube which is welded when the observation is done by using SEM on the material used in the boiler. For comparison analysis used material of ceramic ferrule by using fluent and CFD. The result obtained is a tube material in the form of carbon steel voltage received for 1.18Pa and heat transfer of 1154086 W. In ceramic ferrule obtained voltage received when the material operates for 6.32x10-2 W and heat transfer of 112.53 W. Conclusion of the paper A ceramic ferrule can be mounted at the end of the inlet tube to prevent the occurrence of end crack because ceramic ferrule can be used at high temperatures although the ceramic properties are brittle but can be used to inhibit the occurrence of crack.

### Table 1. Comparison between the boiler tube and ceramic ferrule

|          | Tube            | Ferrule          |
|----------|-----------------|------------------|
| Material | Low carbon steel| Zirconia toughened alumina |
| Pressure | 1.18 Pa         | 6.32e-2 Pa       |
| Heat transfer | 1154086 | 112.53           |

The Power Plant uses fossil fuels [3]. The fuel selection is based on a cleaner power plant and has a higher efficiency than coal. In the paper it is explained that the combustion of high temperature on the tube will be able to cause a change in the ability to receive stress due to imperfect heat transfer due to incomplete combustion. In this paper, a mathematical calculation of the maximum value of hoop stress (internal stress) that can be accepted by the tube that is affected by the thickness value of the tube. From the graph shown can be concluded that the smaller the value of the tube thickness then the voltage received by the tube becomes larger it indicates that the material's ability to accept the smaller pressure. The calculation of the remaining life of the boiler tubes on behalf of longitudinal thermal stress may result from the longitudinal stresses of the hypotheses and the resulting resistance of the boiler tube at higher temperature and Flow rate the remaining life analysis must give logical result in comparison with efficiency calculation. The calculation of efficiency on behalf of hoop stress value gives more accurate result of efficiency on the safety of the modern thermal power plant.

![Hoop Stress vs. Tube Wall Thickness](image)

**Figure 3.** Hoop Stress as a function of tube wall thickness [3].

The causes of failure of the boiler tube (in the steam drum) are corrosion / erosion, corrosion fatigue, thermal fatigue, mechanical fatigue, overheating and other causes [5]. Failure is based on paper can occur due to inadequate water management, bad operation, poor maintenance, other factors (outside management's direct control, such as manufacturing defects, etc.). The conclusion obtained states that the boiler has been operating for 60 years and with poor maintenance conditions so it needs an intensive
corrective action. Need improvement in managerial system. There is a need for replacement of material on boiler tubes where proper material specifications are required in this case.

From the macro visual observation results obtained damage in the form of a hole in the tube [6]. The hole is located on the fire side water-wall tube. From the results of testing the chemical composition found that the tube is in accordance with standard conditions. The result of micro photo analysis showed that there was oxidation corrosion in the material. The result shows that the failure of the tube due to oxidation, which leads to the tube pressure exceeds the bearing limit of the thin tube. Since the oxidation is the root of the tube, it is recommended that the standards of water quality of the boiler water wall tube should be implemented strictly in the operation process, in order to improve the operating environment of the boiler tube, especially to control the oxygen content in the water. In addition, preventing the boiler tube from exceeding the working temperature.

According to incomplete statistics of a thermal power plant accident occurrence of unplanned outage, the boiler "Four Tubes" leakage Caused by unplanned outage times 60% [7]. Seriously study the boiler "Four Tubes" leakage causes and instances preventive measures that are put forward have some practical engineering significance. The conclusions obtained are The above simple analysis of the main types of boilers "Four Tubes" leakage, through the analysis of the leakage on the pressure components of the boiler, the boiler "Four Tubes" installation, maintenance, operation and provide help and reference. To reduce the accident rate of four tube boilers, making the equipment to obtain the controllable, in control, to ensure long-term stable and safe and economic operation of boilers.

From a variety of papers on the analysis it was found that the cause of the occurrence of factor damage often discussed is the result of corrosion and overheating. There is a discussion about the damage as a result of the voltage but still as a supporting cause even though the discussion of the factors causing the failure is not only due to one effect only. However, due to several factors that are related. The portion for discussing the effect of the pressure is still too significant. Many components which need to be added and become inputs from some of the above papers to do analysis is taking maximum pressure of the influence of stress as the main influence.

The analysis of all papers that the failure of the boiler tube is not only caused by a single factor, but several factors that are related to each other. When viewed from the side of stress mechanism that need to be added of the above paper is about the calculation of pressure with the Von Mises equation or use API standard [8].

Von Mises
Below is the calculation of Von Mises criteria (Juvinal,1964)

\[
\sigma_1 = \frac{P \cdot r_{avg}}{t}
\]

\[
\sigma_2 = \frac{P \cdot r_{avg}}{2t}
\]

\[
\sigma_e = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \cdot \sigma_2}
\]

Whereas the calculation of API 530 standard criteria with thickness of 0.108 inch is: (API 530,1996).

\[
\sigma_n = \frac{P \cdot D_o \cdot P \cdot t_{min}}{2 \cdot t_{min}}
\]

Both equations can be used in determining the material's ability to receive stresses that can be related to thickness changes, wherein the correlation between stress and thickness can be used for calculations in determining the life of the material when operated.

Material selection is very important because of it can be used to know the material properties. From the material properties of mechanical property can be used to determine the ability of the material to receive the pressure without causing the failure.
4. Conclusion
Conclusions drawn from the research paper found that the paper discusses the causes of failure caused by several factors that are mutually sustainable. Factors that are often the main cause of damage in the form of corrosion and overheating, while the material capacity factor in receiving pressure is still not reviewed in detail. If we want to do research on boiler tube analysis the things that need to be added as inputs are:
1. Material selection.
2. Perform visual observation, tube failure parts and tube failure location.
3. Perform dimension measurements.
4. Calculate the material's ability to receive pressure with Von Mises equation and using API standard.

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