



Micro analysis of the structure of the boiler pipe after experiencing the heating process and without heating

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ABSTRACT

Piping is a tool that functions to drain fluid from one place to another. The problem at Factory X is the failure of the boiler pipe. Pipe failures that occur are known by indications of leaks in the boiler. The initial process of a failure in an ordinary pipe is characterized by corrosion. The problem of corrosion in boilers is usually caused by feed water or feed water which still contains high oxygen levels. The purpose of the research is to determine the microstructure of the boiler pipe after experiencing the combustion process in the combustion chamber. This research method is an analysis of the chemical composition of boiler pipe material, Visual / Macro and Micro Testing. From the results of the inspection, observation, it can be concluded, the cause of pipe damage on the outside of the fire side caused by erosion corrosion is classified as very severe because it is beyond the optimum thickness of the pipe. Specimen A which is a material that has not received heat treatment has a microstructure, where the condition of the pearlite area is greater than specimen B with heat treatment.

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1. INTRODUCTION

Piping is a tool that functions to drain fluid from one place to another. The problem at Factory X is the failure of the boiler pipe. Pipe failures that occur are known by indications of leaks in the boiler (Lancaster, 1973; Thekkuden et al., 2021). Boilers operate at high pressure and high temperature. When the boiler pipe life reaches its limit, failure will occur. High temperatures on the outside of the pipe, high pressure inside, and also flames that have been contaminated with corrosive residues for a long amount of time will cause pipe failure. The initial process of a pipe failure is usually characterized by corrosion. Corrosion problems in boilers are usually caused by feed water or feed water that still contains high oxygen levels and system leaks, the presence of deposits (under deposit corrosion). This problem can be prevented by providing a plant to reduce oxygen levels accompanied by injection of oxygen scavenger. Pure water which is composed only of H₂O molecules and without any other substances dissolved in it, is not corrosive. Other substances dissolved in water are the ones that trigger water to have corrosive properties. Oxygen is one of the gases that dissolves easily in water and is the main cause of corrosion in pipes (Al-Moubaraki & Obot, 2021; Costa et al., 2023). Water temperature is also one of the factors supporting corrosion. As we all know that the water in the boiler will reach very high temperatures according to the type of boiler used. Water that is at high temperature will have properties that are very different from water at room temperature. At

temperatures above its critical temperature, water will become easier to dissolve various kinds of substances that were previously insoluble (Ding et al., 2020; Wang et al., 2020; Wong et al., 2019).

Piping in an industrial context, such as at Plant X, is a vital component in conveying fluid from one point to another. However, boiler pipes often face complex challenges, especially when it comes to failures that can cause huge losses, both financially and operationally. At Plant X, one of the problems frequently encountered is boiler pipe failure, which often manifests in the form of leaks that indicate structural damage. These boilers operate at high pressures and temperatures, so the reliability of their pipes is key in maintaining a smooth production process (Fioranelli & Bizzo, 2023; Morake et al., 2023).

Boiler pipe failure can generally be caused by a variety of factors, including continuous exposure to high temperatures from the outside of the pipe, high internal pressure, as well as the influence of corrosive remnants in the combustion process that occur over a period of time. The initial process of pipeline failure is usually characterized by corrosion, which is often triggered by the presence of high oxygen in the feed water, or the accumulation of corrosion-inducing deposits beneath the surface of these deposits. To prevent this, preventive measures are required, such as the use of oxygen scavengers to reduce oxygen levels in the feed water (Ali et al., 2020; Gaikwad et al., 2020; Kalu, 2019).

This study aims to examine the microstructure of boiler pipes after undergoing the combustion process in the combustion chamber. By understanding the structural changes and material properties at the micro level, it is expected to provide a deeper insight into the failure mechanism of boiler pipes. This is important to improve our understanding of the factors that affect the reliability and service life of boiler pipes, as well as to design more effective care and maintenance strategies to reduce the risk of failure and extend the service life of these pipes.

2. RESEARCH METHOD

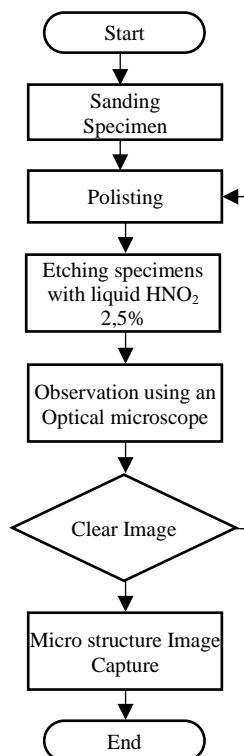


Figure 1. Flow Chart

A. Materials and Equipment

The materials used in this process are pipes that have not undergone the combustion process (standard) and those that have undergone the combustion process in the combustion chamber.

Table 1. Materials and Equipment

Specimen	Inside diameter	Outside diameter
A	40mm	50mm
B	Not flat	50mm

The initial size of this standard material has an inner diameter of 40mm and an outer diameter of 50mm, during the combustion process the material undergoes changes from scale / corrosion and friction from the fluid which results in thinning the surface of the inner pipe hole.



Figure 2. Size of pipe material before and after corrosion

1. The materials used by the author in the data search process are:

Post pipe pieces used in factory boilers and cut into smaller sizes to facilitate the data search process.



Figure 3. Specimen Pipe Raw Materials

2. Pieces of pipe that have experienced combustion activity in the boiler combustion chamber.



Figure 4. Pipe pieces that have undergone combustion activity

3. Chemical Solution for Etching Process

The purpose of etching is to improve the optical visibility of the metal material's microstructure so that it is easy to determine grain size and phase identification. The etching solution is selected based on composition, stress, or crystal structure. While the most widely used etching technique is chemical etching, other techniques such as molten salt, electrolytic, as well as thermal, plasma and magnetic etching have also been used for specialized applications. Chemical etching, which uses chemical solutions that are acidic or basic with oxidizing or reducing agents. Can be done by immersion or swabbing.

B. Equipment

- Measuring microscope
- Stop watch
- Grinding machine
- Coarse and fine sandpaper
- Microscope

C. Micrographic Testing

Micrographic testing is carried out with the aim of knowing the microstructure of the boiler pipe material that has been heated in the combustion chamber and before being affected by combustion and comparing the results of its microstructure. This micrographic testing was carried out at the Materials Laboratory of the University of Sumatra Utara.



Figure 5. Optical microscope

The stages carried out in micrographic testing are:

1. Sanding the test specimen
2. Performing polishing
3. Performing etching using a. 2.5% HNO₃ solution + 75% vol alcohol Aqua regia solution
4. Observing using optical microscope
5. Taking pictures

3. RESULTS AND DISCUSSIONS

1. Visual/Macro Testing Analysis

Visual testing is a test used to see how severe the damage is to a material and becomes a benchmark for determining the type of damage that occurs to the material..



Figure 6. Pieces of pipe that have failed/damaged

2. Micro Testing Analysis

a. Specimen A

This micro test is carried out to determine the microscopic structure that can only be seen using a lens with a certain magnification. The magnification that the author uses first is a 200x magnification of Specimen A. In observations using an optical microscope, a lens magnification of 200x to 500x magnification using material that has not received heat treatment is used.



Image of specimen A using 200 x magnification

Image of specimen A using 500 x magnification

Figure 7. Observation Results of Specimen A

b. Spesimen B

In observations using an optical microscope using a lens magnification of 200x and 500x magnification using material that has not received heat treatment.

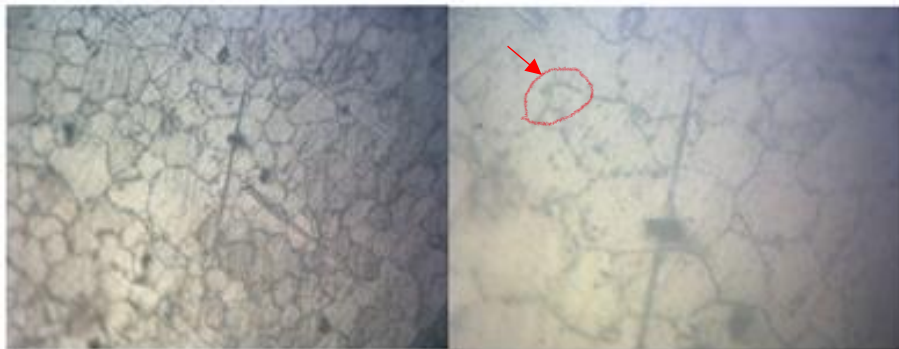


Image of specimen B using 200 x magnification

Image of specimen B using 500 x magnification

Figure 8. Observation Results of Specimen B

Micro Analysis Results

Obtained from the picture above. explains that the microstructure formed is a ferrite and pearlite microstructure. Where, the black area shows the pearlite area and the white area shows the ferrite area. Specimen A which is a material that has not received heat treatment has a microstructure, where the condition of the fearlite area is greater than specimen B with heat treatment. In the picture of the metallography test results it is concluded that the damaged pipe has lost a lot of pearlite area. The amount of pearlite microstructure shows the hardness of a material. The more microstructure in the form of pearlite, it can be said that the structure of the object will have a high level of hardness. Meanwhile, in the picture of the test results above, the pearlite area disappears, so it can be said that the pipe has begun to lose its hardness and the pipe becomes prone to leakage. The formation of phases in steel, such as pearlite is due to heat treatment. Different heat treatments produce different phases of steel. Boiler pipes experience continuous heat exposure.

Because of the heat, the pearlite phase that already exists in the pipe steel can change due to the heat received in the long term. This will change the phase of the pearlite steel. The phase change from pearlite to ferrite causes the hardness to decrease, as a result it is prone to leakage. The superheater platen pipe is traversed by hot steam with a fairly fast flow, so this can cause high pressure in the pipe. Coupled with bends that result in friction with the wall is even higher. Due to the high friction and the material changing phase to ferrite which has less hardness than pearlite, the steam flow erodes the pipe elbow. Hence, leakage at the elbow of the superheater platen pipe occurred (see figure 6).

Appropriate alloying to improve corrosion resistance is one possible strategy to counteract the pipe corrosion problem. The service life of the pipeline will be longer for steel alloys or higher nickel alloy alloys. However, the effects of using such alloying materials are not easy to predict (effects such as chemical reactions, etc. in the duct and turbine follow-up of the pipeline). Alloys with less iron and more nickel, chromium, molybdenum, etc. also increase the price, making the choice less economically viable (Kappenthuler & Seeger, 2021). However, if the effects are predictable, i.e. do not produce harmful compounds (will cause rust, etc.), the application of such alloys would be economically advantageous, unless there are frequent severe fluctuations in steam temperature due to frequent sensor failures, etc. Another explanation that may need to be added is that the occurrence of pipe voids originates from fatigue at high temperatures, which results in the formation of voids in the material. These voids will meet and merge to form intergranular cracks. Intergranular cracks that merge will form larger and larger cracks. Due to the large number of cracks, the material becomes vulnerable and material perforation occurs (Goda & Girardot, 2021; Zhang et al., 2020).



Figure 9: Material that has cracked resulting in a hole

Another additional explanation that may need to be added is that the pipe failure is creep due to operating at high temperatures and pressures (overheating) with long operating times and followed by softening (annealing) so that erosion occurs by the fluid in the pipe which causes thinning of the pipe so that the pipe cannot withstand the workload and failure occurs.

4. CONCLUSION

This research aims to analyze the microstructure of the boiler pipe after it has undergone the combustion process in the combustion chamber, focusing on the problem of pipe failure caused by corrosion. The research method involved analyzing the chemical composition of the boiler pipe material as well as visual and micro testing. The results showed that the damage to the pipe occurred on the outside of the fire side and was caused by very severe erosion corrosion, exceeding the optimum thickness of the pipe. Furthermore, specimen A, which has not undergone heat treatment, has a different microstructure from specimen B, which has undergone heat treatment, with larger ferrite regions in specimen A. These conclusions provide important insights into the importance of

proper feedwater management and the need for heat treatment of pipe materials to prevent corrosion damage in boilers. For future research development, it is recommended to expand the scope of the study by considering additional factors that may affect boiler pipe failure, such as different operational conditions, diverse pipe material types, and variations in feedwater composition. Development of more effective corrosion prevention or protection methods, such as the use of special coatings on pipe surfaces or the use of advanced monitoring technologies to detect corrosion early. Collaboration with industry can also help in testing and implementing the developed solutions in a more practical and efficient manner.

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