MECOMARE, 13 (2) (2024) pp. 50-56

Published by: TRIGIN Publisher

International Journal of Mechanical Computational and Manufacturing Research

Journal homepage: www.trigin.pelnus.ac.id

Identification of hardness values of boiler pipes after heating and without heating process

Suardi[1], Hendra Susilo[2], Mulia[3], Fadlah K. Sinurat[4], Supriadi[5]

[1,2,3] Jurusan Teknik Mesin, Universitas Tjut Nyak Dhien, Medan, Indonesia

ARTICLE INFO

Article history:

Received Jul 5, 2024
Revised Jul 20, 2024
Accepted Jul 23, 2024

Keywords:

ASTM A179 boiler pipe;
Brinne Hardness Test;
High Pressure;
High Temperature.

ABSTRACT

Boilers operate at high pressure and high temperature. When the life of the boiler pipe 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 purpose of the study was to identify the hardness value of boiler pipes after experiencing the heating process and without heating on ASTM A179 pipes. The research method carried out is starting from the preparation of tools and materials, cutting small materials (making specimens), hardness testing, data processing, data analysis and drawing conclusions. The research results are as follows: 1) Obtained average hardness values on standard ASTM A179 pipes in boilers with each brinell, Rockwell, and Vickerss test of 63.67 HRB, 45.20 HRC, and 85.20 HV. 2). The average hardness value of ASTM A179 pipes affected by boiler combustion chamber temperature with each brinell, Rockwell, and Vickerss test is 76 HRB, 50.40 HRC, and 202.30 HV. 3) The value of hardness test results on standard ASTM A179 pipes comparing with after heating has increased hardness in each brinell test by 63.67: 76 HRB, Rockwell by 24.20: 50.40 HRC, and Vickerss of 85.20: 202.30 HV.

Corresponding Author:

Suardi,
Jurusan Teknik Mesin,
Universitas Tjut Nyak Dhien
Jl. Veteran Gg. Utama pasar V Helvetia Kabupaten Deli Serdang, Sumatera Utar, 20373, Indonesia
Email: suardistmmmt@gmail.com

1. INTRODUCTION

Piping systems play a crucial role in various industries, serving as a pathway for fluid transportation from one location to another (Eswanto & Syahputra, 2017; Fitrah et al., 2024; Indarti et al., 2018). Among the various piping components, boilers stand out as critical elements that operate at high pressures and temperatures to produce the steam required in various industrial processes. However, failures in boiler piping become a significant issue that can disrupt overall plant operations. At Plant X, there are frequent leaks in the boiler pipes, which are indicated by material failure in the face of extreme operational conditions (Al-Moubaraki & Obot, 2021). Operating at high pressure and temperature conditions causes boiler pipes to experience significant wear and tear over time. In addition, flames contaminated by corrosive residues also contribute to the acceleration of the material degradation process. The combination of these factors-high external temperature, high internal pressure, and exposure to corrosive environments-pushes boiler pipes toward premature failure. Typically, the onset of pipe failure is characterized by the presence of corrosion, which triggers further degradation of the material's mechanical properties. Materials used in the manufacture of boiler pipes, such as ASTM A179, are often subjected to various working processes such as cold working, hot working, and heat treatment (Gusti et al., 2022; Maulana, 2023;

Muhammad & Muhammad, 2018). Changes in material strength due to these processes can be analyzed by measuring the surface hardness of the material. Hardness testing is an effective method of performing quality control, assisting in determining whether the material has sufficient resistance to compressive deformation to be used in a particular application. In this study, we will evaluate the change in hardness value of ASTM A179 boiler pipe after being subjected to heating and without heating, with the aim of providing a deeper insight into the quality of the material under different operational conditions (Iswanda, 2021; Maulana, 2023; Nasution & Irawan, 2020).

Boiler pipe failure at Plant X has become a critical issue affecting operational efficiency and safety. Leaks that occur in boiler pipes are often caused by material degradation triggered by extreme operational conditions (Lusiana et al., 2019; Maulana, 2023; Purnama, 2017). Boiler pipe materials, such as ASTM A179, face major challenges when exposed to high pressure, high temperature, and corrosive environments. The combination of these factors leads to a decrease in the mechanical properties of the material, especially hardness, which is an important indicator of the material's resistance to deformation and damage. Specifically, the problem addressed in this research is the lack of in-depth understanding of how the heating process affects the hardness of boiler pipe materials. Although many studies have been conducted regarding boiler pipe failure, there is still a gap in the literature that discusses in detail the comparison between the hardness of materials after being subjected to the heating process and without heating. A better understanding of these hardness changes is important for the development of more effective maintenance and repair strategies, as well as to ensure the longevity and reliability of boiler pipes in industrial operations. With a focus on ASTM A179 material, this study aims to identify and analyze the changes in hardness of boiler pipes after being subjected to heating and non-heating processes. The results of this study are expected to provide a more comprehensive insight into the mechanical properties of materials under different operational conditions, as well as contribute to the development of best practices in the maintenance and management of boiler pipes (Chudhoifah et al., 2020; Martua Purba, 2020; WIN, 2024).

This research aims to evaluate and compare the changes in hardness of ASTM A179 boiler pipes after being subjected to heating and non-heating processes. In particular, this research focuses on an in-depth understanding of how different operational conditions affect the mechanical properties of materials, with an emphasis on hardness as a key indicator of a material's resistance to deformation and damage. The main objective of this research is to provide empirical data that can be used to improve quality control procedures and maintenance strategies of boiler pipes in industry. By identifying significant differences in material hardness between post-heating and no-heating conditions, this study is expected to provide new insights that can be implemented in industrial practice to extend the service life of boiler pipes and prevent unwanted failures. The results of this study are also expected to contribute to the development of improved technical guidelines for material selection and use under extreme operational conditions. In addition, this research aims to fill a gap in the existing literature by providing a comprehensive comparative analysis of the effect of heating on boiler pipe hardness. Thus, this research not only has significant practical implications, but also contributes to scientific knowledge in the field of materials engineering and industrial maintenance technology (Maulana, 2023; Nasution & Irawan, 2020; Wardana, 2019).

Although there have been many studies on boiler pipe failure, there is still a lack in the literature that discusses in detail the effect of heating process on the hardness of boiler pipe materials, especially ASTM A179. Most of the previous studies focus more on general aspects such as corrosion, pressure, and high temperature, but few explore in depth the changes in mechanical properties of materials due to heating and without heating. Existing studies tend to provide an overview of the factors that influence pipe failure, without providing a detailed comparative analysis of how heating affects material hardness. The identification of this gap forms an important basis for this research, which aims to fill the gap in the literature by providing comprehensive empirical data regarding the change in hardness of ASTM A179 boiler pipes after being subjected to heating and without heating (Indarti et al., 2018). Through a structured experimental approach, this research will provide a deeper insight into the mechanism of change in mechanical properties of materials, which has been given less attention in previous studies. A unique contribution of this research is the comparative analysis that will provide a clear picture of the differences in material hardness under two different operational conditions. Thus, this research not only fills a gap in the literature, but also provides a strong scientific foundation for the development of more effective boiler pipe maintenance and management strategies. The findings from this study are expected to be an important reference for engineers and industry practitioners in an effort to improve the quality and reliability of boiler pipes in the long term.

This research offers a significant new contribution to the field of materials engineering and industrial maintenance through the hardness analysis of ASTM A179 boiler pipes post heating and non-heating processes. One of the main novelty aspects of this research is the comparative approach which has not been widely explored in the existing literature. This research not only focuses on the general factors affecting boiler pipe failure, but also investigates specifically how heating affects the mechanical properties of materials, especially hardness, which is an important indicator of material resistance to deformation and damage. The justification for this research lies in the importance of understanding changes in material hardness in different operational contexts to improve the reliability and service life of boiler pipes. In an industry that relies heavily on operational sustainability and safety, the findings from this study can provide valuable insights for the development of more effective maintenance strategies. By providing empirical data that can be used to improve quality control procedures and maintenance strategies, this research has the potential to reduce the risk of boiler pipe failures that can disrupt operations and increase maintenance costs. In addition, this study contributes to the scientific literature by filling the knowledge gap on the effect of heating on the hardness of ASTM A179 boiler pipe material. Thus, this research not only has significant practical implications for the industry, but also enriches the scientific understanding of the mechanism of changes in mechanical properties of materials under different operational conditions. This research is expected to be an important reference for engineers, industry practitioners, and researchers in an effort to improve the quality and reliability of boiler pipes and develop more durable and efficient materials.

2. RESEARCH METHOD

The research method carried out is starting from the preparation of tools and materials, cutting small materials (making specimens), hardness testing, data processing, data analysis and drawing conclusions.

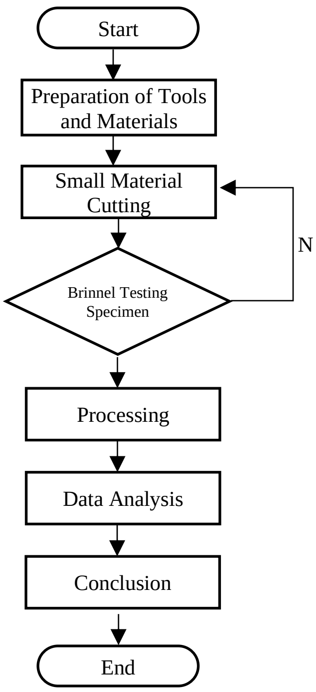

Figure 1. Flow Chart

3. RESULTS AND DISCUSSIONS

A. Materials and Equipment

The material used in this process is ASTM A179 boiler pipe which has not undergone the combustion process (standard) and which has 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..

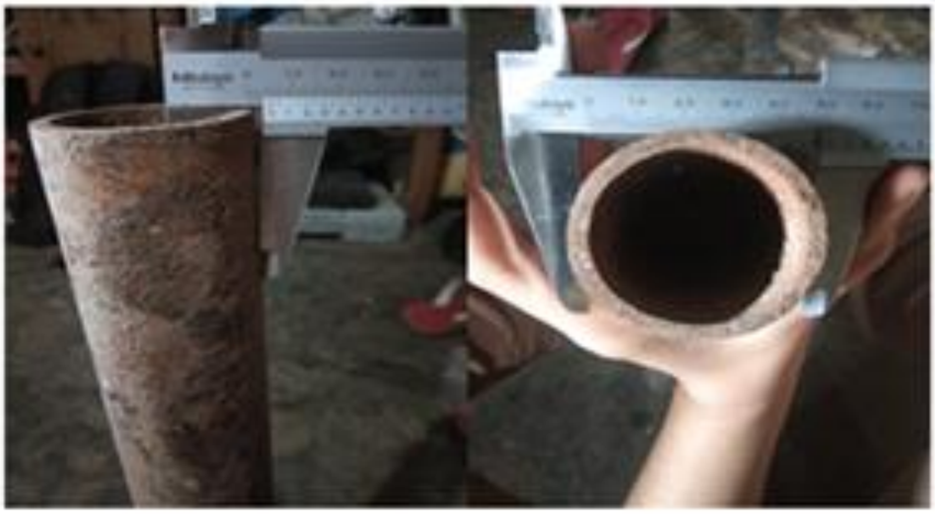

Figure 2. Size of pipe material before and after corrosion

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

B. Equipment

1. Harnes hardness testing machine
2. Steel balls for testing
3. Measuring microscope
4. Stop watch
5. Grinding machine
6. Coarse and fine sandpaper

Hardness testing is used to determine the hardness of the specimen, when tested the specimen is polished again after that the brinnel test is carried out, the test is carried out at the North Sumatra University Laboratory (USU).

Discussion

1. Testing Specimen A

In the brinel test which uses ASTM A179 type pipe matrial before getting heat treatment, this pipe has a diameter of 2 '' testing using a 10 mm diameter indicator and a pressing load of 1500 kg with a pressing time of 15 seconds, then get the results of the indentation diameter as listed in the following table.

Table 1. Testing Results Specimen A

No	Diameter Indentation (mm)	Brinell Hardness Number (mm)
1	4.0	114
2	4.1	109
3	3.9	121
4	3.5	151
5	3.6	142
6	3.4	156

2. Testing Specimen B

In the brinel test using ASTM A179 type pipe material that has received heat treatment in the boiler combustion chamber at ± 600 ° C, this pipe is 2 'diameter testing using a 10 mm diameter indicator and a pressing load of 1500 kg with a pressing time of 15 seconds, then get the results of the indentation diameter as shown in the following table

Table 2. Testing Results Specimen B

No	Diameter Indentation (mm)	Brinell Hardness Number (mm)
1	4.5	89.3
2	4.4	93.6
3	4.3	90.3
4	4.3	98.3
5	4.35	95.9
6	4.41	93.2

3. Average Value Comparison of Specimen A and B

Table 3. Average Value of Comparison of Specimens A and B

No	Data 1	Data 2	Data 3	Data 4	Data 5	Data 6	Rata-Rata
1	114	109	121	151	142	156	132.1667
2	79.6	93.6	90.3	98.3	95.3	93.2	91.71667

4. Average Value Comparison of Specimens A and B in Graphical Form

Based on Table 3 and the graph in Figure 5, it can be seen that the hardness value has decreased at a load of 1500 kgf. The hardness value has decreased which is not too significant when comparing the average test at a load of 1500 kgf, namely from 132.1667 to 91.81667 BHN. That the decrease in hardness is only 0.43%.

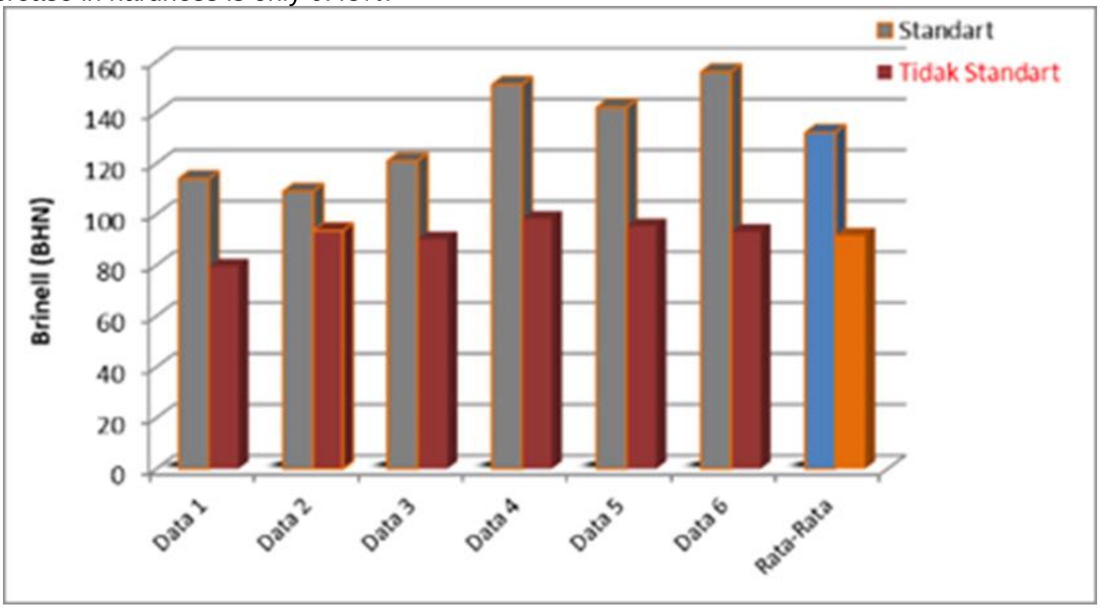

Figure 5. Comparison of Average Values of Specimens A and B

4. CONCLUSION

Based on the findings from the study comparing the hardness values of ASTM A179 boiler pipes before and after exposure to high temperatures in the combustion chamber, several conclusions can be drawn. Firstly, it is evident that the heating process significantly increases the hardness of the pipes, as indicated by the Brinell, Rockwell, and Vickers hardness tests. Specifically, the average hardness values showed notable increments from 63.67 HRB, 45.20 HRC, and 85.20 HV in standard conditions to 76 HRB, 50.40 HRC, and 202.30 HV after exposure to boiler combustion temperatures. This increase in hardness suggests that prolonged exposure to high temperatures and corrosive residues from combustion can lead to material hardening, potentially affecting the structural integrity of the boiler pipes over time. However, the study has several limitations that should be acknowledged. Firstly, the research focused solely on ASTM A179 pipes and did not explore other materials or types of boiler pipes, which could exhibit different responses to similar conditions. Additionally, while hardness tests provide valuable insights into material properties, further mechanical testing such as tensile strength or impact resistance could provide a more comprehensive understanding of how heating affects boiler pipe performance. Future research could expand on this by investigating a broader range of pipe materials, exploring different heating durations and temperatures, and integrating mechanical testing to assess both hardness and structural resilience. Moreover, incorporating simulation or predictive modeling techniques could help anticipate the long-term durability and failure mechanisms of boiler pipes under various operating conditions, aiding in the development of more robust and reliable boiler systems. By addressing these aspects, future studies can contribute to enhancing the safety, efficiency, and longevity of boiler pipe systems in industrial applications..

REFERENCES

Al-Moubaraki, A. H., & Obot, I. B. (2021). Top of the line corrosion: causes, mechanisms, and mitigation using corrosion inhibitors. *Arabian Journal of Chemistry*, *14*(5), 103116.

Chudhoifah, M. N., Suastiyanti, D., & Rupajati, P. (2020). Analisa Kerusakan Pipa Boiler Super Kritikal. *J. Tek. Mesin Iti*, *4*, 24.

Eswanto, E., & Syahputra, D. (2017). Analisa distribusi kapasitas aliran fluida di daerah percabangan pada sistem perpipaan. *JTT (Jurnal Teknologi Terapan)*, *3*(1).

Fitrah, M. A., Balfas, M., Utami, H. H., Thahir, M. T., & Hafid, H. (2024). Karakterisasi Inklusi Terak Pada Pengelasan Pipa SA 106 Grade B Menggunakan Mikroskop Elektron Pemindai. *Journal of Chemical Process Engineering*, *9*(1), 52–59.

Gusti, W. N. L., Prasetyo, T., & Roihatin, A. (2022). Analisis Efisiensi Fire Tube Boiler TWA Kapasitas 6000 kg/jam untuk Pemanas Kilang di PPSDM Migas Cepu Kab. Blora dengan Metode Langsung. *Prosiding Seminar Nasional NCIET*, *3*(1), 13–22.

Indarti, R., Sarungu, Y. T., & Magesang, C. (2018). Karakterisasi Simulator Sistem Proteksi Katodik Metode Anoda Korban Pada Sistem Perpipaan Yang Tertanam Dalam Tanah. *Prosiding Industrial Research Workshop and National Seminar*, *9*, 41–45.

Iswanda, M. (2021). *Analisis Perpindahan Panas Pada Dinding Ruang Bakar Ketel Uap Dengan Kapasitas 45 Ton/Jam*. Universitas Medan Area.

Lusiana, F. C., Martides, E., & Gumilar, G. (2019). Analisis Kegagalan Pipa Boiler Superheater Pada Pabrik Kelapa Sawit. *Jurnal Ilmiah Teknik Mesin. Doi*, *10*.

Martua Purba, Y. (2020). *Analisa Perbandingan Efisiensi Boiler Dengan Metode Heat-Losses Pada Saat Awal Operasi Dan Setelah Overhaul Di Pt. Pomi Paiton*. Politeknik Negeri Jember.

Maulana, M. F. (2023). Analisa Kegagalan Pipa Astm A179 Pada Ruang Bakar Boiler. *Jurnal Multidisiplin Indonesia*, *2*(9), 2553–2569.

Muhammad, I. R., & Muhammad, S. (2018). Distribusi Tegangan Pada Support Pipa Soot Blower Akibat Perubahan Beban Thermal Pada Boiler. *Proceedings of National Conference on Piping Engineering and Its Application*, *3*(1), 277–282.

Nasution, F. A. K., & Irawan, A. (2020). ANALISA KEGAGALAN PIPA ASTM A179 PADA RUANG BAKAR BOILER. *JiTEKH*, *8*(2), 105–108.

Purnama, N. C. (2017). *Analisis Kegagalan Sootblower Terhadap Perpindahan Panas di Pipa Boiler*. Universitas Mercu Buana Jakarta.

Wardana, I. G. P. A. K. (2019). Prevention and Deterrence of Foreigners who Violate Immigration Regulations. *Journal of Law and Border Protection*, *1*(1), 73–86. https://doi.org/10.52617/jlbp.v1i1.158

WIN, T. I. O. D. (2024). *MEMPERTAHANKAN KINERJA KETEL UAP DENGAN MENJAGA UNSUR KIMIAWI PADA AIR KETEL MELALUI PERAWATAN AIR KETEL DI LNG/C EKAPUTRA 1*.