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Influence of Holding Time and Quenching on the Hardness of Carbon Steel in Pack Carburizing Process with Mangrove Charcoal Media

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Abstract

The demand for metal materials in the industry is currently on the rise. However, existing metal materials often fail to meet the desired properties and characteristics. One such material is carbon steel, which is extensively utilized across various industrial sectors, particularly in small and medium-scale industries as a construction material. This study aims to investigate the impact of holding time and quenching variations on the pack carburizing process, as well as to determine the hardness value of carbon steel before and after undergoing pack carburizing. Experimental research was conducted using Rockwell hardness testing on 16 specimens, with 5 points tested on each specimen. The specimens were subjected to pack carburizing using mangrove wood charcoal at a temperature of 900°C, with holding time variations of 30 minutes, 60 minutes, 90 minutes, and 120 minutes. Different cooling media were utilized, including seawater, rainwater, well water, and mineral water. The results revealed that specimens treated with a holding time of 120 minutes and quenched with seawater exhibited the highest hardness of 83.94 HRA. Prior to the pack carburizing process, the hardness was 47.54 HRA, which increased to a range of 60.72 HRA to 83.94 HRA after the process.

Keywords: Carbon steel, pack carburizing, holding time, quenching, rockwell hardness

INTRODUCTION

The demand for metal materials in the industry continues to increase alongside technological advancements and market needs [1]. Despite the variety of metal materials used, not all of them possess the desired properties and meet the required standards. Carbon steel is one type of metal material widely utilized in various industrial applications, particularly in the construction industry, both on small and medium scales [2]. This study aims to investigate the influence of holding time and quenching variations on the pack carburizing process on the mechanical properties of carbon steel [3]. The pack carburizing process is a heat treatment method used to enhance the surface hardness of carbon steel by enriching its carbon content. In this study, researchers seek to understand how variations in holding time and types of quenching media affect the hardness values of carbon steel before and after the pack carburizing process [4].

This research is focused on the importance of understanding the influence of holding time and quenching media variations on the pack carburizing process using mangrove wood charcoal as the quenching medium on the hardness value of carbon steel. Carbon steel is an important metal material in the industry, used in various construction and manufacturing applications. However, to meet the desired quality standards, heat treatment processes such as carburizing are necessary to improve the hardness and wear resistance of carbon steel[5]. In the pack carburizing process, holding time and quenching media play crucial roles in determining the final properties of the resulting carbon steel. Variations in holding time can affect the depth of carbon penetration into the steel,

while variations in quenching media can influence the cooling rate and microstructure formed on the steel surface[6].

Therefore, this study aims to gain a better understanding of how variations in holding time and quenching media in the pack carburizing process using mangrove wood charcoal as the quenching medium can affect the hardness of carbon steel. This information will aid in optimizing manufacturing processes and producing carbon steel with properties suitable for various industrial applications.

RESEARCH METHODS

The research methodology employed an experimental approach conducted at the Bengkalis State Polytechnic laboratory. This research can be outlined in stages as depicted in **Fig. 1**

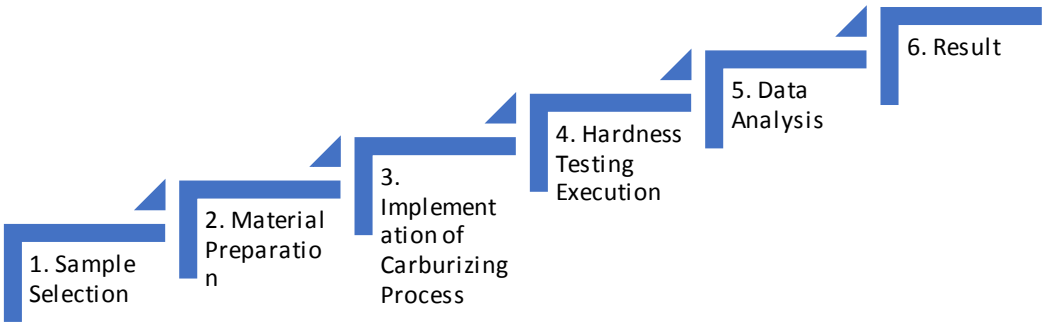

Fig. 1. Research Scheme

1. Sample Selection

   Choose carbon steel samples for hardness testing. Ensure that the samples have been properly prepared for the carburizing process.

2. Material Preparation

   Prepare mangrove wood charcoal powder as the carburizing medium.

3. Implementation of Carburizing Process:

   Conduct the pack carburizing process on the carbon steel samples using mangrove wood charcoal powder at a temperature of 900°C. Apply holding time variations (30, 60, 90, and 120 minutes) for each sample.

4. Hardness Testing Execution

   Utilize the Rockwell scale A hardness testing method using a diamond cone indenter. Apply a minor load of F0 10 Kgf and a major load of F1 50 kgf to achieve a total load of F 60 kgf. Perform hardness testing at 5 different points on each carbon steel sample.

5. Data Analysis

   Record the hardness measurement results at each testing point for every sample. Compare the hardness values before and after the carburizing process for each holding time variation and quenching media. Identify the influence of holding time variation and quenching media type on the hardness value of carbon steel.

6. Results

   Analyze the data and interpret the testing results to determine the effectiveness of the carburizing process in enhancing the hardness of carbon steel.

The initial step in this study involved preparing mangrove wood charcoal powder and preparing various water samples. Subsequently, the pack carburizing process was carried out using mangrove wood charcoal as the medium at a temperature of 900°C, with holding time variations of 30, 60, 90, and 120 minutes. Additionally, different cooling media such as seawater, rainwater, well water, and mineral water were utilized. Hardness testing using the Rockwell method was then performed on 16 specimens, with 5 points tested on each.

This can be seen in sample **Fig.2.**

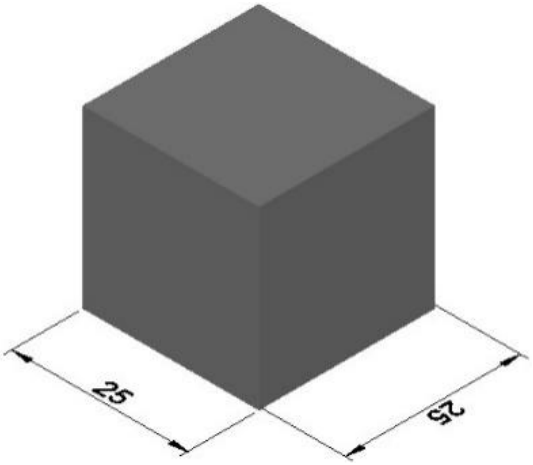

Fig. 2. Rockwell Hardness Test Specimen

Hardness testing was conducted to determine the hardness value of carbon steel during the carburizing process. The hardness testing method employed in this study was the Rockwell scale A test using a diamond cone indenter with a minor load of F0 10 Kgf, a major load of F1 50 kgf, and a total load of F 60 kgf. This testing was performed at 5 points on each test specimen. The testing on the samples can be seen in **Fig. 3**.

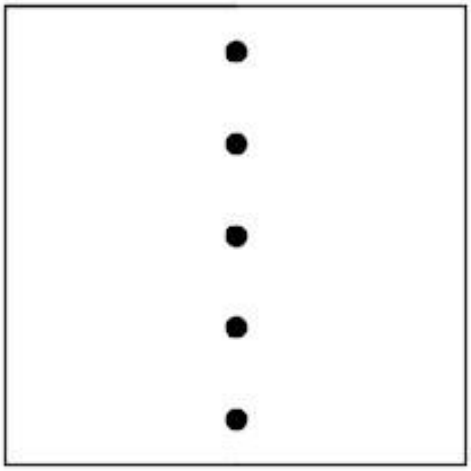

Fig. 3. Testing Points

RESULTS AND DISCUSSION

This study aims to investigate the impact of variations in holding time and quenching in the pack carburizing process on the mechanical properties of carbon steel. In this context, previous research can provide additional insights into how factors such as holding time and quenching type affect the mechanical properties of carbon steel. For example, a prior study conducted by Qin, S., Zhang, C., et al. (2022) explored the influence of holding time variations in the carburizing process on the surface hardness of carbon steel. They found that increasing holding time significantly increased the surface hardness of carbon steel [7]. Source: Effect of carburizing process on high cycle fatigue behavior of 18CrNiMo7-6 steel. To understand the impact of holding time variations in the carburizing process, which can be used as a comparison for ongoing research exploring the effects of holding time and quenching variations on the mechanical properties of carbon steel.

In this study, from the test results, the graph showing the influence of holding time on all specimens can be seen in **Fig. 4,** and the influence of quenching media on all specimens is shown in **Fig. 5**

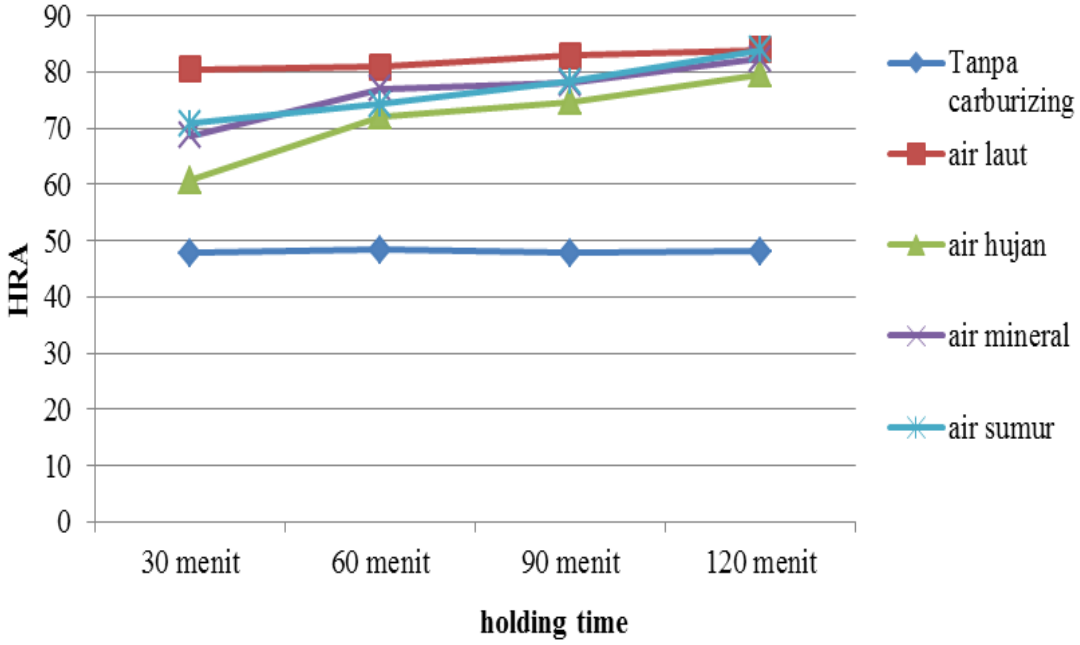

Fig. 4. Graph showing the influence of holding time on all specimens

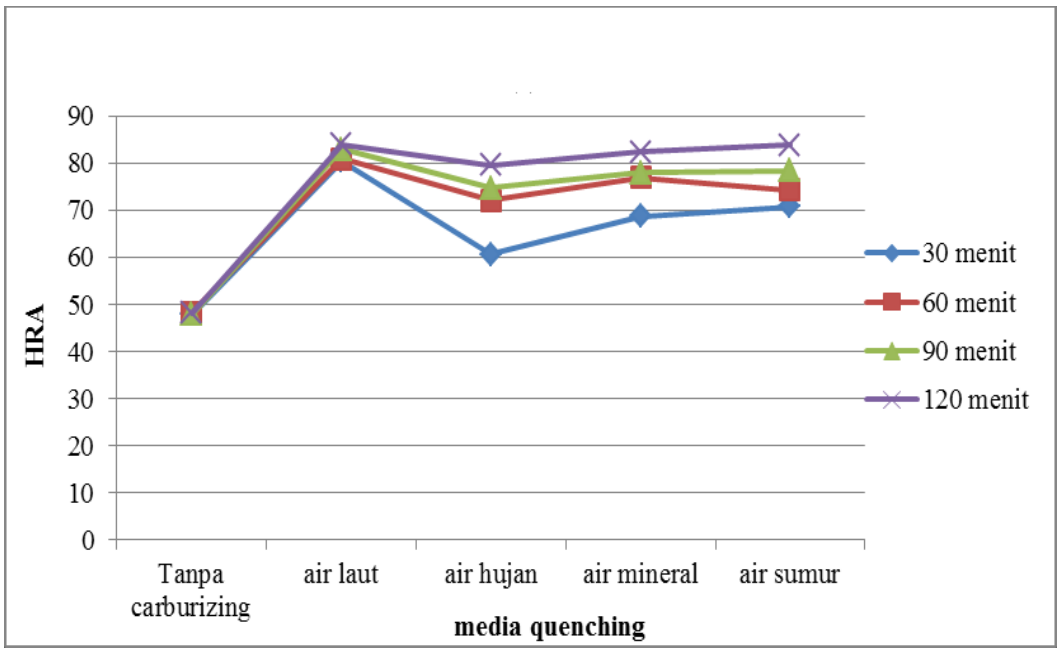

Fig. 5. Graph showing the influence of quenching media on all specimens

In **Fig. 4** and **Fig. 5**, the overall results of the study on the pack carburizing process of St 49 steel with variations in quenching media and holding time are presented. The holding times used were 30 minutes, 60 minutes, 90 minutes, and 120 minutes after reaching a temperature of 900°C. The results indicate that the highest hardness was observed in specimens held for 120 minutes and quenched using seawater, reaching a hardness of 83.94 HRA from an initial value of 47.84 HRA, representing an increase of 36.1 HRA or an average increase of

75.4%. This is attributed to the lower temperature of seawater, which accelerates the cooling rate, trapping more carbon in the austenitic structure and transforming it into martensite. Conversely, the lowest hardness was found in specimens held for 30 minutes and quenched using rainwater, with a hardness of 60.72 HRA from an initial value of 48.34 HRA, representing an increase of 12.36 HRA or an average increase of 25.5%. Factors such as holding time and the density of the quenching media influence the hardness results, with higher viscosity slowing the cooling rate and higher density increasing it. Other studies have also revealed the influence of variations in holding time and salt content in the quenching media on the heat treatment of AISI 1045 steel [8],[9].

This study involves heat treatment processes and the use of quenching with water as the cooling medium, with variations in holding time of 25 minutes, 30 minutes, and 35 minutes, as well as variations in salt content in water of 500 grams, 625 grams, and 700 grams. The results indicate that the highest hardness reached 60.6 HRA in the steel specimen with a holding time of 35 minutes and quenched with 700 grams of salt. The effectiveness of the cooling medium is influenced by several factors, including temperature, viscosity, solution concentration, and the type of base material of the cooling medium. Previous research, such as that conducted by [10], has shown that the holding time in the carburizing process can affect the hardness value of the metal material and the depth of hardening on its surface. Longer holding times tend to increase the hardness of the metal material, and the depth of hardening on the surface also increases.

This research result indicates the influence of holding time and quenching media on the pack carburizing process of carbon steel, as well as the hardness value of carbon steel before undergoing the pack carburizing process.

1. There is an influence of holding time and quenching media on the pack carburizing process of carbon steel towards hardness values, resulting in varying hardness in each specimen. The data showing the highest hardness for each holding time and corresponding quenching can be seen in the **Table 1.** Below.

Table 2. Highest Rockwell Hardness

Holding Time (minute)	Media Quenching	Highest Hardness
30	sea water (A1)	80,48 HRA
60	sea water (B1)	80,98 HRA
90	sea water(C1)	82,98 HRA
120	sea water (D1)	83,94 HRA

Therefore, the highest influence in the holding time variation is the specimen held for 120 minutes, which achieved a hardness of 83.94 HRA. Meanwhile, the highest influence in the quenching media variation is the specimen quenched with seawater, also achieving a hardness of 83.94 HRA. In essence, among all specimens, the one with the highest hardness is the specimen held for 120 minutes with seawater quenching.

2. The hardness value of carbon steel before undergoing the pack carburizing process was 47.54 HRA. After the pack carburizing process, the hardness increased to a range between 60.72 HRA and 83.94 HRA.

CONCLUSION

Based on the data obtained from the study, it can be concluded that there is a growing demand for metal materials in various industries, including carbon steel, due to their wide range of applications in construction. However, existing metal materials often lack the desired properties and characteristics. The study aimed to investigate the impact of holding time and quenching variations on the pack carburizing process of carbon steel, as well as to determine the hardness values before and after the carburizing process. Experimental research using Rockwell hardness testing was conducted on 16 specimens, with 5 points tested on each specimen. The specimens were subjected to the pack carburizing process using mangrove wood charcoal at a temperature of 900°C, with holding time variations of 30, 60, 90, and 120 minutes. Different cooling media were utilized, including seawater, rainwater, well water, and mineral water. The findings revealed that the specimens treated with a holding time of 120 minutes and quenched with seawater exhibited the highest hardness, reaching 83.94 HRA. Additionally, the hardness of the carbon steel increased from 47.54 HRA before the pack carburizing process to a range of 60.72 HRA to 83.94 HRA after the process. In summary, the study highlights the significant influence of holding time and quenching media on the hardness properties of carbon steel during the pack carburizing process. These findings contribute valuable insights for optimizing the manufacturing processes of carbon steel to meet the specific requirements of various industrial applications.

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