International Journal for Educational and Vocational Studies
ISSN 2684-6950 (online)
Homepage: https://ojs.unimal.ac.id/ijevs/index

Analysis of the influence of temperature and hold time in the solid carburization process on the hardness and microstructure of AISI 1020 and 1045 using Oil Cooling

Ferri Safriwardy[1], Muhammad Nuzan Rizki[1]*, Masrullita[2], Muhammad Daniel[1]

[1] Department of Mechanical Engineering Universitas Malikussaleh, Bukit Indah, Lhokseumawe, Indonesia, 24352
[2] Department of Chemical Engineering Universitas Malikussaleh, Bukit Indah, Lhokseumawe, Indonesia, 24352
*Corresponding author: mnuzanrizki@unimal.ac.id | Phone: 082214758964

ARTICLE INFO
Received: 20-03-2023
Received in revised: 10-04-2023
Accepted: 20-04-2023
Available online: 30-4-2023

KEYWORDS
Hardness;
Microstructure;
Quenching;
Solid carburization;

A B S T R A C T

This study aims to determine the effect of variations in temperature and holding time on the value of hardness and microstructure in the carburizing process of low-carbon steel and medium-carbon steel. The temperature variations used during the carburizing process were 850°C and 950°C with variations of the holding time used being 15 minutes and 30 minutes. The types of materials used are AISI 1020 steel and AISI 1045 steel. In the carburizing process, the carbon source used is wood charcoal powder. After the process of adding carbon elements, the material will be quenched in the oil medium. The tests carried out were hardness testing and microstructure observations. The hardness test used the B-scale Rockwell hardness test method. The surface etching process of the material used a nital etching solution, namely a mixture of 3% nitric acid (HNO_3) and 97% ethanol. The results showed that the lowest increase in hardness occurred at 850°C with a holding time of 15 minutes, namely 82.00 HRB for AISI 1020 steel and 95.66 HRB for AISI 1045 steel. Meanwhile, the highest increase in hardness occurred at a temperature of 950°C with a holding time of 30 minutes. namely 93.00 HRB on AISI 1020 steel and 105.33 HRB on AISI 1045 steel. This shows that the higher the temperature and the longer the holding time, the higher the hardness value.

INTRODUCTION

The use of steel-type materials from an economical point of view has not been replaced by non-metallic materials in various construction equipment and machinery. In theory, there are several options for changing the properties of steel, such as by heat treatment of the steel and observing and controlling it with phase diagrams and cooling diagrams (Bhakti, 2007). If the steel also contains other elements in large enough quantities which can change its properties, then the steel is called alloy steel (Fatoni, 2016). One of the most important properties of steel is mechanical properties. Mechanical properties consist of various aspects such as strength, toughness, hardness, ductility as well as modulus of elasticity, and wear resistance (Nasution & Nasution, 2020).

In materials science, there are two ways to increase the hardness of steel, namely by heat treatment and surface hardening. Heat treatment is usually carried out on metals that will be subjected to further processing (Hadi, 2010). Mechanical properties can also be changed through a plastic deformation process, in which the metalworking process is below the crystallization temperature of the material being worked on, then the metal will change its mechanical properties (Suriadi & Suarsana, 2007).

One of the heat treatment processes to harden a metal is the carburizing process. Carburization is a process of adding carbon content in which more is added to the surface compared to the inside or core of the metal so that the surface hardness will be higher than before (Nasution & Nasution, 2020). Then to get the desired microstructural properties of steel can be obtained from the process of heating steel and cooling quickly at a certain temperature. Then the process of rapid cooling (quenching) can be done with oil media, salt solution, or water. The purpose of this study was to understand the effect of temperature, holding time, and the ratio of the increase in roughness value in the solid carburizing process on the hardness and microstructure of AISI 1020 steel and AISI 1045 steel. Based on the background of the problems above, this research was carried out with the title "Analysis of the Influence of Temperature and Holding Time in the Solid Carburization Process on the Hardness and Microstructure of AISI 1020 and AISI 1045 Steels with Oil Cooling Media".

METHODS AND MATERIALS

The approach used in this research is quantitative. In this study, the authors conducted experiments or tests on several specimens with different temperature and time variations to see the relationship between the roughness value and microstructure in the carburizing process of low-carbon steel and medium-carbon steel.

Research design

This study uses a quantitative approach. By testing several variations of the specimen and analyzing its relationship with the roughness value and microstructure of two types of materials, namely AISI 1020 and AISI 1045 steel.

Time, Place, and Object of Research

This research was conducted on 08 February 2022 to 08 March 2022 and took place at the Materials Testing Laboratory, Department of Mechanical Engineering, Faculty of Engineering, University of Malikussaleh.

The object of this research is a specimen consisting of two materials, the first material is AISI 1020 and the second is AISI 1045. The temperature variations used during the carburizing process are $850^{o}C$ and $950^{o}C$ with variations in the holding time used are 15 minutes and 30 minutes. In the carburization process, the carbon source used is wood charcoal powder.

Research Procedure

The initial step in this research was to carry out and study several references such as books, journals, articles, and final assignments from Mechanical Engineering alumni of Malikussaleh University and alumni from other universities related to the formulation of the problem used as a reference in carrying out this final project. Then the process of separating the test specimens, where at this stage the test specimens of AISI 1020 steel and AISI 1045 steel will be separated and given a name for each test specimen.

Followed by the stages of pack carburizing and quenching. Then provide a specimen cementation container. Prepare wood charcoal that has become a fine powder. Put the specimen into the cementation container and mix it with charcoal powder. Insert the specimens (1 and 2) into the electric furnace with a temperature of 850˚C and hold for 15 minutes. Insert the specimens (3 and 4) into the electric furnace with a temperature of 850˚C and hold for 30 minutes. Insert the specimens (5 and 6) into the electric furnace with a temperature of 950˚C and hold for 15 minutes. Insert the specimens (7 and 8) into the electric furnace with a temperature of 950˚C and hold for 30 minutes. Then all the specimens were cooled rapidly using an oil-cooling medium. The pack carburizing and quenching process is complete. The next stage is to carry out hardness testing which is carried out at the Materials Testing Laboratory of the Department of Mechanical Engineering, Malikussaleh University.

Data, Instruments, and Data Collection Techniques

Data collection was carried out by testing the hardness and observing the microstructure which was carried out at the Materials Testing Laboratory, the Department of Mechanical Engineering, Malikussaleh University, using the Rockwell hardness tester, with the following stages of testing:

a. Set the major load weight on the tool (Figure 1a).
b. Install the indenter on the holder.
c. Give a minor load until the small needle on the dial indicator is right at the red point (10kgf) (Figure 1b).
d. Set the dial indicator by rotating until the needle is exactly at zero (Figure 1c).
e. Perform major loading by pushing the lever forward, wait about 10 seconds then pull the lever back to its original position.
f. Record the hardness value according to the number pointed by the needle on the dial indicator.
g. Perform steps C through F for each other specimen.
h. The hardness test is complete.

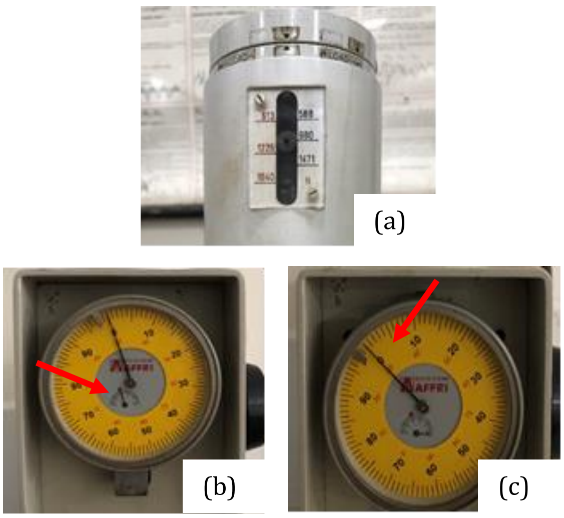


Figure 1. (a) Major weight, (b) Giving minor loads, (c) Sets the indicator needle at zero point.

a. Setting up the polish grinder (Figure 2a).
b. Polishing the surface of the specimen is to be observed for its microstructure until it looks shiny (Figure 2b).
c. Do the etching process on the specimen so that the grain boundaries between the microstructures can be seen clearly. That is by mixing a chemical solution in the form of 3% nitric acid (HNO_3) and 97% ethanol into a measuring cup, then pour it into a smaller container so that the specimen etching process can be carried out more easily (Figure 2c).
d. Dip the specimen surface into the metal etching solution for 10 seconds, then rinse with water and dry (Figure 2d).
e. Turn on the metallographic microscope and computer so that they are connected.
f. Place the specimen in the anvil and bring it close to the optical lens according to the magnification used.
g. Observe the microstructure on the surface of each specimen and save the observed images on the computer.
h. The process of observing the microstructure is complete.

Figure 2. Microstructure observation, (a) Grinding polish, (b) Specimen polishing process, (c) The process of preparing the etching material, (d) The process of etching the specimen.

Data Analysis Techniques

Data analysis was carried out to test the hypotheses of the research so that it can produce conclusions in the form of how much influence temperature and holding time have on the solid carburizing process on the hardness and microstructure of AISI 1020 and AISI 1045 steel with oil cooling media.

RESULTS AND DISCUSSIONS

Raw Material Hardness Data Analysis

The hardness test in this study used the Rockwell hardness test method. Based on the tests that have been carried out on raw material specimens of AISI 1020 and AISI 1045 steel, the hardness values are obtained as follows:

Table 1. Write the title of the table here according to the format that has been determined

Specimen	Hardness value (HRB)			Average (HRB)
	Position 1	Position 2	Position 3	
Raw Material Baja AISI 1045	81	83	80	81,33
Raw Material Baja AISI 1020	66	65	66	65,66

From the results of hardness testing on AISI 1045 steel raw material and AISI 1020 steel, an average hardness value was obtained of 81.33 HRB on AISI 1045 steel and 65.66 HRB on AISI 1020 steel. This means that the material used as a specimen in this study is standard data of AISI 1045 steel and AISI 1020 steel in general. The hardness test on this raw material was carried out as a material for comparison with the material given carburization and quenching treatment.

Data Analysis of AISI 1045 Steel Hardness

Based on the test results on AISI 1045 steel specimens, it can be seen that the hardness value of the treated specimens experienced an increase in hardness compared to the raw material hardness. Specimen 1 with a temperature of 850˚C and a holding time of 15 minutes experienced an increase of 14.33 HRB or around 17%. Specimen 3 with a temperature of 850˚C and a holding time of 30 minutes experienced an increase of 20.00 HRB or around 24%. Specimen 5 with a temperature of 950˚C and a holding time of 15 minutes experienced an increase of 22.67 HRB or around 27%. Specimen 7 with a temperature of 950˚C and a holding time of 30 minutes experienced an increase in hardness of 24.00 HRB or around 29%.

Data Analysis of AISI 1020 Steel Hardness

Based on the test results on AISI 1020 steel specimens, it can be seen that the hardness value of the treated specimens experienced an increase in hardness compared to the raw material hardness.

Specimen 2 with a temperature of 850˚C and a holding time of 15 minutes experienced an increase of 16.34 HRB or around 25%. Specimen 4 with a temperature of 850˚C and a holding time of 30 minutes experienced an increase of 23.67 HRB or around 36%. Specimen 6 with a temperature of 950˚C and a holding time of 15 minutes experienced an increase of 27.00 HRB or around 41%. Specimen 8 with a temperature of 950˚C and a holding time of 30 minutes experienced an increase in hardness of 27.34 HRB or around 42%.

Based on test data on AISI 1045 steel specimens, it can be seen that the hardness value of the treated specimens experienced an increase in hardness compared to the raw material hardness. Specimen 1 with a temperature of 850˚C and a holding time of 15 minutes experienced an increase of 14.33 HRB or about 17%. Specimen 3 with a temperature of 850˚C and a holding time of 30 minutes experienced an increase of 20.00 HRB or around 24%. Specimen 5 with a temperature of 950˚C and a holding time of 15 minutes experienced an increase of 22.67 HRB or around 27%. Specimen 7 with a temperature of 950˚C and a holding time of 30 minutes experienced an increase in hardness of 24.00 HRB or around 29%.

Based on the test results on AISI 1020 steel specimens, it can be seen that the hardness value of the treated specimens experienced an increase in hardness compared to the raw material hardness. Specimen 2 with a temperature of 850˚C and a holding time of 15 minutes experienced an increase of 16.34 HRB or around 25%. Specimen 4 with a temperature of 850˚C and a holding time of 30 minutes experienced an increase of 23.67 HRB or around 36%. Specimen 6 with a temperature of 950˚C and a holding time of 15 minutes experienced an increase of 27.00 HRB or around 41%. Specimen 8 with a temperature of 950˚C and a holding time of 30 minutes experienced an increase in hardness of 27.34 HRB or around 42%.

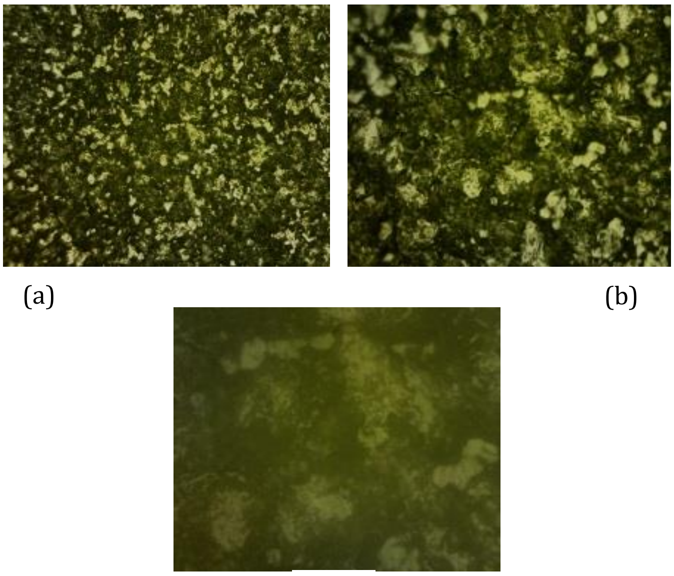
Based on the test results on AISI 1020 steel specimens, it can be seen that the hardness value of the treated specimens experienced an increase in hardness compared to the raw material hardness. Specimen 2 with a temperature of 850˚C and a holding time of 15 minutes experienced an increase of 16.34 HRB or around 25%. Specimen 4 with a temperature of 850˚C and a holding time of 30 minutes experienced an increase of 23.67 HRB or around 36%. Specimen 6 with a temperature of 950˚C and a holding time of 15 minutes experienced an increase of 27.00 HRB or around 41%. Specimen 8 with a temperature of 950˚C and a holding time of 30 minutes experienced an increase in hardness of 27.34 HRB or around 42%.

The highest hardness value in AISI 1045 steel is at a temperature of 950˚C and a holding time of 30 minutes (specimen 7) which is 105.33 HRB. While the lowest hardness value is at a temperature of 850˚C and a holding time of 15 minutes (specimen 1) which is equal to 95.66 HRB. In AISI 1020 steel, the highest hardness value is at a temperature of 950˚C and a holding time of 30 minutes (specimen 8) which is 93.00 HRB. While the lowest hardness value is at a temperature of 850˚C and a holding time of 15 minutes (specimen 2) which is 82.00 HRB. This shows a tendency that the higher the heating temperature, the harder the steel will be. This is because the higher the heating temperature, the more austenite that is formed and the more homogeneous it is. It is this austenite that can transform into martensite during quenching (Fatoni, 2016). The carbon atoms contained in the reagent will decompose and diffuse into the metal surface during the carburizing process. This shows that the longer the holding time, the more carbon atoms will diffuse into the metal surface so that the hardness value of the material will also increase (Waluyo, 2009). The results of this test also show that AISI 1020 low-carbon steel can be hardened by carburizing treatment, which cannot be hardened in conventional ways because of its low carbon content (Masyrukan, 2006).

Direct hardening is only possible on steels with a carbon content above 0.3%. Meanwhile, steel with a carbon content below 0.3% must go through a process of adding carbon (Schonmetz & Gruber, 1985). Even the hardness value of AISI 1020 low carbon steel which undergoes the carburizing process can be higher than the hardness value of AISI 1045 medium carbon steel raw material.

Microstructure Observation Data Analysis

The microstructure of AISI 1045 steel which underwent carburizing and quenching processes can be seen in Figure 4.3a to Figure 4.3b below with the provisions of (a) 20X magnification, (b) 50X magnification, and (c) 100X magnification.

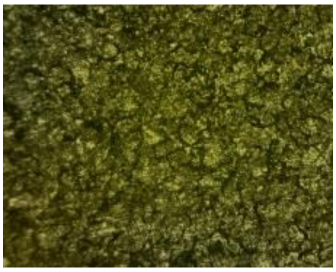


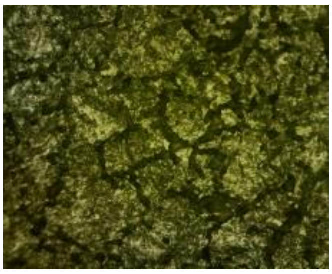
(a) (b)

(c)

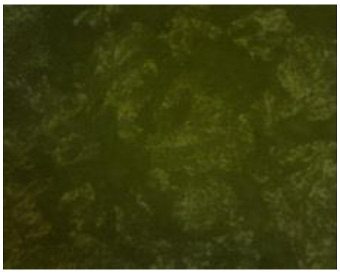
Figure 3. Microstructure of AISI 1045 steel (850˚C - 15 minutes) (a)(b)(c).

The microstructure of AISI 1020 steel which underwent carburizing and quenching processes can be seen in Figure 4.4a to Figure 4.4c below with the provisions of (a) 20X magnification, (b) 50X magnification, and (c) 100X magnification.





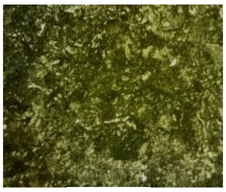
(a) (b)



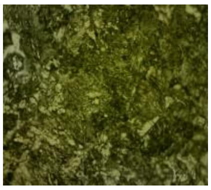
(c)

Figure 4. Microstructure of AISI 1020 steel (850˚C - 15 minutes) (a)(b)(c).

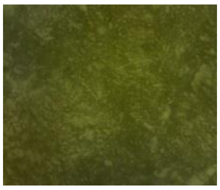
From the results of testing the microstructure using a metallurgical microscope, data obtained from the results of testing the microstructure of the raw material steel AISI 1045 and AISI 1020 can be seen in Figure 5 below with the provisions of (a)(d) 20X magnification, (b)(e) 50X magnification, and (c)(f) 100X magnification as follows:



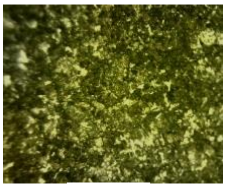
(a)



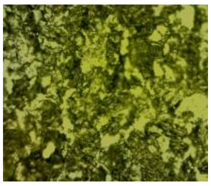
(b)



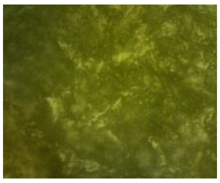
(c)



(d)



(e)



(f)

Figure 5. AISI 1045 steel raw material microstructure (a)(b)(c). AISI 1020 steel raw material microstructure (d)(e)(f).

From the picture above, it can be seen that the microstructure of the AISI 1045 and AISI 1020 steel raw materials is dominated by the ferrite phase. The carbon content contained in the raw material is very small so that the carbon atoms can dissolve into the atoms of a solid solution called ferrite.

From the results of observing the microstructure of the specimens that underwent carburizing and quenching processes as shown in the figure, it can be observed that on the surface the material is composed of martensite and austenite phases remaining after undergoing the carburizing process with variations in temperature and variations in holding time. On the surface, there is a dark martensite phase. The martensite phase is the phase that is formed due to rapid cooling (quenching). In the martensite matrix, there is a ferrite phase but the amount is small, and the color looks a bit dull white. The martensitic phase is very hard, this factor causes the hardness value on the steel surface to increase.

In the picture above it can be seen that the amount of martensite formed is only small so the increase in hardness is small. This is due to the low carburizing temperature (850˚C) and short holding time (15 minutes). In Figure 8 (AISI 1045 steel) and Figure 9 (AISI 1020 steel) it can be seen that the amount of martensite phase increases with increasing temperature and carburizing holding time. The higher the austenization temperature, the easier it is for carbon atoms to diffuse into the steel, and the longer the holding time, the more opportunities for carbon atoms to diffuse into the steel. With increasing carbon content and the addition of the quenching process, a large amount of martensite is formed on the surface of the steel.

CONCLUSIONS

Based on the results of the research and data analysis that has been done, the following conclusions can be drawn; The results showed that the temperature and holding time in the solid carburizing process greatly influenced the hardness values of AISI 1045 steel and AISI 1020 steel. In AISI 1045 steel, the lowest hardness value occurs at a temperature of 850˚C with a holding time of 15 minutes, which is 95.66 HRB, while the highest hardness value occurs at a temperature of 950˚C with a holding time of 30 minutes, which is 105.33 HRB. In AISI 1020 steel, the lowest hardness value occurs at a temperature of 850˚C with a holding time of 15 minutes, which is 82.00 HRB, while the highest hardness value occurs at a temperature of 950˚C with a holding time of 30 minutes, which is 93.00 HRB. The results of microstructural observations show that the raw material's microstructure only consists of ferrite which gives it softness and pearlite which gives hardness to the surface of the specimen. Whereas in the test specimens that had undergone carburizing and quenching processes, it was seen that there was a very hard martensite phase. The more martensite phase formed, the higher the hardness value of the material. Suggestions for further research are to obtain a higher hardness by increasing the temperature and holding time and using a quenching medium with a lower viscosity such as water. The temperature of the heating furnace must be kept stable because the rate of transfer of carbon atoms depends on temperature. Quenching media temperature needs to be controlled to produce research with uniform conditions in each treatment.

Author's Contribution

All authors discussed the result and contributed from the start to the final manuscript.

Conflict of Interest

The authors declare that they have no competing interests.

REFERENCES

Amanto, H., & Daryanto. (1999). Ilmu Bahan. Jakarta: PT Bumi Aksara.

AZoNetwork. (2021). AISI 1020 Carbon Steel (UNS G10200). AZoM.Com. Retrieved from

https://www.azom.com/article.aspx?ArticleID=9145

AZoNetwork. (2021). AISI 1045 Carbon Steel (UNS G10450). AZoM.Com. Retrieved from

https://www.azom.com/article.aspx?ArticleID=9153

Beumer, B. (1980). Pengetahuan Bahan. Jakarta: Barata Karya Angkasa.

Bhakti, R. W. (2007). Pengaruh Waktu Karburising Dengan Media Quenching Oli Terhadap Kekerasan Sproket Sepeda Motor. Yogyakarta.

Callister, W., Rethwisch, & David. (2007). Material Science and Engineering. New York: John Wiley & Sons.

Fatoni, Z. (2016). Pengaruh Perlakuan Panas Terhadap Sifat Kekerasan Baja Paduan Rendah Untuk Bahan Pisau Penyayat Batang Karet. Jurnal Desiminasi Teknologi, 4(1), 56-63.

Hadi, Q. (2010). Pengaruh Perlakuan Panas Pada Baja Konstruksi ST37 Terhadap Distorsi, Kekerasan Dan Perubahan Struktur Mikro. Seminar Nasional Tahunan Teknik Mesin SNTTM ke-9, 1-8.

Masyrukan. (2006). Penelitian Sifat Fisis Dan Mekanis Baja Karbon Rendah Akibat Pengaruh Proses Pengarbonan Dari Arang Kayu Jati. Media Mesin, 7(1), 40–46.

Nasution, M., & Nasution, R. H. (2020). Analisa Kekerasan Dan Struktur Mikro Baja AISI 1020 Terhadap Perlakuan Carburizing Dengan Arang Batok Kelapa. Buletin Utama Teknik, 15(2), 165-173.

Schonmetz, A., & Gruber, K. (1985). Pengetahuan Bahan Dalam Pengerjaan Logam. Angkasa Bandung.

Suratman, & Rochim. (1994). Panduan Proses Perlakuan Panas. Bandung: Lembaga Penelitian Institut Teknologi Bandung.