Hardness and Metallographic Characteristics Analysis of AISI 1040 Steel Utilizing Heat Treatment Processes

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Abstract: - AISI 1040 steel specimens are heat treatment process to obtain hardness values with vickers testing machine with several methods, including quenching using water media and oil media. From the experimental results that have been carried out using the mitutoyo vickers hardness tester for AISI 1040 steel before the heat treatment process has an average hardness value of 10,7 VHN, after the heat treatment process the hardness value of AISI 1040 steel using the oil quenching method averages 83.9 VHN, then the AISI 1040 steel hardness value using the water quenching method averages 104.3 VHN. After that AISI 1040 material is carried out a microstructural test to identify the microstructure profile.

Key-Words: - AISI 1040 Steel, Hardness, Vickers, Heat Treatment.

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1 Introduction

The axle is one of the important parts or components in terms of its relation to installation in a machine mechanism, there are several machines in the manufacturing industry and home industry, including milling machines, threshing machines on coconut fibers, mixing machines, crusher machines, and other types of machines. The shaft has a function that is to continue stating the shaft is made to support the rotating moment and gets torsional stress as well as bending. Meanwhile, the shaft is divided into transmission shafts, spindles and axles. [3]

The function on the axle is very important, which is the reason why this component must be designed and ensured that it is able to work well and good when receiving loading suddenly and static loads, and the shaft has the desired service life. [6]

This research aims to investigate the characteristics of steel material in AISI 1040 by analyzing the hardness value and microstructure results:

- Identifying technological innovations that can later become a solution for the manufacture of a tool.
- What values are resulting in testing the hardness of AISI 1040
- Identifying the shape of the microstructure that occurred in AISI 1040 with the Quenching Method at 800C temperature

2 Historical Perpectives And Current Trens

A. AISI 1040 Steel

AISI 1040 steel is one type of low carbon steel with carbon elements (1,40-1,70)% Ni, (0,90-1,40)% Cr, and (0,20-0,30)% Mo. AISI 1020 steel is equivalent to DIN CK22.C22, JIS S20C steel. According to AISI (American Iron and Steel Institute) and DIN CK22.C22 standards, AISI 1020 steel has a chemical composition of (0,20-0,30)% C, (0,15-0,35)% Si, (0,50-0,70)% Mn, 0,035% P, 0,035% S, (1,40-1,70)% Ni, (0,90-1,40)% Cr, and (0,20-0,30)% Mo. AISI 1020 steel is widely readily available as Gear, billet bar, forging rod, sheet, tube, and welding wire. Typical applications with the hardening process of AISI 1040 steel include changes in mechanical properties with variations in the austenization temperature of AISI 1040 steel quenched with oil.

B. Hardness Test

Hardness testing is one of the most commonly used tests, as it can be applied to small test specimens without any difficulties concerning the specifications.

The hardness of a material should be recognized, specifically for materials that in use will be friction (frictional force) and evaluated from the dimensions of the

mechanical characteristics of the material obtained from plastic deformation. [8]

Vickers hardness uses a diamond pyramid indentor with an almost rectangular shape. The angles between the opposite surfaces of the pyramid are 1360. This specific angle was selected because it closely matches the value of the desired ratio between the notch diameter and the diameter of the impact balls within the Brinell hardness test.

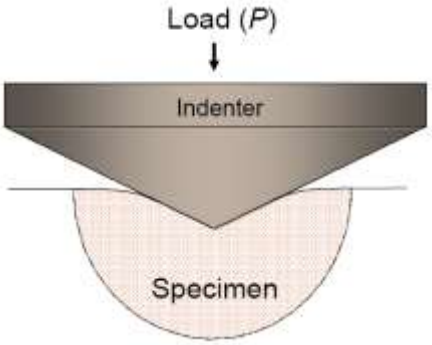

Figure 1. Test Speciment

As the traces made with the pyramid press are geometrically similar and there is no question of size, the VHN is independent of the load. In most cases this is fulfilled, except at very light loads. The loads normally used in the Vickers test range from 1 to 120 kg.

$$VHN = 1{,}854\ P/d^2$$

Where:
VHN : Vickers Heardness Number
P : Applied load (kgf)
d : Length of the diagonal of the Indent trace

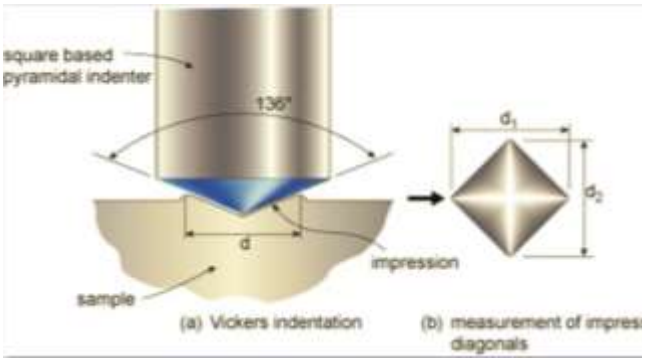

Figure 2. Vickers Hardness Testing

C. Heat Treatment

Heat treatment is a technique used to modify physical characteristics or chemical characteristics of materials. In General, Heat Treatment means heating or cooling the material, typically accompanied by extreme temperatures to realize the required result.[7] Heating is applied until it finally achieves austenite temperature (±912 C) because at that temperature the carbon is completely dissolved into Fe. Holding at this temperature is required for a while to spread the heat over the entire surface of the specimen.

D. Quenching

Quenching is a heat treatment process on a material by heating it to austenite temperature, holding it and then quickly cooling it in a dipping medium until the material will achieve the martesite phase. The media can be water, salt water and oil. The purpose of this quenching is to increase the hardness of the material.

After the hardening process, the quenching process will be performed. Quench is the quick cooling of a metal by dipping in the cooling medium. Maximum hardness can be achieved by quenching samples that have been heated resulting in structural changes. microstructure. The rate of cooling depends on some factors, such as the temperature of the medium, specific heat, heat of vaporization, conductivity of the thermal medium, specific heat, heat of vaporization, thermal conductivity of the medium, viscosity, and agitation (flow of cooling medium).

E. Microstructure Testing Methods

Microstructure is a description of the collection of phases that can be observed through metallography techniques. Microstructure measurements are made to determine the microstructure of a particular metal. These observations generally involve grain boundaries and the phases of the metal or alloy.

Crystal structure is the characteristic array of atoms in a crystals. A crystal structure is constructed by units cells, a specially arranged set of atom, which periodically repeat in three dimensions in a crystal lattice. The spaces between unit cells in all directions are referred to as lattice parameters.

3 Research Methods

The research involved multiple stages, beginning with the preparation of cuts on AISI 1040 steel. The preliminary stage

focused on determining the hardness value of AISI 1040 steel. The heated specimens were then quickly cooled using water and oil. After the cooling process, a hardness test was performed using a Vickers tester to measure the hardness of the AISI 1040 steel. In summary, microstructure testing was conducted to analyze the profile of AISI 1040. The heat treatment results were analyzed at the Hardness Test Laboratory (Rockwell) located at the Mechanical Engineering Department of Muhammadiyah Purwokerto University.

Figure 3. AISI 1040 Steel

3.1. Research Procedure

The fundamental idea in the research carried out is to determine the results of the tests for the hardness test value of the steel axle material by using a hardness analyzer and to get the results of the metallographic tests by using a microstructure analyzer. Figure 4. Research Flowchart

Material Selection

In the process of cutting each material with a lathe, measurements were taken to ensure that all AISI 1040 steel pieces have a consistent size. Additionally, this process involves removing any impurities that may cause sticking.

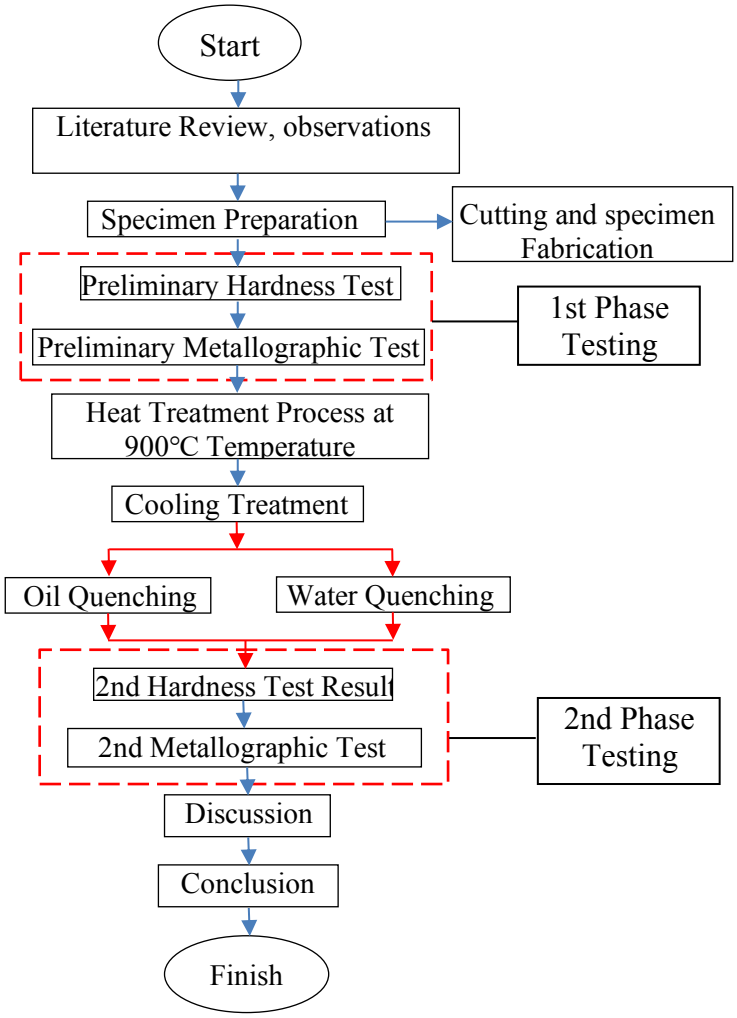

Figure 4. Flowchart

4 Result and Discussion

Every material is cut using a lathe, the length and width are measured equally, so all 1040 aisi steel has the same size.

Description:

- Long : 40mm^2
- Diameter : 25mm^2
- Thick : 15mm^2

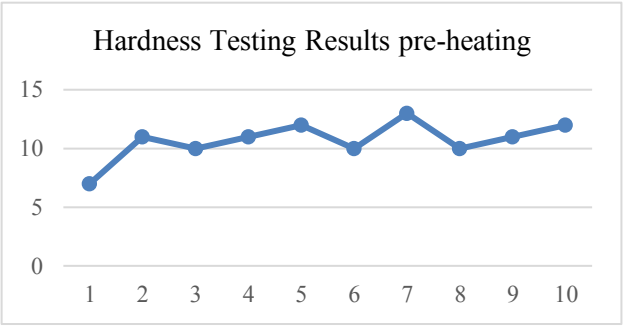

Figure 5. Graph Hardness Testing Result Pre Heating

Figure 6.A AISI 1040 Steel Specimen

Figure 6.B AISI 1040 Steel Specimen

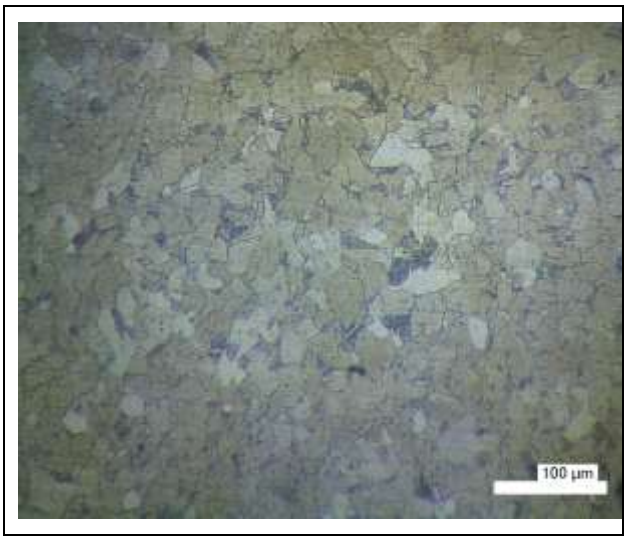

Figure 7.A Microstructure Photograph 100x Magnification

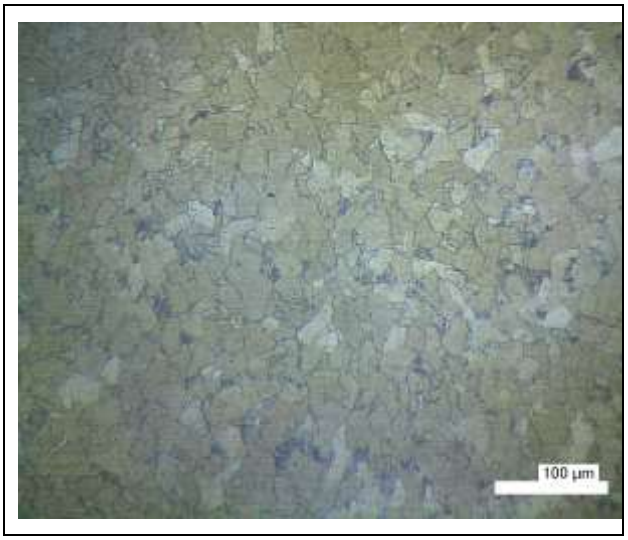

Figure 7.B Microstructure Photograph 100x Magnification

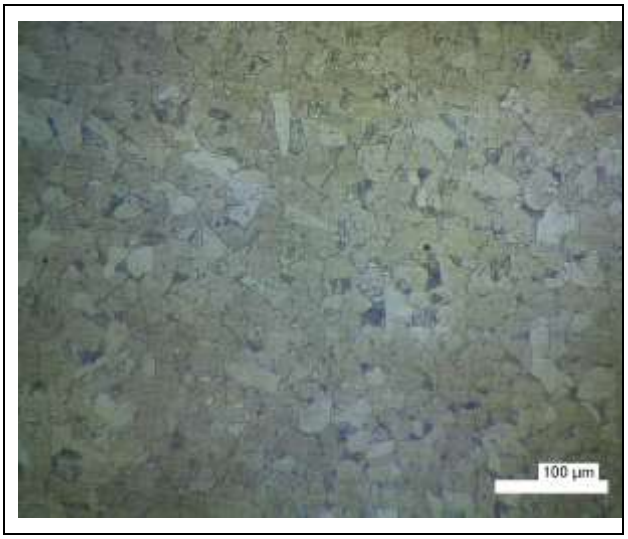

Figure 7.C Microstructure Photograph 100x Magnification

Heat Treatment Process

Figure 8. Heat Treatment process AISI 1040 steel specimens at 900℃.

Figure 9. AISI 1040 After Heat Treatment

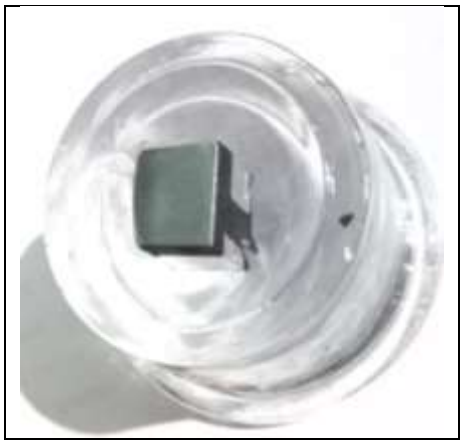

Figure 10.A AISI 1040 After Heat Treatment

Figure 10.B AISI 1040 After Heat Treatment

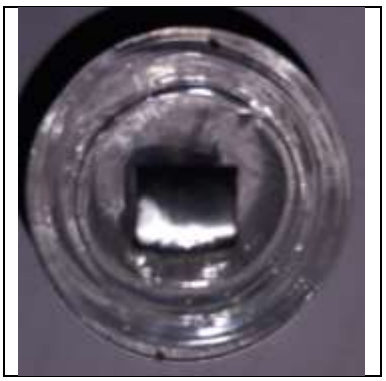

Figure 10.C AISI 1040 After Heat Treatment

Figure 10.D AISI 1040 After Heat Treatment

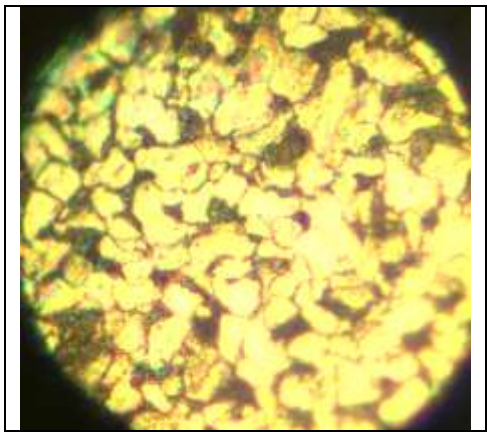

Figure 11.A Microstructure Photograph 200x Magnification After Heat Treatment

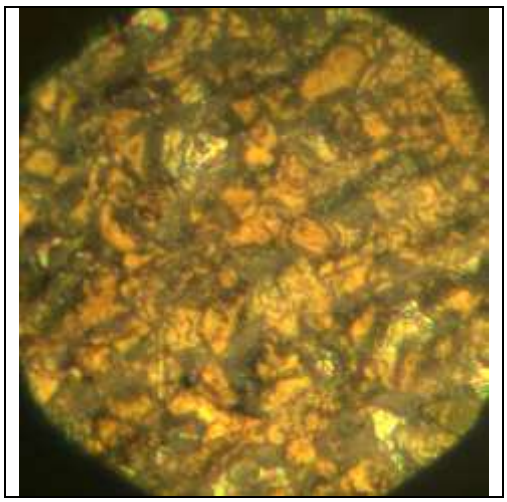

Figure 11.B Microstructure Photograph 200x Magnification After Heat Treatment

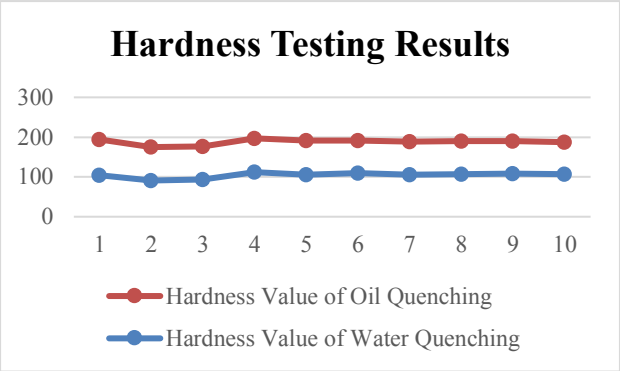

Figure 12. Graph Hardness Value After Heat Treatment bettwen Oil Quenching and Water Quenching

4 Conclusion

In research using AISI 1040 steel material, the hardness value tested before heat treatment process produces an average hardness value of 10.7 VHN. Meanwhile, after the heat treatmen method is performed on the specimen, the results are obtained from the hardness value of AISI 1040 steel using oil quenching media to produce an average value of 83.9 VHN, then the hardness value of AISI 1040 steel using water quenching media with an average hardness value of 104.3 VHN.

References:

[1] H, Nofriady dan Sudarisman,. *Pengaruh Perlakuan Panas Baja AISI 1029 Dengan Metoda Quenching dan Media Pendingin Terhadap Sifat Mekanik dan Struktuk Mikro*. Jurnal Teknik Mesin Vol.5 No.1, **2015.** DOI (https://doi.org/10.21063/jtm.2015.v5.i1.59-64) (**Journal**)

[2] Nofri, M dan Acang T,. Analisis Sifat Mekanik Baja SKD 61 dengan Baja ST41 Dilakukan *Hardening* Dengan Variasi Temperatur. Jurnal Bina Teknika Vol.13 No.2 Page, 189-199, **2017**. DOI (https://doi.org/10.54378/bt.v13i2.218) (**Journal**)

[3] Paul David Rey,. *Pengaruh Aluminizing (Al-Cu) Terhadap Laju Korosi Sambungan Las Busur Tendam Tabung Gas*. Seminar Nasional Cendekiawan ISSN: 2460-8696, 2015. DOI. (https://media.neliti.com/media/publications/173198-ID-pengaruh-aluminizing-al-cu-terhadap-laju.pdf) **(Conference paper)**

[4] Purwanto, Dwi., *Analisis sifat kekerasan dan metalografi pada Baja aisi 1020, aisi 1037 dan aisi 1040 Untuk poros (shaft) dengan Menggunakan proses heat treatment*, Jurnal Suara Teknik., Page 13-20, **2020**. DOI http://dx.doi.org/10.29406/stek.v13i2.4603 (**Journal**)

[5] Purwanto, Dwi., *Effects Of Various Temperatures On Impact Strength, Hardness And Metallography In ST 37 Steel For Plates By Heat Treatment And Quenching Processes*, Vol.8 Page 17-22. International Journal of Mechanical Engineering. DOI (https://www.iaras.org/iaras/filedownloads/ijme/2023/012-0004(2023).pdf) (**Journal**)

[6] Nofri, M dan Acang T. *Analisis Sifat Mekanik Baja SKD 61 dengan Baja ST41 Dilakukan Hardening Dengan Variasi Temperatur*. Jurnal Bina Teknik Vol.13 No.2 Hal, 189-199, **2017.** DOI (https://doi.org/10.54378/bt.v13i2.218) (**Journal**)

[7] *T.* Jukdin saktisahdan., Pengaruh Proses Heat Treatment Terhadap Perubahan Struktur Mikro Baja Karbon Rendah. Jurnal Laminar Vol. 1 No. 28-33, **2019.** DOI (http://jurnal.una.ac.id/index.php/laminar/article/view/1049/914) (**Journal**)

[8] Budiman., *Analisa Pengaruh Variasi Waktu Penahanan Panas Dengan Proses Normalizing Pada Baja ST 41 Terhadap Kekerasan Dan Struktur Mikro*, Jurnal Pilar Teknologi. Vol. 7 No. 2. 26-31 **2022** DOI (https://doi.org/10.33319/piltek.v7i2.141) (**Journal**)

[9] Sarjito, Jokosisworo., *Pengaruh Normalizing Dengan Variasi Waktu Penahanan Panas (*Holding Time*) Terhadap Sifat Mekanik Baja ST 46*. Jurnal Ilmu Pengetahuan dan Teknologi Kelautan, Vol. 15, No. 2, 2018. DOI (https://ejournal3.undip.ac.id/index.php/naval/article/view/19931) (**Journal**)

[10] Suhardan, R. Kohar., *Pengaruh Variasi Temperatur Normalizing Terhadap Besar Butir Dan Kekerasan Material Baja Karbon AISI 1035*. Jurnal Teknik Mesin, Vol. 2, No. 2, **2019**. DOI (https://doi.org/10.33319/piltek.v7i2.141) (**Journal**)

[11] Joko Purnomo Dwi, Budiarto., *Analisa Pengaruh Holding Time Tempering Terhadap Kekerasan, Keuletan, Ketangguhan, dan Struktur Mikro Pada Baja ST 70*. Jurnal Teknik Perkapalan, Vol. 7, No. 1, **2019** DOI (https://ejournal3.undip.ac.id/index.php/naval/article/view/22886/21767) (**Journal**)

[12] Ari Wibawa Budi Santosa., Analisis Kekuatan Tarik, Kekuatan Puntir, Kekerasan, dan Mikrografi Baja ST 60 Sebagai Bahan Propeller Setelah Proses Normalizing dengan Variasi Waktu Penahanan Panas (*Holding Time*). Jurnal Teknik Perkapalan, Vol. 7, No.2, **2019**. DOI (https://ejournal3.undip.ac.id/index.php/naval/article/view/21531/22484) (**Journal**)