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Effect of Changes in Cooling Media and Temperature on Steel Hardness

Anhar Khalid[1]*, Akbar Ela Heka[2], Fitria[3]
Politeknik Negeri Banjarmasin
Corresponding Author: Anhar Khalid anhar.khalid@poliban.ac.id

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A B S T R A C T

The hardness test is one method to determine the effect of heat or cold treatment on the material. This research uses experimental methods. This research uses a type of quantitative research, namely clearly explaining the results of experiments in workshops on test objects, then analyzing the data using numbers. The results of testing using the Vickers method by taking 12 specimens and taking 3 penetrations can be concluded that changes in the structure of the material that has been heat treated results in the structure of the material becoming harder compared to that which has not received treatment.

INTRODUCTION

Industry plays an important role in the rapid development of science and technology means that industry plays an important role in it. With the existence of new industries, it will be possible to create new, more innovative products, thereby encouraging the emergence of new discoveries in both the fields of science and technology. Metal, particularly steel, plays a crucial role in existing industries. This is proven by the large use of steel in various machine components, work materials, and building construction, both in the form of plates, sheets, pipes, profile bars, and so on (Harahap, 2018; Herlina, 2016). The hardness test is the most effective because, with it, we can easily get a picture of a material's mechanical properties. Despite the limited scope of measurements, the hardness value serves as a reliable indicator of a material's strength. A hard test easily classifies the material as ductile or brittle. The hardness test is one method to determine the effect of heat or cold treatment on the material. For materials that have undergone cold working, hot working, and heat treatment, you can get an idea of changes in strength by measuring the surface hardness of materials material. As a result, we can easily perform quality control on materials with hard tests. (Balai et al., 2018).

At present, the heat treatment method remains the most effective technique for altering the mechanical properties of a metal substance. With heat treatment, we can adjust the mechanical properties of the metal to meet our specific needs. A proper heat treatment process is required to soften the material. As a result, the annealing process is a treatment (Fathu Rohman et al., 2014; Nugroho, 2017). As the number of mechanical failures encountered, the development of science and the number of new discoveries, design factors began to increase. One example is the metal fatigue factor. When the fatigue factor is not yet known, the planning of a component is only based on static loading. Based on the explanation above, researchers are interested in conducting research with the title "Effect of Changes in Cooling Media and Temperature on Steel Hardness". In this research the author used ST 42 steel as the research object and that procedure also applies to improving the quality of ST 42 carbon steel products, which have applications in the engineering field, including being used for various purposes in the construction sector.

LITERATURE REVIEW

Hardness Test

In general, hardness expresses resistance to deformation and is a measure of a metal's resistance to plastic deformation or permanent deformation. For design engineers, hardness is frequently defined as a measure of ease and a specific quantity that indicates something about a metal's strength and heat treatability. There are three types of hardness measurements, depending on how the test is carried out, namely: (1) Scratch hardness; (2) Indentation hardness; (3) Rebound hardness. For metals, only the indentation hardness attracts much attention in relation to the engineering field. There are various kinds of indentation hardness tests, including: Brinell, Vickers, Rockwell hardness tests and so on (Admin, 2024; Xometry, 2023).

Quenching

Quenching is a metal working process by cooling rapidly. So that quenching will prevent processes that can occur during slow cooling, such as grain growth. In general, quenching will cause a decrease in grain size and can increase the hardness value of a metal alloy. The rate of quenching depends on several factors, medium, specific heat, heat of evaporation, thermal conductivity of the medium, viscosity, and agitation (cooling media flow). The speed of cooling with water is greater than cooling with oil, while cooling with air has the lowest speed. In general, steel that has undergone a quenching process has high hardness and can reach maximum hardness but is somewhat brittle (Luthfianto et al., 2017).

Heat Treatment

Steel is subjected to a variety of heat-treatment procedures that include heating and cooling metal in order to give it particular mechanical and physical characteristics. Annealing, tempering, quenching, and case hardening are a few examples of these procedures. In order to enhance the strength, hardness, ductility, and other qualities of steel products—such as tools, machinery, and structural components—heat treatment is frequently applied during the production process. Heat treatment is a method used to change the physical properties or microstructure of a metal through a heating process and regulating the cooling speed with or without changing the chemical composition of the material. The heat treatment process can be classified into several methods, namely: (1) Hardening, (2) Anneling and (3) Normalizing. The value of the heating temperature is the first crucial element in the heat treatment procedure. It is the heat treatment process's greatest temperature (Admin, 2023; Hang, 2021).

Vickers Hardness testing Method

Vickers hardness testing is a test to determine the hardness in the form of material resistance to a pyramid-shaped diamond with a peak angle of 136˚ pressed on the surface of the test material. Hardness is the resistance of a material to plastic deformation caused by pressure or scratches from other objects. Hardness is a property of a metal that gives the metal the ability to withstand permanent deformation (bend, damage, or change in shape) when a load is applied. In general, hardness indicates resistance to deformation, and for metals with these properties, it is a measure of their resistance to plastic deformation. In the mechanics of material testing, many interpret hardness as a measure of resistance to bending. For building designers, hardness is often interpreted as a measure of ease and a specific quantity that indicates something about the strength and heat treatment of a metal. From the brief description above, the hardness of a material can be defined as the resistance of the material to the pressing force of another harder material (Bahri, 2020).

In the process of testing hardness, of course, using the principle of the pressed load will produce a hardness value with the calculation of each method

used. The hardness value obtained from one of the methods used is a conclusion that shows the hardness of the material being tested. However, the harder a material is, the more brittle it will be, but this hardness property can be more useful in tools that are easily worn out due to scratches from other objects, such as heavy equipment in agriculture, mining, and others.

Basically, all hardness test methods have their own advantages, but in this study, the test tool for hardness testing used is the Vickers test. This Vickers hardness test is a test method that uses a 360-degree diamond-shaped pyramid as an indenter. The principle of testing this method is the same as the Brinell method; in the Brinell method process, the resulting trace is spherical, while in the Vickers test method process, the resulting trace is a rhombus with diagonals 1 and 2. The length of the diagonal is measured with a scale on the microscope, which measures the resulting trace. The calculation method can be shown in Figure 2.5.1 below. The Vickers hardness test is widely used in research work because, in addition to being easy to use, this method also provides results in the form of a continuous hardness scale.

METHODOLOGY

This research uses a quantitative research method, which explains the results of experiments in the workshop with the test object and analyzes the data using numbers. Experimental research involves observing and manipulating variables to see the effects of such actions. In the Heat Treatment process, the temperature will be set at 800°C, 850°C and 900°C with a holding time of 15 minutes. Next, the material will undergo a Quenching process using media like SAE 10, coconut water, radiator water, and Bayclin. On this study that will be observed are the test of violence and micro-structure testing.

RESEARCH RESULT

Hardness Test Specimens

The material used in this study is ST42 steel, with a diameter of 40 mm and a length of 50 mm. With a total of 36 specimens for each test. Below is a hardness test specimen.

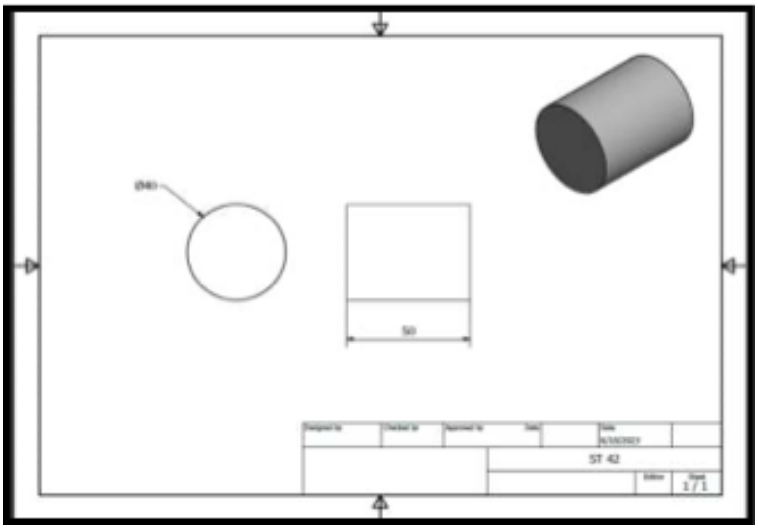

Figure 1. Hardness Test Specimens

Figure 2. ST42 Steel

This research uses a Vickers hardness test tool. The Vickers Hardness Tester is a device used to measure material hardness using the indentation method. The Vickers test is one of the most popular and accurate methods for measuring hardness, especially because it can be used on a wide range of materials, from hard metals to softer materials such as plastic. Vickers hardness testing is widely used in materials research, quality control, and manufacturing industries to ensure materials meet required hardness specifications.

Figure 3. Vickers Hardness Tester

Saw and Lathe Workoing Steps

Next, the workpiece will be installed in a vise on the cutting saw machine with a size of 50 mm. If so, the hydraulics will be lowered until the saw blade touches the workpiece. Then turn on the machine and wait until the object is cut by itself. The following is a figure of the cutting and lathe results:

Figure 4. The cutting and lathe result

Surface Grinding and Vikers Test Process

Surface Grinding Machine in which the iron surface will be smoothed in this process so that it can be used for hardness testing. As in general, we must prepare PPE after it is complete, then the process will begin where the workpiece will be arranged on the magnetic table and the surface will be smoothed slowly until clean. The Vikings test begins by preparing the materials and installing the diamond penetrator on the research tool. Next, the workpiece holder is installed, and then the measuring tool is also installed on the test screen. After the machine is ready, the workpiece will be placed on its holder and raised with its lever. After it is ready, the next step is pressing by lowering the lever next to the tool. The object is pressed with an indenter, then using a timer, it is left to run for 10 seconds, then the weight lever is lowered. After the lever is lifted, the diamond shape will appear on the screen and will be measured immediately. The following is a figure of the results of the object after the Vickers test:

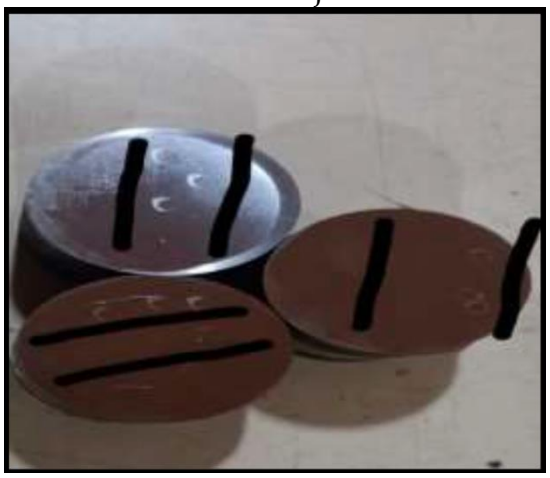

Figure 5. The results of the object after the Vickers test

DISCUSSION

It can be concluded from the diagram that structural changes in heat-treated materials result in harder material structures compared to untreated ones.

The highest hardness value in hardness testing for heat-treated materials occurs at a temperature of 900°C with a value of 452,825 HVN in Bayclin media and for a temperature of 850°C with a value of 304,564 with Coconut Water media and a value for a temperature of 800°C with a value of 111,603 HVN in Radiator Water media, while those without treatment get a hardness value of 79.57 HVN, where structural changes in heat-treated materials result in harder material structures compared to those without treatment. The structure is determined by the carbon content. In low carbon steel with a carbon content of 45% and Fe 55%, the structure is dominated by fernt (light in color). The shape and size are arranged neatly and regularly. Medium carbon steel will experience a phase change to martensite when the heat treatment process continues to become Austenite and finally becomes ferrite and martensite. The higher the carbon content and the lower the iron content, the more martenite will be, while ferrite is only a little or even no pearlite at a temperature of 900°. This is in line with previous research which states that load variations have little effect on the hardness value results (Subagiyo, 2017).

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the study, data analysis, and discussion results on the effect of the heat treatment process with temperature variations of 800°C, 850°C, and 900°C on ST-42 steel material, the following conclusions can be drawn: From the results of hardness testing using the Vickers method by taking 12 specimens and taking 3 penetrations in each specimen in each treatment, the hardness value of the ST-42 steel material heated at a temperature of 800 °C can be obtained as 121.54 HVN in SAE 10 oil media, 88.955 HVN in Bayclin media, 111.603 HVN in radiator water media, and 102.441 HVN in coconut water media. And at a temperature of 850 °C, the hardness value is 210,631 HVN in SAE 10 oil media, 297.96 HVN in Bayclin media, 285,076 HVN in radiator water media, and 304,564 HVN in coconut water media. And at a temperature of 900 °C, the hardness value is 381,493 HVN in SAE 10 oil media, 452,825 HVN in Bayclin media, 345,986 HVN in radiator water media, and 391,373 HVN in coconut water media. For those without treatment carried out with 1 specimen sample with 3 penetrations, the hardness value is 79.579 HVN. So it can be concluded that changes in the structure of the material that has received heat treatment cause the material structure to become harder than those that have not received treatment. This is in line with research conducted by (Subagiyo, 2017).

From the results of the microstructure test, it can be seen that the material in ST-42 steel that has not undergone a heat treatment process has ferrite and perrite precipitates that are evenly distributed in large quantities and have small grain sizes. While observations of the microstructure result in the material after undergoing a heat treatment process at a temperature of 800 °C, the grain distance tends to be close together and has a large size.85This results in materials with a temperature variation of 800 °C having low hardness among materials with other variations. In material with a temperature variation of 850 °C, the precipitation size is large and dense. This results in materials with this variation

having a high hardness value. While material with a temperature of 900 °C appears to have small precipitates but in large quantities and close together compared to material with a temperature variation of 850 °C,. This causes material with a holding time variation of 850 °C to have a hardness below the temperature variation of 900 °C. So from the results of microstructure observations, it can be concluded that the higher the temperature, the higher the value in the hardness test compared to material that does not receive heat treatment, such as research conducted by (Chamim et al., 2023). Through metallography techniques The microstructure of a metal can be seen using a microscope. The structure of medium-carbon steel is dominated by ferrite and martensite. The specimens that were tested for microstructure were specimens without heat treatment, SAE 10 cooling media, bayclin, coconut water, and radiator water with temperatures of 800°C, 850°C, and 900°C. Microstructure testing using the Olympus Micro with photo magnification was obtained from the multiplication of objective and eyepiece lenses. The objective lens used was 10 x eyepiece lens 10 x so that the magnification could reach 100 x. At a distance of 10 strips on the photo for 10x magnification.

ADVANCED RESEARCH

In this study, the author has several suggestions and inputs that may be used to develop further research: During the exca process, PPE, one of which is a mask and gloves, should be used because HNO3 liquid with a high concentration can affect the respiratory senses, one of which is a very sharp odor, and if it comes into contact with the hands, the skin will peel off. When carrying out the heat treatment process or the surface grinding process and testing, be careful and use safety equipment (PPE).

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