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The Influence of Carbon Particle Size in The Carburizing Process of ST-40 Steel to The Surface Hardness

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The Influence of Carbon Particle Size in The Carburizing Process of ST-40 Steel to The Surface Hardness

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Abstract. This research aimed to determine the changes in the microstructure that occurred and changes in the hardness value of the steel surface. This research uses ST 40 steel and carbon powder with an average area of carbon particles $115,103\mu m^2$ and $515,735\mu m^2$. Steel and carbon were put in a closed container and heated at 780^oC for 4 hours. After the carburizing process, the particle area was reduced to $110,051\mu m^2$ and $440,058\mu m^2$. Raw material yields an average solubility of elements in Fe (β%) 5.99%. The solubility of the carburizing material element is higher in the smaller carbon grains. Likewise, the result of surface hardness after the carburizing process is harder by using small carbon granules.

1. Introduction

Steel is an important material used in various industrial activities, such as construction, transportation equipment, and machine tools. The choice of steel material is based on physical and mechanical properties. One of the mechanical properties is hardness. The method of hardening the steel surface that can be done is carburizing [1].

Carburizing is a method of hardening the steel surface by heating the carburized material and powder at an austenite temperature. Carburizing powder can use charcoal, coal, or coke. While the austenite temperature ranges from 780^oC to 930^oC [2]. Carburizing is suitable for low carbon steels. Low carbon steel has high ductility, and is easy to form, but low hardness. Based on the carbon concentration, steel is classified into low, medium and high carbon steels. The carbon concentrations are 0.10 - 0.25%, 0.25 - 0.50% and more than 0.50% C respectively.

Diffusion is the process of transferring atoms from one medium to another which is affected by thermal agitation. In this process, atoms always move randomly from one medium to another, causing a crystal defect in the form of a vacant atomic position. The atomic position's vacancy will provide an opportunity for the infiltration of other atoms [3].

Low carbon steel if there is a change in ferrite's microstructure, then the crystal structure that is formed is BCC (Body Centered Cubic). When the temperature rises at the austenite temperature, the crystal structure changes to FCC (Face Centered Cubic) and will return to BCC after cooling [4].

Research on the effect of particle size and immersion time on the surface hardness of AISI 1018 steel has been carried out [5]. In this experiment, the charcoal and shellfish that had been finely sieved were 212 μm, 425 μm and 600 μm in size to expand the diffusion surface. After the filtering process, the charcoal powder is mixed with the energizer (shellfish) in the proportions of 9 : 1, 8 : 2, 7 : 3 and 6 : 4. The experimental results showed that shellfish containing $CaCO_3$ and small carbon particle size were able to increase hardness.

Carburizing experiments were also carried out around

Research on the effect of temperature and time on the carburizing process on HSS cutting tools has been carried out [6]. The number of specimens was 30 HSS cutting tools with a size of 200 x 14 x 14 mm. Heating is carried out at temperatures of 800, 850, 900 and 950^oC. Each temperature was given a holding time of 60, 90 and 120 minutes. In this experiment, the carbon used came from refined crude palm kernel shells and added $BaCO_3$ as a catalyst. Evaluation of tool performance is carried out by measuring the hardness on the surface of the cutting tool. Experimental results show that using a Barium trioxocarbonate (BaCO3) energizer with a concentration of 25% can increase carbon penetration into the layer of the HSS cutting tool. The high temperature used during the carburizing process with a longer holding time increases the surface hardness.

Experiments on the variation of holding time on v-notch shaft steel have also been carried out by Supriyono & Jamasri [7]. This experiment was carried out using steel, which has a carbon content of 0.17% planted with mahogany type carbon that has been refined. The steel was then heated to a temperature of 930oC with variations in holding time of 2, 3, and 4 hours.

Experiments on the concentration of incoming carbon with the surface roughness of AISI 8620 steel have been carried out by several researchers [8, 9, 10]. The purpose of this experiment is to; 1) investigating the effect of surface roughness on gas carburizing performance, 2) developing a functional relationship between surface roughness characteristics and mass transfer coefficient, and 3) determining the effect of surface roughness on the carbon concentration profile and the depth of carbon diffusion during the carburizing process. The experimental results show that the level of carburizing is highly dependent on the surface roughness before carburizing, but the surface of a finer material with a surface roughness below $1.2\mu m$ (Sq) and $22\mu m$ (St) has no significant effect on the carbon concentration profile.

This research was conducted to see the effect of carburizing results using carbon with an average carbon particles area of $115.103\mu m^2$ and $515.735\mu m^2$ on the hardness value and changes in its microstructure.

2. Methodology

The material used as a means of carbon transfer comes from shredded trembesi wood charcoal to become powder. The charcoal was sieved using a mesh 100 and 500 sieve, respectively. In the 500 mesh process, the sieving was assisted by using an alcohol to produce an average particle area of $515.735\mu m^2$ and $115.103\mu m^2$. The steel material that is carburized is ST 40 steel with a diameter of 30 mm and a length of 6000 mm. the steel material is turned so that the diameter is 28 mm and the thickness is 6.9 mm.

The changes in microstructure after carburizing were observed using the Olympus X1005 TTEPL optical microscope. Tests using were carried out based on ASTM E-3. Magnifications in the microstructure test were 200x and 1000x. Furthermore, the hardness changes in ST 40 steel after carburizing it using Micro Vickers Hardness. Testing standard based on ASTM E-92. Carbon particles were also analyzed before and after carburizing using the ImageJ application.

Carburizing is carried out at a temperature of 780^oC with a holding time of 4 hours. Cooling is done naturally in the oven. After the carburizing process, the etching process is carried out. This etching process aims to damage the specimen surface so that the structure formed will be seen using a microscope.

3. Results and Discussions

3.1. Carbon Particle Analysis

The carburizing process took 4 hours to produce carbon diffusion into the steel surface. After carburizing, the ST 40 steel is cooled slowly in the oven (annealing). In Figure 1.a, the carbon analysis results before using carburizing show that the number of particles in 1647 has an average particle area of $115.103\mu m^2$ or a diameter of carbon particles close to $12.109\mu m^2$.

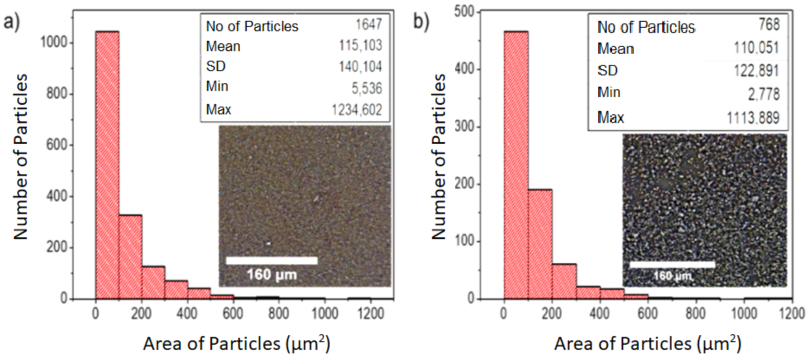

Figure 1: The results of the carbon particle area analysis. a) before using carburizing the average particle area was $115.103\mu m^2$, b) after using carburizing the average particle area was $110.051\mu m^2$

Figure 1.b After the carburizing process is carried out, the carbon particles' size has decreased. The analysis of carbon particles as many as 768 particles resulted in an average particle area of $110.051\mu m^2$ or the diameter of carbon particles close to $11.84\mu m$. The carbon released during the carburizing process was 53.37%. A decrease in carbon mass also indicates the difference in carbon before and after carburizing. The carbon used before carburizing is 2 grams and after carburizing is done, the carbon mass is reduced to 1.6 grams.

The same thing happened to the carbon particle area of $515.735\mu m^2$, shown in Figure (2.a). Prior to the carburizing process, 1199 particles were analyzed resulting in an average particle area of $515.735\mu m^2$ or a carbon diameter of $25.631\mu m$. After going through the carburizing process (2.b), the carbon surface area was reduced to $440.058\mu m^2$ or the particle diameter reached $23.676\mu m$. The amount of carbon released after using carburizing is 2.67%. This is also indicated by reducing carbon mass, from 200 grams used reduced to 1.89 grams.

The rough carbon surface condition has a large enough powder grain size to affect the carbon diffusion process into the steel. This condition is inversely proportional to the smaller grain size of carbon powder, this causes the carbon diffusion process that occurs in low carbon steels to be very easy. It can be assumed that the size of the carbon will determine: 1) the area of the excited carbon particles will increase. The carbon experiences differences in the size of the particle area before and after carburizing process. The diffusion process time was faster and easy during the use of small carbon size.

3.2. Micro Structure and Surface Hardness

The number of points tested on ST 40 steel is 5 sample points provided that the distance of the point one from the edge of 0.5 mm, 1mm of two points, 1.5 mm of triple point, 1.75 mm of fourth point, and 2 mm of fifth point.

The microstructure tested specimens were divided into three types: raw materials, carburizing specimens with an average carbon area of 115.103 μm^2 and comparison specimens carburizing with an average carbon particle area 515.735 μm^2. After passing through a metallographic

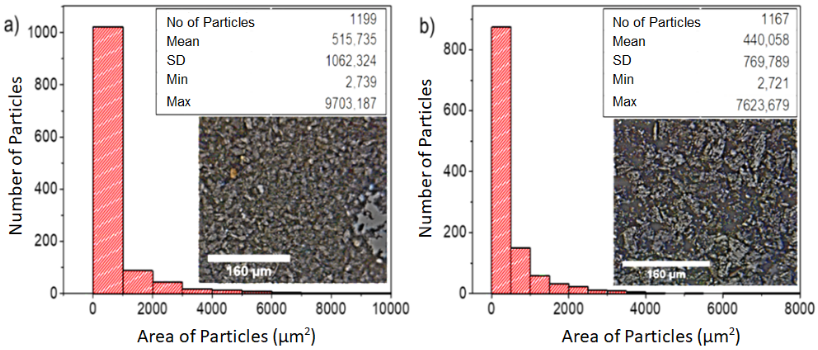

Figure 2: The results of the analysis of the area of carbon particles with the Imagej application; a) before using carburizing the average particle area was $515.735\mu m^2$, b) after using carburizing the average particle area was $440.058\mu m^2$

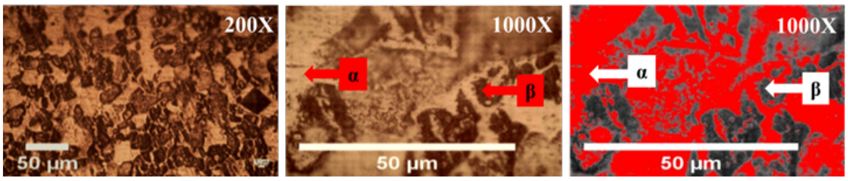

Figure 3: Microstructure of ST-40 steel

microscope, the image is processed again using the imagej application. In Figure 3, the black color indicates the solubility of the element in Fe (β / Fe3C) is hard and the red color indicates the ferrite (β / Fe) is soft.

From Figure 4, the microstructure yield area shows the element solubility (β / Fe3C) of raw material of 5.99%. In ST 40 steel after carburizing with an average area of 515,735 μm^2 carbon particles resulted in an average solubility of elements in Fe (β / Fe3C) of 14.19%. The increase in solubility of element (β / Fe3C) occurred in ST 40 steel after carburizing with an average area of carbon particles from 115.103 μm^2 to 23.49%.

The results of the Vickers hardness test can be seen in Figure 5. The average surface hardness of the resulting raw material is 263 Kg / mm2. The ST 40 steel after carburizing with an average area of 515.735 μm^2 carbon particles resulted in an average hardness value of 193.7 kg / mm2. The ST 40 steel after carburizing with an average area of carbon particles of 115.103 μm^2 resulted in an average hardness of 249.68 Kg / mm2. Based on the test results above, the hardness value of the three samples at each point is different.

In Figure 6, the point value of the solubility of the element is higher than that of the point of hardness. It can be assumed that the factor that affects the rise and fall of the hardness value is the position of the identor vickers on the steel surface. If the identor vickers of the ferrite area (β / Fe), the hardness value obtained will be small because ferrite is a soft structure in Fe.

4. Conclusions

Based on the results of research conducted on the three types of materials, it can be concluded that after the carburizing process, there is a reduction in the area of particles. The number of particles and the weight of carbon used decreases. The microstructure found when the ST-40 steel was pearlite and ferrite after the carburizing process at a temperature of 780^oC. The particle size of $115,103\mu m^2$ was successful in increasing the surface hardness of the steel higher than the particle size of $515,735\mu m^2$.

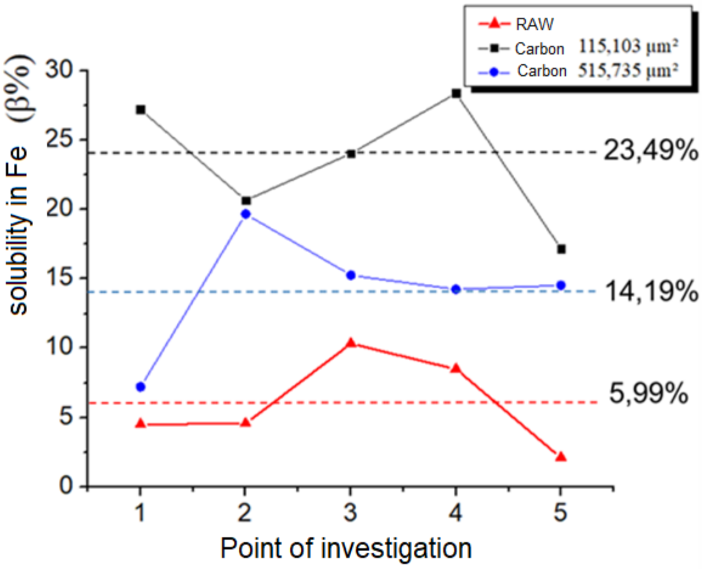

Figure 4: Element solubility in Fe from one to five microstructure test points

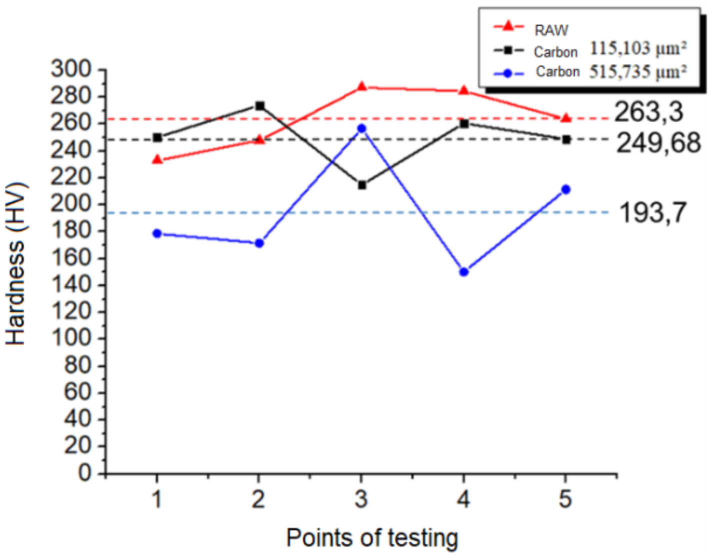

Figure 5: Surface hardness of ST-40 Steel

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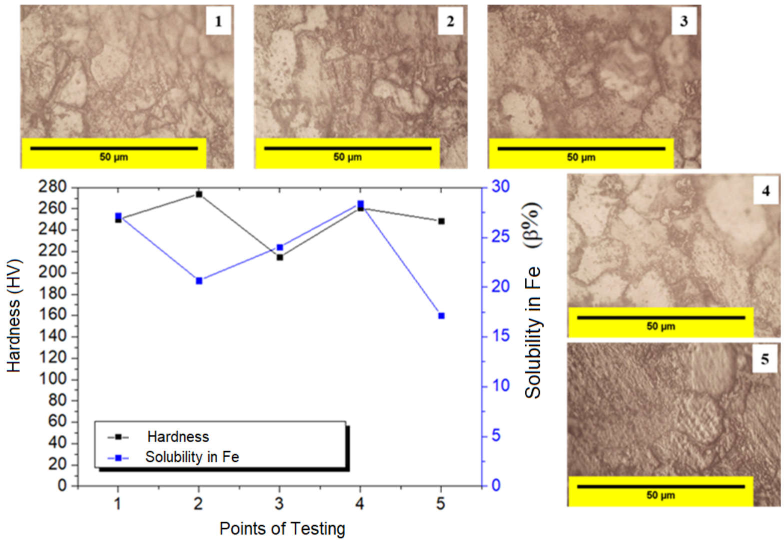

Figure 6: Relationship of hardness to the solubility of ST 40 steel after carburizing with the mean area of carbon particles 115.103 μm^2

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