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Study Experimental the Effect of Normalizing Treatment and Galvanic Pack Carburizing Process on Mechanical Properties of Low Carbon Steel

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Abstract

Steel is the type of metal most often used in engineering. The purpose of this study was to improve the mechanical properties of mild steel in terms of hardness, ductility, and other mechanical properties and to compare the hardness of carburized steel by galvanic treatment with non-galvanic carburizing of the steel. This research was carried out by varying the heat treatment process, namely carburizing with galvanic heat treatment and carburizing without galvanic, where the carburizing process uses activated carbon coconut shell charcoal with a weight percentage of 80% and 20% of K_2CO_3 (Potassium Carbonate) at a temperature of 900^0C with a holding time of 60 minutes, 120 minutes and 180 minutes. The results obtained from this study indicate that the mechanical properties (hardness) of carbon steel increase at a temperature of 900^0C with a holding time of 1 hour on the galvanic heating method with a better hardness value than the hardness of steel on the non-galvanic method. The hardness value obtained in the galvanic method is 94.06 HRB, while in the non-galvanic method, it is 76.4 HRB and the pearlite phase is formed, resulting in an increased hardness value on the surface of the specimen.

Keywords: Carbon Steel, heat treatment, carburizing, galvanic, hardness

1. Introduction

Steel is a type of metal that is widely used in the engineering field because it has many properties and types so its use can contain several alloying elements. Carbon steel is a Fe alloy steel and the carbon content ranges from 0.3 – 0.17%, where the functions of the carbon as a hardener greatly influence the mechanical properties of the steel [1].

The properties of carbon steel are influenced by the percentage of carbon which greatly influences the mechanical properties, while the microstructure of the steel itself is affected by the heat treatment process [2]. Carbon steel itself can be classified into three parts based on its carbon content including steel with a carbon content of less than 0.3% included in the low carbon steel group, medium carbon steel containing carbon ranging from 0.3 – 0.7%, and steel with high carbon content contains carbon as much as 0.7 – 1.7 carbon [3].

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Also, in the manufacturing process, several other chemical elements such as sulfur, phosphorus, silicon, manganese, and other chemical elements are found so that the properties of the steel can be adjusted as needed. The development of industrial technology is very rapid, we often encounter components that experience continuous friction in the process of operation, which can cause components such as gears, pistons, and shafts to experience wear and tear and reduce their service life [4]. To overcome this problem a process is carried out that can increase the hardness of the material, namely by engineering the surface of low-carbon steel which aims to make components that are resistant to friction [1], [4].

This surface engineering process can be carried out using heat treatment methods including normalizing, annealing, hardening, and tempering [2]. The atoms will diffuse into the steel surface through interstitial diffusion where the mechanism of atomic transfer occurs due to the movement of the atoms in the cavity. These atoms experience movement if they have a smaller radius than the parent atom [5] and this carburizing process is also a method used to control corrosion that occurs in metals in addition to increasing the hardness of the steel surface [6].

The carburizing process itself is divided into three methods, namely pack carburizing, liquid carburizing, and gas carburizing in this study we used the pack carburizing method or also known as powder/solid carburizing [7]. Galvanic corrosion is also known as dissimilar metal corrosion or bimetallic corrosion, where this process occurs when two different metals or alloys that are in the same environment and are interconnected [8]. Metals with electrode values A higher potential will result in an oxidation or anodic reaction, whereas a metal with a lower potential value will result in a cathodic or reduction reaction on its surface [9]. In this study, two metals with different electrode potential values were used, namely stainless steel and mild steel which would be carburized as shown in Fig. 1.

There have been several previous studies using the pack carburizing method by providing variations on the carburizing and energizer media used, as was done by Asrofi [10], which used mahogany wood charcoal mixed with 20% Barium carbonate ($BaCO_3$) as an energizer, which was carburized at a temperature of 850° C and 900°C with a holding time of 1 hour, which resulted in an increase in the hardness value and the formation of a martensite phase in the material.

Sujita [11] carried out a pack carburizing process at a temperature of 900°C with a holding time of 7 hours using bamboo charcoal as a carburizing medium using an energizer made from beef bone powder, with a resultant increase in hardness value of 110% from the raw material.

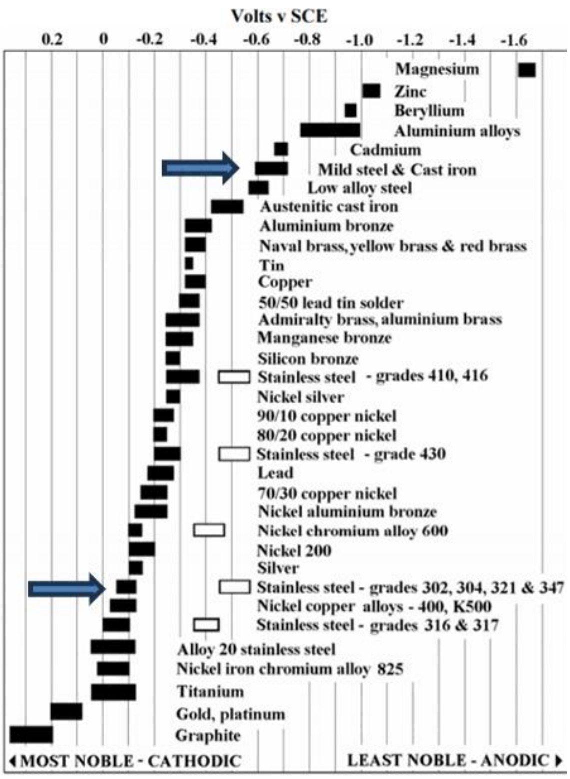

Figure 1. Table of the galvanic series

As it is known that the pack carburizing process is a case hardening process which is very dependent on the coefficient of time withholding time and temperature [5].

From some of the studies above, it can be seen that generally, the pack carburizing process is carried out using heat treatment of the material by providing variations on the addition of activated carbon and energizer only without any other treatment. But in this study, it was carried out by giving it a galvanic heating treatment before carburizing. This galvanic treatment is a process in which 2 metals that have different electrode potential values contact each other either directly or by being connected with a salt bridge [12].

2. Experimental Method

2.1. Materials and tools

The tools and materials used in this study are as follows; The tools that will be used in this research are the furnace used during the galvanic heating process and the carburizing pack process, cementation boxes, 250 mesh sieve, thermocouple, hardness test equipment (hardness Rockwell). The materials to be used include steel, charcoal coconut shell, and potassium carbonate (K_2CO_3) which is used as a catalyst.

2.2. Experimental method

Laboratory experiments are carried out by taking data directly on the object to be observed. Recorded directly to get the data needed. The research process was carried out with a procedure starting from the preparation of test specimens with a size (20 x 20 x 10 mm) of 24 pieces, which would be carburized using a ratio of 80% coconut shell charcoal as carbon and mixed with 20% potassium carbonate (K_2CO_3) was used as a catalyst and hardness testing will be carried out to see the increase in the mechanical properties of the low-carbon steel that has been given the treatment.

In this study, the heat treatment process was carried out with variations in the initial heating temperature and galvanic and non-galvanic carburizing pack processes, namely 500^0C, 700^0C, and 900^0C which will be held with variations of 60 minutes, 120 minutes, 180 minutes in the furnace which can be seen in the Fig. 2 where the carburizing galvanic is done by sticking stainless steel and

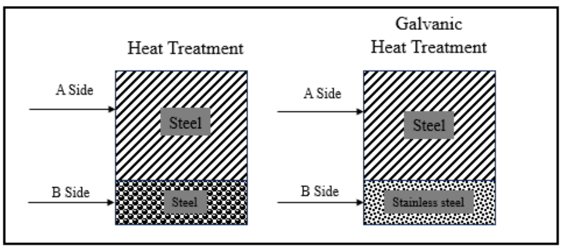

Figure 2. Heating and galvanic carburizing process

carbon steel specimens into a cementation box that has added carburizing compound in it and then put into a furnace where it will be heated at temperatures of 500°C, 700°C, and 900°C and held for 1 to 3 hours.

3. Results and Discussion

The pack carburizing process is one of the surface hardening processes of low-carbon steel materials by utilizing the diffusion of carbon atoms. With the addition of carbon to steel, the hardness properties will increase by carrying out the galvanic treatment process, and the hardness of the carburizing layer will increase. Adding chemical elements to the carburizing medium will increase the carbon potential which will result in a faster diffusion process and the process of entering the atoms into the steel surface will be deeper [13]. Potassium carbonate will decompose at 900°C into potassium dioxide and produce CO_2 ($K_2CO_3 \rightarrow K_2O + CO_2$). his gas will react with carbon from the carburizing medium to produce CO which then activates carbon atoms to diffuse into the steel surface.

3.1. Hardness test data results

The material surface was tested using Rockwell Hardness, using five points on each sample, with a load (P) of 980 Kg. The increase in the hardness of the carburizing layer was due to the addition of carbon and a structural change from austenite to martensite during the carburizing process. Martensite is the hardest structure with hardness values ranging from 500 – 1000 kg/mm^2 depending on the carbon content.

3.2. Normalizing hardness value

The results of the hardness values obtained with temperature variations of 500°C, 700°C, and 900°C with a holding time of 3 hours can be seen in Table 1.

In Table 1, it can be seen that at temperatures of 500°C and 700°C, there has been no change in the hardness value because the temperature given to the specimen has not reached the critical temperature of the specimen so there has not been a change in mechanical properties, while at a temperature of 900°C, the ministerial hardness value has decreased because at this temperature the specimen has reached the austenite phase and in the austenite phase the material undergoes an isothermal transformation into pearlite and ferrite phases due to air cooling so that the hardness of the material decreases[14]. This study proves that heat treatment accompanied by air cooling will cause the hardness value of the material to decrease along with the high temperature of the heat treatment given.

Table 1. Hardness values after normalizing

	Measurement (N)					
	1	2	3	4	5	Average
Raw Materials	**70**	**69.8**	**69.7**	**69.9**	**69.7**	**69.82**
500°C	69.6	69.6	69.4	69.4	69.5	69.5
700°C	69.5	69.5	69.4	69.6	69.4	69.48
900°C	**62.3**	**62.1**	**62**	**62.2**	**62.2**	**62.16**

3.3. Hardness data result of pack carburizing specimen

Before carrying out the carburizing process, the usual heating process is carried out first with temperatures of 500˚C, 700˚C, and 900˚C with a holding time of 3 hours. Then the pack carburizing process was carried out at the same temperature with a holding time of 120 minutes.

Table 2 is the hardness value data from the pack carburizing results. From the table, it is clear that the comparison between the different hardness values between normalizing and carburizing where the specimen with the carburizing process is higher than the normalizing temperature of 900°C. The data shows that the carbon atoms of coconut shell charcoal diffuse into the surface of the specimen, causing the carbon present on the surface of the specimen to increase and increase the hardness value of the specimen with the carburizing method carried out.

Table 2. Average hardness values of normalizing and non-galvanic carburizing results

Specimen Treatment	specimen before treatment	Hardness (HRB)		
		500°C	700°C	900°C
Normalizing	**69.84**	69.5	69.48	62.16
Non-galvanic carburizing		69.52	69.42	**89.6**

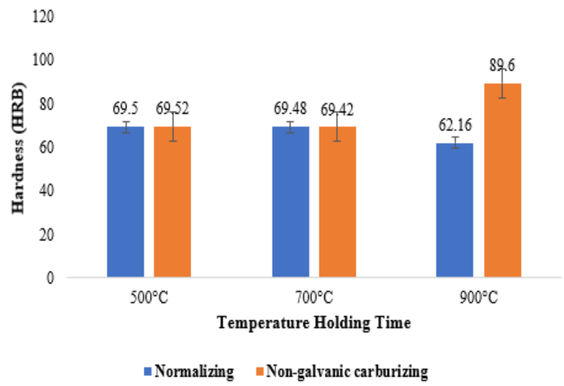

Figure 3. The average hardness values of normalizing and non-galvanic carburizing results

Table 3. The average hardness values of galvanic carburizing and non-galvanic carburizing

Specimen Treatment	Heating Temperature (°C)		
	500	700	900
Non-Galvanic Carburizing	69.48	69.42	89.46
Galvanic Carburizing	69.42	69.4	90.04

The hardness distribution value that is shown in Fig. 3 where Anwar [15] in his research used coconut shell charcoal that obtained a hardness value of 183 HV (90 HRB).

3.4. Hardness data results of galvanic and non-galvanic carburizing pack

This process is carried out 2 kinds of heat treatment carried out namely galvanic heating and ordinary heating with temperatures of 500˚C, 700˚C, and 900˚C with a holding time of 3 hours and at the same temperature pack carburizing is carried out with a holding time of 120 minutes.

From Table 3, it can be seen that the hardness values between galvanic carburizing and non-galvanic carburizing do not show specific numbers or it can be said that there is no effect experienced by galvanic heating before carburizing. Because at temperatures of 500˚C and 700˚C, the material and carburizing media have not undergone diffusion because the material has not yet reached the austenite phase where in that phase the material can already experience diffusion so that the carburizing media which has been compounded on the catalyst in the gaseous form will enter the surface of the specimen so that at a temperature of 900˚C an increase in the hardness value was obtained [16] as shown in Fig. 4.

3.5. Hardness Data Result of Pack Carburizing at Galvanic 900°C HT Temperature 3 Hours

The temperature of 900^0C is used because, in the heat treatment that has been carried out above, a significant change in hardness value is only found at a temperature of 900^0C, but in the carburizing process this time the holding time will be varied, namely 30, 30, 120, 180 minutes, while the holding time will be used in the galvanic heating process and the usual heating are used for 3 hours, this is done to further analyze the effect of galvanic heating on pack carburizing.

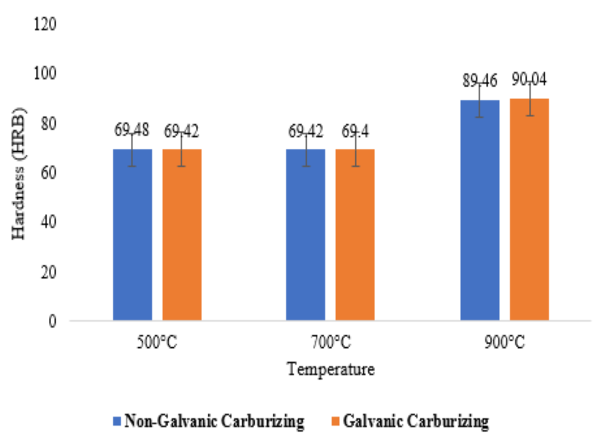

Figure 4. Average hardness values of galvanic and non-galvanic carburizing results

Table 4. Average hardness value data from galvanic heating

No	Holding Time	Galvanic		Non-Galvanic	
		A	B	A	B
1	30 minutes	76.7	74.62	76.4	76.3
2	60 minutes	81.94	75.4	76.16	76.1
3	120 minutes	91.56	91.6	91.54	91.5
4	180 minutes	94.1	94.06	94.02	94.04

Table 4 shows that the results varied at a holding time of 3 hours with a fixed temperature of 900˚C. At a holding time of 30 minutes, the average hardness value for the non-galvanic treatment was 76.4 HRB and the average hardness value for the galvanic treatment was 77.3 HRB. In this experiment, it was found that the effect of the pack carburizing treatment which had previously undergone galvanic heating was pack carburizing on the specimen is that there is an uneven distribution of atomic diffusion into the surface of the material.

Furthermore, at a holding time of 60 minutes, the hardness values obtained in the non-galvanic and galvanic treatments were 76.6 HRB and 82.9 HRB from this experiment it can be seen that the effect of the galvanic heating treatment on the carburizing pack gives a high hardness value but this value is only found on the B side of the specimen, while the hardness value obtained on the A side of the specimen is almost the same as the hardness value of the raw material.

In this experiment, the distribution of atomic diffusion was not evenly distributed as in the previous experiment. From the experimental data above can be assumed that the presence of a given galvanic heating treatment will cause cathode and anode areas which cause differences in hardness values and uneven distribution of atomic diffusion in the specimen [9]. So that in the third and fourth experiments, the hardness value of the specimen reached above 90 HRB, and the effect of this galvanic heating treatment has not been experienced by the specimen due to the reconditioning of the specimen. The average hardness value of the non-galvanic in Fig. 5 and galvanic carburizing packs can be seen in Fig. 6.

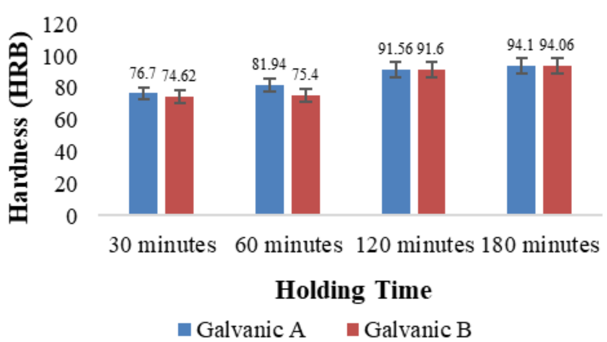

Figure 5. Graph of non-galvanic pack carburizing hardness values

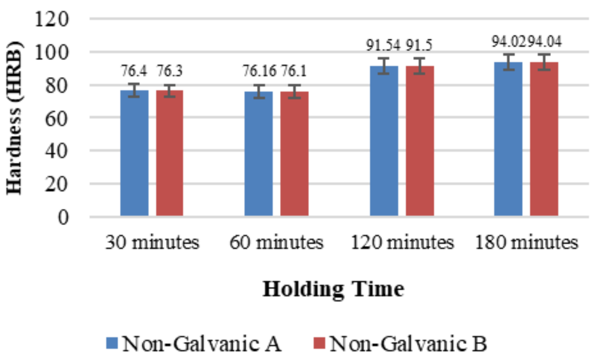

Figure 6. Graph of galvanic pack carburizing hardness value

3.6. Result of microstructure observation

Microstructural observation was carried out on HT 60 minutes of pack carburizing specimen with galvanic heating for 3 hours, and non-galvanic pack carburizing at a temperature 900°C as shown in Fig. 7.

Figure 7 shows the result of testing microstructure of the non-galvanic pack carburizing specimen to from dark pearlite and the light ferrite structure. Figure (a) forms fewer pearlite structure than figure (b) on side B, where more pearlite structure is formed than ferrite structures. This pearlite phase causes an increase in the surface hardness value of the specimen with pack carburizing treatment [10]. From the result of microstructural observation, it can be interpreted that the pack carburizing process is going well, in which a pearlite phase is formed, and an increased hardness value is produced on the surface of the specimen [17].

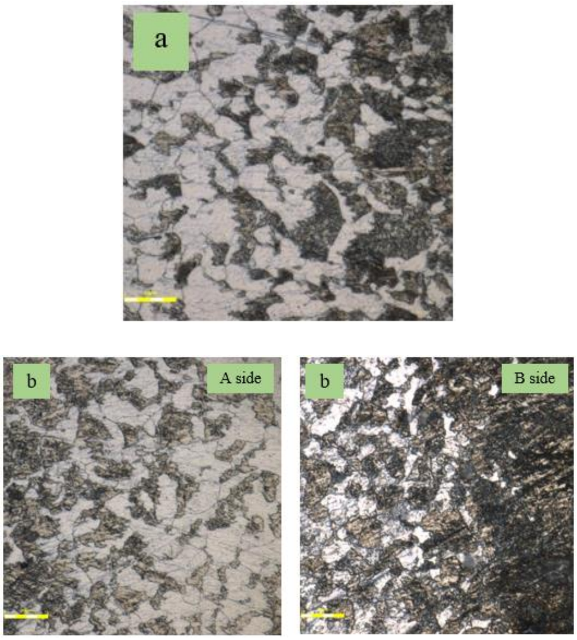

Figure 7. (a) pack carburizing non-galvanic, (b) pack carburizing galvanic

4. Conclusion

Based on the test results and data analysis that has been carried out regarding the effect of heat treatment on low carbon steel after going through the normalizing and heating processes of galvanic carburizing and non-galvanic carburizing, it can be seen that, by carrying out the normalizing and carburizing processes the specimen experienced a decrease in the hardness value of the specimen pack carburizing non-galvanic at a holding time of 30 minutes and 60 minutes at a temperature of 500°C and 700°C, then with galvanic carburizing treatment the specimen will experience a significant increase in hardness at a temperature of 900°C with the highest hardness value obtained in specimens with galvanic carburizing of 94.1 HRB at a holding time of 180 minutes and the lowest was obtained at a holding time of 30 minutes of 74.62 HRB, as shown from the results of the micro structure test where after the galvanic carburizing treatment more pearlite structures were formed which could make the surface of the specimen become harder because the volume of the diffusion rate of carbon increases at a temperature of 900°C, as shown by the increased hardness test results and with the galvanic carburizing process this will improve the mechanical properties of low-carbon steel.

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