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The Carburizing Process of Low Carbon Steel with Charcoal Media

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Abstract

Carburizing process is carried out to improve the power quality of a low carbon steel with a low cost. The material used is a type of low carbon steel with a carbon value of 0.25%. Carburizing process on low carbon steel at a temperature of 900 ^{0}C with a holding time of 90 minutes using goat bone and coconut shell char medial. The use of goat bone charcoal carburizer produces higher hardness values of carbon steel with coconut shell charcoal media. Results of testing the value of carbon steel after carburizing processes with coconut shell was 0,423% whereas after carburizing process with goat bone carbon value of only 1,593%.

Keywords: *carburizing process coconut shell, goat bone, hardness test, Tensile Test, Impact Test, and microstructure*

1. INTRODUCTION

Carburization is the process of adding the element carbon on the low carbon steel surface, carburizing heating carried out at the temperature 900^{o}C until 950^{o}C. Elemental carbon can be obtained from wood charcoal, coconut shell charcoal or materials that contain the element carbon. Carbonization aimed to providing more carbon content at the surface than carbon content at the inner wall, so that the surface hardness increases. Carburizing can be done in three ways, namely pack carburizing, liquid carburizing and gas carburizing. The use of goat bone charcoal and coconut shell in the pack carburizing is carried out at temperature 900°C and holding time 90 minutes.

Carburization is a way of hardening the surface of the metal which heating the metal above the surrounding critical temperature that contains carbon element. In critical temperature, carbon is absorbed into the metal and then become solid solution of carbon-steel form which the outer layer contains high carbon content. At the suitable time, the carbon atoms will have the opportunity to difuse to inside layer. The layer thickness depends on temperature process and reaction time needed.

In the carburization process, steel that already in austenisasi put into an environment which contain high carbon content so that the carbon diffusion process on the surface can be done. Thus, there was a gradient of carbon content between the surface area and the core area. Diffusion process indicates two factors that can be used to control carburization. Absorption of carbon on the surface and diffusion of carbon in the metal can be used to determine the rate of carburization process.

Carburization is one of the case hardening treatment which aim to increase the carbon content in solid steel condition [6]. As the result of the heat treatment, it will obtain the outer layer of steel with a carbon content increases. Carburization is usually carried out at high temperatures between 900 to 950°C [2].

Advantages and disadvantages of the pack carburization process is as follows:

a. Advantages of carburization process is as follows:
   - Can use variety of furnace because it does require a certain atmosphere.
   - Efficiently and economically.
   - Carburization media is easy to earn.
   - Diffusion depth can be adjusted.

b. Disadvantages of carburization process is as follows.
   - Requires cleaning process of the surface layer
   - Difficult to obtain the small depth because of the difficult controlling process.
   - Difficult to control the carbon concentration in the surface area and carbon gradient as the gas carburization process.
   - Not suitable for direct quenching process.

Pack carburization similar to gas carburization, that main gas sources at the surface of carburizing component are carbon monoxide. Voluntary carbon, absorbed by steel surface, form from decomposed carbon monoxide into carbon dioxide and voluntary carbon. Carbon dioxide will react directly with a solid solution to produce the new carbon monoxide form [8].

Steel can be defined as a mixture of carbon and iron, which carbon content (C) will affect the hardness of steel. The steel also contains other elements that are called alloys, alloying elements are phosphorus, sulfur, manganese, silicon. They acts as binds which the number of weight percent based on the standard uses and customized fabrication, which aims to improve the mechanical and physical properties. The physical properties is a natural properties that cannot be changed, For the example is the magnetic properties, metal density, electrically conductive and melting point. Low Carbon steel is one of carbon steel type, where the percentage of the element carbon below 0.25%C, to more clearly shown in Table 1, while the other forming elements such as Mn not more than 0.8%, Si is not more than 0.5%, while Cu element is not more than 0.6%. In addition, Types of carbon steel also grouped by the percentage composition of carbon alloying elements as shown in the phase diagram of Fe - C, steel hypoeutektoid contains less than 0.8% C, eutectoid steel contains 0.8%C, and hypereutectoid steel contains more than 0.8%C.

Table 1. Steel Classification based on Carbon Content

No	Type of Carbon Steel	Carbon Element (%)
1	Low Carbon Steel	≤ 0,25
2	Medium Carbon Steel	0,25 ÷ 0,55
3	High Carbon Steel	> 0,55

Low carbon steel has physical and mechanical properties as follows:

a. Physical Properties
   The physical properties of steel such as having good magnetic properties, high density metal, and high melting point (1600°C).

b. Mechanical Properties
   Mechanical properties is a basic properties that can be changed and influenced by external factors. The effect of heating at a certain time and temperature, so that the metal microstructure change mechanical properties because of the warming.

In the carburization process, free carbon is absorbed into the surface layer of the low carbon steel. Free carbon obtained from gas or liquid in direct contact with the metal surface by chemical reactions that do not directly involve the metal. Study about heat treatment in carburizing process had been done by several researchers [4] which concluded that the addition of elements (C) to the low-carbon steel resulted in the change of the maximum tensile strength owned by subsequent material. The changes in the value of the maximum tensile strength of low carbon steel showed an increase of pre-treatment and the experimental results in their research shows the average value of the maximum tensile strength is approximately 38%.

The study of carburizing heat treatment has been investigated by any researchers [2] and concluded that the carburization process can reduce impact strengh of mild steel, but contrary to the trend observed that activated carbon is carburizer that increase the resilience impact and temperatur carburization. Bone powder is used as the carburizer in the process, so that the strength of mild steel will increase while carburizing process. But it will decrease while increasing temperature carburization. Carburization treatment is followed by cooling process of the oil at a temperature 550°C, greatly affect the hardness and the tensile strength of mild steel.

Carburization process will reduce the energy impact of the mild steel and then the strength decreases while increasing carburization temperature. The mechanical properties of mild steel are found to be highly influenced by the carburizing soaking temperature. Carburized sample is soaked for 15 minutes and the other is soaked at 900°C for 30 minutes and followed by oil cooling process. At temperature 550°C is considered the better condition because they showed a tendency hard surfaces with soft core. Study heat changes, especially about carburization has been investigated by some researchers [1] concluded that the hardness of carburizing samples which are not heated at palm kernel shell and bone animals showed a higher value than the other sample which heated. In the

carburization of sample which used palm kernel cell powder, is involved at a temperature 1000°C until 1100°C. So that palm kernel shell and animal bone potentially to be used as mild steel carburizer, whereas lighter shells have a tendency to be used as a drop carburization.

The study of carburizing heat changing has been investigated by some researchers [6] concluded that the basic material (reinforced concrete KSTY) has hardness (HV) - 915.77 N/mm^2 after surface hardening treatment process, using pack carburizing until Quenching process obtained hardness (HV) = 3178.45 N/mm^2 with carbonization holding time for three hours, or can be involved the increasing surface hardness about 46.22%. The Changing of carbon diffusion in iron KSTY is influenced by the treatment of carbonization process and carbonization resistant time. The percentage of changing surface hardness KSTY consists of one hour from standard until carburizing process involve the increasing of hardness 31.42%.

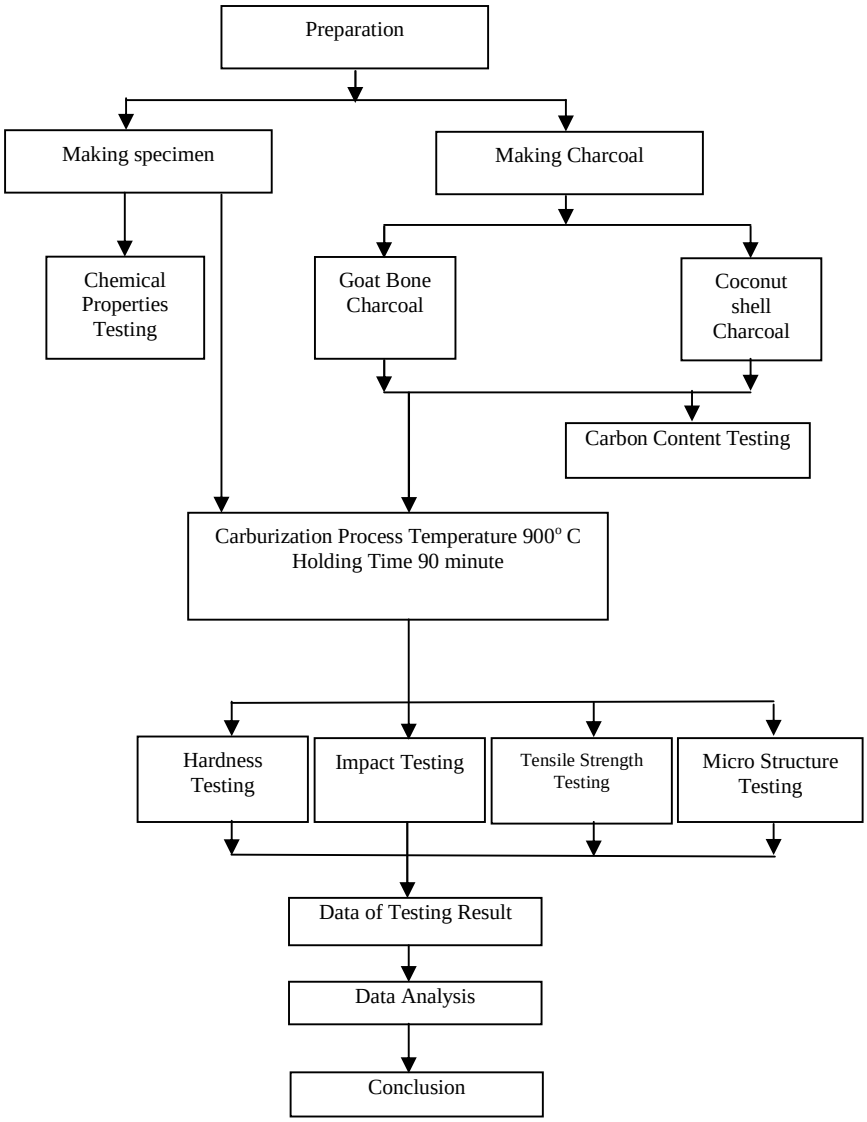


Figure 1. Flow Diagram of The Process

From the carbonization process until quenching process is 38.67% or an increasing average is 35.05%, then two hours of standard until the carburization process violence is increasing 38.67%. From the carburization process until quenching process is 45.47% or an increasing average is 41.17%, then three hours of standard until the carburization process violence is increasing 41.06%. From the carburization process until quenching process is 51.38% or an increasing average 46.22%. The Carbonization process of Pack carburizing with a three-hour detention time and followed by quenching process is very suitable to increase the surface hardness of material power thresher (steel

concrete KSTY). Thus, the researchers were able to conclude that needed to be done further research about the steel with another carburizer media while in this case this research will conduct experiments using carburizer media of goat bone charcoal and coconut shell charcoal.

The study of carburizing heat changing has been investigated by researchers [5] that based on the results of the data studies can be concluded the hardness changing from 212.18 kg/mm^2 increase until 257.5 kg/mm^2 then obtained from impact testing 0.350 Joule/mm^2 until 1.067 Joules/mm^2.

2. METHOD AND PROCEDURE

From several journals literature that have been read, known that carburization process using goat bone charcoal has never done before. Therefore researcher is interested in conducting research using that media, and using coconut shell charcoal for comparative material in this study.

Flow diagram process has been made from preparation of materials, making charcoal, carburizing process, laboratory testing, data analysis and conclusions. And the benefit of this research such to knowing the changing of low carbon physical properties and mechanical properties due to the treatment of carburization process, and compare the carburization with goat bone charcoal media than carburization with coconut shell charcoal media.

Research methods in this study are followed by diagram as shown at Figure 1.

3. RESULTS AND DISCUSSION

Data analysis of the chemical composition goat bone charcoal and coconut shell, done at Chemical Engineering Laboratory Politeknik Sriwijaya on June 5th 2013 using Bomb Calori and Gravimetry apparatus, can be seen in Table 2 :

Table 2. The chemical composition of Goat Bone Charcoal and Coconut Shell Charcoal

No.	Element Symbol	Coconut Shell Charcoal	Goat Bone Charcoal
1	H_2O	1.40	3.40
2	Carbon, C	58.255	59.198
3	Abu	6.17	10.97

Data analysis of the chemical composition low carbon steel before carburization process, done at the Engineering Laboratory PT PUSRI Palembang, Sample Testing of Different Quality using Gra JISS G 3101 SS 400 on March 27th 2013, can be seen in the table below :

Table 3. Chemical composition of low carbon steel before carburizing process

No.	Element Symbol (%)	Before carburization (%)
1	Fe	98.467
2	C	0.25
3	Si	0.329
4	Mn	0.533
5	Cr	0.143
6	Mo	0.013
7	Ni	0.051
8	Al	0.001
9	Co	0.0074
10	Cu	0.128
11	Nb	0.0153
12	Ti	0.0036
13	V	0.0135
14	W	0.025
15	Pb	0.010

Data analysis of the chemical composition low carbon steel after carburization process, done at the Engineering Laboratory PT PUSRI Palembang, Sample Testing of Different Quality using Gra JISS G 3101 SS 400 on March 27th 2013, can be seen in the table below :

Table 4. Chemical composition of low carbon steel after carburizing process

No.	Element Symbol (%)	Goat Bone Carburizing(%)	Coconut Shell Carburizing(%)
1	Fe	97.367	91.167
2	C	1.593	0.423
3	Si	0.025	1.75
4	Mn	0.606	1.27
5	Cr	0.112	0.376
6	Mo	0.0239	0.0948
7	Ni	0.0403	1.28
8	Al	0.0075	0.166
9	Co	0.0088	0.0458
10	Cu	0.148	2.59
11	Nb	0.0284	0.178
12	Ti	0.005	0.0698
13	V	0.0194	0.113
14	W	0.025	0.345
15	Pb	0.010	0.0458

Carburizing process has shown increasing hardness of low carbon steel material. With coconut shell charcoal composition for 59.198% (Table 2), the hardness can increase from 231.65 (kg/mm) to 262.85 (kg /mm). And with goat bone charcoal composition for 58.255% (Table 2), the hardness can increase from 347.63 (kg/mm) to 231.65 (kg/mm). Therefore goat bone charcoal more effective as a supplement in the carburizing process than coconut shell charcoal.

Graph of Vickers Hardness Testing, Low Carbon Steel before carburizing, after carburizing carburizing coconut shell charcoal and goat bone charcoal done in the Mechanical engineering laboratory Politeknik Sriwijaya, can be described as Figure 2 below :

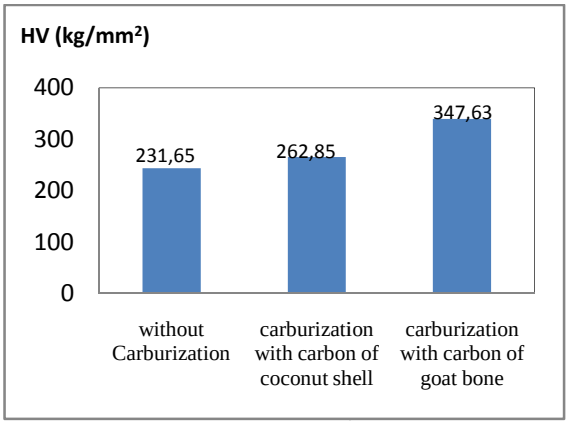


Figure 2. Vickess Hardness Testing of Low Carbon Steel before and after Carburizing

Carburizing process has shown decreasing impact of low carbon steel material. With coconut shell charcoal composition for 59.198% (Table 2), the impact can decrease from 32.3 (Joule) to 13.4 (Joule). And with goat bone charcoal composition for 58.255% (Table 2), the impact can decrease from 32.3 (Joule) to 5.2 (Joule). Therefore coconut shell charcoal more effective as a supplement in the carburizing process than goat bone charcoal.

Graph of Impact Testing, Low Carbon Steel before carburizing, after carburizing coconut shell charcoal and goat bone charcoal done at temperature 900^{o}C and holding time 90 minute in the Mechanical engineering laboratory Politeknik Sriwijaya using Impact 450 Galdabini apparatus on May 31st 2013, can be described as Figure 3 below :

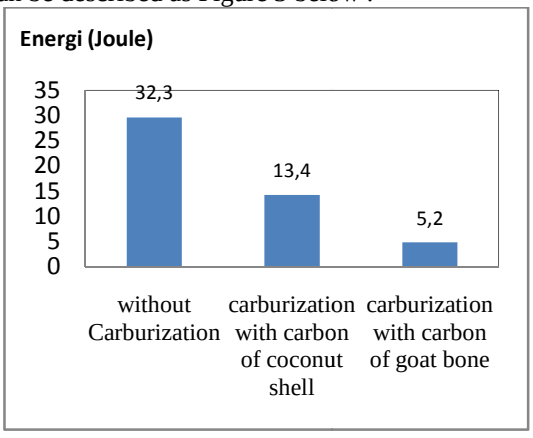


Figure 3. Impact Testing of Low Carbon Steel Before and After Carburizing

Carburizing process has shown decreasing tensile strength of low carbon steel material. With coconut shell charcoal composition for 59.198% (Table 2), the tensile strength can decrease from 552.0 (N/mm²) to 447.08 (N/mm²). And with goat bone charcoal composition for 58.255% (Table 2), the tensile strength can decrease from 552.08 (N/mm²) to 342.86 (N/mm²). Therefore coconut shell charcoal more effective as a supplement in the carburizing process than goat bone charcoal.

Graph of tensile strength testing, low carbon steel before carburizing, after carburizing coconut shell charcoal and goat bone charcoal at temperature 900^{o}C and holding time 90 minute done in the Mechanical engineering laboratory Politeknik Sriwijaya using Hung Ta Type HT 9502 on June 1st 2013, can be described as figure 4 below :

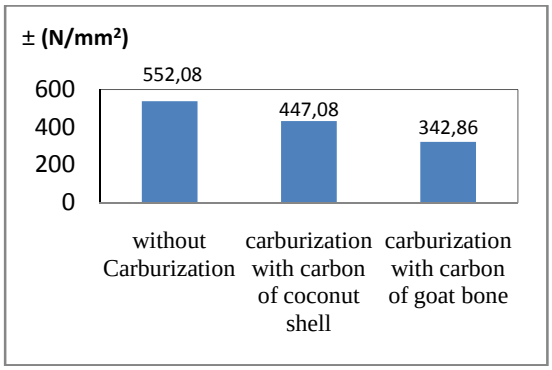
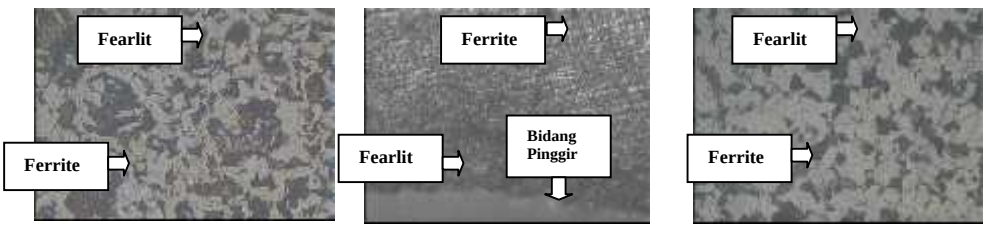
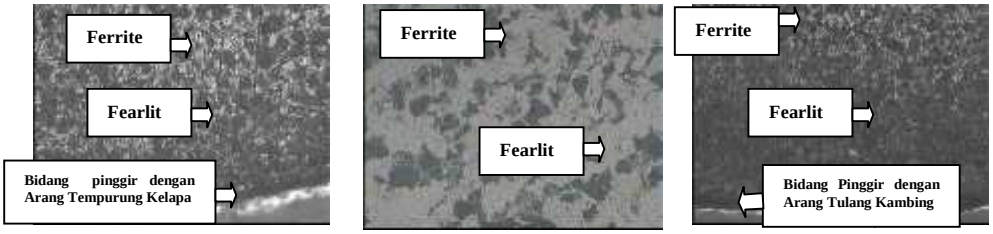


Figure 4. Tensile Strength Testing of Low Carbon Steel Before and After Carburizing

Photograph of micro structure testing, low carbon steel before and after carburizing process done in Mechanical Engineering laboratory on June 1st 2013 Using Olympus Microscope Optic GX41, can be described as Figure 5 below :



A B C



D E F

Figure 5. Micro Structure of low carbon steel a. Before carburization, Middle section, Magnification 200 x, b. Before carburization, Edge section, Magnification 100 x, c. After carburization using coconut shell charcoal (T = 900^{o}C and HT = 90), Middle section, Magnification 200 x, d. After carburization using coconut shell charcoal (T = 900^{o}C and HT = 90), Edge section, Magnification 100 x, e. After carburization using goat bone charcoal (T = 900^{o}C and HT = 90) Middle section, Magnification 200 x, f. After carburization using goat bone charcoal (T = 900^{o}C and HT = 90) Edge section, Magnification 100 x

4. CONCLUSION

Based on the data analysis, the using of goat bone charcoal and coconut shell charcoal can be summarized as follows.

a. Goat bone charcoal as carburizing media can increase the hardness of low carbon steel (347.63 kg/mm^2) than using of coconut shell charcoal (262.85 kg/mm^2). While using of goat bone charcoal will decrease the impact and tensile strength low carbon steel than using of the coconut shell charcoal.
b. Carbon content before carburization process is 0.25%, it means that the materials including to low carbon steel type. While after carburization process using coconut shell charcoal, the carbon content of low carbon steel increase to 0.423%. And after carburization process using goat bone charcoal, the carbon content of low carbon steel increase to 1.593%. Therefore the carbon content after carburization using goat bone charcoal higher than using coconut shell charcoal.

References

[1] A. Oyetunji and S.O. Adeosun., *Effecs of Carburizing Process Variables on Mechanical and Chemical Properties of Carburized Mild Steel.* Journal of Basic and Applied Sciences, 2012.

[2] Aramide F O., *Pack Carburiation of Mild Steel, using Pulverized Bone as Carburizer: Optimizing Process Parameters.* Leonardo Electronic Journal of Practices and Technologies.p. 1 – 12, 2010.

[3] Darmanto., *Pengaruh Holding Time Terhadap Sifat Kekerasan dengan Refining The Core pada Proses Carburizing Material Baja Karbon Rendah.*, Journal Mechanical Engineering Vol.4 No.2, 2006.

[4] Kuswanto B., *Peningkatan Kekuatan Tarik Maksimum Material Baja Karbon Rendah Menggunakan Proses Penambahan Karbon Padat.*, Journal Mechanical Engineering Vol.5 No.3, 2010.

[5] Masyrukan., *Pengaruh Sifat Fisis Dan Mekanis Baja Karbon Rendah Akibat Pengaruh Proses Pengarbonan dari Arang Kayu Jati.*, Journal Mechanical Engineering Vol.7 No.1, 2006.

[6] Mujiono dan Arianto L S., *Meningkatkan Efektifitas Karburisasi Padat pada Baja Karbon Rendah dengan Optimasi Ukuran Serbuk Arang Tempurung Kelapa.*, Journal Mechanical Engineering Vol.10 No.1, 2008.

[7] Mulyadi dan Eka S., *Kajian Perubahan Kekerasan dan Difusi Karbon sebagai akibat dari Proses Karburisasi dan Proses Kuancing pada Material Gigi Perontok Power Thresher.*, Journal Mechanical Engineering, Vol.7, 2010.

[8] Siproni., *Keefektifan Penggunaan Karburizer Arang Tulang Sapi pada Baja Karbon Rendah untuk Pembuatan Alat Pemanen Buah Kelapa Sawit (Dodos dan Egrek).*, Thesis Mechanical Engineering Universitas Pancasila, 2010.