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Influence of Reheating in Pack Carburizing Process with Bamboo Charcoal and Cow Bone Powder Media for Hardness Number and Impact Strength Low Carbon Steel

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Abstract

Pack Carburizing process is the process of adding carbon element (C) into the metal, especially on the surface of the material where the carbon element is obtained from materials containing carbon so that the metal hardness can increase. Carburizing research that has been done with teak wood charcoal media and $BaCO_3$ or $NaCO_3$. The Pack Carburizing process is high costly. This study uses an alternative carburizing media in the form of bamboo charcoal and cow bone powder. The aim of this research is to know the difference of toughness value and hardness of low carbon steel which have undergone pack carburizing process, and reheating process of low carbon steel. The pack carburizing process was carried out at temperature 900^0 C for 7 hours carburizing time. The hardening process was carried out by reheating the specimens at 900° C, for 50 minutes holding time, cooled with air-cooled media, water and water + 30% salt. Then tested toughness and hardness test. While Scanning Electron Microscope (SEM) test is done to see the carbon diffusion after carburizing process in the form of a picture or photo. From this study it was concluded that with 7 hours of carburizing time, carbón diffusion and highest surface hardness were obtained in carburizing process, and cooling process with 30% salt + water cooling medium), the hardness number can increase up to 110% from the initial is 120.08 Kg /mm^2

Keywords: Pack Caburizing, Cooling, hardness, cooling medium, bamboo charcoal, cow bone

INTRODUCTION

All human needs cannot be separated from the metal element. So that metal has an active role in human life and support technology in today. Therefore, human efforts arise to improve the properties of the metal. That is by changing the mechanical properties and physical properties.

The basic metal processing industry (blacksmith) which began to become the attention of West Nusa Tenggara (NTB) Regional government, is one of the bright prospect businesses. The need for equipment from metal is now increasing. However, in the NTB area this industry is still managed by the home industry is not fully managed by NTB local government. The products of home industry are the tools needed by the agrarian sector, such as machetes, hoes, knives, crowbars and others. Low carbon steel is also use for shipbuilding plates, shaft drive rods and others. The base metal used in this industry is low carbon steel which has the properties that is capable of forging and machine ability. Despite this low carbon steel still has a level of hardness number that has not been maximized.

Carburizing is one of the most commonly performed steel heat treatments. For perhaps three thousand years it was performed by packing the low carbon wrought iron parts in charcoal, then raising the temperature of the pack to red heat for several hours. The entire pack, charcoal and all, was then dumped into water to quench it. The surface became very hard, while the interior or “core” of the part re- tained the toughness of low carbon steel [7-9].

Carburizing process is the process of adding carbon element (C) into the metal, especially on the surface of the material where the carbon element is obtained from materials containing carbon so that the metal hardness can be increased, the surface hardening on the metal can be done by adding certain elements to the metal such as carbon, nitrogen, and others. These elements can be obtained around us such as bovine bone, bamboo charcoal and others that may be unused again, but the carburizing process produces less harm to the metal [1][13][14]. Lack of carburizing process is the high cost of carburizing media and low hardness value of the metal can be improved by using alternative carburizing medium and cooling with different cooling media.

The cow bone powder contains Calcium Carbonate and Tricalcium Fospat [2][12]. The results of this study became the reason to conduct research of surface hardening low carbon steel. This study uses air, water and water + 30% salt as cooling medium. The reason the three cooling media have different cooling properties and speed, so it is possible to see be different hardness value and the toughness value in the test specimen.

Low carbon steel is also called mild steel or tool steel. This low carbon steel in the trade of its use is very broad as in the general construction steel which is made in the form of steel plates, strips and steel bars. Based on carbon content then low carbon steel can be use: Low carbon steels containing 0.1 to

0.14% C are used for plate steels and for the purposes of vehicle bodies. Low carbon steels containing 0.15 to 0.25% C are used for the construction of bridges, buildings, or construction steel. Low carbon steels containing 0.26 to 0.30% C are using to make bolts and rivets. This low carbon steel has properties that are easy to do with machine or forged [5][10][11].

Carburizing is the process of adding carbon to the surface of objects, carried out by heating the workpiece in an environment which contains activated carbon, so that carbon diffuses incoming surface.At carburization temperature, the carburization medium breaks down into CO which further decomposes into activated carbon, which can diffuse into the steel, raising the carbon content on the steel surface. Depth of carburizing (thick carburization) is the under-surface distance that reaches a certain carbon concentration, or the total thickness of carbon penetration. As with the other diffusion process, carburizing thickness depends on the temperature and time can be formulated as follows:

$$DC = k\sqrt{t} \quad \text{.......................................(1.1)}$$

Annotation : DC = Depth of carburizing (mm)

k = Constanta difusi, depend on temperature

t = Carburizing time (hour)

Temperature ^0C	875	900	925
Constanta k	0,34	0,41	0,52

The effects of the carburizing temperature and time on the mechanical properties of mild steel carburized with activated carbon, at 850, 900 and 950 °C, soaked at the carburizing temperature for 15 and 30 minutes, quenched in oil, tempered at 550 °C and held for [7]. The present work is focused on the effects of media carburizing temperature and reheating on the mechanical properties of carburized mild steel.

METHODE OF RESEARCH

The materials and tools used in this study are : low carbon steel with a carbon content of 0.19% .The bamboo charcoal as carbon provider, in this study the bamboo charcoal made from bamboo ampel. A cow bones powder as a source of $CaCO_3$ and Ca $(PO)_3$ or as an energizer to accelerate the carburizing process. Supporting equipment used is: Electric Furnace, Hardness tester, Grinding and polishing, Carburization box, Impact test machines , Scanning electron microscope (SEM), Slider, Camera.

Material

The material used as the carburizing medium is as follows

Bamboo Charcoal.

Bamboo charcoal is made from bamboo plants that are five years old or more. The bamboo is then burned in the oven with a temperature of 80^0 C – 100^0 C. The combustion process, also known as pyrolysis, is useful for decomposing organic material contained in bamboo to obtain smaller bamboo molecules.Bamboo charcoal is rich in minerals such as calcium, potassium, sodium, and iron. On the inner cross section of the bamboo charcoal looks a hollow structure that makes the surface area larger, ie 300 – 700 m^2/g. In addition, bamboo charcoal can also emit infrared rays, negative ions, and absorb electromagnetic waves.

Table 1. The Characteristic of Bamboo Charcoal

No.	Species Bamboo	Density	Water content (%)	Ash (%)	Flay Ash (%)	Carbon (%)
1	Ampel	0,52	5,68	6,55	23,84	75,68
2	Andong	0,48	4,60	7,38	23,32	69,30
3	Ater	0,65	6,66	5,55	12,39	82,06
4	Bitung	0,53	4,28	7,46	33,68	54,86
5	Tali	0,40	7,08	5,64	14,01	80,35
6	Bakau	-	5,41	4,48	17,81	77,30

Source : (Fahriadi, 1986)

Cow Bone.

Cow bone contains living cells and intracellular matrices that are covered with mineral salts, calcium phosphate makes up about 80% of mineral matter, and the remainder consists mainly of calcium carbonate and magnesium phosphate. One hundred cm^3 of bone contains 10,000 mg of calcium, as most comparable tissues contain 6 mg per 100 cc, and for blood contains 10 mg per 100 ml. Thus, the bone helps as a mineral container is constantly filled or emptied. According to [2], no other tissue in the body can do excessive growth and absorption as in bone.

Pack Carburizing Process

Carburizing media used in this study is a solid medium, with a predetermined composition with a ratio of 70% bamboo charcoal and 30% bone powder, referring to previous studies Carburizing box is made of low carbon steel with a thickness of 5 mm with a length of 230 mm, a width of 200 mm and a height of 150 mm, the test objects are inserted into the carburizing box arranged as shown below with a distance of each 30 mm specimen.

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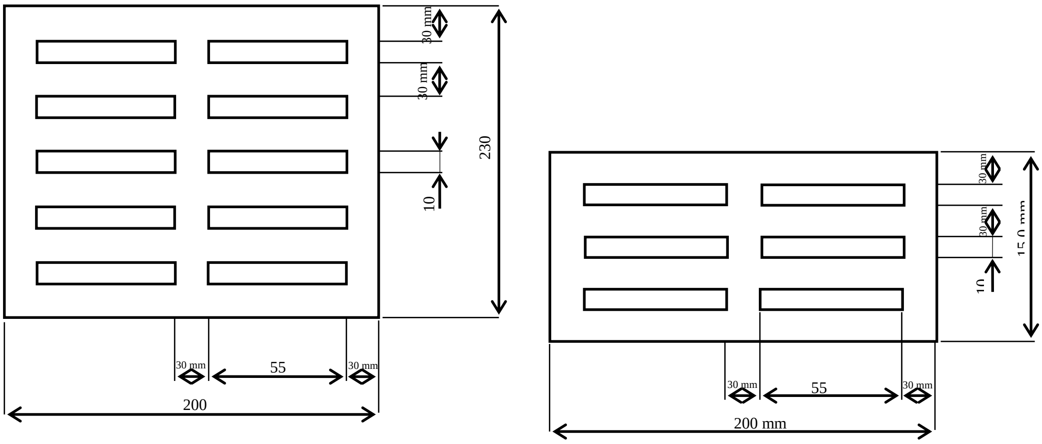


a. Top View

b.Front View

Figure 1. Carburizing Box which has been filled with media carburizer and specimens for impact and hardness tests.

The steps taken in carrying out the carburizing process are as follows: A fully loaded carburization box is inserted into the furnace, then the coconut shell charcoal is inserted as a combustion material, the temperature gauge cable is inserted into the furnace to measure the temperature at the time of combustion. Coconut shell charcoal is then burned and the blower is turned on to set the combustion temperature. The furnace is closed and the temperature gauge is turned on, when it reaches the temperature of 900^0 C, the timing and temperature are adjusted by adjusting the blower so that the temperature can be maintained for seven hours of combustion. After the desired time interval, the blower is turned off and the specimen is taken and cooling with air. The box is disassembled, the specimens is removed and cleaned. The sample is inserted into the oven and heat treated at 900^0C with holding 50 minute . After the desired time, the oven is turned off and the specimen is cooling in water, water + salt 30%, and air cooling. Specimens were taken and cleaned and followed by testing.

Impact Strength Testing

Impact testing to determine the impact strength, energy is absorbed and ductility of the material. Dimensi spesimen seperti gambar (Smith, 1990).

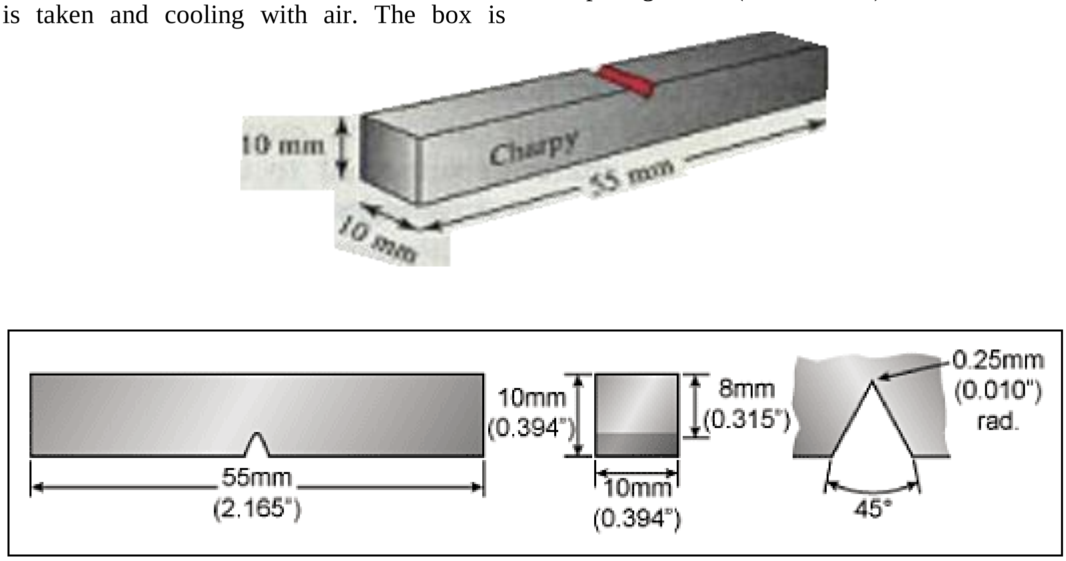


Figure 2. Spesimens of impact testing standar ASTM E 23-56T

(Suherman.W, 1987).

Hardness Number Testing

Hardness testing used in this research is to use the Vickers method. The basic principle of this test is the same as other hardness testing methods, only here using a diamond-shaped diamond pyramid indentor with a peak angle between two opposing sides of 136. Tread press will be square and measured is the second length of diagonal then taken average. Vickers hardness number is calculated by the formula :

$$HV = \frac{\{2.Gt.\sin(\alpha/2)\}}{d^2} = 1{,}854.\frac{P}{d^2} \quad \text{.........(2.1)}$$

Annotatiaon : Gt = Compresive Forse (kg)

d = Average Tread Diameter (mm)

α = Identor Peak Angle = 136^0

RESULT AND DISCUSION

Impact Test Results and Hardness Number

In the impact test method used is the method charpy and the treatment of specimens tested every 5 pieces.

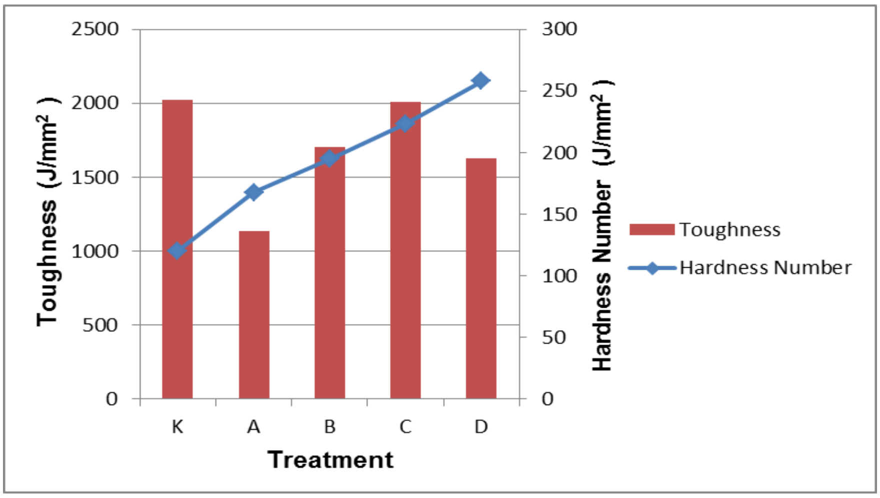


Figure 3. The surface hardness number and tougness of various treatments

Annotation:

K = Specimens without treatment

A = Pack carburizing with 70% bamboo charcoal medium and 30% cow bone at 900^0 C with 7 hours hold time without reheatreatment.

B = Pack carburizing with 70% bamboo charcoal and 30% cow bone at 900^0 C with 7 hours holding and (reheating), hardening at 900^0 C with 50 minutes holding and air cooling process.

C = Pack carburizing with 70% bamboo charcoal and 30% cow bone at 900^0 C with 7 hours holding and (reheating), hardening at 900^0 C with 50 minutes holding and water cooling process

D = Pack carburizing with 70% bamboo charcoal and 30% cow bone at 900^0 C with 7 hours holding and (reheating), hardening at 900^0 C with 50 minutes holding and water cooling + salt 30%.

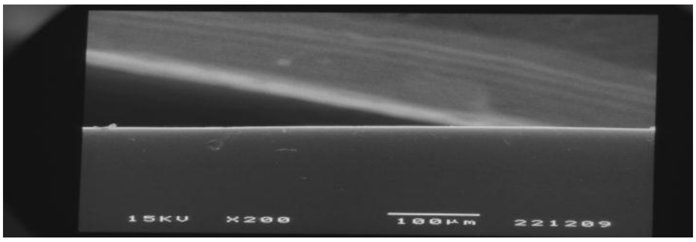
The average toughness value of 1.13 J / mm2 in carburizing pack of 70% bamboo charcoal and 30% cattle bone at 900 0C with 7 hours hold time. This means a decrease in toughness than before the treatment of carburizing pack (toughness value 2.022 J/mm^2). The cause is the diffusion of carbon elements in the steel after the carburizing pack process. The specimen is more brittle than the specimen without treatment.

The process of heat treatment again after carburizing process with 900^0 C terminals with 50 minutes duration time using air conditioning, water, water + 30% salt increase the toughness value. The specimen is more ductile than the carburizing process without reheat treatment, but still more brittle than the specimen without treatment. This is because reheating can reduce residual stress, due to the equalization of carbon content on the steel surface.

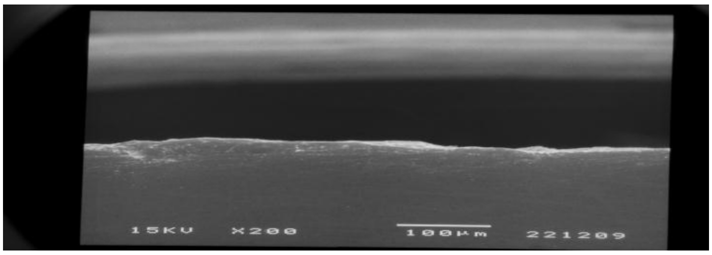
The toughness value of the carburizing process specimen with the reheat treatment depending on the cooling medium used. In air cooling media to get the value of toughness 1.706 J/mm^2, water cooling medium to get toughness of 2.022 J/mm^2 and on water cooling media + 30% salt to get the value of toughness 1.626 J/mm^2. So the lower the toughness value is obtained, the more brittle the specimen is and more, the higher the toughness value obtained, the more ductile the specimen.

Pack carburizing treatment increases the hardness, which means that the element carbon from bamboo charcoal and elements of CaCO3 of cow bones as energizer already diffused into the surface material. The hardness number of the specimen is increasing with the treatment of the reheating and depends on the cooling medium. In the air cooling medium the hardness value 194,774 Kg/mm^2, the water cooling medium hardness value 223,20 Kg/mm^2, whereas at medium cooling water + salt of highest hardness number that is 257,80 Kg/mm^2

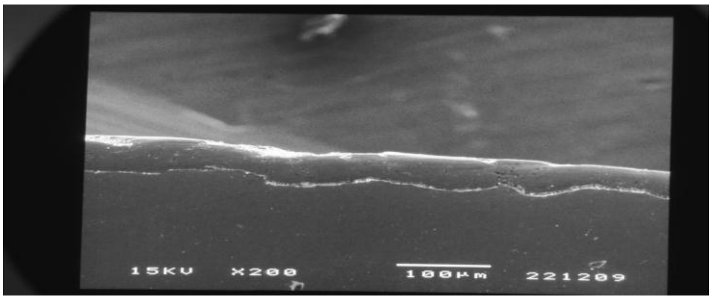
Photo Analysis Scanning Electron Microscope (SEM)



(a)



(b)



(c)

Figure 4: a. The SEM test result of the specimen without treatment

b. The SEM test result of pack carburizing process

c. The SEM test result of pack carburizing process followed by reheating

Specimens without treatment has a soft and ductile properties because it contains less carbon and more containing ferrite, whereas the addition of carbon at the surface of the specimen can cause the specimen into a pretty strong and hard, but rather brittle because it contains a lot of carbon and perlite as a result of carburizing process.Steel that contains a lot of carbon for carburizing processes tend to be brittle, therefore, the brittle nature can be converted into softer by heating back at a certain temperature and holding time or holding time then rapid cooling process (quenching) after carburizing process.

Reheating and quenching with air, water, and water media + 30% salts aims to obtain maximum hardness reducing excessive brittleness and excess stress because at the time of carburizing the steel is heated to a high temperature in the austenite region, the occurrence of excessive grain growth.

The thickness of carbon sequestration (thickness of skin) of the materials after carburizing can be determined by using the formula:

$$DC = k\sqrt{t}$$

$$= 0,41\sqrt{7}$$

$$= 1,08 \text{ mm}$$

So that the carbon diffusion thickness of the material after carburizing at temperature 900^0 C (Constanta k = 0,41) with carburizing time seven hours are 1,08 mm.

CONCLUSION

Maximum toughness occurs in the process of heat treatment again after the carburizing process at a temperature of 900^0 C with a 50 minutes hold time using a water cooling medium, with a toughness value of 2.022 J / mm^2. Maximum hardness occurs in the process of heat treatment again after carburizing process at 900^0 C with resistance time 50 minutes using water cooling medium + 30% salt, with a hardness of 257.80 kg / mm^2. There is a difference of photograph of low carbon steel SEM test which has undergone carburizing process without hardening process and carburizing process by hardening process using water cooling medium + 30% salt.

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