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Study on mechanical properties of pack carburizing ASTM A36 steel with energizer pomacea canalikulata lamarck shell powder

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Abstract

In the present study material low carbon steel ASTM A36 were treated with pack carburizing with carburizing agent, a mixture of gigantochloa apus (Schult.F.) Kurz charcoal (GAC) and pomacea canalikulata Lamarck shell powder (PCSP). The composition of carburizing agent PCSP-GAC was varied at 10%: 90%, 15%: 85%, and 20%: 80%. The process done at carburizing temperature various 875, 900, 930 °C and soaking time for 2 hours. The surface hardness test and an impact test was carried out to determine changes in the surface hardness number and impact toughness. From the results of the study, it was concluded that pack carbrizing with carburizing agent, a a mixture of PCSP and GAC increased the hardness number but decreased the impact toughness of the specimen. The highest hardness number is 537.48 Kg/mm^2, the lowest impact toughness is 158.33 Joules, at a pack carburizing temperature of 930 ^{0}C, the composition of the carburizing agent 20% PCSP : 80% GAC. Microstructural characterization indicates that high toughness of the carburizing steel subjected to the cooling heat treatment process results from a proper multiphase microstructure transition from the surface to the matrix of the steel.

Keywords: Low Carbon Steel ASTM A36; Pack Carburizing; Carburizing Agent; Gigantochloa Apus (Schult.F.) Kurz; Pomacea Canalikulata Lamarck

1. Introduction

ASTM A36 low carbon and structural steel plate is highly used in construction of oil rigs and in forming bins, tanks, bearing plates, rings, jigs, cams, forgings, templates, gears, base plates, stakes, fixtures, sprockets, forgings, brackets, ornamental works, stakes, agricultural equipment, automotive equipment, machinery parts and frames. This steel plate is also used for various parts that are produced by flame cutting. The parts include walkways, boat landing ramps, parking garages, and trenches. The ductility of this steel plate allows the alloy to be used neither as cable nor as reinforcing bar. The weakness of ASTM A36 steel is its hardness and tensile strength is low at about 415 MPa, impact toughness, the ability to absorb impact energy is large, about 129.67 Joules, so research activities are needed to improve it.

Indonesia has very diverse and abundant natural resources. The pomacea canalikulata Lamarck, is a type of animal that we can easily find in rice fields. This animal is a type of mollusk that destroys young rice plants. To protect crops, farmers eradicate golden snails by picking them up and spraying them with pesticides. Although it is detrimental to farmers, now pomacea canalikulata Lamarck can be utilized because it shells contain calcium tricarbonate (CaCO3) [1], which can be used as an alternative energizer in the pack carburizing process.

The heat treatment process to increase the surface hardness of low carbon steel is pack carburizing. Carburizing agent such as teak charcoal, coconut shell charcoal, bamboo charcoal and CaCO3, BaCO3, NaCO3 as energizer or catalyst [2][3].

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Research on the surface hardening of low carbon steel with the carburizing pack method has been carried out by several researchers both from within the country and abroad. A study on the pack carburizing process with alternative carburizing agent, corn cob charcoal powder and pinctada Maxima shell powder, has been carried out by [4][5]. Percentage of pearl oyster shell powder in carburizing media 5, 10, 20 and 25 (% by weight). Variations in carburizing temperature 910 ^{0}C, 930 ^{0}C, 950 ^{0}C, variations in soaking time for 90, and 150 minutes. The results of the study showed that the highest average hardness value was 262.47 Kg/mm^2, under the condition of adding 20% shell powder to the carburizing medium, while the initial hardness of the material was 144.08 Kg/mm^2. From the observation of microstructure and composition test, it is known that surface hardening occurs due to carbon diffusion into low carbon steel.

The work [6][7] on the effect of carburizing media for teak charcoal, bamboo charcoal and coconut shell charcoal on the pack carburising process accompanied by a quenching process on changes in the microstructure and mechanical properties of the ship anchor chain. The results of the hardness test showed that the carburizing process with teak charcoal carburizing media produced the highest hardness compared to bamboo charcoal and coconut shell carburizing media. The hardness value of pack carburising using teak charcoal carburizing media was 487.9 VHN, bamboo charcoal was 438.1 VHN coconut shell charcoal was 385.6 VHN. This is related to the smallest grain size based on the SEM test. While the XRD test results prove the formation of carbon steel phases or Fe, Fe3C, and Fe3O4, where specimens with teak charcoal media have the highest Fe3O4 content.

Research by [8] on the treatment of pack carburizing on low carbon steel as an alternative material for cutting knives in the application of appropriate technology. The process uses a temperature of 900 ^{0}C with a soaking time of 2 hours. From this experiment, it is concluded that there has been diffusion of carbon atoms (C) into the steel structure. is indicated by an increase in the surface hardness of the material and can be seen in the microstructure image. Thus, low carbon steel after being processed by pack carburizing has the potential to be hardened. So low carbon steel that has undergone pack carburizing treatment can be used as an alternative material for cutting knives at a lower price.

The study [9] of physical and mechanical properties of solid carburizing with 200 mesh size bamboo charcoal and shaker mill results. In this study, the Carburizing process was carried out at a temperature of 900 ^{0}C with a holding time of 2 hours with bamboo charcoal media. The results of the comparison of hardness, the highest hardness value is the workpiece in the shaker mill with an average material hardness value of 184.44 HVN. Compared with the value of the workpiece in the mesh 200. with an average material hardness value of 92.16 HVN. Thus the treatment of the carburized workpiece affects the hardness of the material.

In previous studies, the carburizing media has not been used a mixture of bamboo charcoal and golden snail shells. Therefore, it is necessary to conduct research on the use of gigantochloa apus (Schult.F.) Kurz charcoal (GAC) and pomacea canalikulata Lamarck shell powder (PCSP as a carburizing agent on pack carburizing treatment of low carbon steel ASTM A36 . The urgency of gigantochloa apus (Schult.F.) Kurz and pomacea canalikulata Lamarck is very abundant, easy to find in the environment around the island of Lombok.

2. Material and methods

2.1. Materials

The material used in this work is ASTM A36 steel which the chemical composition is shown in Table 1. and the mechanical properties are described as in Table 2. The research supporting equipment used includes Universal Testing Machine (UTM).FB1310M-USA, impact testing XJL-50-Dongua, and SEM (Scanning Electron Microscope) FFI-550-Cina.

2.2. Methods

Carburizing agent used is a mixture of gigantochloa apus (Schult.F.) Kurz charcoal (GAC) and pomacea canalikulata Lamarck shell powder (PCSP). The composition of carburizing agent PCSP-GAC was varied at 10% : 90%, 15% : 85%, and 20% : 80% . The process done at carburizing temperature various 875, 900, 930 °C and soaking time for 2 hours. Specimens and carburizing agent are inserted into the carburizing box which made of heat resistant steel. Then heat on the electric furnace, at various carburizing temperature. Then performed surface hardness test by vickers method, impact tes by izod method, and observation with SEM (scanning electron microscop), to know the microstructure specimens. The dimensions of the specimen for surface hardness test refer to ASTM E92 standart as shown in Figure 1., and specimen for impact test refer to ASTM E23-56T standart as shown in Figure 2,

Table 1 The chemical composition of ASTM A36 steel

The chemical composition	
Element	**Content (%)**
C	0,25-0,29
Cu	0,20
Fe	98,0
Mn	1,03
P	0,04
Si	0,280
S	0,050

Table 2 The physical and mechanical properties of ASTM A36 steel

The physical and mechanical properties		
Density	7,85 g/cm^3	0,284 lb/in^3
Ultimate tensile strength	400-550 MPa	58.000-79.800 psi
Yield strength	250 MPa	36.300 psi
Break elongation (200 mm)	20%	20%
Break elongation (50 mm)	23%	23%
Elasticity Modulus	200 Gpa	29.000 ksi
Poition Ratio	0,260	0,260
Shear Modulus	79,3 Gpa	11.500 ksi

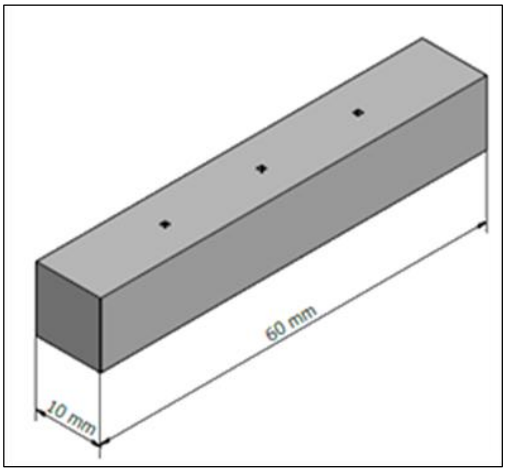

Figure 1 Surface hardness specimen ASTM E92 standart

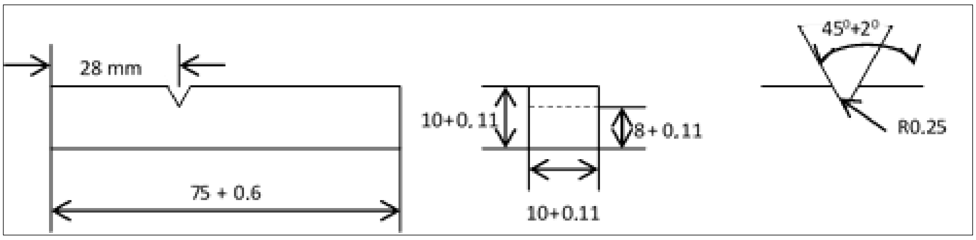

Figure 2 Impact test specimen ASTM E23-56T standart

3. Results and discussion

3.1. The surface hardness of ASTM A36 steel after pack carburizing treatment

From the results of the hardness test using the Vickers method, the highest hardness value was 537.48 kg/mm^2, on specimens treated with pack carburizing at a temperature of 930 ^{0}C soaking time 2 hours, carburizing media 20% PCSP: 80% GAC, the lowest hardness value was 170,3 kg/mm2 on specimens without pack carburizing treatment, shown in Figure 3. Based on these data, it can be concluded that the higher the pack carburizing temperature and the higher the PCSP percentage in the carburizing medium, the higher the surface roughness value of the specimen, the more brittle the ductility of the material decreases.

Changes in the hardness number only occur on the surface to a depth of between 0.75 mm and 4 mm. The difference in the number of surface hardness is caused by the rate of diffusion of carbon that infiltrates the surface of low carbon steel. The higher the percentage of Ca in the enegizer (PSCP), the faster the rate of diffusion, according to the results of the research [10] [11]. This indicates that the pack carburizing process is influenced by energizer, which speeds up a process. Calcium content with the addition of 30 PCL shell powder at carburizing temperature 5 most effective compared to other processes. Shown with the largest steepest line gradient.

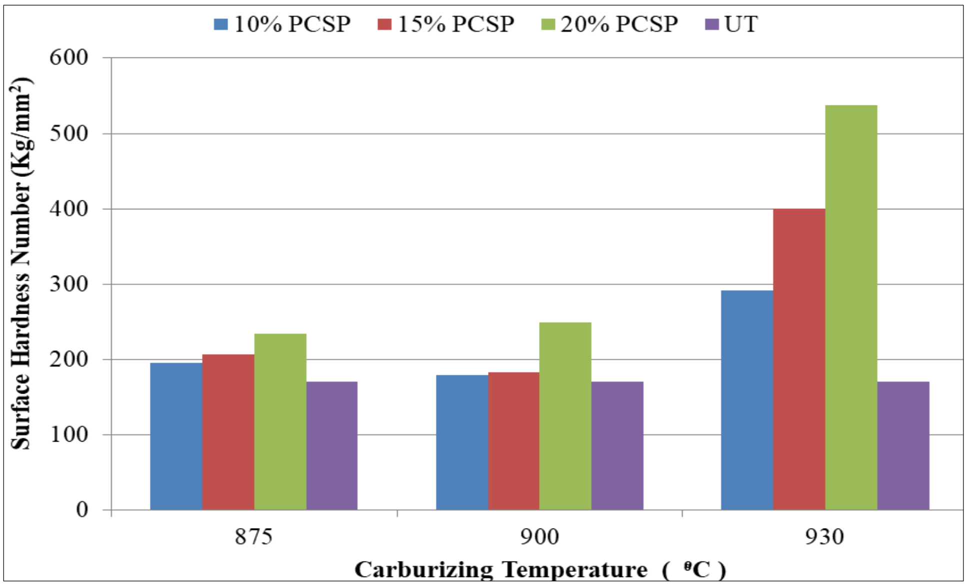

Figure 3 Surface hardness number specimen on pack carburizing treatment at soaking time for 2 hours

3.2. The impact thoughness of ASTM A36 steel after pack carburizing treatment

Impact toughness is defined as the impact energy divided by the cross-sectional area of the notch. From the experimental results, the highest energy was 158.33 Joule in the specimen without pack carburizing treatment, and the lowest average Impact energy was 56.66 Joule, in the specimen with pack carburizing treatment at a temperature of 930˚C soaking time 2 hours, carburizing media 20% PCSP: 80% GAC , as shown in Fig 4

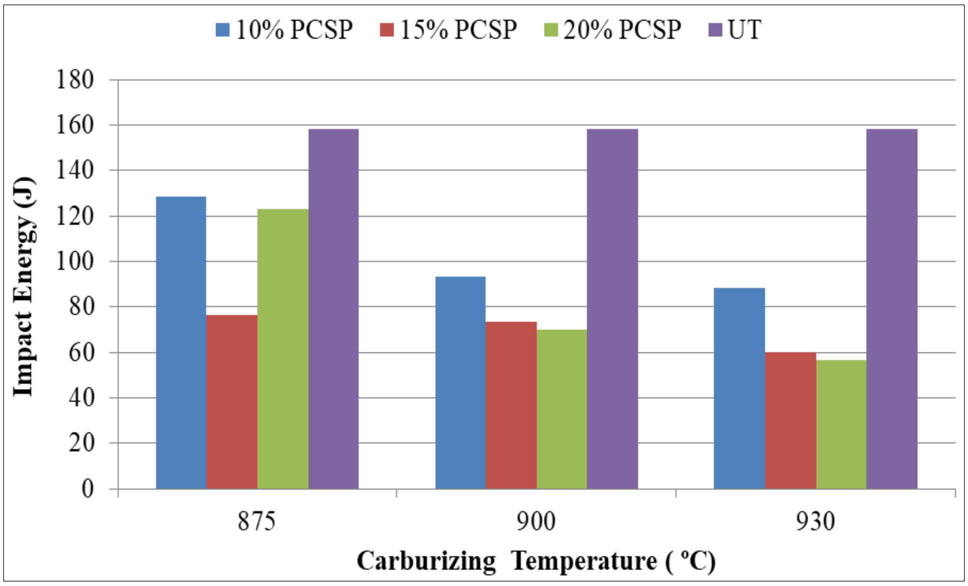

Figure 4 Impact energy specimen on pack carburizing treatment at soaking time for 2 hours

In general, it can be concluded that the higher the pack carburizing temperature and the higher the PCSP percentage on the carburizing medium, the more brittle the specimen will be, the surface hardness number will increase, in other words, the energy absorbed when subjected to impact/shock loads is less, so it can be said that the impact toughness of the specimen is reduced decrease. This statement is in accordance with the results of the study [12][13] . This work report on effects of variation in carburizing temperature and time on HSS cutting tool to enhance its use in engineering applications. The tools were carburized with pulverized carbon (Palm Kernel Shell) using 25 % Barium trioxocarbonate (BaCO3) as an energizer in a muffle treatment furnace of about 1500 ^{0}C. The performance evaluation of the tool was done by measuring its impact thoughness, wear resistance, weight loss and wear rate on all the samples.

3.3. The Microstructure of material magnet composite

The observation of the microstructure aims to determine to determine changes in the microstructure of the specimen after pack carburizing treatment. Microstructural observations were carried out on specimens that underwent pack carburizing treatment at a carburizing temperature variation of 875 ^{0}C, soaking time 2 hours, with variations in the percentage of PCSP weight in the carburizing agent, 10% , 15%, and 20% PCSP. The results of the observation of the microstructure are shown as in the Figure 5.

The microstructure of the specimen on pack carburizing at temperature 875 ^{0}C, soaking time 2 hours with carburizing agent 10% PCSP:90% GAC, has ferrite and perlite phases. The ferrite structure is shown by the dominant white color, the perlite structure is blacker than the ferrite structure, as shown in Figure 5 a.

Figure 5 b. is the microstructure of the specimen after pack carburizing treatment with a temperature of 875 ^{0}C, soaking time of 2 hours, carburizing media 15% PCSP : 85% GAC. At the edge of the specimen, the microstructure shows the presence of martensite and ferrite structures. The use of 15% by weight of PCSP in the mixture of carburizing media causes a martension structure to form, which is shaped like a lamellae. The edges and the inside have differences in the amount of structural content, which on the edges contains more hard martensite while the inside contains more ferrite. The ferrite structure has a relatively soft nature so that the deeper you go, the more ductile it gets, , such as the conclusions of research results [13]. Microstructural characterization indicates that high toughness of the carburizing steel subjected to the cooling heat treatment process results from a proper multiphase microstructure transition from the surface to the matrix of the steel.

The changes in the microstructure of the specimen after pack carburizing treatment with temperature 875 ^{0}C, soaking time 2 hours, carburizing medium 20% PCSP: 80% GAC, are shown in Figure 5 c. At the edge of the specimen, more and more martensitic structures are formed. So that the specimen has the highest hardness compared to the pack carburizing treatment with a content of 10%, 15% PCSP on the carburizing agent.

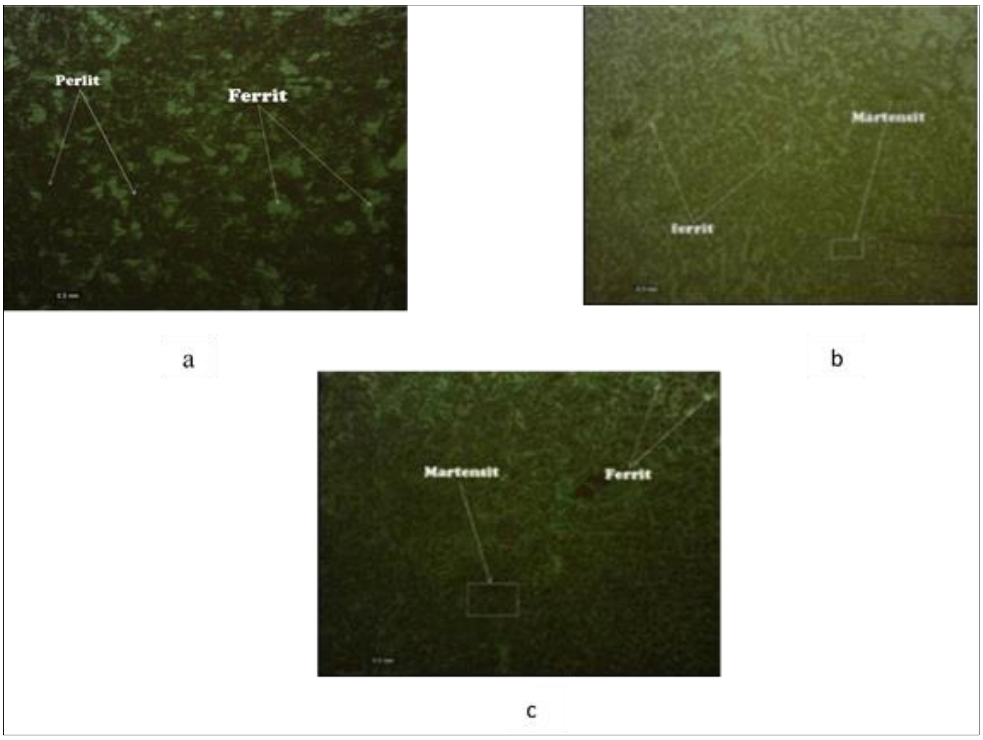

Figure 5 The microstructure specimen on pack carburizing treatment at tempertaure 875 °C, soaking time for 2 hours, (a) 10% PCSP, (b). 15% PCSP, (c) 30% PCSP

4. Conclusion

The use of PCSP affects the hardness number, impact toughness and changes in the microstructure of the specimen, in the pack carburizing treatment with a mixture of PCSP and GAC carburizing media. The higher the percentage by weight of PCSP, the higher the hardness number, the lower the impact toughness and the more martensitic structure formed. The pack carburizing treatment at a temperature of 930 °C, soaking time 2 hours, carburizing media 20% PCSP:80% GAC, resulted in the highest surface hardness number of 753,48 Kg/mm^2, the lowest impact energy was 53,33 Joules and the most formed martensite structure.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest.

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