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Study on Fatigue Strength of Pack Carburizing Steel SS400 with Alternative Carburizer Media of Pomacea Canalikulata Lamarck Shell Powder

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Abstract.

Pack Carburizing process is done to get a high hardness number on the surface of the shaft but ductile in the core. The research has been done by using carburizer media of teak wood charcoal as source of carbon element and $CaCO_3$ as the source of Ca element as energizer or catalyst. Alternative carburizer media applications are still rarely performed. This study discusses the effects of different carburizer media on the fatigue strength of mild steel used in the power tiller shafts and wide industrial applications. Carburizer media used is teak wood charcoal and Pomacea Canalikulata Lamarck (PCL) shell powder. The composition of (PCL) shell powder used: 10, 20 and 30 (% wt). Carburizing is done at temperature 950^0C with Carburizing time for 5 hours, followed by tempering with temperature variations 250^0C, 300^0C, 350^0C and quenching with salt solution (30% NaCl + water) Then performed Rotating Bending Test, observation with SEM (scanning electron microscop), to know the fatigue strength and microstructure specimens. In conclusion, The tempering process followed by quenching in 30% NaCl solution after pack carburizing, can increase the fatigue strength.

Keywords: Pack Caburizing, hardness number, Rotating Bending Test, energizer, fatigue strength

INTRODUCTION

Indonesia's natural resources are very diverse and abundant. One type of animal that is easy we find in the fields is a snail (Pomacea Canalikulata Lamarck) or PCL. The snail is one of the mollusk species that damage young rice plants. To protect the crops, farmers eradicate golden snails by picking them up and spraying them with pesticides. The snail that harms the farmers can now be utilized because PCL shells contain calcium tricarbonate ($CaCO_3$) [11]. which can be used as an alternative energizer in the pack carburization process. The heat treatment process to increase the hardness of the low carbon steel surface is carburizing pack. Carburizer media such as teak wood charcoal, coconut shell charcoal, bamboo charcoal and $CaCO_3$, $BaCO_3$, $NaCO_3$ as energizer or catalyst [6].

The mechanical properties of mild steels (low carbon steels) undergoing pack carburizing processes are influenced by the carburizing temperature, time and post heat treatment [1-4] . The research focuses on 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 60 minutes. It was concluded that the optimum combination of mechanical properties is achieved at the carburizing temperature of 900 °C followed by oil quenching and tempering at 550 °C.

In this study, various carburizing compounds were used to pack carburized mild steel. Various weight percentages of cow bone were used as energizer in the carburizing [2, 5]. The experiment was carried out using a muffle furnace at 900°C for 8 h. Hardness tests were taken using Vickers micro-hardness tester. The result showed that 60 wt% charcoal / 40 wt% cowbone had the best result with an effective case depth of 2.32 mm produced in the case of the carburized steel. The work showed that cowbone can be used as energizer in pack carburization of mild steel. The hardness profile plot of the 60 wt% charcoal/40% cowbone carburized mild steel was also higher than the other compositions.

This work evaluates the suitability of using palm kernel shell, animal bone (mammalian bones from cattle) and sea shell (oyster shell) materials as carburizers for case hardening of 0.078%C mild steel. The carburizing media used were milled into fine powder while Barium carbonate (BaCO3) was used as an energizer in the carburizing process [6, 7, 16]. The results of the carbon analysis show that palm kernel shell and animal bone are potentially suitable to be used as a carburizing media than the sea shell at high temperatures (above 1000^0 C) with holding time above 1 hour.

The effects of varied carburizing temperatures and holding time on the mechanical properties of AISI/SAE1020 steel have been investigated [7, 12, 13]. Standard test samples prepared from the steel sample were subjected to pack hardening process using carbonized palm kernel shell as a carburizer at 800°, 850°, 900° and 950°C and held for 60, 90 and 120 minutes, quenched in oil and temper at 500°C for 60 minutes. The mechanical properties of mild steels were found to be strongly influenced by the process of carburization, carburizing temperature and holding time using carbonized palm kernel shell. It was concluded that the optimum combination of mechanical properties is achieved at the carburizing temperature of 950°C soaked for 120 minutes followed by oil quenching and tempering at 500°C for 60 minutes.

The fatigue crack propagation behavior of low alloy steels subjected to case carburization treatment have been done

[8,14]. These components have to work under fatigue loading during their service life, which occasionally results in fatigue failures. The present work is aimed at investigating the fatigue crack propagation behavior of some commonly used low alloy steels in case carburized condition. The crack propagation mechanisms were investigated through fractographic observations on the fractured surfaces of standard fatigue test specimens failed under four-point rotating bending fatigue tests. The conclusion is the residual compressive stresses induced during case carburization, the majority of the fatigue cracks was founded to initiate at the surface. Crack initiation was followed by transgranular mode of stable crack propagation for all the steels, while subsequent crack propagation behavior was found to be dependent on the contents of alloying elements in a given steel. Steels containing higher amounts of chromium were found to exhibit greater tendency towards the intergranular decohesion cracking.

The fatigue resistance of carburized 16MnCr5 steel is influenced by study of the effect of austenizing and tempering heat treatment temperatures [9, 10, 15]. The rotating bending fatigue specimens were machined from 16MnCr (ASTM 5117) steel rod, and pack carburized at 900°C for 2 hours soaking time. Carburized specimens were then austenized at 900°C for one hour, water quenched, reaustenized at temperatures 750°C, 800°C and 900°C for one hour, then tempered at 200°C temperature. Other carburized specimens were tempered by heating to 760°C temperature, water quenched to room temperature, then tempered at temperatures 200°C, 300°C, and 400°C for one hour. The specimens were tested by rotating bending fatigue machine up to fracture under different stress levels (200, 250, 300, 350, 400) Mpa. Experimental results showed that fatigue resistance of the austenized steel specimens after carburization process has been increased, and the crack length developed on the specimen surfaces was decreased with an increase in austenizing temperature up to 800°C. The research described above has not yet discussed the influence of alternative energizer to changes in the strength of fatigue

METHODE OF RESEARCH

Material

The material used is mild steel type SS400. Their chemical composition as measured by Bruker S1 Turbo SD (XRF analyzer) is Fe: 98.11, C: 0.159, Mo: 0.078, Mn: 0.624, Cu: 0.241, Cr: 0.110, Nb: 0.16 and Ti: 0.008 percent.

The dimensions of the specimen for fatigue strength test refer to ISO test standard 1143 (1975). as shown in Figure 1. Number of specimens prepared for 10 pieces, consisting of 1 uncarburizing initial specimen, 3 specimens were pack carburized at 950^0 C at 5 hours carburizing time with 10%, 20% and 30% PCL shell powder variations and 3 specimens were pack carburized at 950^0 C for 5 hours with 30%

PCL powder for tempering process at 250^0 C, 300^0 C, 350^0 C in quenching with a salt solution cooling medium (water + 30%).

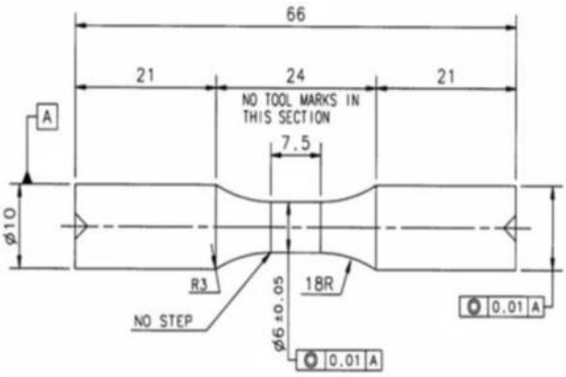
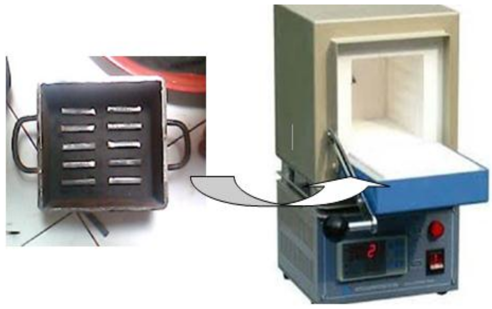


Figure 1. The dimensions of the specimen for Rotating bending fatigue specimens test refer to ISO test standard 1143 (1975).



a. b.

Figure 2. Pack Carburizing Process : a.Carburizing Box b.Electric Furnace

Pack Carburizing Process

Carburizer media used is teak wood charcoal and Pomacea Canalikulata Lamarck (PCL) shell powder. Composition of (PCL) shell powder used: 10, 20 and 30 (% wt). Specimens and media carburizer (teak wood charcoal mixed with PCL shell powder) are inserted into the carburizing box which made of low carbon steel. Then heat on the electric furnace, as shown in figure 2. The carburizing box dimensions with 5 mm thickness of the plate with a length of 100 mm, 100 mm wide and 100 mm high. Pack Carburizing is done at temperature 950^0C with Carburizing time for 5 hours, followed by tempering with temperature variations 250^0C, 300^0C, 350^0C and quenching with salt solution (30% NaCl + water) Then performed Rotating Bending Test, observation with SEM (scanning electron microscop), to know the fatigue strength and microstructure specimens.

RESULT AND DISCUSION

Fatigue Strength Testing Results

Fatigue strength testing by rotating bending fatigue machine up to fracture under different stress levels (150, 200, 250, 300, 350) Mpa. The specimens tested were those that had undergone a pack carburizing process. Carburizer medium used is teak wood charcoal and Pomacea Canalikulata Lamarck (PCL) shell powder. The composition of (PCL) shell powder used: 10, 20 and 30 (% wt). Pack Carburizing is done at temperature 950^0 C with Carburizing time for 5 hours, followed by tempering with temperature variations 250^0 C, 300^0 C, 350^0 C and quenching with salt solution (30% NaCl + water). Fatigue strength test results are shown in Table 1, Table 2, Figure 3, and Figure 4.

Table 1. The values of stress and number of cycles up to fracture for mild steel (SS400) specimens at different media Carburizer.

Load Variation	Number of Cycles (N)			
(MPa)	H1	H2	H3	H4
150	8,00E+05	5,85E+05	5,10E+05	4,60E+05
200	5,00E+05	3,10E+05	2,10E+05	1,40E+05
250	3,10E+05	2,00E+05	1,35E+05	9,50E+04
300	2,40E+05	1,35E+05	9,50E+04	7,00E+04
350	2,25E+05	1,15E+05	8,00E+04	5,00E+04

H1 : Uncarburized specimen

Media Carburizer

H2: 10% PCL Shell Powder

H3: 20% PCL Shell Powder

H4: 30% PCL Shell Powder

From Table1. shows that each addition of PCL shell powder has decreased the number of cycles significantly. The lowest number of cycles 50.000 in the 350 MPa load variation, after carburizing process with carburizer media 30% PCL shell powder and 70% teak wood charcoal. There was77.78% decrease in the number of cycles compared to specimens without pack carburizing process.

From Figure 3 shows that the initial material specimen has a higher number of cycles due to the absence of carbon in the material. Specimens undergoing packs carburizing have greater hardness number compared with this initial material due to the presence of activated carbon and supported by the addition of PCL shell powder as energizers so that faster carbon diffuses into the material. Pack carburizing process with carburizer media composition 30% PCL shell powder has the highest hardness value. As a result the lowest number of cycles. In the process of pack carburizing if the percentage of PCL shell powder increased then the carbon diffuses to the steel will be faster and make the surface hardness number of steel will be greater, so the carbon will more easily diffuse between the gaps Fe atom.

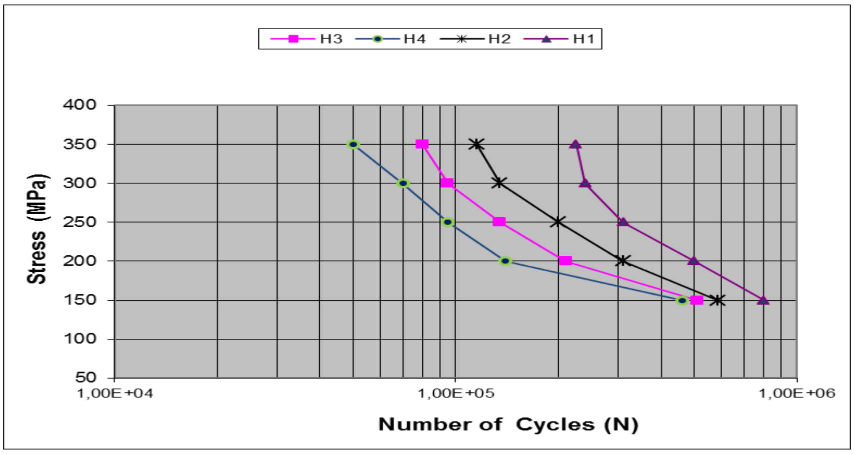


Figure 3. Stress versus number of cycles for Specimens after Pack Carburizing

Table 2. The values of stress and number of cycles up to fracture for mild steel (SS400) specimens at different tempering temperature.

Load Variation	Number of Cycles (N), 10^3				
(MPa)	H1	TT1	TT2	TT3	H4
150	8,00E+05	8,15E+05	9,00E+05	9,50E+05	4,60E+05
200	5,00E+05	6,20E+05	7,00E+05	8,20E+05	1,40E+05
250	3,10E+05	4,00E+05	5,10E+05	6,50E+05	9,50E+04
300	2,40E+05	3,25E+05	4,10E+05	5,00E+05	7,00E+04
350	2,25E+05	2,75E+05	3,25E+05	4,00E+05	5,00E+04

H1 : Uncarburized specimen
H4: 30% PCL Shell PowderTempering Temperature:

TT1: 250^0 C

TT2: 300^0 C

TT3: 350^0 C

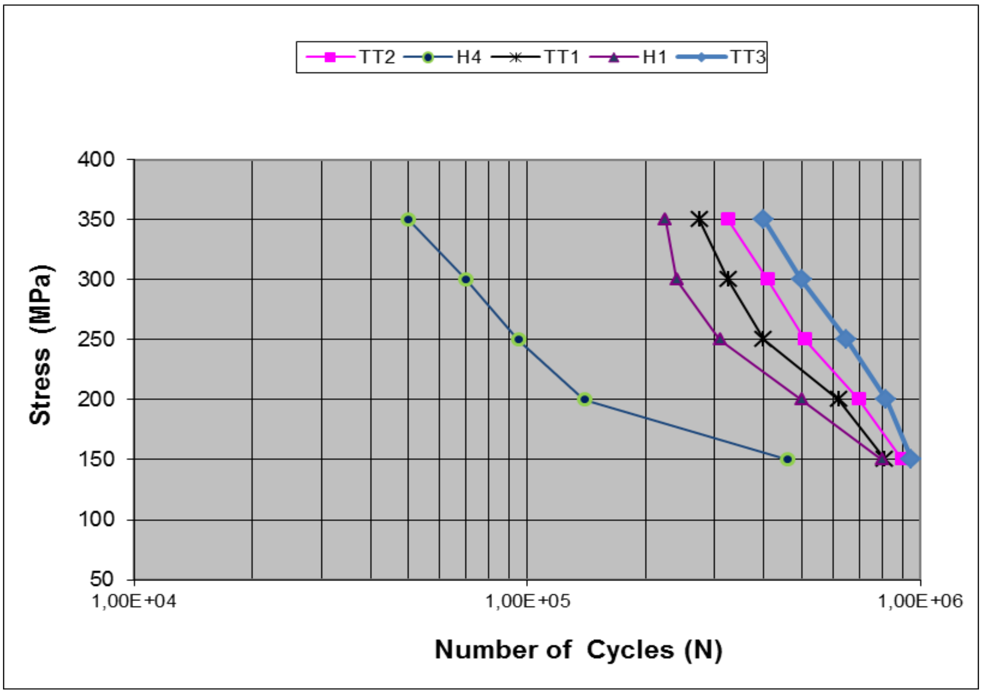


Figure 4. Stress versus number of cycles for tempered Specimens after pack carburizing

Specimens have the lowest fatigue strength (lowest number of cycles), due to pack carburizing process with 30% PCL shell powder composition. To improve the strength of fatigue, tempering and quenching process was done in 30% NaCl solution, the results are shown in Table 2.

In Table 2. It is shown that the tempering temperature increasing will increase the number of cycles (increase of the fatigue strength). In general, the fatigue strength of material after the tempering process is higher than the starting material and the material undergoing pack carburizing with the addition of 30% PCL shell powder. The highest number of cycles is 950.000 at 150 MPa load variation, at tempering process with 350^0 C quenching temperature in 30% NaCl solution. While the number of cycles is 800.000 for materials without pack carburizing and 460.000 for material that packed carburizing. So that tempering process raises fatigue strength 15.79% for materials without pack carburizing and 51.58% for materials that undergo pack carburizing process with 30% PCL shell powder composition.

In Figure 4. appointed that the fatigue strength of specimens decreased due to pack carburizing process (shown in Figure 3.) can be improved with tempering treatment and quenching in NaCl 30% solution. Tempering temperature affects the number of cycles of the specimen. The tempering temperature increases the number of cycles also increases. The number of average cycles of specimens undergoing tempering process is higher than treated pack carburizing or untreated specimens

Microstructure Test Results

The microstructure observation of the initial material before pack caburizing process can be seen in Figure 5:

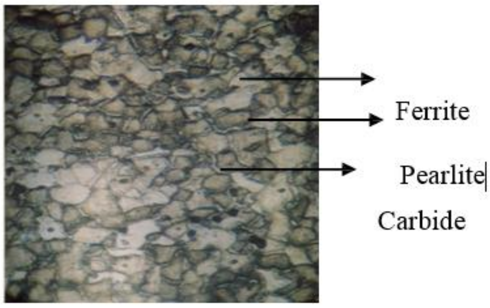


Figure 5. Microstructure of specimens uncarburized with 400 times magnification

Figure 5. shows that the structure of ferrite (colored light and white) is more dominant than the structure of pearlite (colored dark and black). The structure of pearlite and carbide is less than ferite. So that hardness number of the starting material becomes lower because there is no addition of carbon element. While the carbide structure will enlarge if there is heat treatment of the workpiece (mild steel).

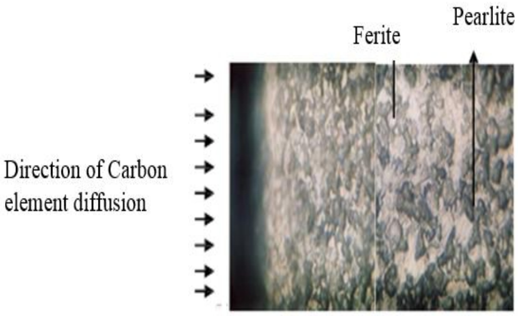


Figure 6. Microstructure of specimens after pack caburizing with media carburizer composition 30% PCL shell powder

Figure 6 shows the observed microstructure of material that has been packed caburizing with composition of carburizer media 70% teak wood charcoal and 30% PCL shell powder at temperature 950^{0}C with 5 hours carburizing time without tempering process.

Pack Carburizing process at temperature 950^0 C and carburizing time 5 hours causes intertisi .diffusion of carbon on specimens surface. Addition of PCL with a 30% composition as energizer can accelerate the process of carbon diffusion into the steel so that it can form more pearlit structures. In Figure 6 it is shown that the number of pearlite structures is increasing and the grain size is evenly distributed along the penetration although on the perlite side there is still a lot of ferrite. An increasing the number of pearlite structures more than the microstructure of the initial material may occur due to the effect of adding carbon elements to the material during the pack carburizing process. This makes the specimen harder than ever and the strength of fatigue (the number of cycles) decreases.

The purpose of tempering and quenching process in 30% NaCl solution increased fatigue strength due to pack carburizing process with variation of PCL composition. The microstructure observation of the material that has undergone pack caburizing and continued with the process of tempering and quenching in 30% NaCl solution can be seen in Figure 7 .

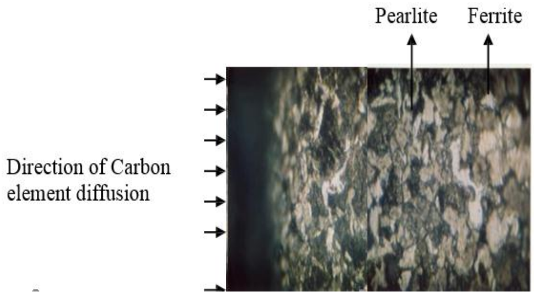


Figure 7. Microstructure of specimens Tempering and Quenching in in 30% NaCl solution

From Figure 7 it is shown that the maximum increase in pearlit compared to other microstructure. In addition, the penetration of carbon is also quite deep and the granules on pearlite size are larger than those without the tempering process. With larger grain size then the hardness numbergenerated will also be larger. This is due to the comparison of additional material in the form of 70% teak wood charcoal and 30% golden snail shell powder as energizer that can accelerate the process of carburization, and supported by the process of tempering and quenching using a salt solution cooling medium. This can increase the amount of carbon that is quite a lot, so that when the heating takes the diffusion of carbon into the steel becomes faster so that it can change the microstructure grains and the highest hardness value in comparison with the previous specimens.

CONCLUSION

In conclusion, the addition of PCL shell powder to the pack carburizing process will increase the hardness number but decrease the strength of fatigue (number of cycles). The lowest fatigue strength occurs in the addition of 30% PCL. The tempering process followed by quenching in 30% NaCl solution, can increase fatigue strength. The temperature of tempering increases as the number of cycles also increases. This is because the number of pearlite structures increases due to the tempering process, resulting in increased ductility and increased fatigue strength.

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