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International Journal of Mechanical Engineering and Technology (IJMET) Volume 9, Issue 5, May 2018, pp. 14–23, Article ID: IJMET_09_05_003 Available online at http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=9&IType=5 ISSN Print: 0976-6340 and ISSN Online: 0976-6359 © IAEME Publication Scopus Indexed STUDY ON MECHANICAL PROPERTIES OF PACK CARBURIZING SS400 STEEL WITH ENERGIZER POMACEA CANALIKULATA LAMARCK SHELL POWDER Sujita Darmo Department of Mechanical Engineering, Mataram University, Mataram, Indonesia Rudy Soenoko, Eko Siswanto and Teguh Dwi Widodo Department of Mechanical Engineering, Brawijaya University, Malang, Indonesia ABSTRACT Pack carburizing process is carried out to increase the material surface hardness by increasing the carbon element by diffusion interstitial. The research has been done by using carburized media of teak wood charcoal as the source of carbon element and CaCO3 as the source of an element as an energizer or a catalyst. Alternative carburized media applications are still rarely performed on research. The purpose of this research is to know the effect of the addition of Pomacea Canalikulata Lamarck (PCL) shell powder on pack carburizing process of physical properties (microstructure) and mechanical (hardness test) of low carbon steel after treatment. The material used in this study is low carbon steel (SS400) in the form of a cylinder. The composition of the PCL shell powder is used: 10, 20 and 30 (% weight). Carburizing is done at temperature 9500C with Carburizing time for 3, 5 and 7 hours. Then the Vickers hardness tested, observation with SEM (scanning electron microscopes), to determine the number of hardness and microstructure specimen. From the discussions so far it can be concluded that, PCL shell powder can replace the function of BaCO3 and NaCO3 as energizer on carburizing pack process Keywords: Pomacea Canalikulata Lamarck, shell powder, pack carburizing, hardness test, microstructure. Cite this Article: Sujita Darmo, Rudy Soenoko, Eko Siswanto and Teguh Dwi Widodo, Study on Mechanical Properties of Pack Carburizing SS400 Steel with Energizer Pomacea Canalikulata Lamarck Shell Powder, International Journal of Mechanical Engineering and Technology, 9(5), 2018, pp. 14–23. http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=9&IType=5 1. INTRODUCTION Indonesia's natural wealth is very diverse and abundant. One type of animal that we easily find in fields is golden snail (Pomacea Canalikulata Lamarck). Pomace Canalikulata Lamarck (PCL) is one type of mollusk animal. This type of animal is most often found in the rice fields and is the enemy of farmers for destroying young rice plants. To protect the crops, the farmers tried to eradicate it by picking up and spraying with pesticides. Evidently the PCL which originally only harmed the farmers now can be utilized because golden snail shells contain calcium [1-3]. Which can be used as an alternative energizer in the solid carburization process. Basically, the materials used in carburizing namely, charcoal, coconut shell charcoal and energizer. To speed up the process of carburizing then added barium carbonate (BaCO3), sodium carbonate (NaCO3) or calcium carbonate (CaCO3). All three materials serve as an energizer in the process of carburizing pack [4-8]. Some researchers [8-14] have attempted to improve mechanical properties of low carbon steel by a pack carburizing process. It has been done in the temperature 8500C, 9000C and 9500C, in an environment containing carbon, for 15 and 30 minutes at this temperature then have been cooled. The result temperature and time of carburizing influenced for mechanical property of a specimen. Several studies [10–18] have been done.by using a media carburizing alternative like that bamboo charcoal, pulverized cow bone, kernel shell charcoal. The research on the effect of carburizing process on the physical and mechanical properties of the blower blower dynamo has been done by [17]. The conclusion in which time hold can affect the value of hardness number. Researchers [18] have studied the influence of temperature and time of pack carburizing process followed by quenching process with oil and tempering to impact toughness mild steel. Researchers [15] have conducted research on the fatigue propagation behavior of alloy steel undergoing carburizing process. After machining, the tool marks

on the fatigue test specimen are removed by polishing with a 120 grit SiC paper. The specimen was carburized to 920°C for three hours, followed by heating at 850°C for 30 minutes and cooling in the oil at 120° C. Finally, the specimen was tempering at 180°C for 2 hours. According to [14-19] low carbon steels containing 0.15% to 0.3% of carbon do not experience a change in hardness. Thus, to improve surface hardness carburizing treatment can change the surface composition of low carbon steel with carbon diffusion and the outer hard surface results with good wear resistance. The low carbon steel was pack carburizing at 9000C for 5 hours. After carburization is done further heat treatment, annealing, normalizing, hardening and tempering treatment. According to [14-21] low carbon steels containing 0.15% to 0.3% of carbon do not change of hardness number if packed carburizing. To increase the surface hardness number after pack carburizing treatment is continued with further heat treatment: annealing, normalizing , hardening and tempering treatment. In order to enhance quality of carburizing sample and increase process cost analysis is done. 2. EXPERIMENTAL SETUP Carburizing box is made of low carbon steel thickness 5 mm, length 100 mm, width 100 mm and height 100 mm, the specimens are inserted into a heated carburization box of the electric furnace. The specimens prepared were 33 pieces, consisting of 3 initial specimens without carburizing, 27 specimens were carburized at 9500 C for 2, 3 and 5 hours with the addition of PCL shell powder of 10%, 20% and 30% by water cooling medium, and 3 specimens were carburized at 9500 C for 5 hours with the addition of PCL shell powder as much as 10% with the cooling medium of salt solution (water + 30%). The dimension of specimen can be seen in Figure 1 below: Figure 1 Dimension of the specimen The tools used in this study are as follows: Carburization box, electric furnace, polish machine, SEM, hardness testing machine, caliper, digital camera, pincer pliers, and abrasive paper (80, 100, 400, 600, 800, and 1000), and Autosol. While the materials to be used are SS400 steel., teak wood charcoal, PCL shell powder. a b. Figure 2 Media carburizer a. Teak wood charcoal b. PCL shell powder Figure 3 Carburizing Box which has been filled with media carburizer and specimens for hardness tests. 3. THEORETICAL ANALYSIS 3.1. Pack Carburizing Pack Carburizing process is the process of adding carbon element (C) into the metal, especially on the surface of the material, so that increasing the hardness number metal surface. The carbon element is obtained from materials containing carbon like that charcoal. Metal surface hardening can be done by adding certain elements to the base metal such as carbon, calcium carbonate, nitrogen, and others. To speed up the process then added barium carbonate ($BaCO_3$) calcium carbonate ($CaCO_3$) or sodium carbonate ($NaCO_3$) as energizers. The charcoal, energiaer and specimen are inserted into the carburizing box then heated in the electric furnace [5-6]. On pack carburizing use of charcoal mixed with 10% - 40% $NaCO_3$, $BaCO_3$, steel is incorporated into this mixture, placed in a carburizing box and then heated at 8500C - 9500 C [1-2]. After holding time, the process is continued by hardening with quenching to achieve high hardness, and tempering to reduce excessive brittle and residual stress. During heating, there are two kinds of gas ie: CO_2 and CO with the following reaction. $CO_2 + C \rightarrow 2CO$ (1) With higher temperatures the reaction equilibrium is more likely to the right, more CO. On the steel surface CO will decompose $2CO \rightarrow CO_2 + C$ (2) The C element formed in the form of carbon atom, which actively enters diffuses into the austenite phase of the steel. With the energizer the process will be easier because even the air trapped in the box is very small, but the energizer provides the CO that will immediately begin activating the next reactions. The decomposition reaction of $BaCO_3$: $BaCO_3 \rightarrow BaO + CO_2$ (3) Similarly, using energizer calcium carbonate ($CaCO_3$) will experience a reaction: $CaCO_3 \rightarrow CaO + CO_2$ (4) The next reaction as described above. 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 any other diffusion process, this carburization thickness depends on the temperature and time that can be formulated as formula (5) : $DC ? k t$ Annotation, DC : depth of carburizing (mm) k: The diffusion constant, the magnitude depends on the temperature (5) t: Time of carburizing (h) Temperature 0C 875 900 925 Constant (k) 0,34 0,41 0,52 3.2. Pomacea Canalikulata

Lamarck Pomacea Canalikulata Lamarck (PCL) conch is one type of mollusk. This snail is derived from swamps in South America such as Brazil, Suriname and Guatemala. First time, this PCL was imported from Taiwan around 1980. In 1981, this animal was introduced to Yogyakarta as an aquarium fauna.Around 1985- 1987, this animal spread very quickly and popular in Indonesia [3]. PCL young snails of 2-5 mm have eaten algae and soft plant parts. The initial growth lasts for 15-25 days. At the age of 26-59 days, PCL is very greedy consume food, while after 60 days, is ready to breed. The PCL needs about 3-4 hours during marriage in an area that always gets water throughout the year. The shell can be seen in Figure 1 below. Figure 4 Pomacea Canalikulata Lamarck 3.3. Surface Hardness 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 to press will be square and measured is the second length of diagonal then taken average. Vickers hardness number is calculated by the formula (6): HV ? ?2.Gt.sin?? / 2? ? d 2 ? 1,854. P d 2 (6) Annotation, Gt: Compressive force (Kg) d: Average of diagonal (mm) ɑ: Angle of peak identor = 136 0 Hardness testing is intended to determine the surface hardness of the test specimen and specimen carburizing process without treatment. This test was performed using a Vickers hardness test machine with a pyramid-shaped indentor at the peak of 1360. Tests carried out at some point to get good data validity of the change in hardness at different points due to previous treatment. In this study each specimen was tested at five points, as in the following figure: Figure 5 Specimen of Hardness Testing After the hardness testing then determined the average diagonal by summing diagonal 1 and diagonal 2, to determine the value of Vickers hardness the diagonal of the indentor as measured by using a microscope. Figure 6 Diagonal of Identor 4. RESULTS AND DISCUSSIONS 4.1. Hardness Test Result The surface hardness test used is the Vickers method to load (P) of 60 Kg. Figure 3 indicated carburizing time increment affect the rise in hardness number specimen. The specimen initial material having a very low hardness number, because no additional carbon in materials. Specimens with time carburizing 3 hours at 9500C temperature have more hardness number value compared with this initial material, due additional of activated carbon and supported by PCL shell powder as an energizer so that carbon diffuses faster into the material. The composition 30% PCL shell powder has the most hardness value after the pack carburizing process at a temperature of 9500 C. If the percentage of PCL shell powder increase, the faster the carbon diffuses into the Fe gaps. The increasing number of C atoms causes the surface hardness number of steel to increase. In the carburizing process with the addition of 20% PCL powder shell by using media coolant of salt solution (30% NaCl + water) obtained the highest hardness number of 277.46 Kg/mm2 with carburizing time 5 hours, followed by the addition of 30% PCL shell powder by using freshwater cooling medium of 262.30 Kg/mm2 with carburizing time 7 hour and raw material with a hardness number 144.08 Kg/mm2. 300.00 Vickers Hardness Number (Kg/mm^2) 250.00 200.00 150.00 100.00 50.00 0.00 0 1 2 3 4 5 6 Carburizing Time (hour) 7 8 10% PCL Shell 20% PCL Shell 30% PCL Shell Initial HRV cooling medium (water + 30% NaCl Figure 7 Influence carburizing time for hardness number of specimens Based on the figure of the PCL shell powder addition has an effect on to increase of hardness number of specimens. The greater the percentage of PCL shell powder, the hardness also increases. 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 Vickers Hardness Number (Kg/mm^2 250.00 300.00 200.00 150.00 100.00 50.00 0.00 0 10 20 30 PCL Shell Powder (% wt) 40 3 h 5 h 7h Initial sample cooling Medium (water + 30% NaCl) Figure 8 Influence PCL shell powder additional for hardness number of specimens 4.2. Micro Structure Test Results The result of micro structure observation of the starting material before pack carburizing treatment can be seen in Figure 9 below Figure 9 Initial material micro structure with 400 times magnification From Figure 9 shows that ferrite (light-colored and white) and pearlite (dark and black) are larger in

size than carbides. The carbide will enlarge in case of heat treatment of the workpiece (low carbon steel). Then the structure is more dominant than the ferrite pearlite structure are fewer in number, so that the hardness of the initial material becomes lower. This occurs because there is no addition of carbon element given to the initial material and corresponds to the carbon content contained in the starting material of 0.159% C. The observation of the microstructure of a material that has undergone pack carburizing the concentration ratio of 85% carbon and 30 % PCL shell powder at temperature 9500 C with carburizing time of 7 hours using fresh water cooling medium can be seen in Figure 10 below. Figure 10 Initial material micro structure with 400 times magnification After pack carburizing (9500 C, 7 hour, 30 % PCL, fresh water cooling medium) From Figure 10 it is shown that the pearlite structures are increasing in number and the grain size is evenly distributed along the penetration, although on the pearl it side there is still a lot of ferrite. The increased amount of pearlite more than the microstructure of the starting material may occur due to the effect of adding a carbon element to the material during the diffusion process of carbon interaction. Way of heating the material at temperature 9500 C for 7 hours. The addition of PCL shell powder with a concentration of 30% (% weight) as an energizer accelerates the process of carbon diffusion into the steel so as to form more pearlit structures. So the specimen becomes harder than before and also influenced by the rapid cooling process so that it can change the physical properties of steel. The result of observation of microstructure from material that has been packed caburizing with ratio of 80% concentration of teak charcoal and 20% PCL shell powder at 9500 C with 5 hours carburizing time using salt solution cooling medium can be seen in Figure 11 below. Figure 11 Initial material micro structure with 400 times magnification after pack carburizing (9500 C, 5 hour, 20 % PCL, salt solution cooling medium) From Figure 11 shows that the most increase in pearlit compared to other micro structure. The penetration of the carbon is also quite deep and the granules in pearlites are larger in size than the previous concentrations. The larger grain size causes the resulting hardness to be greater. This phenomenon occurs because the comparison of additional material in the form of 90% teak wood charcoal and 10% PCL shell powder as an energizer which is a power generator in the process of carburization, and the quenching process using a salt solution cooling medium. This can increase the amount of carbon that is quite a lot. So when the heating of carbon diffusion into the steel becomes faster so as to change the grain micro structure and harder hardness value compared with the previous test material. 4.3. Composition Test Result Table 1 Results of chemical composition test before treatment (Raw Materials SS400 steel) and after treatment (carburizing) with a variation of 30 % PCL powder with a hold time of 7 hours and a temperature of 9500 C heating. Table 1 Results of chemical composition No Name of Element Raw Material % average After Pack Carburizing % average 1 Fe 98.11 92.91 2 C 0.159 0.78 3 Mn 0.624 0.70 4 Cr 0.110 1.29 5 Mo 0.078 0.47 6 Cu 0.241 0.34 7 Nb 0.016 0.03 8 Ti 0.008 0.80 From the data in Table 1 above, the composition test results on specimens before and after treatment, there was an increase in carbon content in which the raw materials contained 0.159% C while the carburizing on the surface according to the composition test contained 0.78% C. This proves that carbon has entered the surface of low carbon steel. 5. CONCLUSION In the present work experiments were conducted on the addition of PCL shell powder 10%, 20% and 30% and carburizing time for 3, 5 and 7 hours, the surface hardness number increases. The average hardness number of 10% PCL shell powder and carburizing time of 3, 5 and 7 hours were 172.73, 210.21 and 238.38 (Kg/mm2), 20% PCL shell powder were 174.13, 232.05 and 254.34 (Kg/mm2) and 30% PCL shells were 222.18, 241.53 and 262.30 (Kg/mm2). From the photo observation of micro structure on the starting material there is a more ferrite structure in comparison with the micro structure photo after treatment (carburizing). Conversely a mount of pearlite after treatment becomes more than the previous material. The hardness numbers of SS400 steels were found to be strongly influenced by the process of pack carburizing, carburizing temperature, the percentage increase PCL powder and media quenching. The sample pack carburized with the addition of 20% PCL powder at

950°C temperature for 5 hours time carburizing and followed by salt solution (30% NaCl + water) quenching are considered better. Because they showed the highest hardness number of 277.46 Kg/mm2 in the case. Conclusion PCL shell powder can replace the function of BaCO3 and NaCO3 as energizer on carburizing pack process. REFERENCES [1] Amanto, H. and Daryanto. Material Science, 2nd Edition. Jakarta: Bumi Aksara, 1999, pp. 140. [2] Higgins, R. A. Engineering Metallurgy Part 1: Applied Physical Metallurgy, 5th Edition. ELBS with Edward Arnold, Kent, 1991, pp. 40 and pp. 162. [3] [4] Jekti. Biology Textbooks 1, 3th Edition. Mataram: Mataram University, 1990, pp.124. Koswara, Engkos. Metal Materials Testing. Bandung: Humaniora Utama Press, 1999, pp.23. [5] [6] [7] Shewmon, G. P. Diffusion in solids, series in material science and Engineering. Tokyo: Mc Graw Hill, 1963. Hochman, R. and Burson, J. The Fundamentals of Metal Dusting, New York: API Division of Refining, 46, 1966, pp. 331. Fatai O. A., Simeon A. I., Isiaka., Oluwole O., and Joseph O. B. Pack Carburization of Mild Steel, using Pulverized Bone as Carburizer: Optimizing Process Parameters. Leonardo Electronic Journal of Practices and Technologies, ISSN 1583-1078, issue 16, 2010, pp. 1-12. [8] [9] [10] [11] [12] Ahmad, J. K. Carburizing of Steel. International Journal of Materials Science and Applications, (2015). 4(2), 11. https://doi.org/10.11648/j.ijmsa.s.2015040201.13 Aramide, F. O., Ibitoye, S. A. and Oladele, I. O. Pack Carburization of Mild Steel using Pulverized Bone as Carburizer. Optimizing Process Parameters, 16, 2010, pp. 1–12. Ihom, P. A. Case hardening of mild steel using cowbone as Energiser. African Journal of Engineering Research, 1(October), 2013, pp. 97–101. Ngakan, D. and Putra, K. Carburizer Effectiveness from Different Carbon Sources on Pack Carburizing Process, 2(1), 2016, pp. 5–10. Oluwafemi, O. M., Oke, S. R., Otunniyi, I. O. and Aramide, F. O. Effect of carburizing temperature and time on mechanical properties of AISI/SAE 1020 steel using carbonized palm kernel shell. Leonardo Electronic Journal of Practices and Technologies, 14(27), 2015, pp.41–56. [13] Aramide, F. O., Ibitoye, S. A., Oladele, I. O. and Borode, J. O. Effects of Carburization Time and Temperature on the Mechanical Properties of Carburized Mild Steel Using Activated Carbon as Carburizer. Materials Research, 12(4), 2009, pp.483–487. https://doi.org/10.1590/S1516-14392009000400018 [14] Priyadarshini, S., Sharma, T. and Arora, G. Effect of Post Carburizing Treatment on Hardness of Low Carbon Steel. International Journal of Advanced Mechanical Engineering, 4(7), 2014, pp. 763–766. Retrieved from http://www.ripublication.com [15] Saini, B. S. and Gupta, V. K. Fatigue Crack Propagation Behaviour of Some Low Alloy Steels in Case Carburised Condition, 3(September), 2012, pp. 330–339. https://doi.org/10.1504/IJMATEI.2012.049270. [16] M. Cai, H., Ding, J., Zhang, L. And Li, Z. Tang, Deformation and fracture characteristics of ferrite/bainite dual-phase steels, Chinese Journal of Materials Research, 5(2), 2009, pp. 673–683. [17] Setiyawan, A. Effect of Carburizing Process on Physical and Mechanical Properties of Blower Dinamo Ampere Blade on Diesel Car, Thesis, Surakarta: Universitas Muhammadiyah Surakarta, 2003. [18] Liu, C. C., Xu, X. J. and Liu, Z. A. FEM Modeling Of Quenching and Tempering and Its Application in Industrial Engineering, International Journal of Finite Elements in Analysis and Design, 39, 2003, pp. 1053-1070. [19] Xu, D.H. and Kuang, Z. B. A Study on The Distribution of Residual Stress Due To Surface Induction Hardening, International Journal of Engineering Materials and Technology, 118, 1996, pp. 571-575. [20] Ennis, P J. and Lupton, D F. The relationship between carburization and ductility loss, Behaviour of High Temperature Alloys in Aggressive Environments, In: Proceedings ofthe International Conference; 1979, Oct. 15-18, London: The Metals Society; 1980, pp. 979-991. [21] Ward D.M., Influence of carburization on the properties of furnace tube alloys, In: Corrosion and Mechanical Strength at High Temperatures Guttmann, V. and Merz, M. (Eds.), Applied Science Publishers, Ltd., London, 1981, pp. 71-83 Study on Mechanical Properties of Pack Carburizing SS400 Steel with Energizer Pomacea Canalikulata Lamarck Shell Powder Sujita Darmo, Rudy Soenoko, Eko Siswanto and Teguh Dwi Widodo Study on Mechanical Properties of Pack Carburizing SS400 Steel with Energizer Pomacea Canalikulata Lamarck Shell Powder Sujita Darmo, Rudy Soenoko, Eko Siswanto and Teguh Dwi Widodo Study on Mechanical Properties of Pack Carburizing SS400 Steel with Energizer

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