

INVESTIGATION ON TEMPERATURE EFFECT OF CARBURIZED STEEL USING POWDER AND PASTE COMPOUND

Muhammad Hafizuddin Jumadin*, Bulan Abdullah, Muhammad Hussain Ismail, Siti Khadijah Alias, Samsiah Ahmad

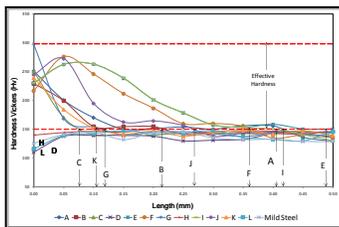
Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor Malaysia

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*Corresponding author
muh.hafizuddin@yahoo.com

Graphical abstract



Abstract

Carburizing temperature plays an important role for carbon to disperse deep inside the steel surface. Pack carburizing requires higher temperatures to disperse the carbon compared to gas carburizing and bed carburizing. Introduction of different carburizing media (powder and paste compound) might contribute toward the effectiveness of this process. This paper investigates on the effect of different temperature (700°C-1000°C) using powder and paste compound towards the carbon dispersion in carburized steel. Mild steel was used as the substrate material which has been carburized using the powder and paste compound with a ratio of 1:1 and 3:1, respectively. The temperatures has been set at 700°C, 800°C, 900°C and 1000°C for 8 hours. The effects of carbon dispersion layers were observed by the increasing depth of case hardness. The chemical composition analysis was done by using a spectrometer to see the increment of carbon content of the carburized steel. Results showed that the paste compound at a temperature of 1000°C significantly influenced the hardness properties and carbon composition as compared to the carburized steel obtained from the powder compound.

Keywords: Pack carburizing, paste, temperature effect, mild steel, carbon dispersion, diffusion layer

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1.0 INTRODUCTION

Carburization promotes a case hardening process which increases the carbon content inside the surface of the steels. By providing enough carbon, the hardness properties will increase and contribute to the life cycle of machinery product (gear, shaft and beam). Carburizing is a surface hardening technique that added carbon by introducing the steel with carbon rich environment and heated to austenization temperature for few hour [1]. At this austenization temperature, a thermodynamically stable phase acquire where the carbon become soluble with steel [2,3]. Steel need to achieve certain temperature for ferrite to become austenite depending on the carbon contain of steels. Austenite is crystalline structures which allow carbon to diffuse into the iron. The temperature can be determined in the Fe-C phase

diagram. During the process, microstructure will transform from ferrite to austenite. Austenite will allow the carbon diffuse inside the material and become hard. A. Fatai Alumni studied on the effect of different temperature on the tensile stress of carburized steel [4]. There has been a rapid development of pack carburizing from time to time. Pack carburizing process has been discovered in early century where people used charcoal and bone as the media [1]. By using the solid (powder) compound, the parts that need to carburize were packed along in the box made of steel and heated until red heat temperature for several hours [3]. The surface of the steel will picked up nitrogen and carbon. Due to the soaking time, the carbon will disperse inside the surface of the steel. Pack carburizing indicates much less impact to the environment compared to other types of carburizing [3, 5]. The ability to reduce the time taken and

temperature are crucial in order to increase its case hardening effectiveness. Even though pack carburizing is cheaper and easy to manage, but it required longer soaking time and higher temperature. Therefore the pack carburizing is less famous compared to the other type of carburizing. Nevertheless, few researchers, showed their interest to study the mechanism of pack carburizing with different compound [5, 6, 7]. The potential of pack carburizing can be enhance and research shows that the improvements of carburizing medium bring a good contribution on increasing carbon diffusion to carburized steel. A paste medium for pack carburizing process has increased the prospective in steel heat treatment fields [5, 6, 7]. S. K. Alias et al., and D.C Lou et al. have discovered that paste acted as self-protected during the carburizing process which increases the case depth of carbon diffusion compare to conventional powder carburizing [5, 6]. A deeper study has been done to see the effectiveness of paste carburizing media towards the dispersion of the carbon. Dolgmair stated that using different media demonstrate different properties due to the medium characteristic and carbon concentration [8]. This study focused on the effect of different temperature towards the hardness properties, and carbon dispersion of carburized steel by using different medium. At the end of this study, the results were compared between powder and paste carburizing to

see the effectiveness of carbon dispersion and the optimum temperature for carburized steel.

2.0 EXPERIMENTAL PROCEDURE

2.1 Sample Preparation

Mild steel, ASTM 850 Grade 70 steel was used. Samples were prepared with dimensions of 2 mm width x 2 mm length x 2 mm height. Carburizing compounds were prepared with 3 differents compound, (2 paste compound and 1 powder compound). Paste compound were prepared according to weight ratio of distilled water to powder (activated charcoal powder was mixed with Sodium Carbonate (Na_2CO_3) and Barium Chloride (BaClO_3)), a paste 1:1 compound and paste 3:1 compound. Powder compound has been as a benchmark for representing the conventional carburizing process.

2.2 Heat Treatment Process

Samples were placed in a steel box and covered with the carburizing compound. Steel box then heated in the furnace according to set temperature, 700°C, 800°C, 900°C and 1000°C for 8 hours. Steel box was taken out from the furnace and left to cool in room temperature. Table 1 shows the parameter used for this research to carburized the sample.

Table 1 Carburizing parameter with different type of compound and temperature variables

Sample	Carburizing Parameters (Compound/Temperature)	Sample	Carburizing Parameters (Compound/Temperature)
A	Powder/1000°C	G	Paste 1:1/800°C
B	Powder/900°C	H	Paste 1:1/700°C
C	Powder/800°C	I	Paste 3:1/1000°C
D	Powder/700°C	J	Paste 3:1/900°C
E	Paste 1:1/1000°C	K	Paste 3:1/800°C
F	Paste 1:1/900°C	L	Paste 3:1/700°C

2.3 Experiment Preparation

The samples were slice into cross section, hot mounted and grind (with sand paper from grit 120 to grit 1000). Samples were polished with diamond paste (size 9, 5, 3 and 1 micron). The samples were etched with Nital 5% . Samples were placed under Mitutoyo Hardness Vickers tester, and indented using 1kg load. The value were taken from the surface of the steels through its interior. A minimum of 3 times indention with different places was taken in order to get average data for the hardness. Sample for

spectrometer were prepared by cleaning up the carbon scale of the carburized sample. Then the samples were sparked with Optical Emission Spectrometer (OBE-5500) to get the chemical composition data of carburized steel. Minimum of three sparked were taken at different area of the sample to get the average composition of each carburized sample.

3.0 RESULTS AND DISCUSSION

3.1 Hardness

Figure 1 shows the hardness profile of 13 samples. Hardness level of metal was influenced by the carbon content of its composition [9]. Increasing the carbon content will increase the hardness. Hardness of untreated samples indicates hardness value of 118 Hv to 150 Hv along the cross-section. The value of 150 Hv became indicator for this study as effective hardness to compare the change of hardness in carburized sample. The thickest case depth was sample E, (>0.5 mm) followed by sample I (0.43 mm) and sample A (0.41 mm). Sample F showed that it has 0.37 mm case depth, followed by sample J (0.25 mm) and sample B (0.15 mm). Sample G, Sample K and sample C were carried out with temperature 800°C. Each of their case depth has a range value between 0.05 mm to 0.1 mm. Sample H, sample L and sample D applied 700°C and results of the case depth failed since the hardness value were not exceeding 150 Hv.

Sample E has highest hardness value among all, 300 Hv. Sample E was carburized with paste 3:1

compound at 1000°C. Paste 1:1 compound produced large amounts of carbon monoxide (CO) during the chemical reaction between H₂O with the activated carbon because paste reduced the activation energy of the carburizing medium compared with the powder compound [6]. Liquid reduced the activation energy for carbon powder and create more CO for carburizing adsorption [6, 8]. At temperatures between 200-500°C during the carburizing process, paste were dry and became a self protecting layer which increase higher chance of carbon diffusion [4]. It is important for substrate to be exposed with as much rich carbon environment so high carbon solubility and high carbon concentration can disperse into steel. Paste also offers a protective layer for carburized sample which trapped the carbon from escaping to somewhere else [4, 5].

As the temperature rises, the study showed the hardness length and the case depth of the sample also increased. This shows that the carbon was induced deeper inside the steel surface. During the carburization process, austenization phase was required so that the carbon were soluble to the steel.

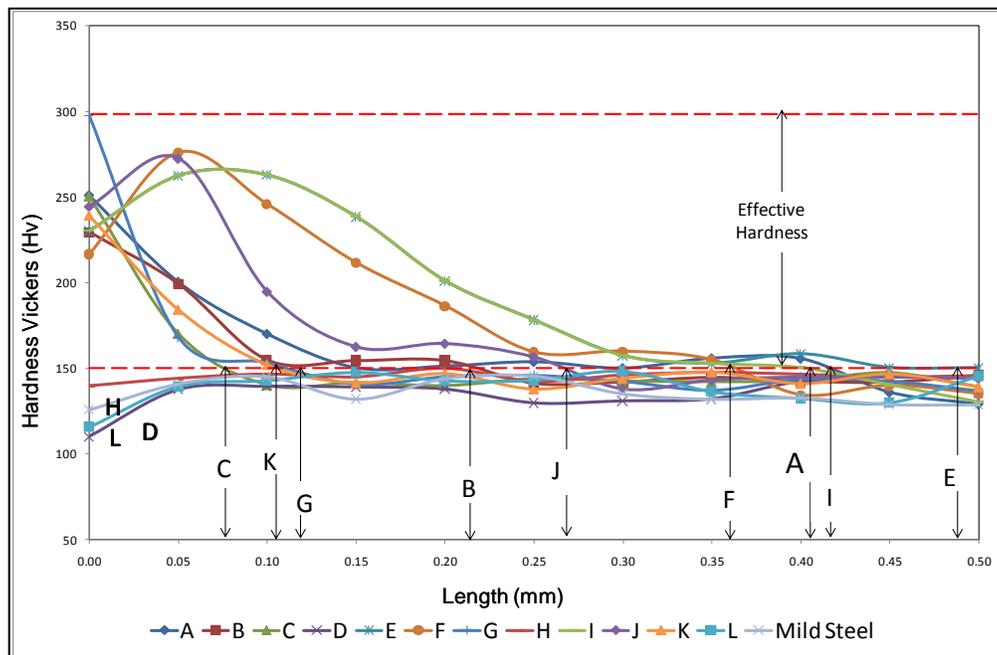


Figure 1 Hardness profile for carburized sample with different temperature

In order to achieve that phase, the steel was heated to 750°C and above. As the temperature increase, the activation energy of the carbon was increasing so thus the mild steel (Fe) molecules [4]. Distance of iron molecules in the steel were stretchable and it allows the C to induce inside the steel which was less concentrated compared to the outside [5]. Sample I has less carbon dispersion compared to sample E. Sample I has less distilled

water dilution compared to sample E, which mean sample I has more concentration. Carburizing process needs additional time for powder compound in order to dissolve the carbon powder particle and diffuse into the steel surface compared to carbon paste particle. Sample A dispersed carbon much less because it has more fine particles which requires higher temperature. Temperature of 700°C was below the austenization temperature. It required

more energy for the transformation of centered cubic body for metal to become carbon solubility [1-3]. It transforms the ferrite microstructure to austenite. During the carburization process, the austenite which is soluble in carbon will allow carbon to diffuse and become a pearlite microstructure.

3.2 Spectrometer

Spectrometer analysis was conducted in order to observe the carbon content and other chemical composition of the carburized steel. The hardness level of metal can be influenced by its carbon composition (wt% C) [9]. Increasing the carbon content will increase the hardness of the material. So, from the chemical composition obtained with the spectrometer, the carbon composition will be investigated and compare for this study. Figure 2 shows a graph of carbon composition for carburized samples. Untreated sample had 0.135 wt% C. Sample E indicates highest carbon content among all. It increased to 0.472 % wt C. Second highest were sample I with 0.3722 wt% C, then, followed with

sample A with 0.318 wt% C. These 3 samples (sample E, sample I and sample A) have among highest carbon content in this study because they applied highest temperature parameter, 1000°C. The temperature allowed large amounts of ferrite to transform to austenite, (much more soluble microstructure to carbon). [10] Samples that used 900°C and 800°C ranked next highest wt% C position in the graph features in Figure 2. These samples, B, H and L, have carbon percentage above 0.15 wt% C. Results showed that carburizing process were delayed at this temperature and it indicated that the sample with paste compound have higher dispersion than powder compound. Sample D, H and L have the lowest carbon content. They have the same level of carbon content as untreated sample. It showed samples that were heated below 750°C were not exceeding the austenization phase and had not enough solubility for carbon to diffuse in this temperature. The results concluded that this temperature is not fit for carburizing heat treatment [10].

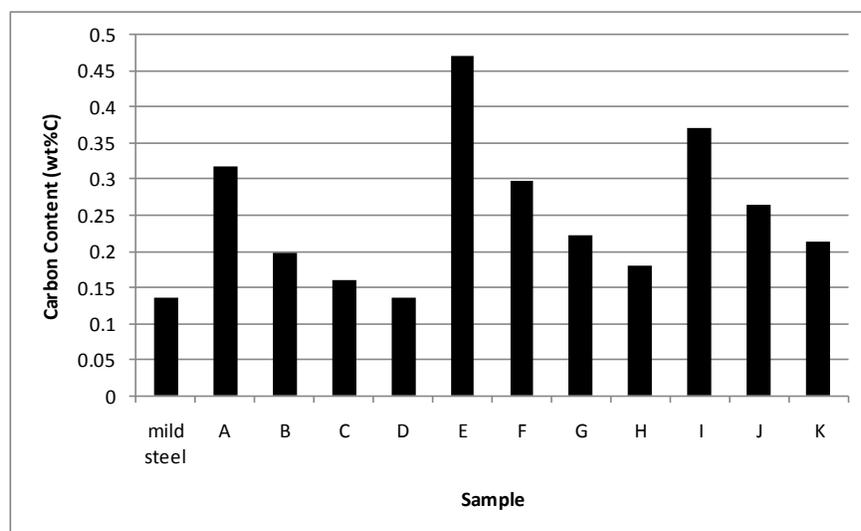


Figure 2 Carbon content of carburized samples

4.0 CONCLUSION

- Higher temperature has higher carbon dispersion compared to lower temperature. Temperature below austenization phase is not suitable for the process even carburized with paste compound. Hardness profile proof that higher temperature diffuses more carbon composition and deeper length compared to low temperature.
- It was conferred that the type of carburizing compounds influenced the dispersion layer formation and the hardness through the carburized steels. Paste compound with high

concentration will generate the great dispersion of carbon compared to powder.

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References

- [1] Rajan, T. V., Sharma, C. P. and Sharma, A. 2004. *Heat Treatment Principle and Techniques*. S.1. : Prentice Hall of India.
- [2] Kalpajian, S. and Schmid, S. R. 2010. *Manufacturing Engineering and Technology, Sixth Edition In SI Units*. Pearson Publishing.
- [3] Sharma, C. P. 2004. *Engineering Materials: Properties and Application of Metal and Alloys*. PHI Learning Private Limited.
- [4] Aramide, F. O., Ibitoye, S. A., Oladele, I. O. and Borode, J. O. 2009. Effects of Carburization Time and Temperature on the Mechanical Properties of Carburized Mild Steel, Using Activated Carbon as Carburizer. *Material Research*. 12(4): 482-487.
- [5] Lou, D. C., Solberg, J. K. and Børvik, T. 2009. Surface Strengthening Using a Self-Protective Diffusion Paste and its Application for Ballistic Protection of Steel Plates. *Materials and Design*. (30): 3525-3536.
- [6] Alias, S. K., Abdullah, B., Abdullah, A. H., Latip, S. A., Wahab, N. A. and Ghani, M. A. A. 2013. The Effect of Carburizing Medium on Carbon Dispersion Layer of ASTM A516 steel. *Applied Mechanics and Materials*. 393: 525-530.
- [7] Dragomir, D., Cojocaru, M. O. and Dumitru, N. 2013. The Effect of Change of Carburizing Media Nature on Growth Kinetics of Layer. *U.P.B. Sci Bull, Series B*. 75: 181-192.
- [8] Druga, D. Dragomir and Leontin. 2001. The Advantages of Fluidized Bed Carburizing. *Material Science and Engineering*. A302: 115-119.
- [9] Elzanaty, H. 2014. The Effect of Carburization on Hardness and Wear Properties of the Mild Steel Samples. *International Journal of Innovation and Applied Studies*. 6: 995-1001.
- [10] Kulka, M., Pertek, A. and Makuch, N. 2011. The Importance of Carbon Concentration-Depth Profile Beneath Iron Borides for Low-Cycle Fatigue Strength. *Materials Science and Engineering*. 528(A) : 8641-8650.