The Effect of Quenching Media on Hardness and Carbon Content in Carburized Steel

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Abstract. The influence of quenching media after carburizing process was investigated and analysed. Austenitic stainless steel AISI 316L was used as specimen. The carburizing process was carried out at 900°C for 7 hours followed by quenching process. Water, SAE 40 oil, and air were used as the quenching media. Arc Spectrometry was used for analysis of carbon content at surface specimen. The result shows that carbon content increased from 0.031at% (untreated specimen) up to 0.627 at%, 0.117 at%, and 0.106 at% (carburized specimen with water, oil, and air quenching). The significant increase in carbon content lead to increasing hardness of specimens from 101 Hv (untreatment) to over 364 Hv, 277 Hv, and 269 Hv (carburized specimen with water, oil, and air quenching). Microstructure of carburized specimen was investigated by optical microscopy.

1. Introduction
Austenitic stainless steel (ASS) type AISI 316L plays important role in industries sectors. It was widely applied in medical, manufacture, structural and another industrial sector. It has high corrosion resistance and biocompatibility according to its chromium content [1-3]. However, ASS has low mechanical properties such as low hardness and wear resistant. This has implications for the limited use associated with friction. Surface engineering has been developed to improve mechanical properties [4-5].

One surface engineering uses the diffusion method. Diffusion method involves heat treatment. Diffusion method can be done by carburizing. Carburizing is the process of adding carbon elements to low carbon steel by diffusion to increase carbon content on steel surfaces [6]. An easy type of carburizing is solid carburizing or pack carburizing. The solid carburizing involves specimens heated in a closed box containing carburizing media, which are carbon-rich materials such as charcoal. [7].

Carburizing is followed by quenching, which is cooling the specimens just after the specimen has undergone a heating process. Quenching can be done with various media such as air, SAE 40 oil, and water. Quenching media is a fluid that has a different cooling rate. Hardness of steel depends on the carbon content and the rate of cooling or quenching [8]. Therefore, it is necessary to do carburizing followed by various quenching media in order to find out the hard properties of AISI 316L stainless steel. In this present study, we investigate the microstructure, carbon content and hardness of carburized steels followed by quenching. Characteristics of specimens analyse by Vickers microhardness test, optical microscopy and spectrometer arc.
2. Materials and Method
Solid carburizing process was performed at 900°C for 7 hours. Coconut shell charcoal was used as carbon source and AISI 316L steel as substrate. The carburizing process followed by quenching processes with various media, such as: air, SAE 40 oil, and water. The characterization of carburized specimens was conducted through the Spectrometer Arc Metorex 8000 to determine the carbon content. Hardness testing of specimens was carried out with Micro Vickers Hardness Tester TH712. Microstructure was investigated by BX51 Optical Microscope.

3. Results and Discussion
Hardness data of the specimens are shown in Figure 1. The hardness value of carburized specimens increases significantly compared to untreated specimen. This is due to the insertion of carbon atoms resulting from carburizing at grain boundaries which can inhibit atomic dislocation. Atomic dislocations can be inhibited because carbon atoms on the grain boundary stop slips from one item to another. When the dislocation movement is closed, the specimen becomes harder. Increased hardness is proportional to the increase in carbon content tested with the Spectrometer Arc. The hardness value of the specimen from the smallest to the largest uses quenching air media at 269.47 HV, SAE 40 oil at 276.57 HV, and water at 363.67 HV.

![Figure 1. Surface hardness of AISI 316L specimens](image)

The microstructure of carburizing specimens followed by quenching with air media, SAE 40 oil, and water has a phase change to untreated specimens, namely from austenite to ferrite as in Figure 2. The ferrite phase is formed because of the reaction of Fe-C eutectoid during the cooling process, so that austenite decomposes to form ferrite and carbide. Carbide is formed from the interstitial of carbon at the grain boundary because of the carburizing process.
The results of testing the carbon content with an Arc Spectrometer is presented in Figure 3. Carbon content increase significantly in carburized specimens followed by quenching with various medium. The increase in carbon content proves the diffusion of carbon atoms during the carburizing process.

**Figure 2.** Microstructure of untreated (a), carburized and quenched by air (b), oil (c), and water (d)

**Figure 3.** Carbon content at surface of untreated and carburized specimens
The increase in carbon content of quenching media depends on the nature of the fluid that is able to cool the specimen. The rapid rate of cooling can cause atoms to not escape from the specimen, so that carbon atoms are trapped into the surface of the specimen. The water cooling rate is faster than SAE 40 oil, and the cooling rate of SAE oil 40 is faster than air. Therefore, at the same heating temperature, the highest increase in carbon content uses quenching water, SAE 40 oil, and the lowest increase in carbon content using air quenching media. The carbon content values of specimens with quenching water media were 0.627%, SAE 40 oil was 0.117%, and air was 0.106%.

4. Conclusion

The microstructure of carburizing specimens at 900°C on air quenching media, SAE 40 oil, and the water has the dominant phase change from austenite to ferrite with carbide. The highest hardness and carbon content in carburizing specimens at 900°C was obtained using the water quenching.

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References

[1] I. Boromei, L. Ceschini, A. Marconi, and C. Martini. 2013. Wear 302 899.
[2] A.M. Oliviera, R.M.M. Riofano, L.C. Casteletti, G.F. Tremiliosi, and C.A.S. Bento. 2003. Revista Brasileira de Aplicações de vacuo 22 (2) 63.
[3] P. Ahmadi and T. Czerwiec. 2008. IUST Int. J. Eng. Sci. 19 51.
[4] Istriyogh, I.N.G Wardana, and D.J Santijojo. 2014. App. Mech. Mater. 493 755.
[5] A. Kosmac. 2015. Mater. Appl. Ser. 20 1.
[6] K. Budinski. 1983. Engineers Material Properties and Selection. McMillan Publishing Company, Ohio, USA.
[7] Istriyogh, M.A. Pamungkas, G. Saroja, M. Gufron, and A.M. Juwono. 2018. IOP Conf. Series: Mater. Sci. Eng. 299 012048.
[8] R. Adawiyah, Murdijani, and Ahmad Hendrawan. 2014. J. Poros Teknik 6 (2) 88.