Characteristic of Low Temperature Carburized Austenitic Stainless Steel

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Abstract. Low temperature carburizing process has been carried out on austenitic stainless steel (ASS) type AISI 316L, that contain chromium in above 12 at%. Therefore, conventional heat treatment processes that are usually carried out at high temperatures are not applicable. The sensitization process due to chromium migration from the grain boundary will lead to stress corrosion crack and decrease the corrosion resistance of the steel. In this study, the carburizing process was carried out at low temperatures below 500 ° C. Surface morphology and mechanical properties of carburized specimens were investigated using optical microscopy, non destructive profilometer, and Vicker microhardness. The surface roughness analysis show the carburising process improves the roughness of ASS surface. This improvement is due to the adsorption of carbon atoms on the surface of the specimen. Likewise, the hardness test results indicate the carburising process increases the hardness of ASS.

1. Introduction
Austenitic stainless steel has has a good resistance to corrosion, so, is widely used in the manufacturing industries and structural sectors. However, its mechanical properties, especially its hardness and resistance to wear are relatively low, hence, limiting its applications, mainly those related to friction [1-2]. Modifications of its surface, based on the diffusion process, have been developed to increase the hardness and resistance to wear of ASS, such as through nitriding and carburising [3-4]. Interstitial solid solution hardening is a technique that is considered effective without causing sensitization and stress corrosion cracking [5-6].

The solubility of carbon and nitrogen in Fe-C alloy, in the phase diagram is very low, and increases with increasing temperature. However, for the case of stainless austenitic, with a relatively high content of chromium will mobile at high temperatures, and tends to form precipitates. The presence of precipitates, either chromium precipitates, or iron precipitates, indeed increases the hardness of the steel. However, it decreases the corrosion resistance. Therefore, the process of interstitial diffusion at low temperature is an option treatment for modifying the surface of the stainless steel austenitic. Low temperature carburizing (LTC) is the process of improving the hardness of steel by increasing carbon content in the parent material. A specimen of steel resulted from carburising process is being harder on its surface. This will also increase corrosion resistance and resilience of fatigue [7]. Meanwhile, from

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the investigation of the process of low temperature plasma carburizing for steel of AISI316, it was concluded that the hardness obtained from carburising process was due to the presence of supersaturated carbons [8].

Coconut shells and rice husks are a lot of waste around us. coconut shell and rice husk has a high enough carbon content that has the potential as a carbon sumbrant in the process of carburising.In present study, we investigate carburized austenitic stainless steels, produced by low temperature solid carburizing (LTC) with coconut chacoar and rice husk caccao as carbon source. Vickers microhardness test, optical microscopy, and non-destructive profilomètre are utilized to investigate the characteristic of carburized specimens.

2. Experiment
Austenitic stainless steel type AISI 316L was used as substrate. The specimen dimension is 2 x 2 cm$^2$ and 0.1 cm in thickness, respectively. The specimens were degreased to remove surface contaminant. Ultrasonic cleaner system with alkali solution was used for cleaning and degreasing.

Coconut shell and rice husk after cleaning and dried, then carbonized at 600°C. then powdered and sieved using mesh 50 meshes. After that, specimens were dried. Finally, both specimens and carbon source were packed by aluminium foil, then inserted stainless steel carburizing pack, and heated in high temperature furnace. Carburizing was performed at 400°C for 8 hours.

Furthermore, specimen analyzed by Vickers microhardness testing tools. Asahi vickers microhardnes operated with load 50 g. Olympus LOM utilized to analysis of specimen microstructure. Surface roughness evaluated by a Hommelwerke T2000 stylus profilomètre.

3. Results and Discussion
Microstructure of untreated AISI 316L austenitic stainless steel and carburized specimens are shown in figure.2. Untreated specimens are dominated by ferrite phase that appear as white grains. The size of the ferrite phase grains is unchanged on LTC carburized specimens. This behavior indicates there is no grain growth and grain coalescence. The carbon distribution on the surface of the carburized specimen shows that the carburized specimen with coconut shell charcoal carbon source is distributed more homogenly than carburized specimens with rice husk carbon source, as can be seen in fig. 2b and 2c. This is related to the characteristics of the two carbon sources. Coconut shell charcoal has a
65.6% carbon content while rice husk charcoal has a bonded carbon content of 41.3%. In addition, rice husk has enough high silica content. This will affect the properties of adsorption and diffusion of carbon into steel matrix.

The adsorbed carbon on the surface increases the surface roughness of the specimens as can be seen in Table 1. The average roughness values of the specimens increased from 0.26 μm (untreated specimens) up to 0.46 μm and 0.31 μm for carburized specimens with coconut shell charcoal and charcoal rice husk, respectively.

The carbon diffusion into the steel matrix is the diffusion of interstitial [9], where the carbon will occupy the interstitial site position. Furthermore, the diffused carbon has an opportunity to become a solid solution or to precipitate with Fe / Cr. It depends on the condition of the carburizing process. Generally, in LTC, carbon diffuse to form a solid solution. At low temperature, both Fe and Cr are not mobile so no precipitate formation occurs.

![Pearlite, Ferrite](image1)

![Pearlite, Carbon](image2)

![Pearlite, Carbon](image3)

**Figure 2.** Microstructure of untreated AISI 316L (a), carburized (LTC) AISI 316L at 400 °C for 8h with coconut charcoal (b), and carburized (LTC) AISI 316L at 400 °C for 8h with rice-husk charcoal (c).
The presence of carbon in the steel matrix will affect steel hardness. Figure 3 shows the results of measuring the hardness of specimens before and after carburizing process. Hardness of carburized specimens increased up from 26% to 40% compared to untreated specimens.

| Treatment condition               | Ra (micrometre) |
|-----------------------------------|-----------------|
| Untreated                         | 0.26            |
| LTC coconut charcoal              | 0.46            |
| LTC rice-husk charcoal            | 0.34            |

![Figure 3. Surface hardness of AISI 316L specimens](image)

4. **Conclusion**

Low temperature carburizing (LTC) on austenitic stainless steel does not affect grain size which indicates no grain growth and grain coalescence. The adsorbed carbon on the specimen surface increased roughness and hardness of the specimen compared to untreated specimen.

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