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CARBON SIZE AND TEMPERATURE EFFECTS TO JIS S45C CARBURIZED STEEL

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Abstract

Wear on a metal can be naturally found in components that operate in a friction environment, such as in a transmission system. However, it can be a substantial problem when the wear rate is not within the permitted limit. Surface hardening is a popular way to improve surface wear resistance for metals with various parameters that can be controlled during the process. In this study, pack carburizing was conducted for plain carbon steel JIS S45C. The carburizing process is conducted on the steel by varying the carbon size and temperature during the heating process. The carbon size consisted of mesh sizes of 5 and 15. The heating process was conducted for 2 hours at 800°C and 900°C. The carbon media and catalyst used in this study were coconut charcoal and calcium carbonate (CaCO3). In addition, the hardness Vickers test was conducted to evaluate the surface hardness. It was found that the hardness of Vickers increased with an increase in heating temperature and mesh size of carbon.

Keywords: *Carbon Size, CaCO3, JIS S45C, Wear Rate.*

1. INTRODUCTION

The naming of the JIS S45C steel alloy refers to the standards set by Japanese industrial standards where the steel is categorized as plain carbon steel with a carbon content of 0.45% wt. [1-2]. If it is compared to the American Iron and Steel Standard (AISI) standard, JIS S45C is equivalent to AISI 1045. JIS S45C is mainly used for the transmission components such as shafts, gears, clutch pulleys, etc. [2]. Due to its working environment, JIS S45C steel must withstand a certain level of wear. Therefore, an effort is needed to develop the wear resistance of this steel alloy. Case hardening by applying particular heat treatment conditions on the metal surface has been applied for particular alloy steel for increasing the wear resistance. It has been reported that a significant hardness has been increased by applying case hardening. Several case hardening methods were divided based on the media used for surface coating, for example, carburizing, nitriding, etc. [3-6].

Pack carburizing is an economical and effective method that can increase the hardness of a metal surface. However, not all types of steel can be applied to the pack carburizing process [5-8]. For example, steel alloys with low carbon composition make the pack carburizing process less effective because carbon is insufficient to form a martensitic structure [5-6]. Conversely, the pack carburizing process on high carbon steel can cause the steel to become very brittle and break easily due to the amount of martensite structure that is too large [8]. Based on some literature, most types of medium steel are ideal for heat treatment

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because of the effectiveness of atomic diffusion time on the amount of carbon present during the heating and cooling processes [1-2, 8-14]. Furthermore, the carbon size can also determine the effectiveness of surface hardening for the steel [12].

Negara et al. conducted a pack carburizing study on low-carbon steel types using carbon media derived from bamboo charcoal and a catalyst called barium carbonate ($BaCO_3$) [6]. The composition of carbon and catalyst used in the furnace is 80% and 20%, respectively. The hot temperature for the pack carburizing process is 950 ºC, with a holding time of approximately 4 hours. In addition, the Vickers hardness testing process is carried out to determine the hardness trend formed in the steel. Significant increase in steel hardness and strength on the steel surface after the pack carburizing process.

On the other hand, the toughness value has decreased. Sujita conducted research related to the surface hardening process using the pack carburizing method on AISI 1018 steel [5]. The carbon media comes from finished wood charcoal, and the catalyst media comes from golden snail shell powder. The carburizing process was carried out at several temperature variations with two holding times of 90 and 150 minutes. From the results of the Vickers hardness test, it was found that the increase in hardness occurred in a composition of 80% wood charcoal and 20% golden snail shell powder. This increase can also be seen from the dominance of carbide on the steel surface.

In this study, an investigation regarding the effect of the pack carburizing process on the surface hardness level of JIS S45C carbon steel was investigated. Parameters of time and carbon mesh size were applied to determine the level of hardness on the steel surface. The hardness was examined by the Vickers hardness method following the ASTM E384. In addition, the microstructure of the hardened surface was observed by using an optical microscope.

2. METHODS

The pack carburizing process was carried out in a fully packed condition. The steel metal was placed in a box (packing) made of steel, and then a carbon medium and a catalyst were placed around the box. For the optimal carburization process, the sidelines of the box were sealed entirely to prevent the carbon escaped. Finally, the box was put into the furnace to be heated at a specific carburizing for 2 hours and under two different temperatures of 800 and 900 ºC. After the heating process, the carburized specimen was quenched in the water. A typical carburization method in this study can be schematically illustrated in Figure 1.

Prior carburizing process, the specimen of JIS S45C was normalized. After the carburizing process, the Vickers hardness method examined the hardness by following ASTM E384 [15]. The parameters developed in the carburizing process were the heating temperature of 800 and 900 ºC, and the carbon mesh size at 5 and 10 mesh. The carbon media comes from coconut charcoal, and the catalyst is $CaCO_3$. Microstructure observations on the carburized surface were carried out using an optical microscope to determine the physical impact of the carburizing process.

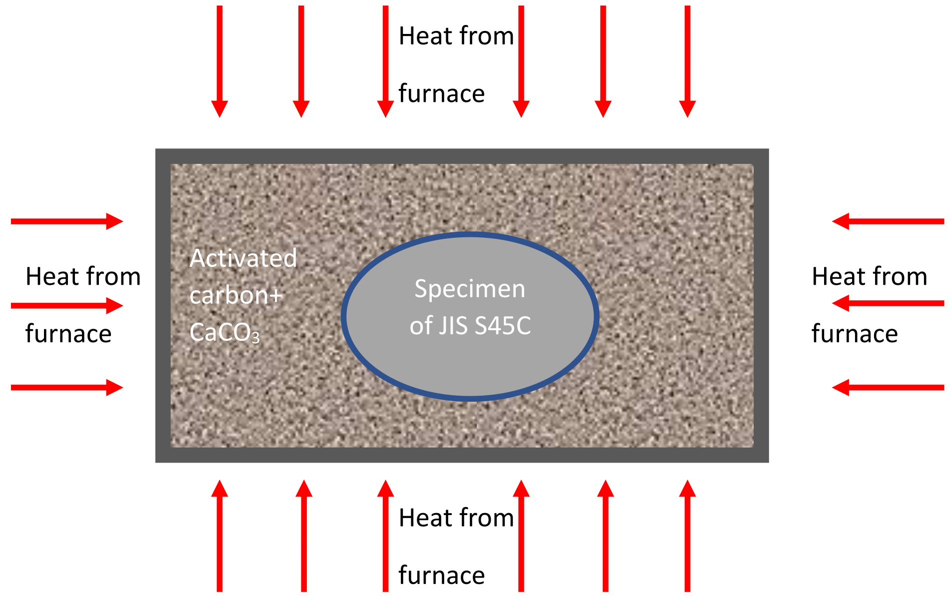

Figure 1. Schematic illustration of carburizing process for JIS S45C.

3. RESULTS AND DISCUSSIONS

Figure 2 shows the hardness Vickers result for JIS S45C as-received (normalized) and carburized steel. The as-received has the lowest hardness of 193 HV since a typical normalized process will recover the residual stress and increase the toughness. Typical normalized steel has a ferrite and pearlite structure, as shown in Figure 3. Ferrite is known to have a characteristic of ductility, while pearlite is a compound of carbon and ferrite, increasing steel's strength. Since the normalized steel is dominated by ferrite, the hardness will be the lowest compared to the other treated steel. After the normalizing process, all steel performs a significant hardness on its surface after being carburized. Higher heating temperatures and mesh carbon size will increase the surface hardness. The highest hardness is obtained at 850 HV when the heating temperature was applied at 900 ^{o}C with a mesh carbon size of 15. The higher carbon mesh means a smaller size of carbon.

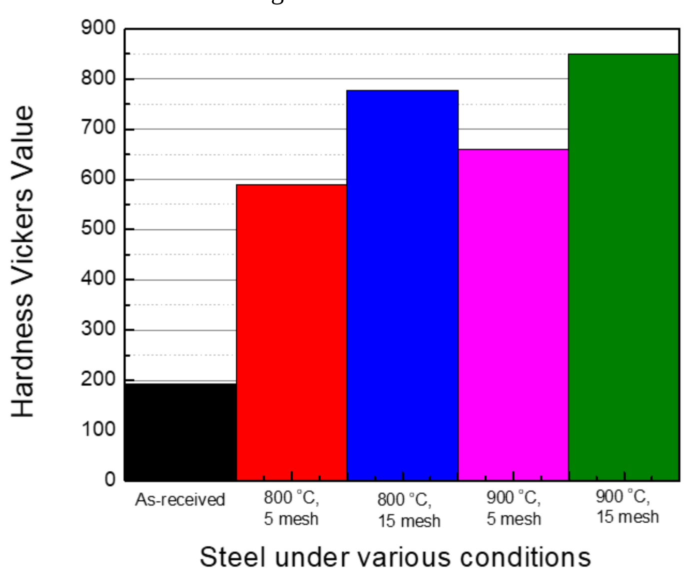

Figure 2. Vickers hardness test result for JIS S45C.

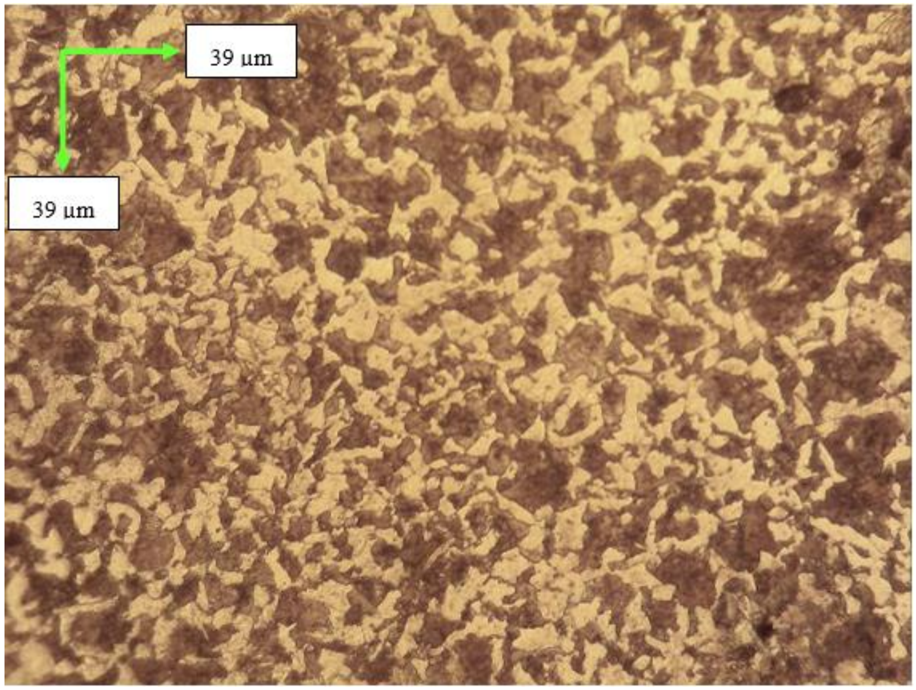

Figure 3. The microstructure for as-received (normalized) JIS S45C.

The heating temperature significantly affects the hardness of JIS S45C since temperature influences the solubility rate of carbon on the steel. The applied temperature in this study was applied an austenized temperature. Hence when the cooling time is applied rapidly, the hardest martensite structure is developed. Figure 2 shows that the level of austenite temperature gives an increase in hardness. The martensite structure will be more massive in quantity since the rate of carbon solubility becomes higher, as shown in Figures 4 and 5. The prediction method for calculating the quantity of microstructural components in steel cooled from the austenitizing temperature using the regression method has been reported by Trzaska [17]. By following this method, the martensite quantity for JIS S45C at 800 ^{o}C with five mesh sizes the quantity around 70%, and the for JIS S45C at 900 ^{o}C with 15 mesh has the quantity around 80%. Furthermore, the hardness increase can also be produced due to high dislocation density at higher austenite temperatures. Abidah et al. emphasized that the dislocation density due to carbon solubility will be generated with higher and extended holding temperatures [4].

From Figure 2, the hardness increases with the larger mesh or, the smaller carbon size. Silberberg has reported that the chemical reaction rate will increase when the carbon element becomes smaller [16]. The smaller size of carbon caused the comparison of the area with volume to become more significant. With the large surface area, the contact surface between carbon and another element will be generated in large quantities. This large contact surface will increase the hardness. According to Adly et al., the smaller size of carbon can generate a small gap between carbon grains [9]. The small gap will have a small size of oxygen that obstruct the production of CO_2. With the extra quantity of CO_2, the carburization process rate will vary. Leman et al. reported that there was an optimum carbon grain size to produce the CO_2. The optimum carbon grain size will increase the hardness. This preliminary experimental result shows that the highest hardness is obtained at the carbon grain size of 15 mesh.

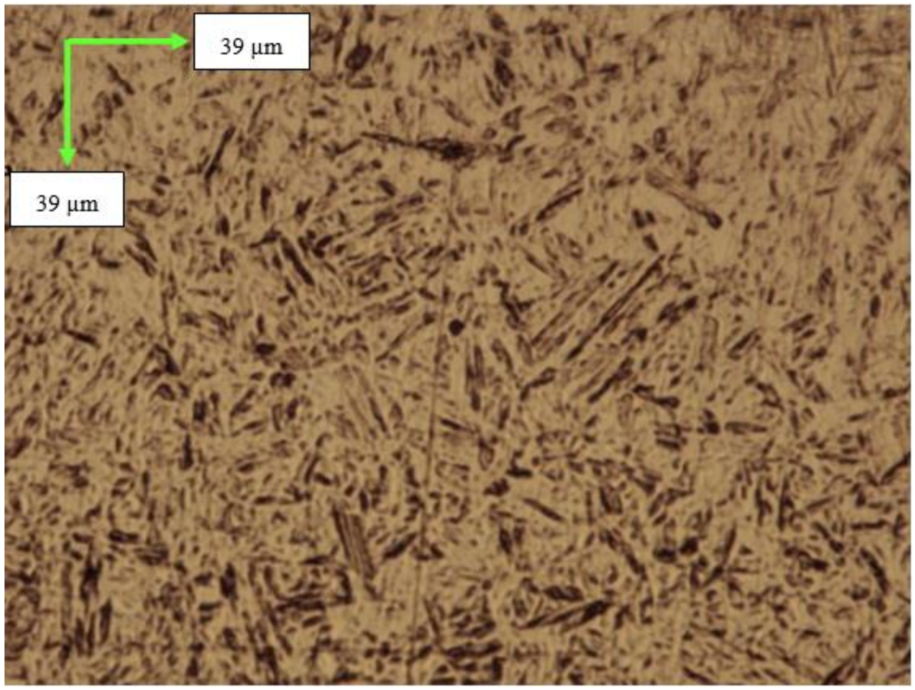

Figure 4. The microstructure for JIS S45C at 800 oC with 5 mesh size.

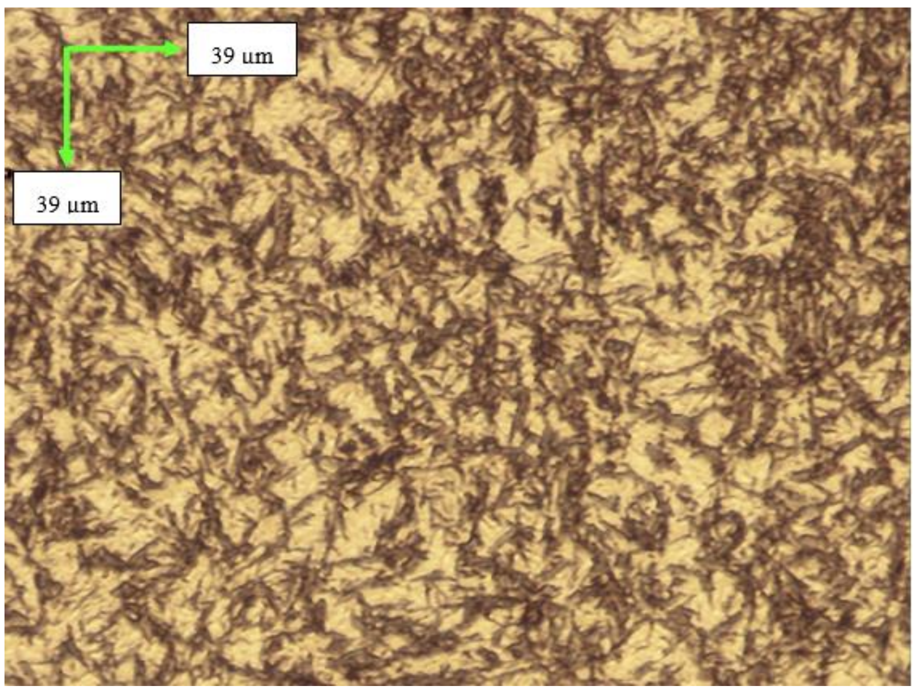

Figure 5. The microstructure for JIS S45C at 900 oC with 15 mesh size.

4. CONCLUSIONS

This preliminary study shows that the heating temperature and carbon grain size influenced the hardness and microstructure of JIS S45C steel. The higher heating temperature increased the hardness, and the smaller carbon grain size increased the hardness of the steel. However, further experiments are required to determine an optimum carbon grain size.

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