PAPER 183 – EFFECT OF CARBURIZATION TIME AND TEMPERATURE ON HARDNESS PROPERTIES OF MILD STEEL

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ABSTRACT

The service conditions of automobile steel components such as crankshaft, gears and cams to mention but a few require high hardness to enable them satisfy their design requirements when in operation. In this study, hardness properties of carburized mild steel rods were investigated to determine the impact of carburization parameters on the steel. Mild steel rods were carburized using coconut charcoal powder and periwinkle shell powder. The samples were carburized at temperatures of 850°C, 900°C and 950°C respectively; and were soaked for 1 hour, followed by water quenching. Leeb hardness tester was used to determine the hardness values of the carburized mild steel rods. The highest hardness value of 774 HL was obtained with carburization parameters of 436.80g of coconut shell charcoal, 150.23g of periwinkle shell powder, carburization temperature of 900^{0}C and at a soaking time of 109 minutes. It was established that locally sourced materials (Carburized coconut shell and periwinkle shell) could serve as effective carburization ingredients for mild steel due to the improvement in hardness of the mild steel.

1. INTRODUCTION

Carburization is a surface-hardening heat treatment process which is carried out to enhance the performance of parts such as bearings and gears in order to improve the hardness of the surface to resist wear and the toughness of the interior to resist impact during service (Binzhou et al., 2018). This is due to the loads arising from vibration, speed of rotation and the nature of applied stresses they experience in service (Salawu et al., 2019). Case hardening has also been described as the process of hardening the surface of steel by infusing elements into the metal surface forming a hard, wear resistance skin but preserving a tough and ductile interior (*Metals Handbook, 1981)*. The various case hardening processes are carburizing, cyaniding, citrating, carbonitriding and flame/Induction hardening. The focus of this study is carburization which improves specific mechanical properties of low carbon steel by the addition of carbon materials at elevated temperature (Orisanmi et al., 2017). Carburization has proved very effective in improving mechanical properties of mild steel and increase in thickness of surface layers (Afolalu et al., 2018). Several materials have been used in the literature for carburization process. These include egg shell, periwinkle shell, coconut shell, palm kernel shell, cow bones and horns. The processing time and bonding efficiency of these materials are subjects for discussion with respect to different steels (Sanni and Fayomi 2018). The effect of soaking time on mechanical properties of mild steel subjected to packed carburization at temperatures of 850°C, 900°C and 950°C using pulverized bone as the carburizer was investigated in (Aramide et al., 2010). After quenching in oil and tempered at 250°C, better mechanical properties were revealed for samples that were soaked at the carburizing temperature of 900°C for 15 minutes and 30 minutes respectively.

A study carried out using combined coconut shell charcoal and periwinkle shell as carburization materials was reported in (Agbo et al., 2017) where carburizing time, case depth and carburizing materials (75% weight of pulverized coconut shell charcoal and 25% weight of pulverized periwinkle shell) were used for the carburization of 18 samples of 0.08% carbon content mild steel rods of length 55 mm and 14 mm diameter. The carburization temperature was maintained at 900°C and it was found that case depth and hardness values increased with increase in different carburizing time (1, 2 and 3 hours). Periwinkle shell was also found to be a good cost effective

carburizer when used with $BaCO_3$ as energizer in the improvement of hardness and impact strength of low carbon steel with 0.182% carbon (Adzor et al., 2016).

The use of wood charcoal as carburizer and $BaCO_3$as energizer in the carburization of mild steel with carbon content of 0.17% at different temperatures (750-950°C) and different times (1-3 hours) revealed that the hardness and tensile properties of the material were improved (Obolo et al., 2017). Pulverized wood charcoal (70% weight) and (30% weight) egg shell also proved useful in the carburization of grey cast iron at 700°C, 800 °C and 900°C respectively (Salawu et al., 2019). Increase in hardness of the samples was revealed with respect to carbon concentration at different carburizing temperatures.

Efforts have been made to investigate the suitability of locally sourced organic carburizers and energizers as replacement to commercially available chemical ones. For example in (Ihom & Azoro, 2019; Ihom et al., 2012; Ihom et al., 2013), the effects of charcoal carburizer and periwinkle shells, cow bones, banana peels (Ihom and Azoro 2019); and rice husk, sugar cane, melon shell, egg shell energizers (Salawu et al., 2019; Umunakwe et al., 2017) on case depth and hardness of mild steel enhanced the case depth and hardness of the material compared to use of chemical energizers ($BaCO_3$, Na_2CO_3, $CaCO_3$). The suitability of palm kernel shell and coconut shell mixture was investigated for the carburization of low carbon steel (0.16% C), energized with 20% by weight of $CaCO_3$ (Umunakwe et al., 2017). The hardness and tensile properties were enhanced by an order of magnitude using the mixed carburizers compared to the use of the carburizers individually. Charcoal carburizer and mixture of cow bone and coconut shell using different carburizing temperatures (900°C, 950°C and 1000°C) were found to improve the hardness property of low carbon steel (Miswanto et al., 2019).

In a recent study, the tensile and fatigue strengths of low carbon steel were improved by carburization using coconut shell charcoal as carburizer (Syahid et al., 2020). At pack carburizing temperature of 900°C, the tensile strength increased from 356.66 N/mm^2 to 541.15 N/mm^2 while the fatigue strength increased from 161 MPa to 232 MPa. These results have shown the reliability of coconut shell charcoal as carburizer.In this study, mild steel was carburized using coconut shell charcoal and periwinkle shell powder as carburizing ingredients in order to investigate the suitability of these materials for carburization of mild steel and their effect on hardness properties of the steel.

2. THEORETICAL ANALYSIS

During carburization, the residual air in the carburizing box combines with carbon to produce CO gas. Carbon monoxide gas which is unstable at the process temperature decomposes as it contacts the iron surface. The process is governed by the following reactions (*Metals Handbook, 1981)*:

$$2C + O_2 = 2CO$$

$$2CO = C + CO_2$$

The atomic carbon enters the steel through the following reactions:

$$Fe + 2CO = Fe(C) + CO_2$$

$$C + CO_2 = 2CO$$

Where Fe(C) is carbon dissolved in austenite. Carbon is absorbed by the steel surface, and subsequently diffuses towards the centre of steel sample. CO_2 thus formed reacts with the carbon (C) of the carburizing medium to produce CO, and thus, the cycle of the reaction continues. Charcoal is the basic source of carbon during solid carburization (*Metals Handbook, 1981)*. As entrapped air inside the box may be less to produce enough CO_2 particularly in the beginning of the carburization, it is thus common practice to add energizer usually $BaCO_3$ which decomposes during the heating up period as:

$$BaCO_3 = BaO + CO_2$$

The CO_2 formed then reacts with the carbon of the carburizer to produce CO gas. Thus, $BaCO_3$ makes CO_2 available at an early stage of carburization and hence it is called energizer. The case depth increases with rise in carburization temperature and time.

3. MATERIALS AND METHODS

The materials used for this study include mild steel, coconut shell and periwinkle shell; details can be found in (Adedipe et al., 2023a; Adedipe et al., 2023b). The as-received mild steel rods were carburized using different weights of coconut shell charcoal and pulverized periwinkle shell powder at temperatures of 850, 900 and 950oC respectively; and at different times (1 to 3 hours). The equipment used are muffle furnace (Model: HSX-2-6-13), ultrasonic sieve shaker (Model: DYS-1000), purposed developed carbonization chamber, grinding machine (Model: TW-IP-12), Ball mill (Model: XMQ 240 X 30), digital weighing balance (Model: I-JA503) and Leeb hardness tester. The equipment are located at Mechanical Engineering Department, Federal University of