Effect of different carburizing media on the case depth and mechanical properties of 1030 steel components

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ABSTRACT: Machine components are prone to wear during their service lives. This is a serious menace in engineering because of the consequent failure of the component and eventual economic loss. This study has examined the causes, and analyzed the media which enables the carbon mass that is responsible for the hardness and the case-depth to be transported into the surface of steel. A 12 sample 1030 steel carburized component was prepared for micro-examination by mounting, grinding, polishing and etching. Solid and Liquid Carburizers were used to effectively determine their performance. The mechanical properties and the case-depth variation at different temperatures in solid carburizing were compared with the liquid carburizer. The Volutish appearance on the case revealed high case-depth with retrogressive increase toward the core due to martensite formation. While, Pk, recorded highest tensile strength of 610.6 N/mm² compared to WC, BC, and Ce-80B with a respective 570.1N/mm², 4452 N/mm² and 410.3 N/mm². This will hopefully can be a substitute to the existing carburizers as studied to satisfy the local content demand.

Nomenclature: HRC – Rockwell Hardness; C7 -Case-Depth; WC-Wood Charcoal; PK-Palm Kernel; BCh-Bone Charcoal; Ce-80B- Ce- Constant 80B

Keyword: Carburizing media; mechanical properties; case-depth variation.

INTRODUCTION

Carburizing is a heat treatment process in which iron or steel is heated in the presence of another material (but below the metal’s melting point) which liberates carbon as it decomposes. The outer surface or case will have higher carbon content than the original material. When the iron or steel is cooled rapidly by quenching, the higher carbon content on the outer surface becomes hard, while the core remains soft and tough (Robert et al., 1994, Adegbola, 2004). This manufacturing process is characterized by low-carbon work pieces; work pieces are in contact with a high-carbon gas, liquid or solid; it produces a hard work piece surface; work piece cores largely retain their toughness and ductility; and it produces case hardness depths of up to 0.25 inches (6.4 mm) (Oberg et al., 1989).

Surface deterioration in metal parts is usually dangerous. It causes failure and surface treatment such as case hardening and thermo chemical processing are widely used in the industry to increase the useful life of the components in aerospace, automobile, industrial machines and defence industries. In particular the surface engineering treatments will produce extensive re-arrangements of atoms in metals and alloys resulting in surface hardness. Production of effective case depth requires the use of proper and optimized processes variables (Agraval 1989; ASTM 1999; ASTM 2004; Flowes and Mendoza, 1970, Johnson et al., 2005, Skewman, 1989). The response of particular steel to carburizing is dependent on the diffusion of carbon into the steel; the depth of penetration is controlled by temperature and time. The most typical carburizing temperature varies between 800°C to 950°C, although lower temperatures may be used to reduce distortion or improve control of the case depth tolerance. The disadvantage of

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reducing temperature is that the time necessary to achieve the specified case is increased. In all cases, the carbon diffused into the steel is provided by a carbon rich gaseous environment. Early carburization used a direct application of charcoal packed onto the metal (initially referred to as case hardening or Kolsterising), but modern techniques apply carbon-bearing gases or plasmas (such as carbon dioxide or methane) (Oberg et al., 1989).

Some methods of carburizing had been used by metallurgists in the past to improve the surface condition of materials (ferrous alloy) but had some limitations amongst which are, uncontrollable heating, inappropriate furnace, determination of carbon profile, inability to determine the effect of carburizing media on the mechanical properties of carburized steel material, abilities to determine the percentage carbon concentration on the case-depth of the carburized steel materials (Kal et al., 2005, Rajan et al., 1998, Rasheed 2004). This formed the basis of investigating the effects of different carburizing atmospheres, temperatures, and time as the process variables on the case-depth and the mechanical properties of 1030 steels, which found a wide application in rollers, heavy duty industrial gearing, and mill gears. Automobile parts such as crankshaft, pinions, bearings which also require high wear resistance, and fatigue strength are normally carburized (Aramide et al., 2009).

**MATERIALS AND METHODOLOGY**

**Materials**

1030 Steel samples were used in this work. Carburizing Media used are Wood Charcoal (WCh), Palm Kernel (PK), Bone Charcoal (BCh), and Liquid Carburizer (Ce80B). Rockwell hardness tester, grinding and polishing facilities, Mounting Press Machine as well as metallurgical microscope were used.

**Methodology**

An AISI 1030 Steel Sample of 0.30% Carbon was used in this work. Thirteen samples of 1030 steel were prepared, 12 were carburized and the remaining one is reserved as a control sample. Carburizing media were ground into powdery form and mixed in appropriate proportion with binder and energizer (Sodium Carbonate). A local material (honey) was adopted as a binder. While, Ce Control and covering foam were also blended together in a simple and accurate proportion before transforming into liquid form to obtain a liquid carburizer.

The 12 samples of 1030 steel were preheated in the preheating furnace at a temperature of 400°C for one hour. Three samples were austenitized separately in each medium at temperature ranging from 800°C---950°C for a period of say three hours (1-3hrs)

The samples were quenched in Salt bath at 180°C for 5 minutes before the samples were rinsed in hot water at 90°C in order to remove any salt particle that might have cleaved to the surface. Samples were later rinsed in cold water. Hardness and case depth values were obtained to determine the level of hardening and carbon penetration (Adegbola 2004, ASTM, 2004). This is achieved by using diamond indenter on a Rockwell Hardness tester. This machine provides a faster means of reading without conversion.

The samples were later tempered at 200°C for 1 hour. This was aimed at relieving induced stresses in the components. The samples were finally rust-proof in anti-corrosion fluid before viewing under the metallurgical microscope to obtain the microstructure using a magnification of x 500.
RESULTS

3.1 Micro structural Examination

Fig1: 1030 Steel carburized using PK X500 mag

Fig2: 1030 steel carburized using BCh X500mag

Fig3: 1030 Steel carburized using WCh X500 mag

Fig4: 1030 Steel carburized using Ce-80B X500mag

Fig 5: Variation of Case-Depth (mm) at different Carburizing Temperature °C and time (hour) using B Ch

Fig 6: Variation of Case-Depth (mm) at different Carburizing Temperature °C and time (hr) using W Ch
Fig. 7: Variation of Case-Depth (mm) at different Carburizing Temperature °C and time (hr using PK)

Fig. 8: Variation of Case-Depth (mm) at different Carburizing Temperature °C and time (hour using Cc 80B)

Fig. 9: Stress (N/mm²) against the Strain For WC @ 900°c for

Fig. 10: Stress (N/mm²) against the Strain @ 900°C for BC in 3Hours

Fig. 11: Stress (N/mm²) against the strain at 900°C for PK in 3Hours
From Figs 1 to 4, the microstructures revealed that, the hardness reduces progressively from the surface inwards until it reaches the soft core. This necessitated the caution for not grinding the parts excessively, otherwise the resulting surface hardness and strength will be significantly diminished. However, hardness values in solid carburizing are high compared with the liquid carburizer. This is evident in the microstructures on the case. The Volutish appearance on the case revealed high case-depth with retrogressive increase toward the core due to martensite formation.

In figs 5-8, it could be observed that, the case-depth values are directly proportional to the carburizing temperature in a particular period. This is due to the fact that, the diffusion process is temperature and time dependent. However, the variation in Fig.8 is rather different from its peers. This is largely due to the acicular martensite that developed after quenching and tempered at 200°C for Ce-80B (Ross, 1995). This gave coarse needles of martensite which though is hard, but brittle. Figs.9-14, depict the effect on the mechanical properties vis-à-vis, the yield strength, ultimate tensile strength, and the fracture strength revealed that the tensile strength of 610.6 N/
mm²) for the PK is the highest compared to WCh, BCh and Ce-80B which respectively gave 570.1, 445.2, and 410.3 (N/mm²) ultimate tensile strength. In other words with PK as a carburizer, will enable the Carburized parts to be tough, that is, hard case and soft core having been tempered to 200°C for 1 hour. This is further established from the strain imposed on the material when Ce-80B is used. PK and Ce-80B would allow a strain of 0.15 but with PK capable of higher strength of 0.15/610.6 N/mm² compared to Ce-80B of 0.15/410.3 N/mm² tensile strength / ductility ratio. Interestingly, the summary of the performance is depicted in Bar chart (Figs 13 and 14), where PK recorded the highest value of Case-depth of 1.06mm, and 610.6N/mm² with large percent elongation This comparatively shows the relative ease with which carbon diffuses into the metal surface.

CONCLUSION

Case-Hardening treatments offer a means of enhancing the strength and wear properties of parts made from relatively-inexpensive easily worked materials. Generally, the process is applied to near finished components; the processes impart a high-hardness wear-resistant surface which, with sufficient depth, can also improve fatigue strength. This formed the basis behind case-depth evaluation. In addition, with the urge to add local content to our technology; it is hoped that Pk can be a substitute for the usual carburizers that have long been in the market.

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