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# Case hardening of mild steel using cowbone as energiser

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**ABSTRACT**

In this study, various carburizing compounds were used to pack carburised mild steel. Various weight percentages of cow bone were used as energizer in the carburizing compounds. The experiment was carried out using a muffle furnace at 900°C for 8 h. Hardness tests were taken using Vickers micro-hardness tester. The result showed that 60 wt% charcoal / 40 wt% cowbone had the best result with an effective case depth of 2.32 mm produced on the case of the carburized steel. The work showed that cowbone can be used as energizer in pack carburization of mild steel. The hardness profile plot of the 60 wt% charcoal / 40% cowbone carburized mild steel was also higher than the other compositions.

**Keywords:** Cowbone, energizer, case hardening, wear resistance, carbonates.

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## INTRODUCTION

Pack carburization or solid carburization uses solid carburizing material as the carbonaceous source. Commercial pack carburization utilizes energizers in the case hardening of mild steel. Different types of energizers are used together with carbonaceous materials to increase the carbon potential of carburizing materials. The commonly used energizers are $BaCO_3$, $Na_2CO_3$, and $CaCO_3$. Over the years, the efficacy of different energisers has been tested. In a work carried out by Okongwu in 1989, he assessed the efficacy of some naturally occurring mineral carbonates as energizers in pack carburization, the objective of the research work was to reduce cost and pollution problem associated with the use of chemically pure or commercial carbonates of calcium, sodium, and barium. The researcher observed that reasonable case depths were obtained with the naturally occurring mineral carbonates, when compared with the commercial carbonates. In the work, he concluded that it was possible to substitute the commercial carbonates with the naturally occurring mineral carbonates (Okongwu, 1989). Ihom et al. in 2013 carried out a research on the use of waste egg shells as energizers in the case hardening of mild steel the result was impressive as he observed a case depth of 0.71 mm after pack carburizing for 3 h (Ihom et al., 2013). Aramide et al. in 2010 used bones for the pack carburization of mild steel. The operation was carried out at temperatures of 850, 900, 950°C and soaking time of 15 and 30 min. Despite the short interval of soaking time, he had impressive result with improvement in the case depth and other mechanical properties of the mild steel (Aramide et al., 2010). This can be linked to the fact that bones contain both calcium carbonate and carbonaceous material. A typical bone mineral composition is as presented in Table 1.

The composition shown in Table 1 explains why bone alone was used as a carburizing material by Aramide et al. (2010). The organic component serves as the carbonaceous material while the carbonate in the inorganic component serve as energizer. As observed by Okongwu, the use of the naturally occurring carbonates reduces cost of buying commercial chemical carbonates and also pollution problems. Cowbones constitute solid waste problem therefore exploring ways of utilizing them is very crucial and good.

The objective of this work is to case harden mild steel using cowbone as energizer. Mild steel finds application in engineering components such as gears, shafts, car bodies, and several other areas and case hardening is normally applied to increase the wear resistance of these components. It gives the component a hard case and a tough core (Ihom et al., 2012).

**Table 1.** Typical bone mineral composition.

| Chemical components | Amount present (%) |
|---|---|
| Organic component | |
| Collagen, muco-polysaccharides, elastin and fat | 30 |
| | |
| Inorganic component | |
| Calcium phosphate (calcium hydroxylapatite) | 38.25 |
| Calcium carbonate and trace ions | 6.75 |
| Water | 25 |

Source: Ihom (1991).

**Table 2.** Mild steel composition used.

| C | Si | Mn | P | S | Cr | Mo | Ni | Sn | Cu | V |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.13 | 0.15 | 0.47 | 0.043 | 0.006 | 0.01 | 0.01 | 0.01 | 0.001 | 0.03 | 0.002 |

**Table 3.** Compounds used for the pack carburizing.

| Compound | Composition |
|---|---|
| A | 100 wt% Charcoal |
| B | 75wt% Charcoal - 25wt% cowbone |
| C | 70 wt% Charcoal - 30 wt% cowbone |
| D | 60 wt% Charcoal - 40 wt% cowbone |

## MATERIALS AND METHODS

### Materials

The materials used for the work included, RST 37 grade steel rods of 16 mm diameter obtained from Delta Steel Company, Aladja, acetone, water, clay, and carburizing compounds of various mixtures. The composition of the steel used is shown in Table 2 and the composition of the carburizing compounds is shown in Table 3.

### *Equipment*

The equipment used were, heat resisting steel pack carburization boxes, a large muffle electric furnace with a temperature sensitivity of ±5°C, lathe machine, hack saw, grinders and polishing disc, and Vickers Microhardness testing Machine model MHT-1 No: 8331 made by Matsuzawa Seiki Co. Ltd. of Japan.

### Methods

### *Material preparation*

The steel samples for carburization were cut from RST 37 grade steel rods of 16 mm diameter. Each sample measured 30 mm in length. These 3 0mm long rods were thoroughly washed in acetone and dried and their faces (ends) coated with ceramic clay. This was done to remove foreign material from the samples to avoid the occurrence of soft spots and to prevent carburization from occurring at the ends.

To make a pack for carburization, a 20 mm thick layer of chosen compound was first poured into the box, and the steel specimens were placed in position inside the box and the box filled up with the compound. The lid was then sealed with clay in order to make the box air tight and eliminate possibility of air ingress during pack carburization process.

### *Pack carburisation process*

A large muffle electric furnace with a temperature sensitivity of ±5°C was used. The temperature distribution in the furnace over the 800 to 1000°C range was first established and it showed the existence of a uniform temperature within the central region of the furnace extending over an area of 320 × 320 mm and up to 150 mm high from the furnace floor. The pack boxes were introduced into the muffle furnace within the uniform temperature zone which had already attained the

**Table 4.** Effective case depths obtained using various carburizing compounds.

| Carburizing compound | | Effective case depth dc (mm) |
|---|---|---|
| **Code** | **Composition** | **8 h of carburization** |
| A | 100 wt % charcoal | 1.56 |
| B | 75 wt % charcoal / 25 wt % cowbone | 1.40 |
| C | 70 wt % charcoal / 30 wt % cowbone | 0.96 |
| D | 60 wt % charcoal / 40 wt % cowbone | 2.32 |

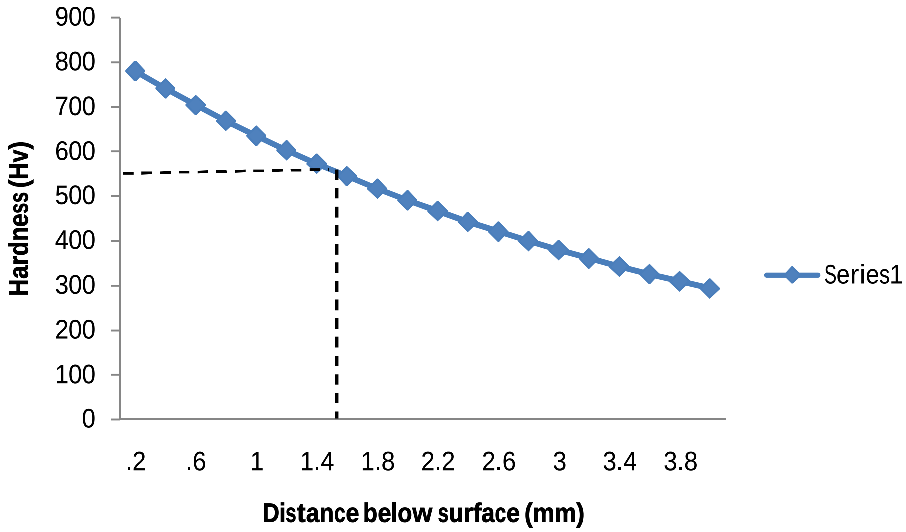


**Figure 1.** Hardness profile of mild steel carburised using 100 wt % charcoal.

carburizing temperature. The heating-up time needed to make up for the sudden temperature drop which followed the introduction of the packs into the furnace was less than 10 min and was therefore negligible compared to the carburizing time. Pack carburization runs with all the carburizing compounds were carried out at 900°C for 8 h. At the end of the carburization time the specimens were taken out and quenched in water. It was then tempered at 150°C for 1 h.

### Hardness testing and effective case depth determination

Steel discs of 10mm thick were cut from the central region of each of the carburized rod specimens and labeled. They were then prepared and polished for hardness measurement on a microhardness indenter. Microhardness measurements on all the specimens were carried out on Vickers Microhardness Testing Machine Model MHT-1 No: 8331 made by Matsuzawa Seiki Co. Ltd., of Japan. The machine had a maximum test load of 1000 gf with a load holding time of 5 to 30 s. Indentations were made starting 0.2 mm from the edge end at an interval of 0.2 mm, to a distance of 4 mm towards the middle and was repeated when specimens were turned at right angles from the first measurement. From the hardness values obtained for each specimen, hardness profiles were plotted and effective case depths at various times were extracted.

## RESULTS AND DISCUSSION

The results of the work are as presented in Table 4 and Figures 1 to 4.

Table 3 shows the chemical composition of the steel used for carburizing. The 0.13% carbon content indicates that it is mild steel (Higgins, 1983). Table 2 shows the various carburizing compounds used for the work. One of the compounds is without energizer and is the control carburizing compound.

Table 4 shows the effective case depths of the carburized mild steel using the various carburizing compounds. 100 wt% charcoal had an effective case depth of 1.56 mm. 75 wt% charcoal / 25 wt% cowbone had an effective case depth of 1.4 mm, 70 wt% charcoal / 30 wt% cowbone had an effective case depth of 0.96 mm and 60 wt% charcoal/ 40 wt% cowbone had an effective case depth of 2.32 mm. The result showed that 60 wt%

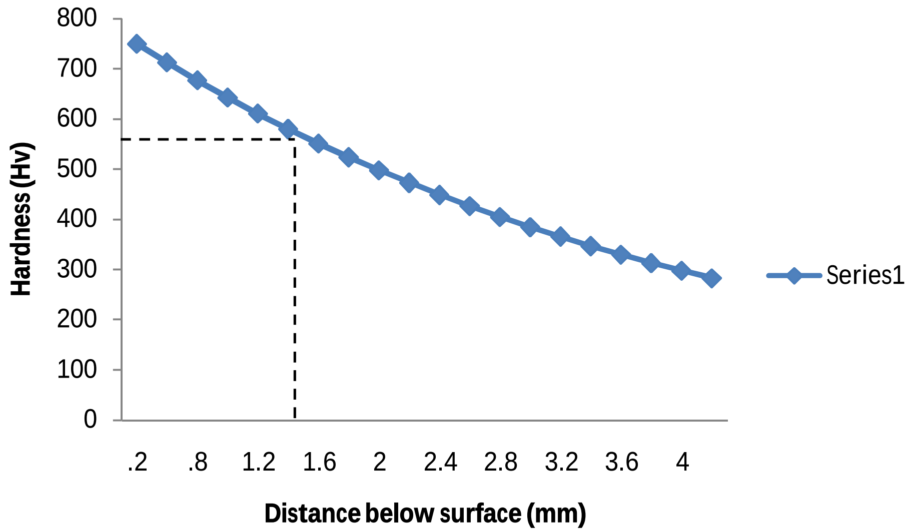


**Figure 2.** Hardness profile of mild steel carburized using 75 wt % charcoal and 25 wt % cowbone.

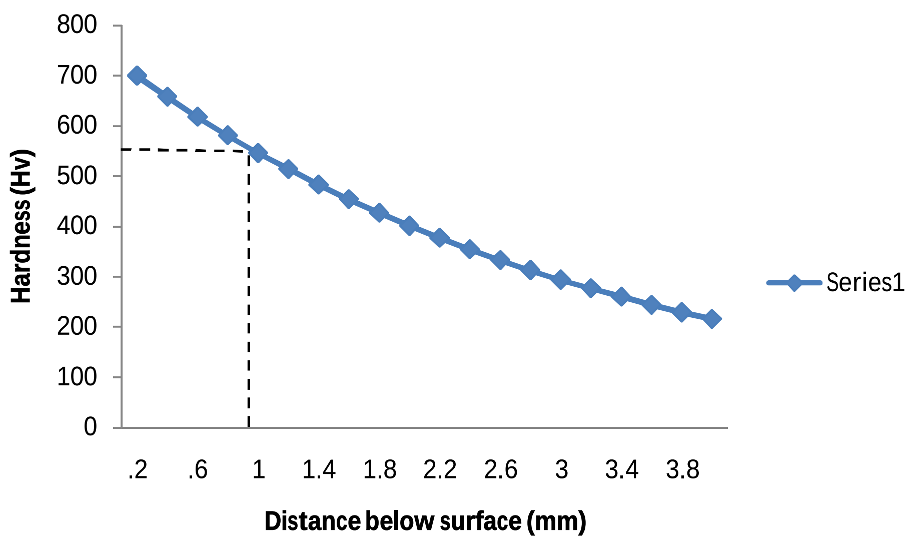


**Figure 3.** Hardness profile of mild steel carburized using 70 wt% charcoal and 30 wt % cowbone.

charcoal / 40 wt% cowbone had the highest effective case depth of all the carburizing compounds used, followed by 100 wt% charcoal. Previous work on the use of cowbone as energizer have shown that the effect of the cowbone on case depth depend on the composition of the carburizing material with the cowbone. Variation of the cowbone (10 to 20 wt %) have yielded effective case depth up to 2.6 mm and average case up to 2.2 (ASM Committee on Gas Carburizing, 1977). Ihom (1991) showed that there is normally a drop in the average case depth, when 25 wt % - 30 wt % cowbone is used with charcoal before subsequent increase produces increase in effective case depth, he explained that physiochemical changes and reaction may be responsible, details is yet to be known.

Several authors have confirmed that cowbones can be used as energisers in pack carburization of steel (Ihom, 1991; Ihom et al., 2012; Higgins, 1983; ASM Committee on Gas Carburizing, 1977; Ihom et al., 2011). It improves the hardness above the value of the hardness obtained when charcoal is used alone (Ihom, 1991; Ihom et al., 2012; Higgins, 1983; ASM Committee on Gas Carburizing, 1977; Ihom et al., 2011). The presence of $CaCO_3$ in the cowbone plays the role of an energizer, as explained earlier in the work under introduction. The $CaCO_3$ on dissociation assists in supplying the nascent

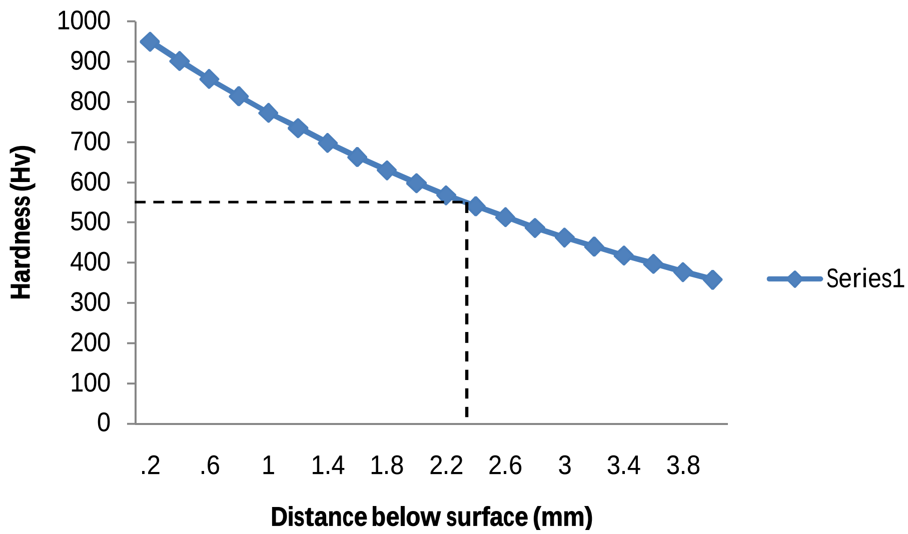


**Figure 4.** Hardness profile of mild steel carburized using 60 wt % charcoal and 40 wt % cowbone.

carbon for the carburization (Okongwu, 1989; Ihom et al., 2013; Aramide et al., 2010; Ihom et al., 2012).

Figures 1 and 4 shows the hardness profiles obtained with the various carburizing materials. It was from these profiles that the effective case depths were extracted. The hardness profile all have the same shape rising on the left and descending on the right indicating that the hardness of the carburized steel specimen decreases as you move towards the core of the steel. This is typical of all carburized steels; a hard case and a soft core (Ihom et al., 2012; Ihom et al., 2012; Shragger, 1961). The plots showed that Figure 1 at 0.2 mm had hardness value of 780 Hv and at 4 mm a hardness value of 294 Hv. Figure 2 at 0.2 mm had hardness value of 750 Hv and at 4 mm a hardness value of 283 Hv. Figure 3 at 0.2 mm had hardness value of 700 Hv and at 4 mm a hardness value of 216 Hv. Figure 4 at 0.2 mm had hardness value of 950 Hv and at 4 mm a hardness value of 358. This profile is higher than the other three profiles. All the hardness values showed a drop in hardness as measurement was taken towards the core of the steel. 60 wt% charcoal/ 40 wt% cowbone had the highest hardness value for both the 0.2 and 4 mm measurement. This is an indication that 40 wt % cowbone is a better amount to use when using cowbone as an energizer. It is better than all the other percentages tried. The value obtained was even higher than that of 100 wt % charcoal; the control carburizing compound.

## Conclusions

From the study, the following conclusions were drawn:

1. Cowbone can be used as energizer in pack carburization.
2. 60 wt% charcoal/ 40 wt% cowbone having given a good result that is better than using charcoal alone is a recommended composition to use.
3. The study showed that at certain percent of cowbone the hardness obtained dropped before it rose again.

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