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Research article

VARIATION OF EFFECTIVE CASE DEPTH WITH HOLDING TIME OF MILD STEEL USING VARIOUS CARBURISING COMPOUNDS

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ABSTRACT

The study ''the variation of effective case depth with holding time of mild steel using various carburizing compounds'' has been carried out. The study was undertaken with pack carburization of mild steel using four different carburizing compounds. The effective case depths were extracted from hardness profiles obtained using Vickers Microhardness Tester Machine. The average case depth was equally determined. The result showed that the carburizing compound with 80% charcoal and 20% cowbone had the highest average case depth of 2.2 mm. The work also clearly showed that the effective case depths were increasing as the holding time of the samples were increased in all the carburizing compounds used. It therefore implies that effective case depth of mild steel during pack carburization is a function of time.

Keywords: Pack carburization, Variation, Effective case depth, Mild steel, Time, and Cowbone.

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1. INTRODUCTION

Engineering materials are evolving on daily basis; however, the usage of these materials is determined by availability, cost, corrosion resistance, wear resistance, durability and other functional requirements [1]. In developing countries like Nigeria, availability is a strong determining factor for usage of materials for engineering purpose. One of the commonly available constructional materials in the developing world is mild steel which is used for various construction purposes. Mild steel is commonly used for machinery construction in the developing world for its availability and cost effectiveness [2]

This engineering material has its limitations particularly as regarding wear resistance, hardness, and strength. Most machines constructed in the developing world using this engineering material do not last long, especially when moving components of these machines like gears, shafts, valves, discs, cams etc which require a tough core and a hard surface are constructed of mild steel without casehardening heat treatment [3]. In several works carried out by one of the authors and other researchers [4-6] it had been pointed out that casehardening of mild steel increases the case hardness of the mild steel resulting in the wear resistance of the mild steel; the thicker the case depth the harder the mild steel. This gives the mild steel material better performance and durability as a moving part than the untreated mild steel component.

The casehardening of a material can be accomplished by subjecting the component to high temperatures in the presence of a carbonaceous material which may be solid, liquid or gaseous. Energizers are often used to speed up the process. Ihom, et al [7] have observed in a previous work that the effective case depth is a good measure of carbon penetration and thus the efficacy of an energizer can be assessed by the depth of case hardening (dc). He further said that by International Standard Organisation , standard ISO 2639-1973 as well as SS 1170 08 Depth Case is defined as the distance from the surface to a plane at which the hardness is 550Hv [1,7].

In another work carried out by Ihom, et al [8] and published in American Journal of Material Science and Engineering, the researcher was able to show that mild steel can be casehardened using carbonaceous material and a mixture of egg shells as energizers with a case depth of 0.71mm obtainable after some hours of carburizing. The author was able to relate diffusion, holding time, and temperature of case hardening to the case depth obtained. In the two works mentioned above the author clearly pointed out that the effective case depth attained during casehardening is related to the holding time of the components in the furnace. Aramide et al [9], in their work also agree with the above position as stated by Ihom.

The objective of this work is to find out the relationship between effective case depth and holding time of mild steel using various carburizing compounds.

2. MATERIALS AND METHOD

2.1 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 1 and the composition of the carburizing compounds is shown in Table 2.

Table 1: 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 2: Compounds used for the Pack Carburising

Compound	Composition
A	100% charcoal
B	90% charcoal – 10% cowbone

C	85% charcoal-15% cowbone
D	80% Charcoal- 20% cowbone

2.12 Equipment

The equipment used were, heat resisting steel pack carburization boxes, a large muffle electric furnace with a temperature sensitivity of ± 5^0C, 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.

2.2 Method

2.21 Material preparation

The steel samples for carburization were cut from RST 37 grade steel rods of 16mm diameter. Each sample measured 30mm in length. These 30mm 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 20mm 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.

2.22 Pack Carburisation Process

A large muffle electric furnace with a temperature sensitivity of ± 5^0C was used. The temperature distribution in the furnace over the $800^oC – 1000^OC$ 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 x 320 mm and up to 150mm high from the furnace floor. The pack boxes were introduced into the muffle furnace within the uniform temperature zone which had already attained the 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 minutes and was therefore negligible compared to the carburizing time. Pack carburization runs with all the carburizing compounds were carried out at 900^oC for 2 hours, 4 hours, 6 hours, and 8 hours. At the end of a carburization time the specimens were taken out and quenched in water. It was then tempered at 150^oC for 1 hour.

2.23 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 1000gf with a load holding time of 5-30 seconds. Indentations were made starting 0.2mm, from the edge end, at an interval of 0.2mm to a distance of 4mm 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.

3. RESULTS AND DISCUSSION

3.1 Results

The results of the work is as contained in Table 3 and Figures 1 -4

Table 3: Average Case Depths Obtained with Different Carburising Compositions of Charcoal-cowbone

Code	Composition	Average Case Depth (mm)
A	100% charcoal	1.14
B	90% charcoal- 10% cowbone	1.34
C	85% charcoal-15% cowbone	1.41
D	80% Charcoal-20%cowbone	2.20

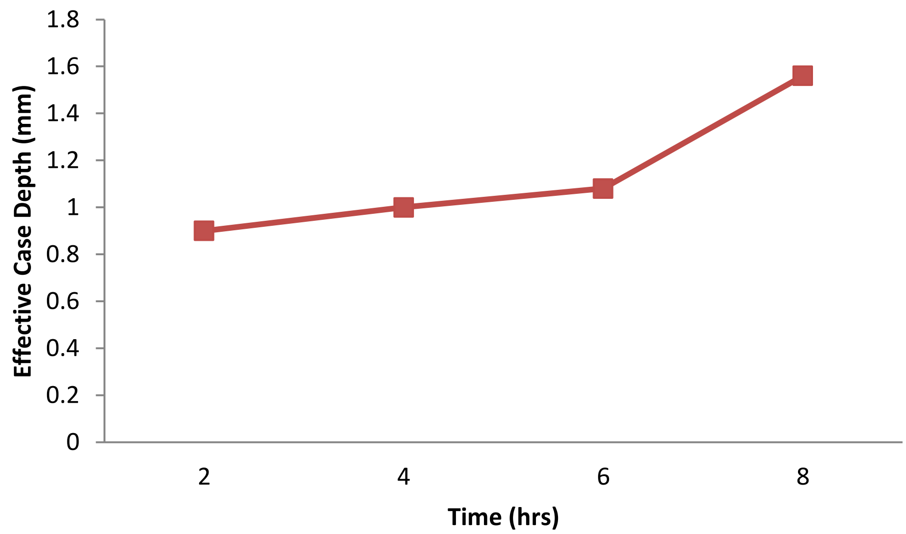

Figure 1: variation of effective case depth of mild steel with time using 100% charcoal

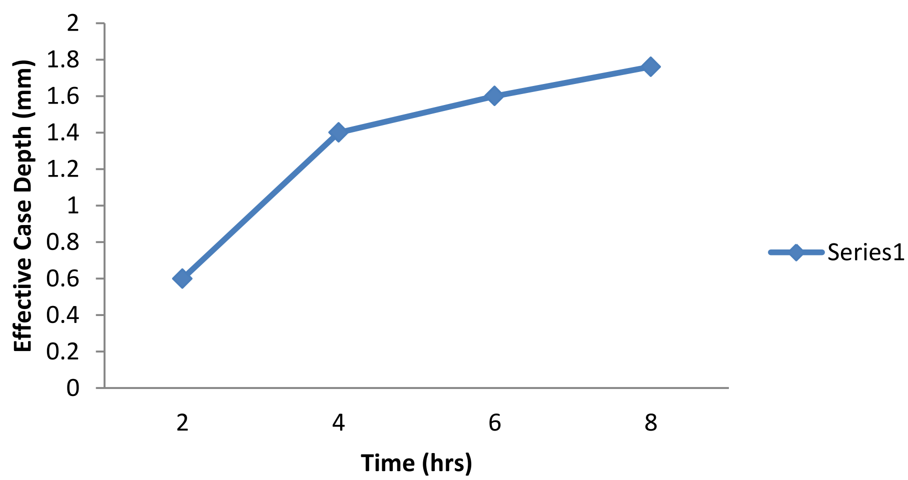

Figure 2: variation of effective case depth of mild steel with time using 90% charcoal/ 10% cowbone

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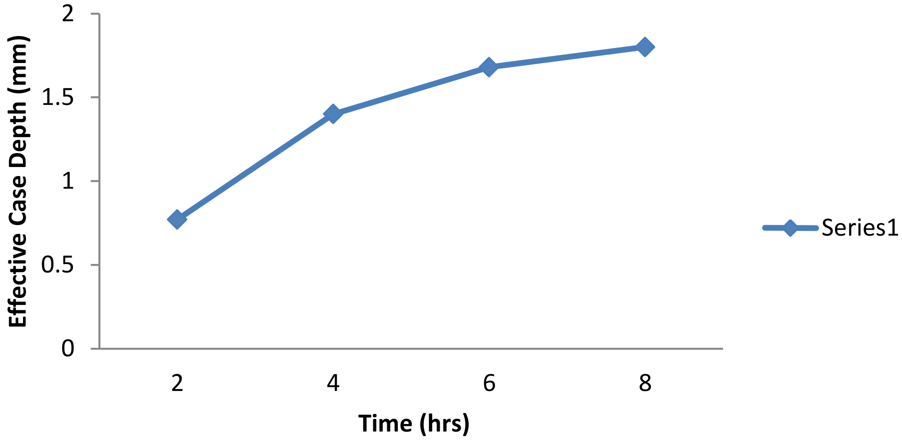

Figure 3: variation of effective case depth of mild steel with time using 85% charcoal /15% cowbone

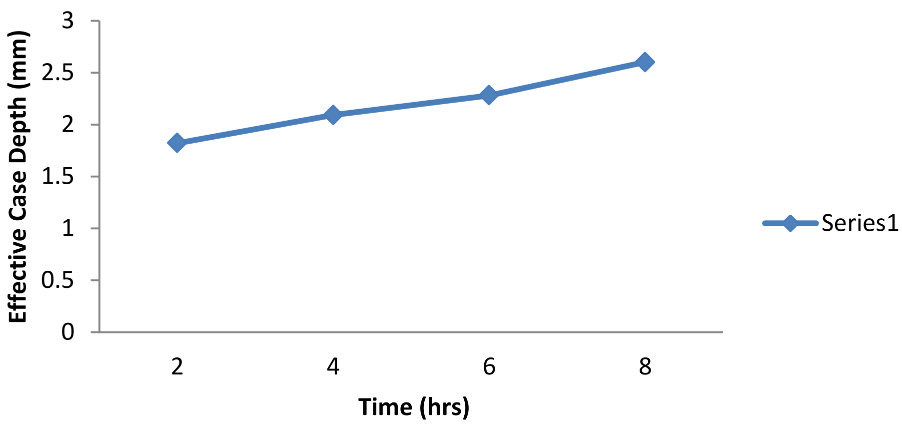

Figure 4: variation of effective case depth of mild steel with time using 80% charcoal / 20% cowbone

3.2 Discussion

Table 3 shows the average case depth obtained with various carburizing compositions. 80% charcoal/ 20% cowbone had the highest average case depth of 2.2 mm. 100% charcoal has an average case depth of 1.14 mm, the overall result however showed that as the cowbone is added to the carburizing compound from 10% to 20% the average case depth showed a gradual increase from 1.14mm to 2.2mm. Ihom [2], in a previous work had explained the increase in the average case depth to be as a result of the cowbone ability to act as an energizer in the carburizing mixture, he further explained that cowbones contain calcium carbonate which is a known energizer in pack carburization. Other researchers have observed the same thing [9-11]. Ihom , et al[8] had observed the same effect when egg shells were used as energizers in place of known energizers like sodium carbonate, calcium carbonate and barium carbonate for health reasons. According to Ihom; these equations are responsible for the increase in the average case depth of the mild steel due to the role of the cowbone as energizers.

$$CaCO_3 \longrightarrow CaO + CO_2 \quad (1)$$

$$CO_2 \longrightarrow 2CO \quad (2)$$

$$2CO \longrightarrow C + CO_2 \quad (3)$$

$$CaO + CO_2 \longrightarrow CaCO_3 \quad (4)$$

The carbonaceous material is the charcoal, the role played by the cowbone can however be seen in equation 1, the calcium carbonate in the bone dissociate to CaO and CO_2, the CO_2 in the presence of small oxygen converts to carbonmonoxide which on dissociation at high temperature on the surface of the mild steel releases the nascent carbon which diffuses into the mild steel. The CaO in the presence of carbondioxide still at high temperature combines to form calcium carbonate and the cycle continues. This phenomenon is illustrated by equations 1-4. This explanation by Ihom explains how the energizer assists the carbonaceous material with the supply of nascent carbon for case hardening [2]. Okongwu [11], however, observed in his work on the efficacy of some energizers for carburization that the role of an energizer during pack carburization is more complex than explained by Ihom, the work could not explain further than Ihom's explaination.

Figure 1 shows the variation of effective case depth with time during case hardening using 100% Charcoal. The curve is seen rising as the carburization time was increased from 2 hours to 8 hours. The effective case depth of 0.9mm was obtained after 2 hours and after carburizing for 8 hours an effective case depth of 1.56mm was obtained. The graph showed that as the carburization time was increasing so also was the effective case depth increasing. This observation agrees with previous works carried out by the authors listed in ref. [8-11].

Figure 2 shows the variation of effective case depth with time during case hardening using 90% charcoal/ 10% cowbone. The curve of the graph is indicating that as the carburization time is increasing, the effective case depth is also increasing. 2 hours of carburization gave an effective case depth of 0.6mm and after 8 hours of carburization an effective case depth of 1.76mm, this carburization compound has also exhibited the same pattern seen in figure 1.

Figure 3 shows the variation of effective case depth with time during case hardening using 85% charcoal/ 15% cowbone. The graph showed that as the carburization time was increasing so also was the effective case depth increasing. 2 hours of carburization gave an effective case depth of 0.77mm and after 8 hours the effective case depth obtained became 1.41mm. Carburization with this carburizing compound also had the same pattern as the previous ones.

Figure 4 shows the variation of effective case depth with time during case hardening using 80% charcoal/ 20% cowbone. The graph showed that as the carburization time is increasing the effective case depth is also increasing this pattern agrees with the previous three cases for the other carburization compounds. 2 hours of carburization gave an effective case depth of 1.82mm which rose to 2.6 mm after case hardening for 8 hours. Based on the above result and results obtained by several other researchers [2, 8-12] this inference can be drawn that as the holding time is increased during case carburization, the effective case depth also increases, irrespective of the carburizing mixture. The difference may be in depth of carburization, as can be seen from the preceding, where 80% charcoal / 20% cowbone had the highest effective case depth of 2.6mm after 8 hours of case hardening.

4. CONCLUSION

The work,'' variation of effective case depth with holding time of mild steel using various carburizing compounds has been carried out.'' From the results the following conclusions have been drawn.

1. The increase in holding time of mild steel during case hardening results in the increase of effective case depth
2. The variation in effective case depth with time holds irrespective of the carburizing compound used, the difference may only be in the effective case depth attained after the carburization period.

3. The carburizing compound with 80% charcoal / 20% cowbone gave the highest average case depth of 2.2 mm and therefore better than the other three compounds.
4. The average case depth was increasing as the cowbone in carburizing mixture was increased.

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