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Comparative Effect of Some Carbon Rich Materials on the Hardness Property of Carburized Low Alloy Carbon Steel

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Abstract
This work focuses on the effects of carburization process, on the hardness property of carburized low alloy carbon steel, at temperature of 890^0C with varied soaking time of 1 hour, 2 hours and 3 hours, after which the samples were later quenched in air. The carbon rich materials used in this work include: coal dust, snail shell particulate, palm kernel shell and cow bone while 20% limestone was used as the energizer. Thirteen specimens were machined to specifications from 10mm diameter mild steel and each set of the specimens were randomly assigned to hardness test. Twelve pack boxes measuring 150mm x 75mm x 75mm was fabricated from gauge 18 mild steel. Carbon rich materials and specimens were carefully placed into the pack boxes, a specimen each was packed into the four boxes meant for coal dust, snail shell, carbonized palm kernel shell and cow bone respectively. Each box was labeled accordingly, and were loaded into heat treatment furnace and carburized at a soaking temperature of 890^0C. At appropriate times, each sets of boxes were removed, open and air cool. Hardness testing of the various specimen were conducted using Vickers hardness test machine. Both coal dust, snail shell, palm kernel shell and cow bone were observed to have increase the hardness of the samples when compared with the as-received sample. As holding time of specimen increase in each carbonaceous materials, carbon diffusion and penetration increases which resulted to increase hardness values recorded in samples with 3 hours holding time.

1. Introduction
Heat treatments are operations use to modify the properties of metal without changing its shape. They are important processes in metal production which improves certain desirable features of metal while allowing for further work to take place [1]. Carburizing or carburization is a heat treatment process in which iron or steel absorbs carbon while the metal is heated in the presence of carbon-bearing materials, such as charcoal or carbon monoxide. The intention is to make the metal harder [2]. Carburizing hardens metal at the surface while the interior remain soft. This leads to the formation of metal known as the surface case [3-5]. Low alloy carbon steel has little carbon content range of 0.05% to 0.3%. Its lower carbon content makes it more malleable and ductile than other steel type. Low alloy carbon steel is the most available type of steel. Carbon steel is an alloy of iron and carbon as it major constituent materials. However other elements are present in carbon steel, with little percentages. These elements are manganese with 1.65% maximum, silicon with a 0.60% maximum [6].

[7-9] evaluated the suitability of using carbonized palm kernel shell, animal bone, oyster shell, animal bone from cattle and sea shell material as carburizing for case hardening of 0.078% mild

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steel [10-12]. The carburizing temperature varying between 700 – 1100^{0}C whiles the holding time varying between 1 – 5 hours. The boxes and its contents were allows to cool down to room temperature in the furnace after carburization. The work centered on the influence of locally sourced carbon rich materials such as animal bone, snail shell, and periwinkle shell on the mechanical properties of mild steel, carburized at varying temperature of 700, 800, 900, 1000 and 1100^{0}C held at various carburizing time of 5hours, 4hours, 3hours, 2hours and 1hour. The sample is cooled in oil and tempered at 350^{0}C for 45minutes [12-15]. However, this present work tend to focus on effect of locally sourced carbon rich materials such as coal dust, cow bone, snail shell and carbonized palm kernel shell using holding time of 1hour, 2hours, and 3hours respectively, so as to know their resultant effect on hardness property of low alloy carbon steel.

2. Materials and Methods

The following are used for this work: Low alloy carbon steel, Carbon rich materials (coal dust, animal bone, snail and palm kernel shells), and lime stone.

Carburizing heat treatment operations was carried out on the samples as follows: Coal dust, snail shell, palm kernel shell and cow bone are the carbon rich environment and lime stone as the energizer. Boxes measuring 150mm by 75mm by 75mm with covers were made from gauge 18 mild steel sheets. From the granulated materials, fine powders were sieve using sieve with different sizes of micron. However, 75 micron was used, because the smaller the microns the higher the surface area of the carbonaceous material in contact with the samples. After which equal volume of granulated coal dust, snail shell, palm kernel shell and cow bone were put into the twelve boxes so as to fill each to 1/3 full, adding about 20% lime stone as catalyst. Care was taken so that the specimens were completely covered by the carbon rich materials. The cover of the boxes was made air tight using clay. Carburizing temperature of 890^{0}C was use for all samples. Soaking time of one hour, two hours and three hours was maintained for each mixture. All the samples were later quench in air. This study follows the systematic approach by [3]

Hardness tests specimens were cut from the heat treated specimens. The hardness specimens were smoothened through grinding and polishing, and mounted on the Vickers Hardness Testing Machine for hardness test. Each sample was subjected to a load of 980.7 MN for 10seconds by means of a pyramid-shaped diamond. The indention is observed under a microscope and the Vickers Hardness value read from a conversion table.

3. Results and discussion

From table 1, the Spectrochemical analysis results shows that the steel has a carbon content of 0.2210, which is a low carbon steel and will be the best grade of steel that will easily form interstitial solid solution at the austenitization temperature of 890^{o}C.

Table 1. Mass Spectroscopic Analysis of control sample

Elements	**C**	**Si**	**Mn**	**S**	**P**	**Cr**	**Ni**	**Cu**
Comp.(%)	0.2210	0.1450	0.6820	0.0590	0.0390	0.0850	0.0800	0.2660
Elements	**Al**	**B**	**W**	**Mo**	**V**	**Ti**	**Nb**	**Fe**
Comp. (%)	0.0340	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	98.3890

Table 2 shows the changes of hardness values of low alloy carbon steel carburized in coal dust. The hardness results serve as basis for comparison, from where the reaction of low alloy carbon steel to surface hardness can be viewed with changes in carburizing time in hours. The coal dust was catalyzed with 20% $CaCO_3$ and hardness values are as follow: Control sample 162.77 Hv, 1 hours (196.55 Hv), 2 hours (228.77 Hv) and 3 hours (254.60 Hv). It was observed that as the soaking time increases, hardness results also improve. The increase in hardness results is effective due to the increase in interstitial carbon atoms formed at the surface of the steel. Which is why the coal dust proved to be most competent carbon rich material?

Table 2: Hardness Values Number (Hv) of samples in coal dust/$CaCO_3$ at temperature of 890^0C and at varying carburizing holding time

S/N	Carburizing time hours	Hardness Value Number (Hv)
1	Control sample	162.77
2	1	196.55
3	2	228.77
4	3	254.60

Table 3 show the changes in hardness result of low alloy carbon steel when carburized in carbonized palm kernel shell. The palm kernel shell was catalyzed with 20% $CaCO_3$ and hardness results are: Control sample 162.77 Hv, 1 hours (196.55 Hv), 2 hours (217.24 Hv) and 3 hours (230.45 Hv). It was noticed that as soaking time increases, hardness results equally improves. This assertion is not far fetch from the study by [2] that the influence of microhardness on low carbon steel carburized particles are often attributed to the inherent particulates and responses.

Table 3. Hardness Values Number (Hv) of samples in palm kernel shell/$CaCO_3$ at temperature of 890^oC and at varying carburizing holding time

S/N	Carburizing time hours	Hardness Value Number (Hv)
1	Control sample	162.77
2	1	196.55
3	2	217.24
4	3	230.45

From Table 4 the changes in hardness results of low alloy carbon steel when carburized in carbonized Snail shell. The Snail shell was equally catalyzed using 20% $CaCO_3$ and hardness results obtained are: Control sample 162.77 Hv, 1 hours (178.54 Hv), 2 hours (196.24 Hv) and 3 hours (205.50 Hv). It was noticed that as soaking time increases, hardness results also improves.

Table 4. Hardness Value Number (Hv) of samples in snail shell/$CaCO_3$ at temperature of 890°C and at varying carburizing holding time

S/N	Carburizing time hours	Hardness Value Number (Hv)
1	Control sample	162.77
2	1	178.54
3	2	196.24
4	3	205.50

Table 5 shows the changes in hardness results of low alloy carbon steel when carburized in pulverized cow bone. The cow bone was catalyzed with 20% limestone and hardness results are noticed as follow: Control sample 162.77 Hv, 1 hours (170.39 Hv), 2 hours (228.85 Hv) and 3 hours (235.13 Hv). It was noticed that as the holding time increases, hardness results as well increases. Obtained results from the above carbon rich materials that were worked on are in line with those quoted by [5, 6] for the same class of mild steels. [6] reported values of 194.2 Hv to 236.9 Hv for mild steel carburized and quenched from 850 °C, while [5] described surface hardness of between low carbon carburized properties to exist between 166.4 Hv to 345.9 Hv at 900 °C. However results obtained by these authors were from industrial carburizing materials. The Effect of some carbon rich materials and varying soaking time on the hardness property of low alloy carbon steel was computed and described in Figure 1. It is seen that the hardness properties is more significant especially at 3 hours from all processed bio-materials with about 250 Hv for coal dust effect.

Table 5. Hardness Value Number (Hv) of sample carburized in cow bone/$CaCo_3$ at temperature of 890°C and at value carburizing holding time.

S/N	Carburizing time hours	Hardness Value Number (Hv)
1	Control sample	162.77
2	1	170.39
3	2	228.85
4	3	235.13

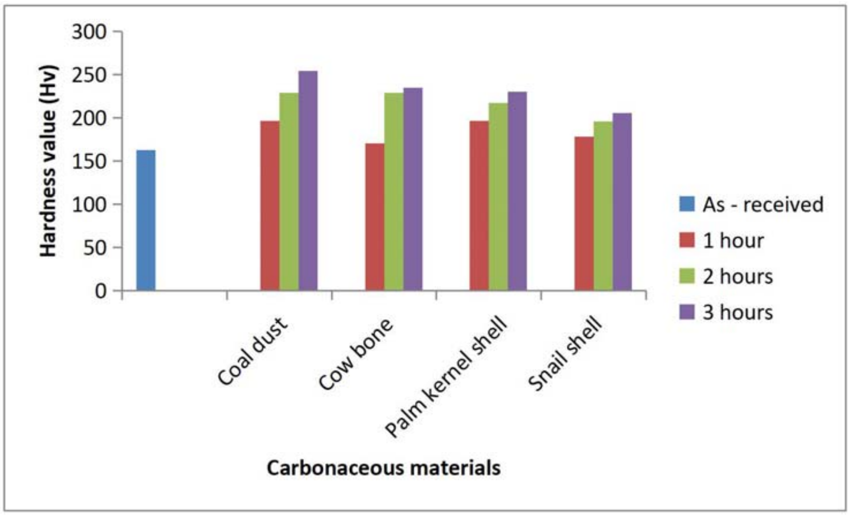

Figure 1: Effect of some carbon rich materials and varying soaking time on the hardness property of low alloy carbon steel

Conclusions

1. It was observed from this research that coal dust, snail shell, carbonized palm kernel shell and cow bone carbon rich materials have impact on the hardness property of low alloy carbon steel.
2. It was also noted that as holding time of the specimen increases in each carbonaceous materials, carbon diffusion and penetration increases which resulted to increase hardness values recorded.
3. For the 1 hour holding time, cow bone was noted to have the least hardness value, while at 2 hours, coal dust and cow bone were seen to have the highest hardness values of 228.77 and 228.85 Hv respectively with Snail shell recording the least hardness value of 178.54 Hv.
4. At 3 hour holding time, coal dust was observed to have the highest hardness value of 254.60 Hv, with Snail shell recording the least value of 205.50 Hv.
5. Coal dust carburizer proof to be the most effective carburizer, followed by palm kernel shell, cow bone with Snail shell been the least effective carburizer. The noticed improvement in hardness value could be due to the increase interstitial carbon atoms formed at the surface of the steel.

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