



IMEETMCon 2016



IMEETMCon

2016

**International Conference of Mechanical
Engineering, Energy Technology and
Management**

7th – 9th September, 2016

**Conference Centre, University of Ibadan,
Ibadan, Nigeria**

**Theme: Green Technology, Energy Systems and
Environmental Protection for Sustainable Development**

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IMEETMCon 2016

Welcome Message

This is to welcome you all to the International Conference of Mechanical Engineering, Energy Technology and Management (IMEETMCon) 2016 being hosted by the Department of Mechanical Engineering in collaboration with the Faculty of Technology, University of Ibadan from 7th to 9th September, 2016 at the University Conference Centre. This 3rd edition in the conference series by the Department on energy issues is being organized under the theme “*Green Technology, Energy Systems and Environmental Protection for Sustainable Development*”. This conference builds on the maiden edition held in 2012 under the theme “*Energy Technology & Management for Sustainable Development*” and the 2nd edition under the theme “*Energy Technology and Adaptability to Climate Change for Sustainable Development*”.

The general objective of this conference is to promote research and application of the sustainable green energy technologies while the specific objective is to situate these technologies in the context of sustainable development. I dare say that the conference theme and the objectives are very much in line with Goal 7 of the Sustainable Development Goals (SDGs) aimed at “*Ensuring access to affordable, reliable, sustainable, and modern energy for all*”; a goal driven by the following underlying factors, and, I quote:

...The scarcity of energy resources will grow ever greater. Between now and 2030, high-income economies will continue to consume large amounts. They will be increasingly joined by countries which are growing rapidly and consuming more. And by 2030, when the planet reaches around 8 billion people, there will be 2 billion more people using more energy. All this energy use will create enormous strains on the planet. These challenges are enormous. But so are the opportunities. Done right, growth does not have to bring huge increases in carbon emissions. Investments in efficient energy usage, renewable energy sources, reducing waste and less carbon-intensive technologies can have financial benefits as well as environmental ones. Tools are already available. We can reach large-scale, transformative solutions worldwide with more investment, collaboration, implementation and political will.

Energy supply to meet demand is a serious problem in Nigeria despite its considerable energy resources – non-renewable and renewable. The country has a long way to go in solving her energy problem. Universities have important role to play through education, training, research and innovation towards providing viable energy supply mix to meet the growing and varied demands. The challenges of sustainable development demand collaboration among the disciplines. It is therefore worthy of note the multidisciplinary nature of the participation in this conference which has attracted a wide range of practitioners – engineers, scientists, technologists, government officials, Architects, private practitioners and actors in engineering systems, environmental pollution control and energy industries, etc. - to share knowledge and exchange information on their work and also discuss future strategies for green energy sustainability. This is indeed heartwarming.

I am also happy to note that over 90 papers will be presented under the various sub-themes by participants drawn from within the country and outside. This is a very much welcome evidence of the increasing intensity of research activities and capacity building in the Nigerian University system, which has hitherto been characterized by a rather weak research capacity, most especially due to the paucity of research funds. Research is gradually occupying the pride of place in the Nigerian University system, while the Tertiary Education Trust Fund (TETFund) should increase its allocation to the National Research Fund (NRF), which has energy research as one of its thematic areas for research funding.

Finally, we acknowledge the invaluable contribution of the Postgraduate School, University of Ibadan towards the organization of this conference as I welcome you all, once more, to a successful meeting.

Prof. O.A. Bamiro FAS, FNSE, FAENG

Conference Chairman

Former Vice-Chancellor, University of Ibadan, Ibadan, Nigeria

(December 1, 2005 to November 30, 2010)



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**P060: CARBO-NITRIDING OF AISI 1018 STEEL PLATE WITH ANIMAL HORN*****Ahmed I. I., Mohammed A. T., Adebisi J. A., Yahaya T. and Ambali I. O.**

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Corresponding author: ismaila.ahmed@yahoo.com*Abstract**

The research on the carbonitriding of AISI 1018 steel with animal horn was carried out with the aim of converting waste to wealth through re-use approach of waste management. Cattle horn was processed into two different morphologies namely: powder and flakes. Carbonitriding heat treatment was carried at 850°C and 450°C for carburizing and nitriding dominated processes respectively. Vickers hardness measurement was carried out on samples heat treated with horn powder and flakes. Optical metallography was carried out on carbonitrided sample for microstructural examination following the heat treatment. The results of the investigation showed that hardness gradient occurred with higher hardness value at the near surface and decreasing towards the core. Sample heat treated with horn flakes showed higher hardness than those that was heat treated with horn powder. Microstructural examinations of carbonitrided samples revealed the presence of martensite and retained austenite. From the result of study, it was concluded that the high hardness values observed was attributed to the diffusion of carbon and nitrogen atoms to the interstices of the host atom. Again the solute atoms helps to stabilise austenite microstructures which later transformed to martensite observed in the optical micrographs.

Keywords: Abattoir; carbonitriding; hardness; horn; keratin; steel; waste**Introduction**

Animal horn is one of the residues from food industry (abattoirs), often discarded into the environment, and this remains a challenge in waste management hitherto. In contrast, while the bones from abattoirs may be processed as animal feeds, large proportion of horns from abattoirs are discarded into the environment (see Figure 4) and sometimes burnt in open field, thus constituting pollution to the environment and hazard to public health (Adeyemi and Adeyemo, 2007). Though, small portion of horns have been used for jewellery (Balogh-Horváth, 1983, Schoenberger, 1951) and in recent time, animal horns are been used as a source of nitrogen for production of glycerol (Kurbanoglu, 2003).



Figure 4: Pictures showing dump sites for cattle horns, hoofs and bones

One of the proactive means of solving the problem of environmental pollution is by processing animal horn into a raw material for carbonitriding of low carbon steels, thereby converting what is considered wastes to wealth. The use of animal horn for surface treatment of steels has been around since early nineteenth century (Gustav, 1905). Few Indigenous blacksmiths still practise case hardening intuitively by rubbing slices of animal horn on forged products with the belief that it enhances the performance of the workpiece. Study on animal horn shows that it is composed of a sheath of keratin (which is a class of resistant and insoluble fibrous protein) overlying a bony core of mostly ruminant artiodactyls animal's skull (Li et al., 2010). They also reported there are two distinct groups of keratin namely, alpha and beta keratin. Recent studies by Mikulikova *et al.* (Mikulíková et al., 2012), on analysis of saiga horn using high performance liquid chromatography with mass spectrometry and polyacrylamide gel electrophoresis, revealed the presence of basic protein namely: keratins and collagen. One of such example of β -keratins is fibroin, which is characterised with antiparallel molecular chains having an alternating C $\rightarrow$ N orientation (Choo et al., 1996, Li et al., 1996).

In engineering, numerous machine components require a wear and fatigue resistant, on the outer surface known as case and a relatively softer, tougher interior of parts referred to as core (Pearson, 2013, Sidney, 1974). This is achieved through the process of case hardening, often carried out on low carbon steels to develop components with a balanced of tougher inner core and hard outer shell (George, 1967). Case hardening helps to transform a thin layer of material at the near surface of the part, through carbon or nitrogen enrichment, to a relatively harder shell than the base metal alloy. Typical example is heavy duty gears in which teeth surfaces are subjected to continuous and severe frictional contact. Case hardening may be achieved through the method of carburizing (ASM, 2013, Wei, 2013), nitriding (Vijendra, 2009) and carbonitriding (Sidney, 1974), if it involves the change in chemical composition by the addition of carbon, nitrogen and both carbon and nitrogen respectively, in solid state (Vijendra, 2009).

Other hardening which does not involve diffusion of carbon and/or nitrogen atom onto work piece include Laser hardening (Schaaf, 2002), flame hardening (Silvia and Breznak, 2011) and induction hardening (Khare and Duliba, 1986). One major advantage of carbonitriding is that, the nitrogen absorbed during processing lowers the critical cooling rate of steel. This suggests, hardenability of the case is significantly greater when nitrogen is added during carbonitriding than when the same steel is



carburized. This permits the production of steels on which ordinarily, uniform case hardness may be difficult to achieved if it is only carburized and quenched. Carbonitriding permits the use of low-carbon steels, which cost less and may have better machinability or formability (Total Material Article, 2010).

Case hardening is a thermo-chemical process in which some heat is needed to enhance the diffusion of hardening elements into the steel surface. The depth of diffusion is time dependent according to Equation 1:

(1)

Where, the diffusivity constant, K , depends on temperature, the chemical composition of the steel, and the concentration gradient of hardening element. The diffusivity constant increases exponentially as a function of absolute temperature. Concentration gradients also depend on surface kinetics and reactions of a particular process (ASM, 2013). The diffusion process during the case hardening is governed by Fick's laws of diffusion (Equation 2) which relates the diffusive flux to the concentration under the assumption that a solute will move from a region of high concentration to a region of low concentration across a concentration gradient.

(2)

Where, J is the diffusion flux in amount of solute (atoms, or grams, or moles) per unit area per unit time, C is the concentration of solute in amount (atoms, or moles, or grams) per unit time, x is the distance, $[dc/dx]$ is the concentration gradient across the plane and, D is the diffusion co-efficient in (square length) per unit time. When C is in atoms/cm³, x is in cm, and D is in cm²/s, the flux, J , is equal to the number of atoms moving across the plane at x in the x -direction per cm² of the plane per second (Rajesh and Venkatesh, 2014).

The aim of this work is to carry out carbo-nitriding of AISI 1018 steel plate with animal horn. The above aim will be achieved through the following objectives: the Processing of animal horn into two morphological forms namely: powder and horn flakes for carbonitriding process. This was followed by carbonitriding heat treatment of low carbon steel. Then micro hardness measurements on the carbonitrided steels and lastly, microstructural study and correlation with microhardness results for different morphologies of the horn used for carbonitriding heat treatment.

Experimental procedures

Materials

Animal Horn

The animal horns used for the carbonitriding heat treatment was cattle horn. The horn was obtained from Ipata market (abattoir), Ilorin (Figure 5).



Figure 5: Cattle horns from Ipata market abattoir



Low carbon steel

The material used for the experiment was mild steel, AISI 1018 steel. The chemical composition of the mild steel AISI 1018 used is given in Table 1. The chemical composition was determined by spectrometric analysis carried out at Nigerian Foundry Limited (NFL) Songo – Ota, Ogun state. The steel sample was sectioned into dimensions 26mm × 31mm × 13mm for the length × width × height respectively, with hack saw under running water to reduce heat generation during cutting. The sectioned sample was further processed for carbonitriding heat treatment.

Table 1: Chemical composition (weight percent) of AISI 1018 steel plate used

C	Si	S	P	V	Mo	Mn	Ni	Cr	Cu	Fe
0.152	0.181	0.020	0.014	0.001	0.001	0.676	0.015	0.025	0.028	98.8

Methods

Carbonitriding Heat Treatment of Steel

The sectioned steel sample was then grinded wet with abrasive papers with grit sizes: P240, P400, P800 and, P1200 which indicates decreasing order of abrasive grain. This was carried out to remove layers of oxides and deep scratches on samples prior to carbonitriding heat treatment.

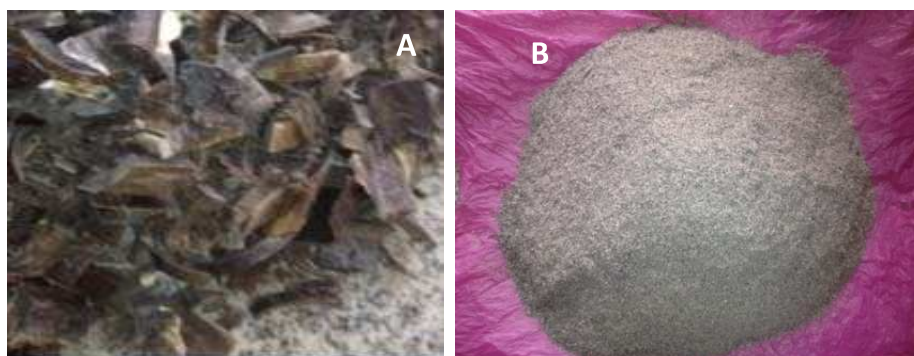


Figure 6: Picture of horn flakes (A) and horn powder (B)

Carbonitriding with cattle horns was carried out in two morphological forms namely: powdered and flaky forms (Figure 6). The powdered horn was achieved using manual grater and then subsequently blended into finer powder form. This was done to ensure a uniform grain size powder. Powder grain size of 0.60mm used was achieved using sieve analysis. On the other hands, flaky form was achieved by cutting the horn with manual hacksaw into pieces. An average flake size of 60mm × 25mm was used for the experiment. The amount of powdered and flaky horn used for the heat treatment was 150 g.

Two cylindrical crucibles, each with dimensions length × diameter of 110 mm × 96 mm, were labelled I and II for powdered and flaky horn carbonitriding samples respectively (Figure 7). Two steel samples were placed in each crucible initially without horn, covered with lids and then placed inside the muffle furnace (model number CWF13/5). The steel samples in the crucibles were preheated to 850°C to ensure homogeneous heating. The crucibles were brought out of the furnace and 150g of powdered and flaky horn were introduced into each of the crucible, covered and were quickly returned back to the furnace to allow for carburizing heat treatment. The temperature was allowed to reach 850°C again and then soaked for 60 minute. After soaking for 60 minutes, the sample was then furnace cooled 450°C and another 150 g of powdered and flaky horn were introduced into the crucibles again and



returned back into the furnace for nitriding dominated heat treatment. The samples were soaked at 450°C for another 30 minutes, before the samples were finally taken out of the crucible and quenched in water (see Figure 8).

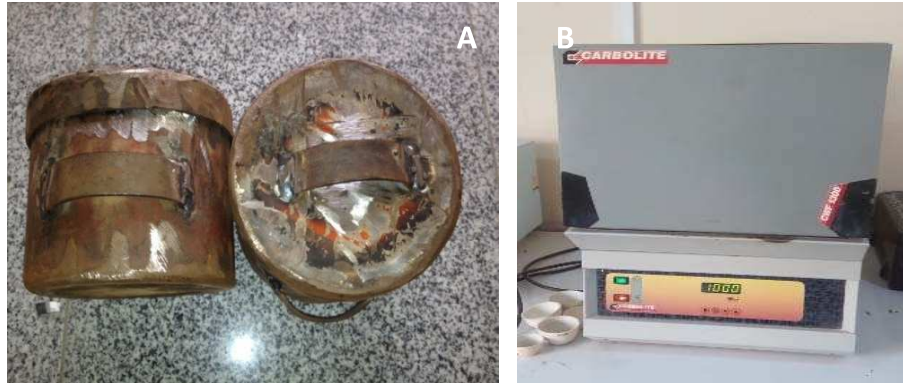


Figure 7: Fabricated crucible (A) and muffle furnace (B)

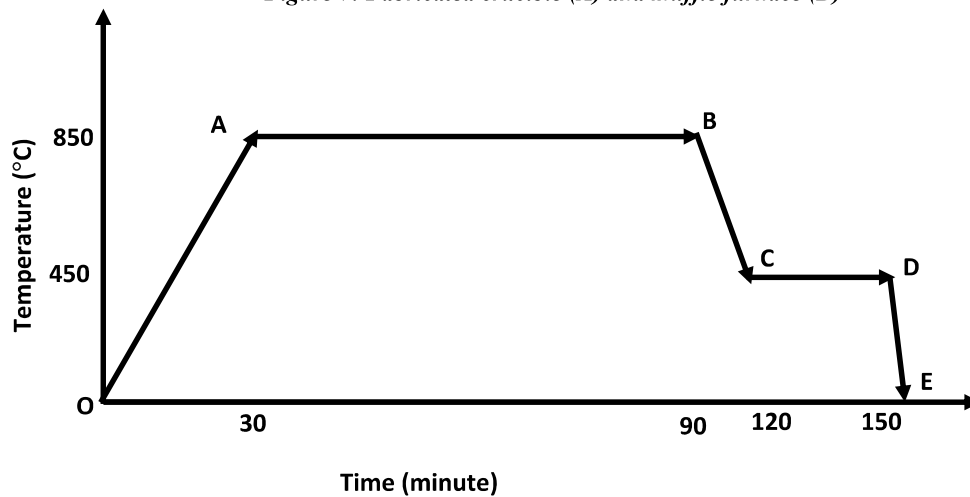


Figure 8: Schematic illustration of carbonitriding process

Micro-Hardness Measurement

The carbonitrided samples were prepared for micro-hardness measurement. Surface to be tested required a metallographic finish, considering the smaller the load used for micro-hardness indentation. The carbonitrided samples were then grinded wet with abrasive papers with grit sizes: P240, P400, P800 and, P1200 which correspond to decreasing order of abrasive grain. The grinded samples were then polished with diamond pastes of grain sizes 0.5 μm and 0.25 μm . This was carried out to obtain a scratched-free surface required for micro-hardness measurement.

The Vickers hardness test was carried out at Engineering Materials Development Institute (EMDI), Akure. The test involved application of diamond pyramid indenter with a controlled pressure of load 980.7 mN for a standard time of 10 s. The diagonal of the resulting indentation was measured under precision microscope at higher magnification of $\times 50$ and measured to an accuracy of $\pm 0.5 \mu\text{m}$. The length of the diagonal of indentation and the test load were used for the calculation of Vickers hardness value. The Vickers Diamond Pyramid harness number, H_V was calculated according to Equation 3, where F is applied Load in kgf, d is mean of the two diagonals, d_1 and d_2 in mm .



(3)

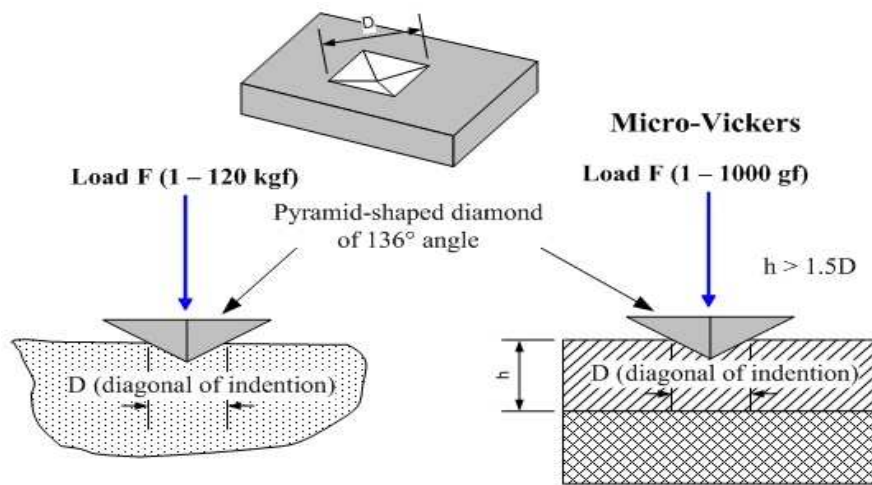


Figure 9: Schematic illustration of micro-hardness test procedure (www.subtech.com, assessed on 17/12/2015)

Optical Metallography

The carbonitrided samples were also prepared for post-heat treatment optical metallography. The optical metallography was carried out at Engineering Materials Development Institute (EMDI) Akure. The carbonitrided samples were subjected to wet grinded with abrasive papers with grit sizes: P240, P400, P800 and, P1200 which indicates decreasing order of abrasive grain. The grinded samples were then polished with diamond pastes of grain sizes 0.5 μm and 0.25 μm . This was carried out to obtain a scratched-free surface required for metallographic examination of the materials. The polished sample was etched with 2% Nital solution to reveal the microstructures and particularly the interface between the hard shell and the core.

Results and Discussion

Hardness Results

One of the main goals of this research was to investigate the potential of animal horns as candidate material for carbonitriding and to determine the difference by comparing and contrasting the results of horn powder and horn flakes sample results. The results of the micro-hardness test carried out on carbonitrided 1018 steel are shown in Table 2.

Table 2: Vickers Hardness Result of Carbonitrided 1018 steel

Distance from surface (mm)	Mean Vickers Hardness values Hv (Kgf/mm ²)		Standard Deviation	
	Powdered	Flakes	Powder	Flakes
1	147	201	34	53
2	122	154	4	7
4	118	133	3	13
7	112	112	5	1



From Table 2, it can be deduced that steel samples carbonitrided with flaky horn possess higher hardness values compared with sample heat treated with powdered horn. Again, the hardness value was relatively higher at the near surface (case) and reduces towards the centre (see Figure 10). It was observed that the hardness value at the centre of all the samples happened to be the lowest. Hence, the hardness at the centre of each sample was considered to be the control sample hardness value.

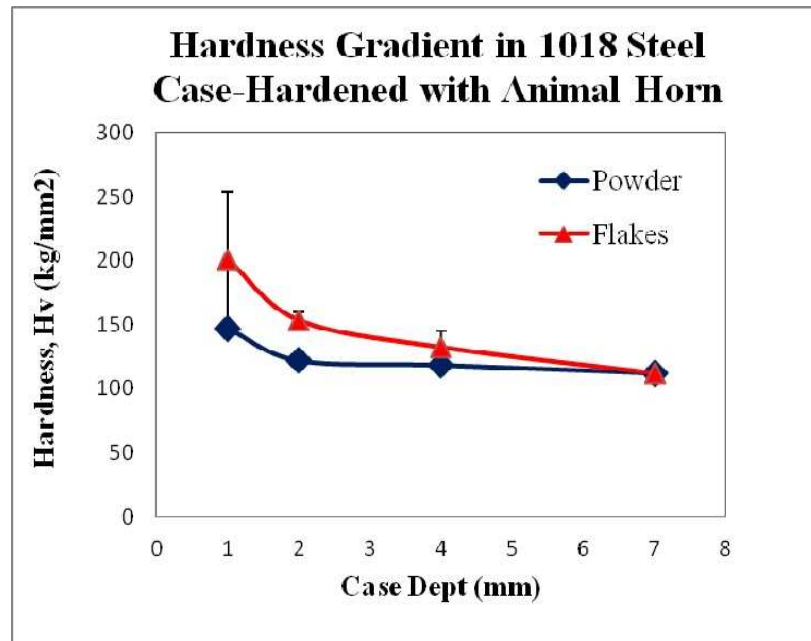
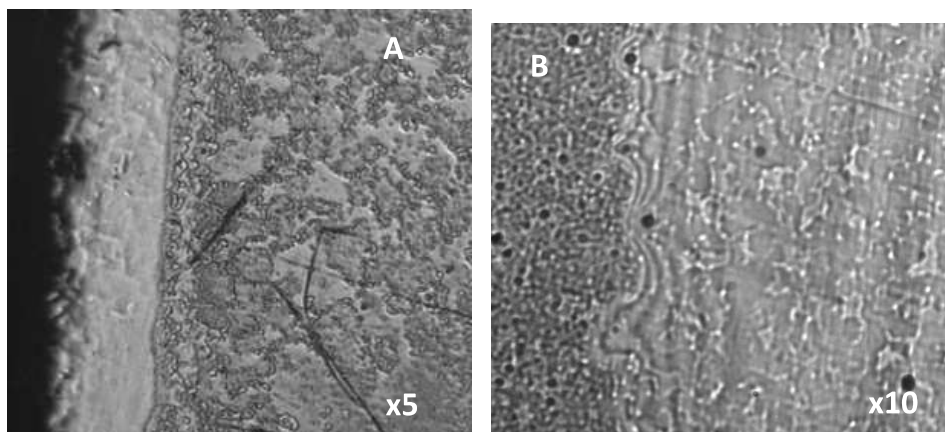


Figure 10: Micro-hardness of 1018 steel carbonitrided with cattle horn

Microstructural analysis

The optical micrographs of steel samples carbonitrided with horn powdered are shown in Figure 11. Figure 11Error! Reference source not found.A and B showed the optical micrographs of as-polished specimens at low (x5) and high (x10) magnifications which indicated the depth of hardened case near the surface. Figure 11Error! Reference source not found.C and D showed the micrographs of the etched specimens at magnifications x10 and x20 respectively. The dominant microstructures observed in the etched specimens were martensite (light) and limited amount of retained austenite (dark) on the grain boundary regions.



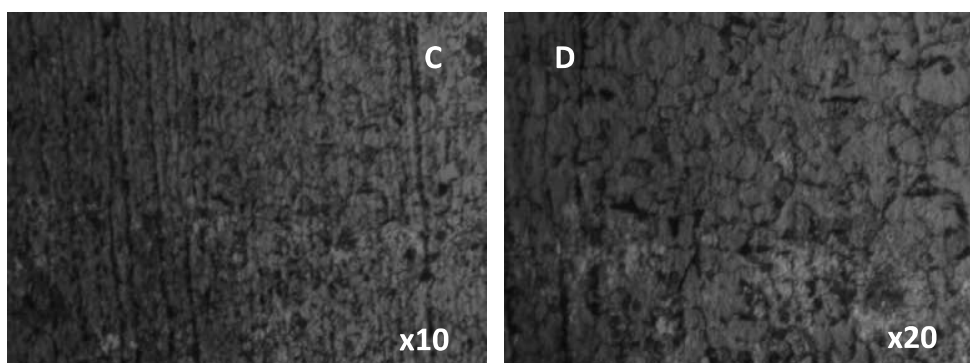


Figure 11: Optical micrographs of 1080 steel carbonitrided with horn powder

The optical micrographs of steel samples carbonitrided with horn flakes are shown in Figure 12. Figure 12A and B showed the micrograph at magnification x10 and x20 respectively. The microstructures are consistent with that observed in sample with horn powder. The notable difference from the powder horn sample was that, the amount of retained austenite was conspicuously more in horn flakes samples.

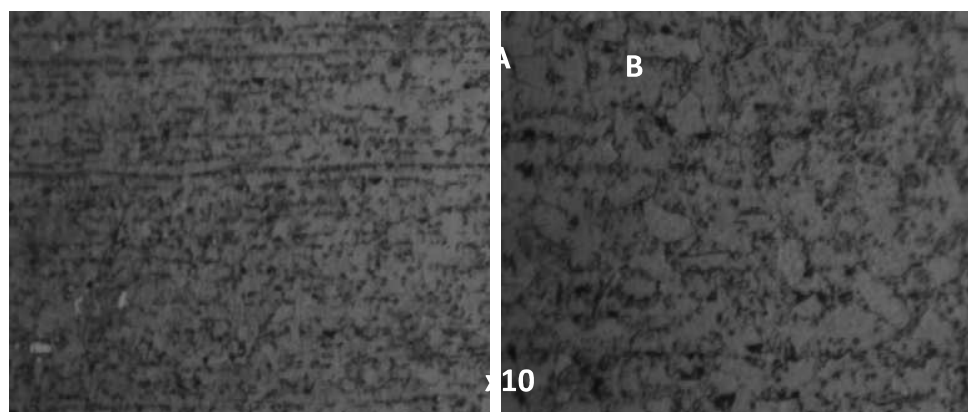


Figure 12: Optical micrographs of 1080 steel carbonitrided with horn flakes

The average hardness value measured on the samples carbonitrided with horn flakes was relatively higher than samples carbonitrided with horn powder. The difference was higher at the near surface and decreased toward the core which ended with same hardness value. The higher hardness value at near surface is consistent with the established hardness profile of carburizing, nitriding and indeed carbonitriding (Herring, 2011). This can be attributed to the diffusion of carbon and nitrogen to the interstices of the host atom. The hardness gradient observed was consistent with the variation of diffusion of the carbon and nitrogen with distance as indicated by Ficks first law of diffusion (Rajesh and Venkatesh, 2014). The hardness value decreases with distance from the surface depending on factors with include density of the host atom.

The lower hardness values observed in horn powder sample was attributed to large surface area of horn powder compared to horn flakes. The horn powder must have burnt sufficiently faster enough to rapidly release the volatile matters and oxidised carbon at higher temperature. It is suggested that the flakes would have burnt relatively slower than the horn powder and hence conserve the release of volatile matters and oxidation of carbon needed for diffusion into the steel.

The observed martensite on the optical micrographs occurred from diffusion-less transformation of austenite during quenching. The retained austenite was probably made possible due to stabilising effects of both carbon and nitrogen on austenite microstructure above A1 temperature line. The presence of carbon and nitrogen must have made austenite stable even below the A1 temperature line



and sufficiently available for transformation to martensite during water quenching from 450°C to room temperature (Herring, 2011, Offor et al., 2011).

This work demonstrated that animal horn could be used as alternative material for carbonitriding rather than been discarded indiscriminately into the environment. This will help to reduce both environmental impact, consequent of air pollution from indiscriminate burning and health hazard associated with dumping ground.

Conclusion

The following conclusions are made at the end of study investigating the potential of animal horn for carbonitriding of AISI 1018 steel.

1. The study showed that animal horn can be processed as an alternative material for carbonitriding of steel.
2. Carbonitriding heat treatment of AISI 1018 steel was carried out with cattle horn processed into two morphological forms namely: powder and flakes.
3. The hardness values measured on samples heat treated with flaky horn was relatively higher than those treated with of powdered horn.
4. Carbonitriding with animal horn showed hardness gradient with higher values at the near surface and decreasing trend towards the core in both cases. The observation is consistent with established concentration gradient in case hardened materials.

This research work showed that animal horn could be considered as candidate materials for carbonitriding of steel. The use of animal horn as a secondary material for steel production will help to control indiscriminate waste disposal to the environment and ensure healthy living. In addition the conversion of wastes to wealth arising from the use of animal horn will help in the creation of job opportunity.

Acknowledgement

The authors wish to thank Mr S.O. Awojobi and Mr R. A. Yahya of Materials and Metallurgical Engineering Department, University of Ilorin for their technical support during the experimentation. The unrestricted access to Geology laboratory equipments is also acknowledged and the Author sincerely expressed their appreciation to the Head of Department of Geology and Mineral Science, Dr R. B. Bale.



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