Surface Hardness Improvement of Mild Carbon Steels using Arecaceae Waste Flower Droppings.

Paul A. Ihom, Ph.D.[1*]; Geoffrey B. Nyior, Ph.D.[2]; and Mannaseh Ambayin, M.Eng.[1]

[1]National Metallurgical Development Centre, PMB 2116, Jos, Plateau State, Nigeria.
[2]Ahmadu Bello University, Department of Metallurgical and Materials Engineering, Zaria, Nigeria.

E-mail: paulihom@yahoo.co.uk*

ABSTRACT

Arecaceae flower droppings have been used for the surface hardness improvement of mild carbon steel; the specification commonly used as cast mild steel was used for the work. The specimens were mixed with the arecaceae flower droppings in special heat resistant steel sealed containers, and placed inside an electric muffled furnace which was heated to 920°C and held for the duration of 180 minutes. The heating temperature was maintained at a gradient of 400°C/ hr, which was moderate enough for the containers, the hardening agent and the specimens. After the diffusion treatment the specimens were quenched so as to retain the diffused elements in solution.

The untreated specimen was tested along -side with the treated specimen; the result revealed that the untreated specimen had a constant hardness profile with minor variation, when hardness measurements were taken from the surface towards the core of the specimen. The hardness profile of the arecaceae treated specimen had the highest value of 56HRC on the surface of the specimen and the hardness dropped with progressive measurements towards the centre of the specimen. The effective case depth which was measured according to ISO and ASM Committee on gas carburizing standard had a value of 0.70mm. Microstructural examinations revealed a ferrite-pearlite structure for the untreated, while the treated specimen had a compound layer on the surface, a diffusion layer and the substrate layer.

The result of the work has clearly indicated that arecaceae flower droppings can be use for the surface hardness improvement of parts produced using mild steel. Worthy of note is that the process is cheap and economical and is recommended where liquid and gaseous hydrocarbons are either expensive or scarce.

(Keywords: surface hardness, mild steel, improvement, arecaceae, waste, and flowers)

INTRODUCTION

Iron was known to the ancients as 'metal from heaven' or 'metal from the stars' from which we may conclude that such iron as was used in those times was of meteoric origin. The deliberate smelting of iron ores seems to have originated some 3500 years ago and by that time the Iron Age can be said to have arrived. Presumably historians would agree that we are still in the Iron Age for, despite the developments of aluminum alloys and plastics materials during the present century, steel undoubtedly remains our most important engineering material (Higgins, 1983). It is unlikely that the present state of technological development could have been achieved in any field without the help of steel as our main structural, constructional and tool material- and all this at a relatively low financial outlay. Steel is essentially an alloy of iron and carbon containing up to roughly 2.0% carbon (Higgins, 1983; Shrager, 1961).

By varying this carbon content and the heat treatment of the resultant alloy we can obtain an enormous range of mechanical properties, whilst the addition of alloying elements such as nickel, chromium and molybdenum extends the properties still further. Nevertheless it is a sobering thought that, but for the polymorphic changes which occur in iron, the heat treatment of steels as we practice it would be impossible and that iron/ carbon alloys would then have extremely limited properties. The relatively small carbon atoms dissolve interstitially in iron. Since the very early days of metallography, the microstructure of steel has been extensively studied (Avner, 1974). Dead-mild steels containing up to 0.15% C are used for general presswork and other applications where high ductility is necessary in forming.

Mild steels contain 0.15- 0.3% C. Wrought forms are used as rolled stocks (RSJ) and other structural members, shafting, levers and various forgings. Steels used for sand castings usually contain 0.3-0.35% C they are also considered as mild steels (Higgins, 1983; Shrager, 1961). These set of steels described above do not respond to hardening heat treatment, but only annealing treatment for grain refinement (Saita, 2008). However, given their wide area of application they do encounter service limitations, one of such limitations have to do with low hardness and wear resistance particularly when used as shafts and other rotating parts of machines. To improve on the hardness and wear resistance several casehardening methods are normally used which include nitriding, carbonitriding, cyaniding, carburizing etc just to mention a few surface hardening techniques. These techniques are used in improving the surface hardness of mild steel. The techniques involve the use of various raw materials for the impregnation of different elements in the surface of the mild steel to improve on the hardness and wear resistant properties. This normally improves the service life of the part made of mild steel (ASM, 1977; Iwata, 2008).

This research work examines the efficacy of the waste flower droppings of a wild date palm commonly used as ornamental tree for the improvement of surface hardness of mild steel. This wild date palm is from the family of arecaceae or palmae. This specie is closely related to phoenix dactylifera and phoenix sylvestris which are used for the production of date sugar. The date palm grows about 23 meters (75 feet) tall. Its stem, strongly marked with the pruned stubs of old leaf bases, terminates in a crown of graceful, shining pinnate leaves about 5 meters (16 feet) long. Floral spikes branch from the axils of leaves that emerged the previous year. Male and female flowers are borne on separate plants.

Under cultivation the female flowers are artificially pollinated. The date is a one-seeded fruit, or berry, usually round to oblong but varying much in shape, size, color, quality, and consistency of flesh, according to the condition of culture. More than 1000 dates may appear on a single bunch weighing 8kg (18 pounds) or more (Encyclopedia Britannica, 2010). There is no available literature indicating that research has ever been conducted using arecaceae flower droppings for surface hardness improvement of mild steel. The chemical composition of these waste flower droppings of arecaceae is unique and may impart enhanced surface hardness on mild steel.

The objective of this research paper is to investigate the possibility of using waste flower droppings of arecaceae as a material for surface hardness improvement of mild steel.

MATERIALS AND METHODS

Materials

Materials used for the research included, mild steel rod of 20mm, arecaceae flower droppings, sodium hydroxide, water, polishing powder. All of the materials were locally sourced within National Metallurgical Development Centre, Jos. The composition of the mild steel is presented in Table 1 and a plate of the arecaceae tree from which the flowers were collected is shown in Plate 1.

Table 1: Composition of Mild Steel Used.

Element	**C**	**Si**	**Mn**	**P**	**S**	**Cr**	**Ni**	**Mo**	**Al**
%	0.303	0.196	0.74	0.066	0.032	0.082	0.038	0.0059	0.010
Element	**Cu**	**Co**	**Ti**	**Nb**	**V**	**W**	**Pb**	**B**	**Sn**
%	0.258	0.0055	0.0020	<0.0030	0.0017	0.020	0.0055	0.0009	0.015
Element	**Zn**	**As**	**Bi**	**Ca**	**Ce**	**Zr**	**La**	**Fe**	
%	0.0049	0.0058	<0.0020	0.0059	0.0041	0.0024	0.0037	98.18	

Plate 1: The Arecaceae Tree from which the Flower Dropping were Picked.

Equipment

The equipment used were a hacksaw, grinding and polishing equipment, electric furnace, heat resistant steel boxes, hardness testing machine (Rockwell) and metallurgical microscope.

Methods

Specimen and Material Preparation: Specimens for the work were cut from a mild steel rod of diameter 20mm. The size of each specimen was 20mm x 20mm. The arecaceae flower droppings were picked from under the arecaceae tree shown in Plate 1. They were screened to ensure that they were not mixed with any other material. All the steel specimens were washed in sodium hydroxide to remove dirt and the scales were scrubbed using a steel brush.

Heat Treatment / Casehardening Process: The mild steel specimens were packed into boxes half filled with arecaceae flower droppings; the mild steel was then completely covered with the arecaceae flower droppings. The box cover was fixed and sealed using clay to avoid air ingress. The boxes were then transferred into the heat treatment furnace. An appropriate temperature gradient of 400^{o}C/hr. was set and the specimens were heated to 920^{O}C and held for 3hrs. The specimens were then quenched in water and allowed to cool before removing them.

Hardness Test: The quenched specimens were tested for hardness according to ISO 6508-1: 1999 metallic materials standard. Using Rockwell hardness testing machine, a calibration standard block of 59.6HRC was used to check all the measurements taken. The testing process required the selection of scale C with a preliminary test force of 98.07N, additional test force of 1373N, and the total test force of 1471N. The preliminary force was expected to set the specimen before the application of the final testing load. The result of the test was then displayed on the dial, and readings were taken from the C scale. The hardness profile for determination of case depth was obtained by cutting the specimen into two. The cut face was then ground and polished. Hardness values were obtained from the surface edge towards the centre of the specimen at an interval of 0.5mm and five readings were taken.

Metallography: The specimens for metallography were taken by cutting the test specimen into two. The cut face was ground using grit 240- 600 silicon carbide grinding paper on the grinding belt. It was then transferred to the polishing disc. 1 micron alumina powder was used for the pre-polishing and the final polishing was undertaken using 0.5micron silicon carbide powder. The specimens were thoroughly washed using distilled water. Warm air from the air blower was used to dry the specimens. Each specimen was then etched in nital solution and washed in distilled water and dried using an air blower before it was examined using a metallurgical microscope equipped with a camera.

RESULTS AND DISCUSSION

Results

The result of the work is here by illustrated in Figures 1-2. The microstructure of the un- treated and treated steel is shown in Plates 2 and 3, respectively.

Discussion

Figure 1 is the plot of the hardness profile of the untreated mild steel. The plot of the hardness against the distance from the surface to the core is more of a horizontal straight line showing the constancy of the hardness profile of the untreated mild steel. The profile of Figure 1 can be clearly distinguished from that of Figure 2 which is the hardness profile of the treated mild steel.

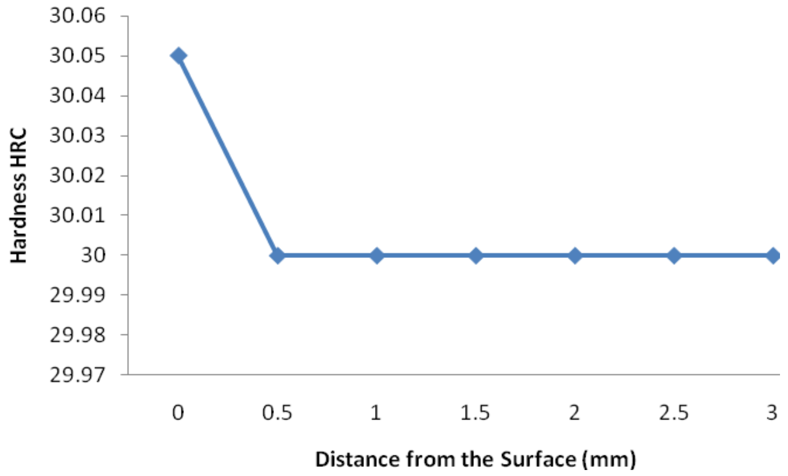

Figure 1: Hardness Profile of the As-received Mild Steel Specimen.

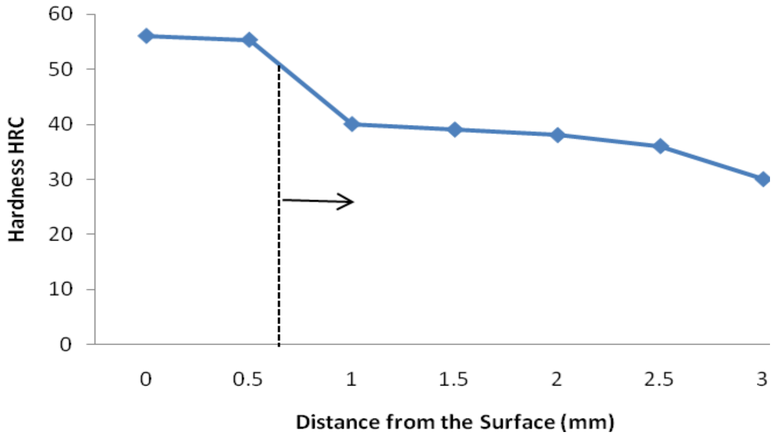

Figure 2: Hardness Profile of the Case Hardened Mild Steel using Arecaceae Flower Droppings.

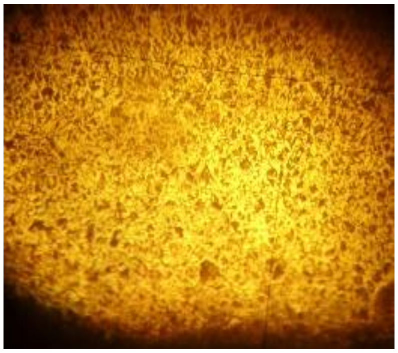

Plate 2: Microstructure of the Untreated Steel showing Pearlite Structure within a Ferrite Matrix. X100.

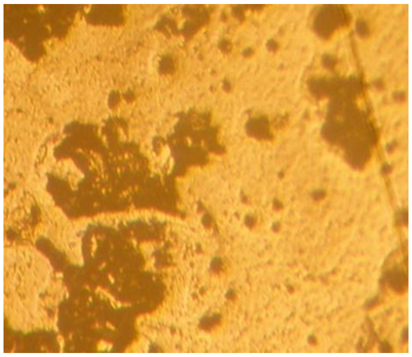

Plate 3: Microstructure of the Mild Steel after treatment with Arecaceae Flower Droppings showing Precipitates (dark phase) from the Treatment. X100.

From Figure 1 it can be observed that the hardness variation from the surface to the core is small, this minor variation in hardness may be as a result of scales, segregations, inclusions or some defects resulting in non-homogeneous microstructure or macrostructure which tend to vary the hardness of the steel. The hardness distribution is more or less constant and this trend is normal of most rolled stocks. Harder surfaces are however not a rare occurrence because of scale formation (Higgins, 1983; ASM, 1977).

Figure 2 which is the plot of the hardness against the distance below the surface of the casehardened mild steel has been used to deduce the effective case depth. According to ISO standard and ASM Committee on gas carburizing, effective case depth is the perpendicular distance from the surface of a hardened case to the farthest point at which a hardness of 50HRC is measured. In Figure 2 the effective case depth corresponds to 0.70 mm below the surface of the mild steel, this value is within the range as the effective case depth can be up to 1.5-2.0mm depending on temperature, holding time, and carburizing or nitriding agent used (ASM, 1977; Iwata, 2008; JIS, 2008).

The figure showed that the highest hardness of 56HRC occurred on the surface of the steel. The high surface hardness may be traced to the chemical composition of the arecaceae. In literatures reviewed it has been discovered that the fruit of this plant has sugar content of more than 50%, 2% each of protein and fat (Encyclopedia Britannica, 2010). Ihom et al. (2010) also revealed that fruit juice extracts of this plant has served as good corrosion inhibitors in several corrosive media. It must be noted that sugar is a good source of carbon, and protein and fats contain nitrogen. Carbon and nitrogen from arecaceae must have been absorbed at the surface of the mild steel and diffused into the steel to give it the high surface hardness, and the hardness profile exhibited (ASM, 1977; Iwata, 2008).

According to ASM (ASM, 1977) carbonitriding is a process in which austenitized ferrous metal is brought into contact with an atmosphere containing both carbon and nitrogen whereby the elements are simultaneously absorbed and diffused into the metal to produce the case. Typically, carbonitriding is carried out at a lower temperature (705 to 900^{o}C) and for shorter time than carburizing in order to obtain a hard, wear-resistant case that is shallower than is usual in production carburizing. Another author argues that the dominant reaction between 500^{o}C to 570^{O}C is nitriding and the dominant reaction between 750 to 1010^{O}C is carburizing (Khanna, 2008; Bolton, 1999). The fact remains that the result of the surface hardness obtained tilts more towards carbonitriding and the mechanism is well understood, the protein and the fat at elevated temperature decomposes producing nascent nitrogen which is absorbed at the surface of the steel through absorption and diffusion. When the steel gets austenized the FCC structure of the steel makes room for more interstitial carbon. Nascent carbon produced through decomposition of sugar, protein and fats gets deposited on the surface of the mild steel and through absorption and diffusion it gets to the surface and inside the steel producing a diffusion layer and compound layer on the surface of the steel (Iwata, 2008). This gave rise to the increased hardness on the surface of the mild steel. This type of treatment can be given to gears, rollers and shafts to increase their wear resistance (Higgins, 1983; Iwata, 2008).

Microstructure Examination

Plates 2 and 3 show the untreated and the surface hardened mild steel samples respectively. Plate 3 reveals the compound layer and the diffusion layer clearly distinguished from the core which is clear with a ferrite matrix interspersed with cementite phases; the case is darker and denser. Plate 2 microstructure shows no such distinction as plate 3. It is just the normal ferrite–pearlite structure associated with rolled mild steel stocks (Higgins 1983, ASM 1977, Bolton 1999). The grain boundaries are not so clear but the dendrites of cementite are clearly revealed at the magnification of 100 (JIS 2008).

CONCLUSION

This study has revealed that arecaceae flower droppings are potentially suitable for increasing the surface hardness of mild steel. Gears, shafts, rolling parts, and agriculture hand implements which need wear resistance can be hardened using this material. The material imparts hardness through the deposition of carbon and nitrogen on to the surface of the mild steel which diffuses into the steel imparting hardness to the steel. The process was carried out at a temperature of

920^{o}C for 3 hours and it imparted a hardness value of 56 HRC and an effective case depth of 0.7 mm to the mild steel. This is high hardness and good case depth can be attained by only a few carburizing agents within this short time of holding.

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ABOUT THE AUTHORS

Dr. Paul Ihom, is the National Vice President of the Nigerian Metallurgical Society, a researcher who has been at the forefront of materials and metallurgical development in Nigeria. He has masters of engineering degree in production engineering, PGDM, MBA (Management), and Ph.D. (Materials and Metallurgical engineering). He is a member of several professional bodies and has trained in surface finishing technology for improving metal property in Japan.

Dr. Geoffrey Nyior, is a Senior Lecturer with Ahmadu Bello University Zaria, Nigeria. He has his Ph.D. in Metallurgical Engineering. His research interests are in the areas of materials testing and failure analysis, he has researched extensively on locally produced constructional steel in Nigeria. He is a member of several professional bodies.

Mannaseh Ambayin, is a researcher with the National Metallurgical Development Center, Jos. He has worked previously as the production manager of Makeri Tin Smelting Company, Jos, Nigeria and as a lecturer and Head of Department of Metallurgy at the Plateau State Polytechnic Bakin Ladi Jos, Nigeria. His research interests are in extractive metallurgy of nonferrous metals. He has Masters degree in Metallurgical Engineering.

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