EXPLORING THE POTENTIALS OF USING PALM KERNEL OIL ESTERS (PALM KERNEL OIL+BITUMEN) FOR AUSTEMPERING PROCESS OF MEDIUM CARBON AND HIGH CARBON STEEL

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ABSTRACT: *Exploring the potentials of using palm kernel oil esters as quenching media on medium and high carbon steel was investigated for a more efficient production of engineering and industrial materials that requires steel as its major raw material since steel and steel industry is one of the catalysts for a number of industries such as the automobile, shipbuilding, containers, railroads, constructions and a lot of domestic appliances which will complement each other in economic growth. The samples were austenitized at various temperatures (850^{0}C to 950^{0}C). Tensile strength, impact strength and hardness test were used to measure the quenching strength of the media. The microstructures and mechanical properties were used to determine the severity of the palm kernel ester. From the results obtained, it shows that the hardness values for both 0.56%C and 0.76%C-Steel were higher (502 and 513 HV) than the as received values (321 and 406 HV) which shows better improvement as a result of formation of bainite structure and diffusion of carbon precipitates in the steel samples. The research carried out showed that palm kernel oil+bitumen can be used as quenching media in austempering process.*

KEYWORDS: Medium Carbon Steel, High Carbon Steel, Palm Kern Oil+Bitumen, Holding Time, Austempering, Austenitizing Temperature.

INTRODUCTION

Iron has been a vital material in technology for well over three thousand years but until the industrial revolution, its mining, smelting and working were largely done by industries with larger source of income hence a decline in the economy. Each mine, forge, and blacksmith usually employed only a few dozen men at most of the things involved. Steel, however was another matter which will help out even though its production is even more expensive but with the availability of the abundant scraps in Nigeria, researchers began to explore the oppournity of using it in production of some parts. Steel and steel industry is one of the catalysts for a number of industries such as the automobile, shipbuilding, containers, railroads, constructions and a lot of domestic appliances which will complement each other in economic growth. Because of the tremendous decline in the use of other metals, the increase in the usage of steel will have a great effect in the economy. It equally plays a vital role in engineering applications because of high range of physical and structural properties obtained by changes in carbon content and heat treatment practice hence it is always used materials in industrial applications due to its low monetary value, high strength, and durability[Feng,c and Tahir l, 2008]. Some engineering components need higher hardness value so that they will be used successfully in components meant for heavy duty activities and to achieve that, hardening is required which involves heating the alloy to a particular temperature, holding at that temperature then cooling rapidly in a media [Hassan S.B et. Al 2009]. The rapid cooling will eventually cause increase in the hardness of the alloy as a result of the phase transformation which is austenite and low temperature transformation of austenite is martensite which is the hard part of the steel [Rajan T.V et.al 1988; Keenha, E 2004]. This process of cooling steel rapidly is called quenching and the media in which that is done is quenchant [Hassan S.B and Aigbodion V.S 2013]. Steel can be defined as an alloy of iron and iron carbide (carbon ranging from 0.015% to 2.14%) with other alloying constituents such as manganese, silicon, sulphur, phosphorus [Hassan S.B and Aigbodion V.S 2013]. There are several methods of making steel, the more important of which are the Bessemer process, the open hearth process, the electric arc furnaces process and the direct reduction process. They are based on the same principle, which are: remove all the impurities from molten pig iron by oxidation and add known quantities of carbon and other elements to the molten iron to obtain steel of the desired composition. Pig iron, scrap iron and scrap steel are the raw material that is used for making steel [Osei Y. A, 2004]. There are various types of steel which include mild steel (0.15-0.30%C), medium carbon steel (0.35-0.65%C), high carbon steel (>0.65%C) and stainless steel. Austempering is hardenabilty process that includes austenitizing, followed by cooling to prevent formation of pearlite to a temperature above the martensite start and then holding until the desired microstructure is formed. Heat treatments can be applied to steel not only to harden it but also to improve its strength, toughness or ductility in order to change the original coarse grain structure which the steel has. Austempering is one of the quench hardening methods applied to alloys so as to improve the mechanical properties of the alloy under research and it will be possible when carried out in an austempering media. The austempering media often used in both in industries are molten bath, air oil, brine e.t.c. a lot of researchers have done a lot of works on this austempering with various austempering media; they include

Mineral oil and salt bath have been found to have best cooling procedure but they are expensive, toxic and non biodegradable. A lot of researchers have done a lot of works on this austempering with various austempering media they include M Dauda et.al they carried out work on the effectiveness of the palm kernel oil, cotton seed oil and olive oil as quenching medium in the hardening process of steel; from there work, it was found that palm kernel oil and olive oil lower hardness value than that of as-received thereby making the quenchant undesirable for hardening. The strength stability of medium carbon steel plays an important role in automobile industries. Medium and hard steels can be heat treated to produce steels with var5ious degrees of hardness through heating of the steel to a hot region and cooling slowly, the steel gotten is very hard and brittle and to remove the brittleness and increase its tensile strength, the steel is reheated to a particular temperature and allowed to cool and this is known as tempering [Osei Y.A 2004]. Palm kernel seed oil is edible plant oil derived from the kernel of the oil palm elaeis guineenis. Palm kernel seed oil is semi-solid at room temperature and saturated than palm oil. It does not contain trans-fatty acids/cholesterol. The saponification value of palm kernel seed oil is 183.92mgKOH/g while the iodine value of kernel seed oil is 63.59mgI_2/g. Palm kernel seed oil is has some bacteria in it which will attack any specimen when been heated hence high risk of distortion. Bitumen is a black/brown viscous liquid (thermoplastic in nature) consisting mainly hydrocarbons and their derivatives, which can dissolve in carbon disulphide [2]. The physical properties of bitumen as conducted by KRPC are: Softening point – 50.10˚C, Ductility - > 150, Specific gravity – 1.01, Flash point - 378˚C, Boiling point - 350˚C. The softening point of bitumen can help remove the bacteria in palm kernel seed oil thereby making palm kernel seed oil+bitumen a good austempering media, also all other properties of bitumen can combine well with palm kernel seed oil. Palm kernel oil esters have great potentials in the cosmetic and pharmaceutical industries due to the excellent wetting behavior of the esters without the oily feel. Addition of bitumen was to act as the product that will give rise to the formation of the esters and was chosen because of its softening

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point which will help in the refining process to help remove the chloroester precursors prior, bacteremia and endocarditic to the deodorization step. Bitumen was not used alone in this experiment because of reduced strength of the material which can lead to limit of the material to areas where high stresses are needed as a result of voided nature of the material. It was just added to palm kernel seed oil so as to eliminate the bacteria found in palm kernel seed oil so as to reduce distortion or decline in the life spam of the material.

This research is to explore the potentials of using palm kernel seed oil+bitumen as a quenching media (a locally sourced material) during austempering of steel which will help growing engineers, foundry men without money during heat treatment operations instead of importing the other quenchants which are costly thereby boosting our economy through the equipments they were able to produce with steel when heat treated. The potentials of using the above quenching media is done using the mechanical properties of the annealed steel samples quenched with the above quenching media, the mechanical properties are: tensile strength, impact strength and hardness test.

MATERIALS AND METHODS

Materials

Medium carbon steel is used as test samples to evaluate palm kernel seed oil+bitumen as austempering media. The chemical composition of the alloys is shown in table below. The equipment used during the experiment were: electrically heated furnace with temperature 1200^0C, medium sized kerosene and pot for heating the palm kernel seed oil+bitumen, struner's hot mounting press for mounting all metallographic samples, laboratory mercury thermometer, Pendulum type Charpy Impact Testing Machine (Denilson model), TEC-C- 100 tensile testing machine, Avery hardness machine, Heat treatment furnace, weighing balance, starter pH meter, H_2SO_4 and HCL, Tensometer, Lathe machine, Metallurgical microscope.

Table 1: Chemical composition of the steel used

Element	c	Mn	Si	S	P	Fe
0.76%C	0.76	1.11	0.33	0.03	0.05	Fe
0.56%C	0.56	0.96	0.26	0.05	0.33	Fe

METHODS

Palm kernel seeds were purchased from local palm processors in Ekwuluobia, Anambra state. Palm kernel oil was extracted from the palm kernel seeds using the traditional method of heating. Bitumen was purchased from C & O civil engineering laboratory Awka, Anambra state. Laboratory thermometer was placed into the steel pot containing the kernel seed oil+bitumen and heated to its boiling temperature. The alloys were machined to impact and tensile samples with their various specifications as 10 × 10 × 55 mm with a 2.5mm notch (for impact test) and 70 × 10 mm (for tensile strength). One sample each from the alloys was taken from the samples and kept aside (as untreated) before heating the other ones. The remaining samples were given a normalizing heat treatment by heating the samples in an electrical furnace at various temperatures starting from 850^0C to 950^0C, soaked at various time intervals ranging from 5 mins to 2 hours, removed and cooled in air. One sample each

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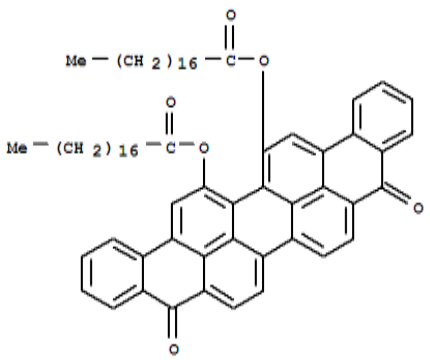
were taken and kept aside as normalized sample. Normalized tensile and impact test samples of the three alloys were austempered as detailed below. a. Normalized samples of 0.56%C-steel were taken and placed in a crucible, loaded into the furnace, heated to 900^{0}C , soaked for one hour and quenched in hot kernel seed oil+bitumen boiling at temperature of 420^{0}C. After some minutes, the first set of samples were removed from those quenching medium as listed above, cooled in air and washed in kerosene, then with soap solution. Another set of samples were removed after 5 minute, 30 minutes, 1 hour, and 2 hours cooled in air and washed in kerosene then in soap solution. Bitumen was added in a small quantity to avoid under reaction or over reaction. The ratio of the addition was four: half.

Chemistry of the Equation:

The chemical equation of the reaction between palm kernel seed oil and bitumen is shown below:

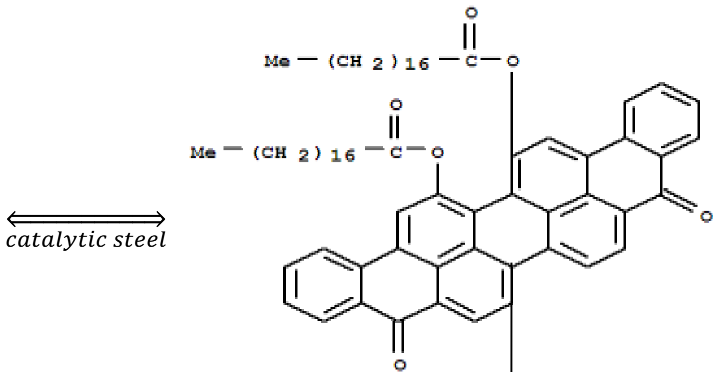


+

CH$_2$-OH + R-COOH$_2$ –COOR

CH$_2$-OH+R-COOHCH-COOR + 3H2O

CH$_2$-OH+R-COOHCH$_2$-COOR



CH$_2$-OH + R-COOH$_2$ –COOR

CH$_2$-OH+R-COOHCH-COOR

CH$_2$-OH+R-COOHCH$_2$-COOR

$CO_2 + nH2O$

Where R = CH_3

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Metallographic Samples Preparation for Microstructure.

All the samples both untreated and heat treated involved in this experiment were subjected to thorough metallographic sample preparation processes as described below:

a. Rough machine grinding of all samples was carried out successively on 60, 80, 120 and 180 grifts abrasive emery grinding papers.

b. Fine machine grinding of all samples was carried out on 200, 400 and 600 grifts abrasive emery papers using wet type process.

c. All the ground samples were polished on a polymet polishing machine.

d. All the polished samples were tested for hardness at different three points on the same surface of metal sample and average taken.

e. All the samples were re-polished after the hardness and etched.

RESULT AND DISCUSSION

The microstructure of the as-received and the quenched samples are presented in micrographs below

Metallographic and mechanical properties analysis:

To evaluate the quenching strength, metallographic analysis of the received and quenched prepared specimen were carried out. Microstructure examination of the treated and untreated samples was carried out. Each sample was carefully grounded progressively on emery paper. The grinding surface of the samples were polished on a micro clothe. The crystalline structure of the specimens was made visible by etching on the polished surfaces. Microscopic examination of the etched surface of various specimens was undertaken using microscopic and during the microscopic examination, a camera was used to take the resulting microstructure of the samples. The micrographs of the as-received 0.76%C-steel and 0.56%C-steel and the heat treated samples are shown in the micrograph below. The structure of as-received 0.76%C-steel and 0.56%C-steel shows ferrite in pearlite matrix which is shown in the first micrographs. Normalized 0.56%C and 0.76%C-steel are equally shown in sample 2 and showed pearlite structure the normalized sample showed that the size of the original austenite grains were influenced to a remarkable extent because the sample revealed a pearlitic matrix in which shorter graphite flakes than in annealed sample existed. The microstructure of the specimens when quenched at with kernel seed oil +bitumen (3-6) shows that the martensite structure when rapidly quenched from its austenite temperature, that the austenite will decompose into a mixture of carbon martensite and fewer pearlite, and as a result of this microstructure which is hard there will be an increase in tensile strength and other mechanical properties. The micrographs of the sample quenched in bitumen+kernel seed oil from 5 minute to 2 hours shows that in both steels, at the initial austempering time, combination of retained austenite and martensite was obtained but for high values of austempering times and at various austenitizing temperatures, a mixture of retained austenite and bainite was also obtained. It is also assumed that the low distribution of martensite at lower soaking time is caused by the short heating times resulting in a non-homogeneous austenite. This shows complete diffusion of carbon into the austenite phase

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and a concentration gradient exists. With increasing austempering time, however, carbon diffusion is enhanced and a more homogeneous austenite evolves resulting in higher martensite transformation distribution upon quenching. The structures obtained from the practical microstructural investigation correlate with hardness predictions and are in agreement with findings in the introduction. It has also confirmed that the above heat treatment process is realistic and reliable for the development of structures with improved mechanical properties comparable to those of austempered samples.

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To evaluate the strength of the media on the mechanical properties of the received and quenched specimens, graphs were drawn based on the results obtained. The graphs are shown below:

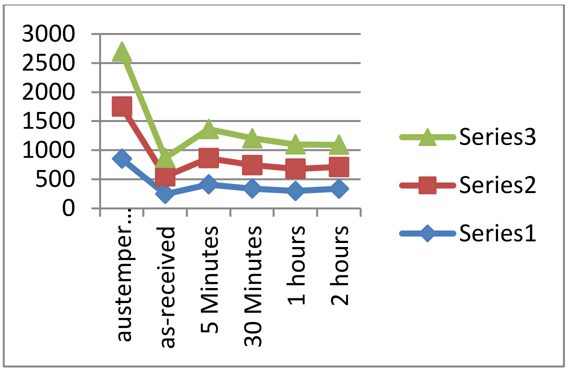

Figure 1: Hardness for 0.56%C-Steel

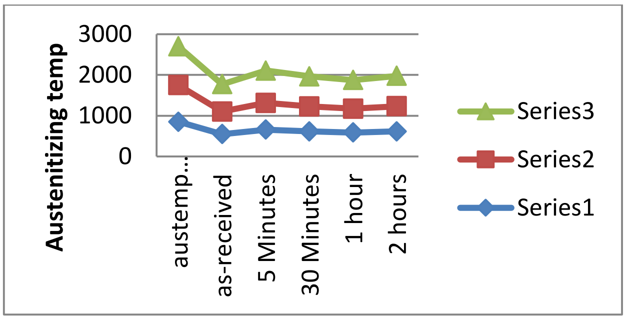

Figure 2: tensile strength for 0.56%C-Steel

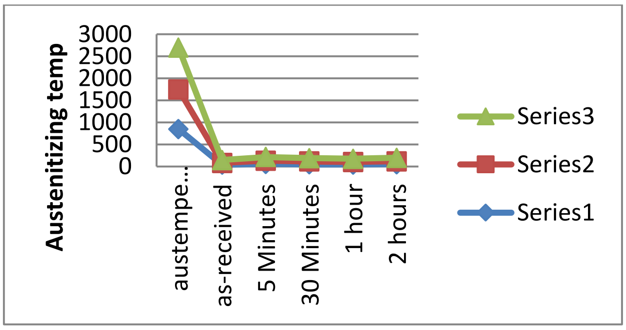

Figure 3: %e for 0.56%C-Steel

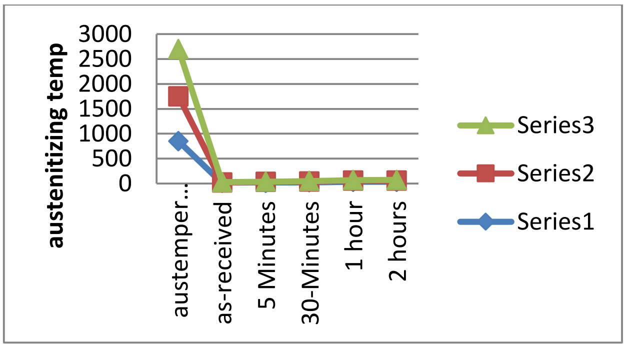

Figure 4: impact test for 0.56%C-Steel

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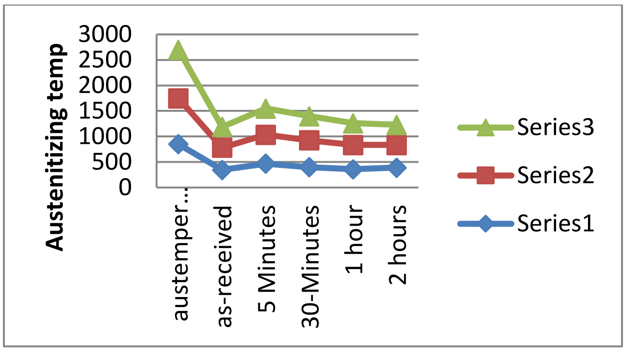

Figure 5: hardness for 0.76%C-Steel

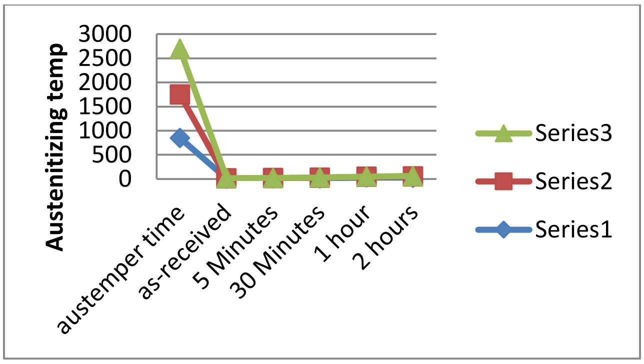

Figure 6: impact test for 0.76%C-Steel

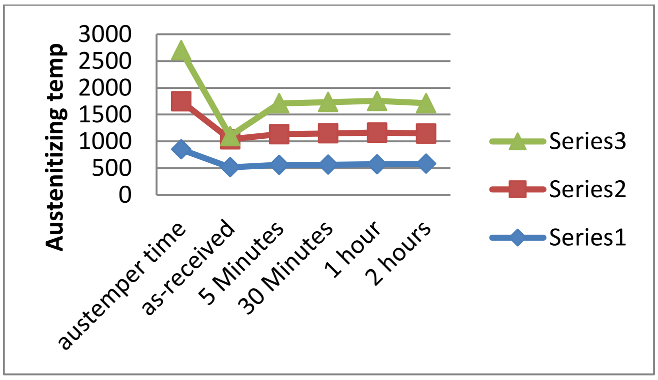

Figure 7: tensile strength for 0.76%C-Steel

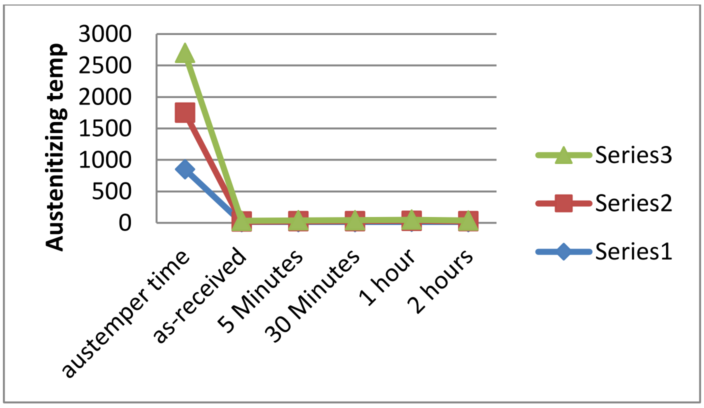

Figure 8: %e for 0.76%C-Steel

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From the graph above, figure 2 and 3 shows the tensile strength and percentage elongation on 0.56%C-Steel. From the graph the tensile strength increased when quenched at a time of 5 minutes and then decreased. This increase is attributed to the formation of ausferrite in the matrix of 0.56%C-Steel, the decrease was noticed indicating that the reaction crossed from toughening stage to embrittlement. Figure 1 shows the value of the hardness on 0.56%C-Steel. At all the transformation temperature, hardness values decreased as the holding time increased. The decrease was a result of the transformation of austenite to bainite. Figure 4 shows the impact test on 0.56%C-Steel. From the graph, the impact toughness increased with increase in holding time as a result of the size of the austempered structure. Figure 5 shows the hardness value on 0.76%C-Steel and from the graph, there was an increase when the holding time was 5 minutes and after that, there was a decrease. The existence of the hard and brittle phase martensite is the main reason of the higher hardness values obtained, at the other transformation temperatures, the hardness values decreased as holding time increased which might be as a result of the uniformity in the grain size. Figure 6 is the impact test on 0.76%C-Steel, at each austenitizing temperature, the impact strength increased as the holding time increased because of the formation of bainite structure. Figure 7 and 8 is the effect on tensile strength of 0.76%C-Steel, there was an increase in the tensile strength when the holding time increased because there were less austenite to transform to martensite and the reason behind bainite formation are fine grain size, high carbon content.

CONCLUSION

The strength of the palm kernel oil esters as quenching media in the hardening process of medium carbon and high carbon steel has been assessed using hardness values, percentage elongation, tensile strength and impact energy. From the results obtained, the following conclusions can be drawn:

1. Palm kernel oil+bitumen can be used for hardening of steel because the values obtained were higher than the as-received values.

2. palm kernel oil + bitumen is cost effective since it was locally sourced hence local heat treatment industries in the area of austempering should adopt this method, this will equally help boost the local heat treatment industries because they will need less capitals for production of parts involving steel than importing those quenchants and once those parts are produced, Nigerian economy will rise once they are exported.

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