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PERFORMANCE EVALUATION OF SELECTED VEGETABLE OILS AS QUENCHING MEDIA IN HEAT TREATMENT PROCESS FOR MEDIUM CARBON STEEL.

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ABSTRACT

The focus of this investigation is to find the suitability of some selected oils abundantly available as effective alternatives to the conventional media, water and SAE oil. While water usually causes distortion corrosion and cracking of component due to its high quenching severity, SAE oil on the other hand has low quenching

Introduction

The commonly used quenching media are water, SAE oil, brine, and synthetic solutions. Water though abundant and low cost has the drawback of inducing crack or dimensional changes on the quenched component due to its high cooling rate and oil has the problem of not inducing enough hardness. Polymer quenchants though can provide severity between those of water and oil but has the problem of varying concentration during the quenching process and it is also more expensive.

Brine produces more quenching severity than water; but it also has a problem of corrosive attack on the components and the equipment used for the quenching operation. Therefore

severity for many applications, high cost, non-biodegradable and excessive fume generation during the quenching operations. A comparative study was carried out to investigate the suitability of these selected vegetable oils as alternative quenchant to SAE40 engine oil for industrial heat treatment of Medium Carbon steels. The study involved the characterization of physicochemical properties of (jatropha seed oil, neem seed oil, cotton seed oil and castor seed oil. The quenching performance of these vegetable oils was conducted at quenchant bath in a control agitation machine at different temperatures, serving SAE40 engine oil and tap water as control. The effect of cooling rates of the quenching media on mechanical properties and microstructure of the quenched steel samples were investigated. The results obtained show that the different vegetable oils have different viscosity and viscosity-temperature behavior just as their molecular structures were different. Hence vegetable oil is suitable as alternative quenchant to petroleum based SAE40 engine oil for quenching medium carbon steels, without cracking or distortion, the most suitable among them being palm kernel oil.

Keywords: Fatty Acid, Engine oil, Mechanical Properties, Microstructure Quenching, Vegetable oil.

there is a need for the development of a quenching medium with good economics like water, environmentally friendly and having less severity of quench and yet producing appreciable hardening characteristics [Hassan, S.B 2010]. Hence this work is aimed at investigating the suitability of using various non-edible seed oils as alternative quenching media for hardening process in low and medium steels, with and without agitation effects.

No doubt, the ferrous metal group (steels & cast irons) constitute the most widely used in engineering this is because this alloy group has many applications including, automobile, construction, electrical & electronics, domestic appliances, marine, aeronautics, nuclear etc. fields [Kobasco

2010]. Again this feat is possible due to the fact that different properties can be developed in these metals to meet the demands of numerous applications by both alloying process and thermal process called heat treatment. Heat treatment involves heating the ferrous metal into the austenite temperature range and followed by a controlled cooling such as in the furnace (annealing), air (normalizing) or a liquid medium (quenching/ hardening)[Agboola, J.B. 2014]

Hardening essentially involves heating the metal alloy to a sufficiently high temperature, holding at that temperature followed by rapid cooling in a media usually water, oil or salt bath [Yekinni A.A, 2014]. This consequently causes an increase in hardness of the metal/alloy, which due to phase transformation which accompany rapid cooling that occur at a considerably low temperature leading to the formation of non equilibrium products [Bogh N 1994]. The transforming phase is austenite and the product of low temperature transformation of austenite is martensite which is a hard micro-constituent in steel [Maruf 2015],. The presence of this micro constituent in rapidly cooled steels thus accounts for the increase in hardness of steel [Totten G.E 2005,].

Due to internal stress quenched steel and ductile cast iron is extremely hard but brittle, Therefore the quenching process is followed by another heat treatment process called tempering when the component cannot be used is as quenched condition.

Plain carbon steels are widely used for many industrial applications and manufacturing on account of their low cost and easy fabrication [Shuhui Ma 2006]. They are classified on the basis of their carbon content as their major alloying element is carbon. . The carbon content of high carbon steels usually ranges within 0.6-1.5%. Hardness and other mechanical properties of plain carbon steels increase with the rise in concentration of carbon dissolved in austenite prior to quenching during hardening heat treatment [Shuhui Ma 2006], which may be due to transformation of austenite into martensite [Totten G.E 2007]. Therefore, the mechanical strength of medium carbon steels can be improved by quenching in appropriate medium. However, the major influencing factors in the choice of the quenching medium arec omposition of the steel, the sizes and shapes of the parts [Totten G.E 2007].

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Applications of steels for engineering components require a complete understanding of material properties and design requirements. Through the last few decades a category of steels known as high strength steels have undergone constant research [Srikanth.V 2003]. As a result, quenched and tempered micro alloyed steels are most likely candidate materials for the next generation of high – strength steel sheets. For a given alloy content, quenched and tempered micro alloyed steel exhibit good combination of strength and toughness [Totten G.E (2007)].
Traditionally, quenched and tempered steel sheets are employed in automotive industry in the areas of structural members, power transmission and impact resistance systems. Certain engineering components require high hardness values so that they may be used successfully for heavy duty processes. Hardening as a form of heat treatment has been used to achieve these requirements in metal or alloy components.

METHOD

Test Samples was machined from the medium carbon steel. One set of the machined test samples from medium carbon steel (for hardness, tensile and impact) will be kept aside to be tested in the as-received condition,. The remaining samples in each case will be taken into the furnace and austenitized at 880oC for medium carbon ,and soaked using a furnace for 1hr before been removed and cooled in air.
The samples will be taken back into the furnace and heated to 880 0_c, again, soaked for 1hr after which a set of test samples for (hardness, tensile, impact) each will be removed and quenched in water, SAE engine oil castor, Jatropha respectively. The quenched samples will then be removed, cleaned and subjected to hardness, tensile and impact tests respectively.

Production of test pieces

The test piece sample was selected from building rod of 10mm diameter. A sample was taken for composition test to know the carbon percentage in the sample. the composition test was done using a spectrometer. The test result shows that it is a medium carbon steel with carbon content of

0.55%. the test pieces were produced from the same material[building rod] and machined for three major tests; tensile, impact and hardness test. Seventeen test pieces were produced for each test, that is fifty one specimens in total.

Heating process

First of all, three of the specimens were set aside as received, the remaining test specimens were normalized; that is to say they were heated in the furnace at 880 0_c, then the temperature[880 0_C] was maintained for 30minutes after which it was allowed to cool down in air[quenching in air].a set of the specimen was set aside again as normalized specimen. After normalizing, the specimens were heated to 880 0_C and then quenched in the four quenching mediums [Jatropha, SAE, water and castor oil]. The specimens were grouped in three per batch with respect to the three tests[tensile, impact and hardness] .The quenching process was carried out in four different conditions for each quenchant ;for no agitation, low speed agitation, medium speed agitation and high speed agitation. An agitation speed 3000 rpm was the optimum speed to produce maximum increase in hardness.

Table 1. Agitation Procedures

	Agitation Conditions			
Quenchants	No agitation Samples	Low speed agitation Samples	Medium speed agitation samples	High speed agitation Samples
Jatropha	3	3	3	3
Neem	3	3	3	3
Castor	3	3	3	3
Water	3	3	3	3
SAE	3	3	3	3

For each of the three sets of specimen tensile, impact and hardness test specimen with respect to agitating conditions were performed.

S/N	Specimen	Impact Energy (Joules)
1	SAE[No agitation]	133.65
2	SAE[low agitation]	11.45
3	SAE[Medium agitation]	168.75
4	SAE[High agitation]	94.50
5	Water[No agitation]	171.45
6	Water[low agitation]	12.15
7	Water [Medium agitation]	24.30
8	Water [High agitation]	13.17
9	Castor [No agitation]	162.00
10	Castor [low agitation]	91.80
11	Castor [Medium agitation]	72.90
12	Castor [High agitation]	86.40
13	Jatropha [No agitation]	117.45
14	Jatropha [low agitation]	226.80
15	Jatropha [Medium agitation]	103.95
16	Jatropha [High agitation]	82.35
17	Neem [No agitation]	98.22
18	Neem [low agitation]	102.11
19	Neem [Medium agitation]	145.43
20	Neem [High agitation]	179.33
21	Normalised	91.80
22	As recieved	76.33

This experiment was repeated for tensile and hardeness test piece as follows:

Hardness values were determined from the as-quenched specimens. The hardness impressions were taken transversely in two perpendicular directions along the crosssection of the quenched steel specimens using Rockwell hardness testing machine (Leco LM 700 AT) under applied load of 477.5 MN and dwell time of 9 sec. on a “C” scale (HRC). Hardness values were recorded for the three samples [No agitation, low agitation and high agitation]

Tensile tests were conducted on an Instron Universal Testing machine Model 3369 by using standard tensile test specimens of 10 mm in diameter and gauge length of 25 mm. The tensile strength, percentage reduction in area and percentage elongation were determined from the Load-extension curves. The impact energy test was carried out to measure the toughness of the as-quenched steel specimens on Izod impact testing machine Model IT-30 according to ASTM D256 in various selected quenching media.

Results and Discussion

Table 1 gives the average chemical composition of the steel used.

The effect of selected quenching media on the mechanical properties of the quenched medium carbon steel is entered in Table 2. Figures 1-4 are the bar charts of hardness values, tensile strength, percentage elongation, and impact energy of the quenched medium carbon steel.

The quenching characteristics of medium carbon steel in the selected vegetable oils were studied in this research work to evaluate the possibility of using vegetable oils as alternative quenchant to SAE40 engine oil for industrial heat treatment of Medium Carbon steels. The hardness, tensile strength, percent elongation, percent reduction in area and impact energy were used as major criteria in assessing each vegetable oil under investigation. The study has shown that an increase in the speed of an agitation machine increases the mechanical properties of the specimen, hence the values for high speed agitation were considered in determining the most suitable quenchants.

Table 1. Chemical composition by weight of medium carbon steel(chem. Lab Kaduna Poly)

Elements	Si	Mn	C	P	S	Fe	Cr
Percentage composition	0.16	0.7	0.3	0.03	0.041	98.2	0.41

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Table 2. Effect of quench media at high agitation speed on mechanical of medium carbon steel

Quenched sample	Average tensile strength(Nmm2)	Hardness(HRC)	Izod Impact value(J/m)	Percentage elongation(%)
Neem seed oil quenched	520	13.0	16	0.5
Jatropha seed oil quenched	420	29.2	12	0.4
Castor oil seed quenched	410	22.2	13	0.3
SAE Engine oil quenched	480	21,22	0.4	0.2
Water quenched	230	48.23	1	0.2
As received	568	9.9	29	0.7

Fig.1 Tensile strength of steel in various quenchants at high agitation speed

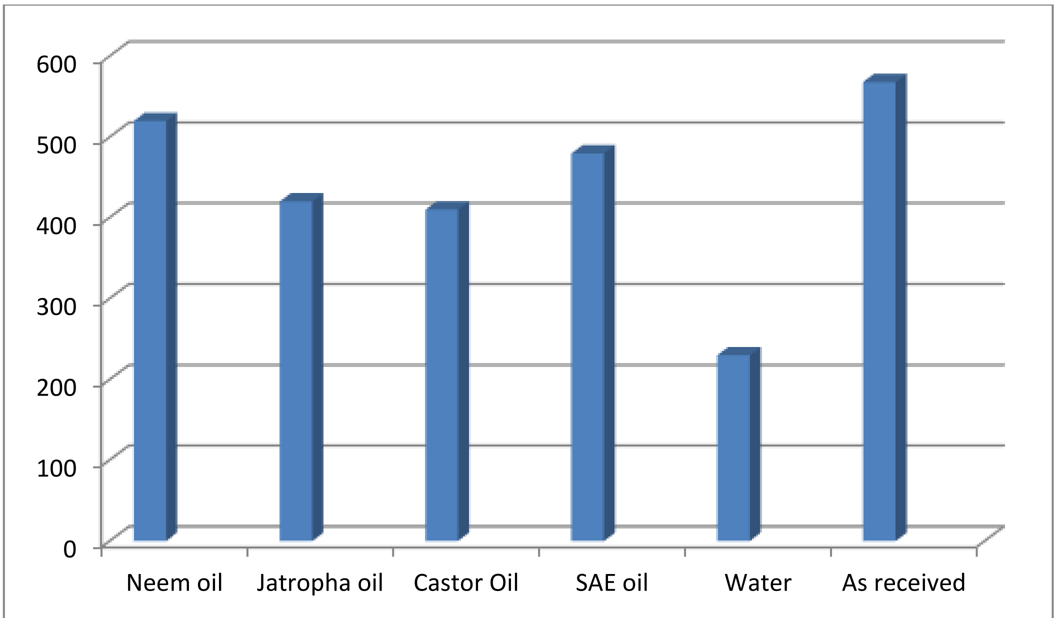

Fig 2. Hardness of sample quenched at high speed in various quenchants

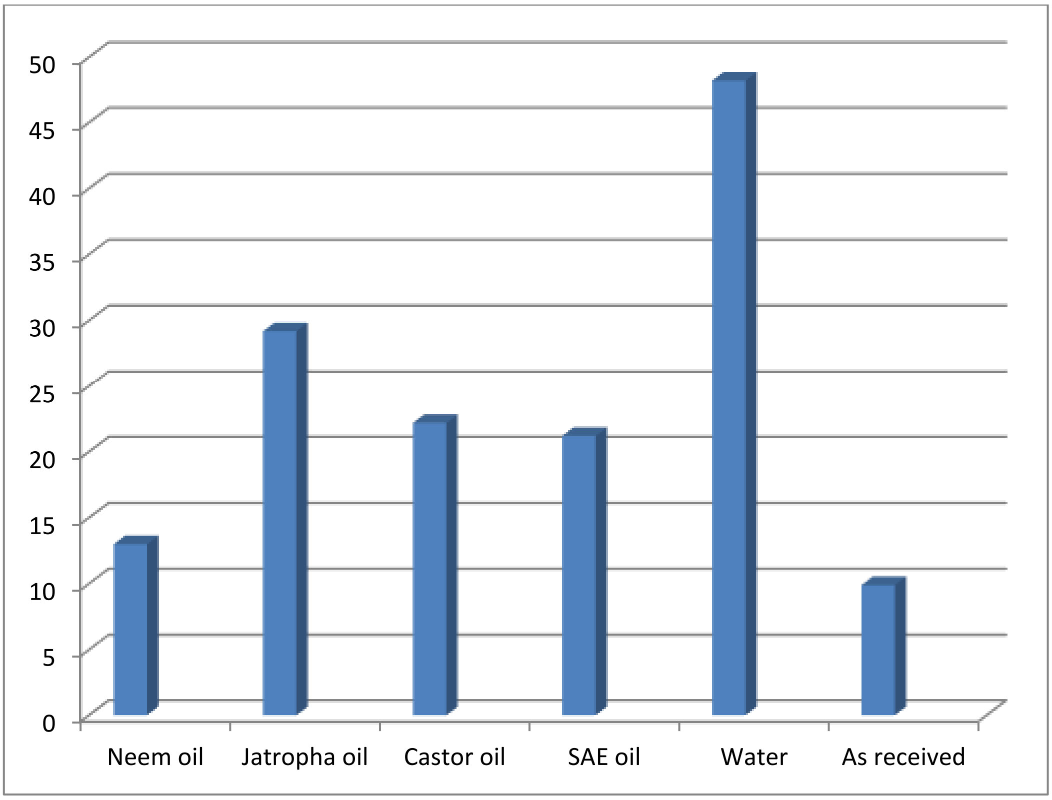

Fig 3.Izod impact values of samples quenched in various samples at high speed

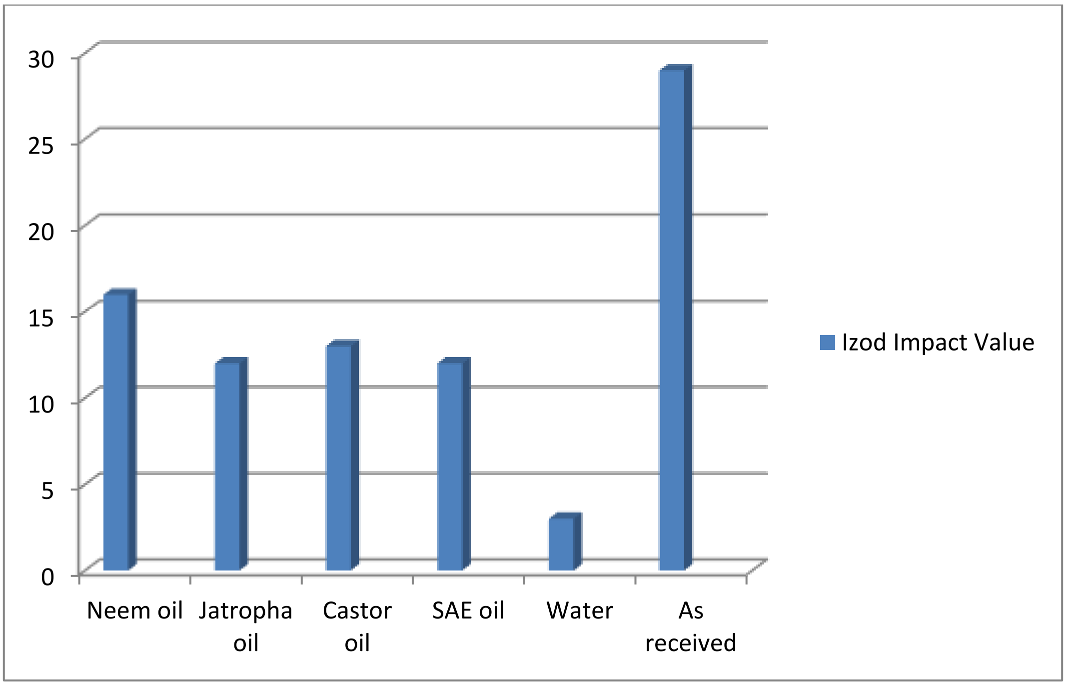

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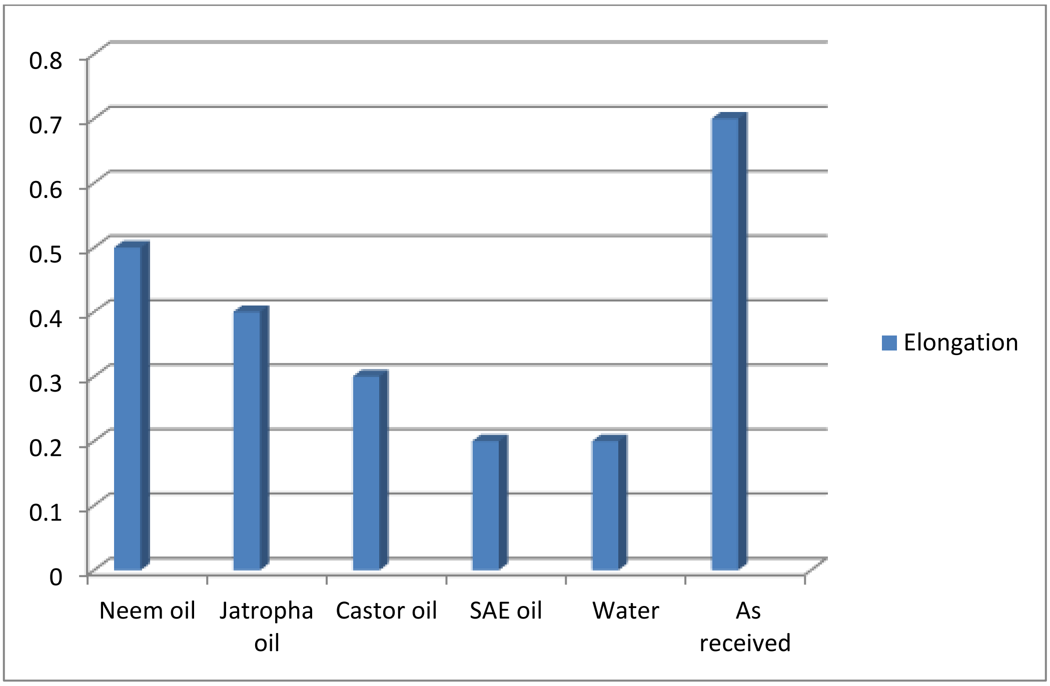
Fig 4. Percentage elongation of samples quenched at high agitation speed in various quenchants



Non edible seeds vegetable oil quenched specimens exhibited higher Izod impact values compare to the water-quenched specimen and there was no cracks observed in the specimens indicating suitability of the media for quenching of this particular specimen. Neem oil quenched sample exhibited superior mechanical properties in relation to hardness values compared to other vegetable oils used.

CONCLUSIONS

At the completion of the research work, the severity of various quenchants was determined, The effect of agitation on the hardening characteristics of test samples through variable agitation rate was also obtained and compared with test samples using SAE engine oil and water as quenchants. The derivatives from this comparism gives the non-edible seed oil a better alternative in terms of quench severity, commercial availability,and environmentally friendliness. Two of the vegetable oils (Jatropha and Castor seed) exhibited substantially fast cooling during the quenching period as reflected by their hardness values obtained which suggest that they would be suitable as alternative to petroleum based SAE40 engine oil for quenching low hardenability steels such as medium carbon steels without cracking or distortion. The most suitable among them being Jatropha oil based on mechanical properties of its quenched steel sample as compared to others. Based on the heat flow parameters, Jatropha oil can be used as fast quench medium while Castor seed oil and neem seed oil may be used as slow quench oil. Among the oils tested, Neem oil exhibited the least quenching ability. Average hardness value ranked in descending order as: Water > Jatropha seed oil > SAE40 > Castor oil > Neem seed oil.

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