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Performance Assessment of Quenchants on Mechanical Properties of Steel Grade A1046

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Abstract: *The main aim of the study is to assess the performance of ghee oil, coconut oil and sea water quenchants on mechanical properties of A1045 steel. The procedures comprise the production of tensile steel specimens, heat-treat them into electrical oven at 850°C for one hour, quench them in ghee oil, coconut oil and sea water separately. The quenched samples were again tempered separately at the temperature of 400°C. Then all the specimens taken for the mechanical tests such as hardness, tensile, impact test and also to calculate the percentage of elongation, having completion of tests, microstructural analysis had conducted to view the structures contain in each specimen. The results obtained on these processes determine whether these oils can be used as local industrial quenchants. The facilities required for the research is include material testing laboratory, heat treatment workshop, machine shop and metallographic laboratory to mentioned but a few. The material selection is steel grade A1045, that have been normally utilize in metal industries for the production of machine parts and structural components*

Keywords: Quenchants, tensile test, hardness test, percentage elongation

I. INTRODUCTION

Steel is important alloy od iron and carbon employed widely in most of the industries as it comprises excellent fabrication properties at economics cost in construction. There is requirement of better properties i.e. high hardness, tensile strength and impact strength of metals to be utilized for heavy duty works [1]. Therefore, for getting improvement in these properties, metals are heat treated and quenched in different media such as water, oils etc. [2].The use of various quenchants such as vegetable oils, animal oils , salt bath had been investigated by many authors [3].Cotton seeds, groundnut oils also had been employed for evaluating the effect on mechanical properties of plain carbon steels[4].This papers is focused to assess the effect of ghee oil, coconut oil and sea water as quenchants for A 1045 steel.

II. MATERIALS AND METHODOLOGY

The materials used for this research include the followings: A1045 steel obtained from Nigeria foundries, coconut oil, ghee oil and sea water. The chemical analyses of the A1045 steel and the oils used are presented in (Table 1). A1045 steel is part of the medium carbon steel group, which comprises grades like 1045, 1050, and 1060. Related to lower carbon steels, it offers higher strength and hardness but lower ductility. It is not as hard or wear-resistant as high carbon steels like 1095, but it offers better machinability and toughness

Table 1 Chemical Composition of A 1045 Steel

Element	C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Fe
Comp. %	0.44	0.16	0.68	0.016	0.007	0.017	0.0062	0.007	0.004	0.003	Balance

As quenchants, ghee and coconut oils are used. Ghee oil is yellowish white coloured and skimmed off raw cow milk. The cow milk has 99 % fat, maximum 0.5% moisture and it is having good properties for deep fry. Coconut oil is extracted from the coconut palm and is used in food as well in medical industries. It is extracted from Kamel having high saturated fat so slow to oxidize and shows resistance to acidification. The chemical composition of ghee oil and coconut oil is represented in Table 2.

Table 2 Chemical Composition of Coconut and Ghee Oils

Analyses	Coconut Oil	Ghee Oil
Iodine Value (g/100g)	86.67	76.56
Viscosity (at 30°C)	182.35	145.46
Flash Point (°C)	296.34	232.50
Density (g/cm³)	0.986	0.955
Saponification's Value (mg KOH)	187	198
Free Fatty Acid (wt%)	6.68	5.97
Acid Value (mg KOH)	6.5	6.8

The methodology used for this study is presented in Figure 1 and shows the different steps followed in investigating the effect of different quenchants on A 1045 steel.

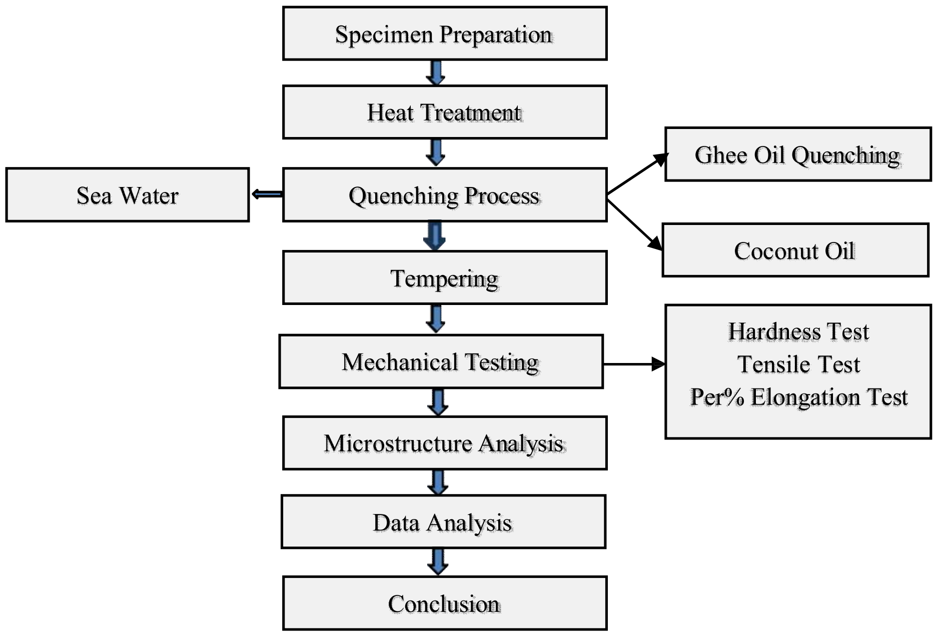

Figure 1 Methodology Adopted for Study

In the first step of methodology, specimen have prepared as per the standard dimensions. Thereafter, the specimens are heat-treated in electrical oven at 850°C for 1 hour. This process ensures transformation of microstructure of A1045 steel to get the desired mechanical properties. In the third step quenching process was carried out. One set of specimens quenched in ghee oil, second in coconut oil and third in sea water. In next step, all specimens were tempered at 400°C to relieve internal stresses and to improve ductility. In Mechanical testing, hardness test, tensile test was conducted following the calculation of percentage elongations. Under microstructure examination of the specimens, sample preparation, etching and examinations performed in metallux electrical microscope. Data analysis completed using standard formulas for calculating mechanical properties.

III. RESULTS AND DISCUSSION

Each quenchants having different properties and different quenching sternness that make it difficult to select the adequate quenchant for quenching purpose also the cooling ability of quenchant vary from one to another. There are various restrictions to choose quenching media i.e. ease of availability, economics, reusability, maintainability, mechanical, chemical properties and thermal properties etc.

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Metallographic Analysis

The microstructures of the as-received and as-quenched samples are presented in Micrographs A1-A4. To evaluate the quenching effectiveness, metallographic analysis of the received and quenched prepared specimen were carried out and compared for A1045 steel carbon content. The as–received sample of a recycled steel A1046 un-heat treated that shows (Figure 4-A1) the martensitic tendencies observed in due to the appearance of carbon in black spotted regions with the boundaries pearlite as a result of the initial given heat treatment. It has been seen at (magnification X100) under the microscope. The as-quenched in sea water sample shown in Figure 5-Micrograph A2, is showing martensite structure (dark) with retained austenite (white). The microstructure seen in this same steel grade A1046 is a result obtained from the sea water as quenching media. The microstructures of austenite grains with twining boundaries are seen in (magnification ofX100) metal structure under the lens of the microscope.

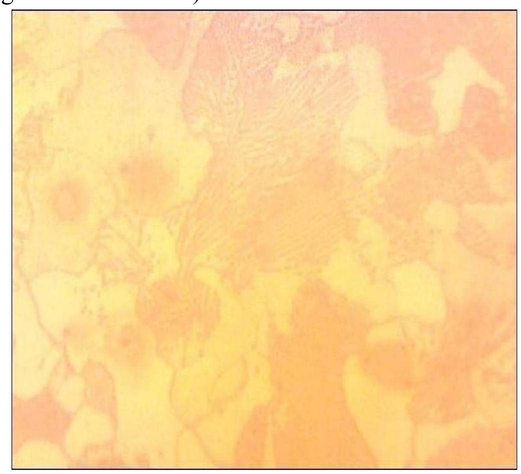

Figure 5: A1-Martensitic tendencies observed in un-treated steel structure

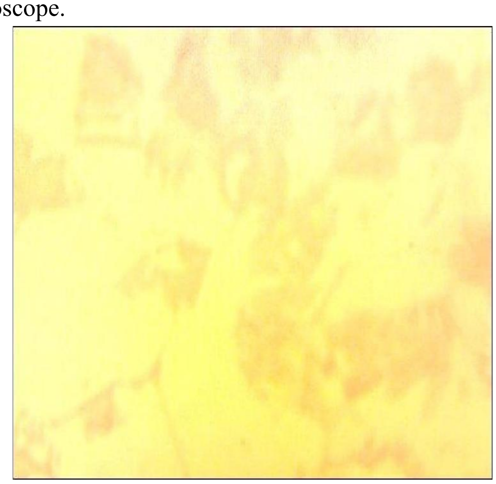

Figure 2:-A2-Martensite structure (dark) with retained austenite (white)

Figure 4- A3-Showing full martensite (dark) when quenched in Ghee Oil

Figure 3-A4- showing low proportion of martensite structure (dark) in ferric(white) matrix when quenched in Coconut Oil.

The sample quenched in ghee oil as shown in Figure 6-Micrograph A3, is showing full martensite (dark). This type of microstructure of the same steel with pearlite blocky spotted has been captured by the images of the microscope. The material has been heat-treated at 850-900°C and quenched in Ghee oil and later tempered at 400°C and allow to cool in the furnace, the martensitic spotted areas show the carbon and other elements re-grouping due to the variations of heating and cooling treatments.

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The sample quenched in coconut oil shown in Figure 7-Micrograph A4, is showing low proportion of martensite structure (dark) in ferric(white) matrix. The sample quenched in coconut oil is showed in A4, is showing low proportion of martensite structure (dark) in ferric (white) matrix. All these three microstructures are in par with what is obtainable in literature [5]. However, water quenched specimen has the highest presence of martensite phase with retained austenite. Also, evidence of less retained austenite and martensite was seen more in the A1045 steel specimen quenched in the ghee oil, coconut oil and sea water.

Mechanical Properties Analysis

The A1045 steel specimen hardened in these oils showed an increased precipitation of ferrite due to the transformation of retained austenite. The results obtained in the present study are at par with the earlier observation of [6]. To evaluate the effectiveness of the media on the mechanical properties of the received and quenched specimens, comparisons were carried out based on the results obtained. From the results obtained, the hardness value of both the A1045 steel increased after quenching in all the media. The quenched samples in the various quenching media have a lower hardness value as compared to sea water.

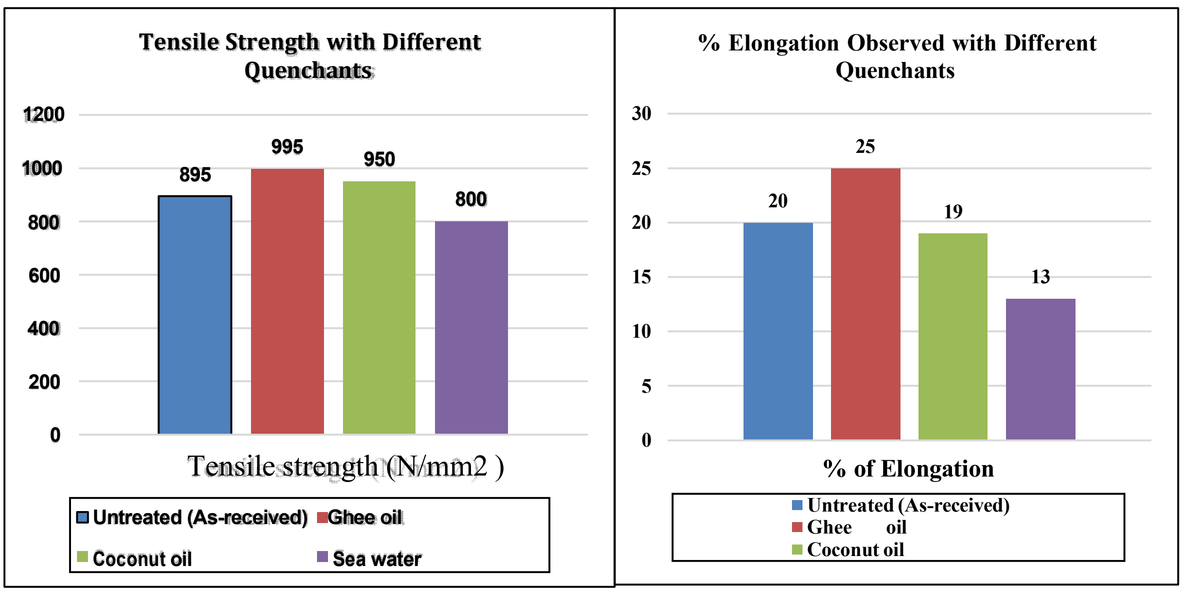

Figure 8 and 9: Tensile Strength and % Elongation for Different Quenchants

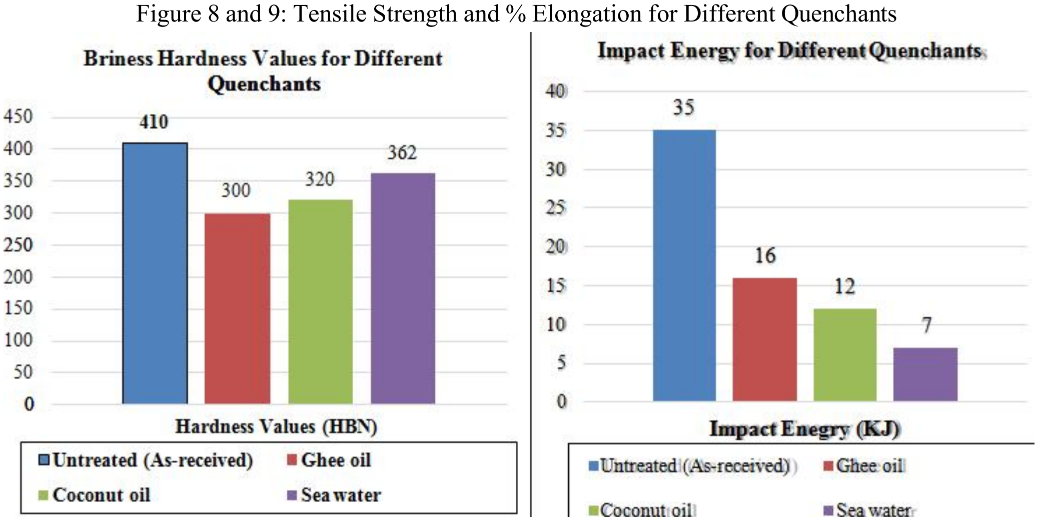

Figure 10 and 11: Hardness and Impact Energy Values for Different Quenchants

This may be attributed to the fact that sea water has a higher cooling rate and highest free carbon in martensite than ghee oil and coconut oil respectively. This is as reported by other researchers [7-8]. Furthermore, presence of fine dispersion of small particles in the pro-eutectoid ferrite and paralytic ferrite, which will hinder the dislocation movement, may have also contributed to higher hardness value of the sea water-quenched sample [7].

Figure 8 shows values the tensile strength of the as-received conditions, ghee oil, coconut oil and sea water quenched are 895, 995, 950 and 800 N/mm2. Although samples quenched in sea water showed the least tensile strength and ghee oil produced the highest after quenching. The result of sea water quenched A1045 steel specimen could be ascribed to internal and transformation stresses developed after rapid quenching. These results also agreed with the earlier works of [9-10].

Figure 10 shown above illustrated the results of hardness values carried out on A1045 steel. The hardness values of the as-received conditions, ghee oil, coconut oil and sea water are 410,300,320 and 362 HBN respectively. From the bar chart, samples quenched in sea water produced the highest hardness value and ghee oil produced the least after quenching and tempered at 370 °C. The high values obtained for samples quenched in sea water can be ascribed to the hard structures (martensite, retained austenite, bainite) obtained during quenching. Coconut oil developed hardness between that of sea water and ghee oil. Similar findings had been reported during investigations of quenching media for steel products 10].

Figure 9 shows percentage elongation of the as-received, ghee oil, coconut oil and sea wate to be 20,25,19, and 13%, respectively. These results show that oils are effective and in line with the findings of [9]. The water quenched samples produced least value and are also in line with the explanation given on microstructure observed for water, coconut oil and ghee oil on impact energy discussed above. It also agreed with the previous works [10].

The impact energy results obtained from the quenched and tempered at 370 °C was illustrate in Figure 11. The impact energies of the as-received conditions, ghee oil, coconut oil and sea water are 35, 16, 12 and 7 K J respectively. Sea water has the least impact energy before fracture. The least impact strength observed for the quenched samples in sea water could be attributed to the hard structure (martensite) obtained [8]. The impact strength in both coconut oil and ghee oil were improved significantly after quenched and tempered[10]. This direction showed that after tempering, there was an increased in precipitation of cementite which was in fine structure of ferrite and bainite as a result of the decomposition of martensite and retained austenite. These findings were also in line with [10].

IV. CONCLUSION

The effectiveness of the ghee oil, coconut oil as quenching medium in the hardening process of A1045 steels has been quantitatively assessed using tensile strength, hardness values, percentage elongation and impact energy in particular.

The use of ghee oil and coconut oil as quenching media in the hardening process of A1045 steel had been assessed using tensile strength, hardness values, impact energy, percentage elongation and microstructures.

Conclusions drawn from the results obtained in this work are:

- Ghee oil and ghee oil have hardness values less than that of sea water and un-treated steel. Coconut oil is having hardness more as compared to ghee oil.
- Both the ghee and coconut oil improved the toughness of A1045 steel since they have higher impact energy values than that of sea water which is the common quenching medium.
- Both the ghee oil and coconut oil can be used for hardening process in A1045 steel which produced properties in between that of sea water and as-received conditions. When hardened and tempered at 370 °C, the mechanical properties of the A1045 steels were optimized.
- The microstructures of the A1045 steel in the different media revealed the following structures: ferrite – pearlite, retained austenite, martensites, bainite in matrix.
- Environmental pollution has caused the search for new products in hardening of A1045 steels. The use of coconut and ghee oils as quenching media are new and when compared with sea water there are many advantages concerning the environment and the health of workers.
- Hence, ghee oil, coconut oils can be used where cooling severity less than sea water is required for hardening of A1045, while for the kernel ghee oil and coconut oil, it was found that the hardness was lower than that of the as-received after quenching, hence, it means the quenchant is a slow quenchant which makes it undesirable for

hardening. This could be further explained by its inability to form martensite but rather formed softer structures like ferrite and pearlite plus retained austenite. Ghee oil and coconut oil can be used to improve the toughness of these samples since it has higher impact energy values than sea water which is the common quenching medium.

- The steel Grade A1046 used in this research is produced by using quenchant Ghee oil and coconut is strengthen locally produced to ascertain its suitability for the production of automotive shafts, gears and structural beams in comparison to ASTM 897 standard.

The result of this research shows that there is some improvement in the property that has been achieved for the production of machine parts and structural components. That to achieve specified gauge of mechanical property requirement, carbon content of the steel must be increased to certain percentage to promote increased quantity of bainite formation or by introduction of acceptable percentage of elements contents of austenite formation and stabilization of alloying elements like nickel and chromium.

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BIOGRAPHY

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