INVESTIGATING THE EFFECT OF SOME LOCAL VEGETABLE OILS AS QUENCHING MEDIA ON MECHANICAL AND METALLURGICAL PROPERTIES OF NST 60-2 STRUCTURAL STEEL

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ABSTRACT: *The hardening characteristics of NST60 - 2 structural (medium carbon) steel quenched in palm Kernel oil, groundnut oil, palm oil, Shea butter oil, air and water were investigated and evaluated. This study was conducted on the possibility of improving it wear performance. The investigation was carried out in two parts; the effect of some quenching media on microstructured steel. A micro-structural examination of the quenched specimens was undertaken to ascertain the efficiency of some quenchants on the surface hardening. The results obtained indicate that all the quenching media responded well to all surface hardening with palm kernel oil giving the highest hardness value, being more efficient than groundnut oil, palm oil and shea butter oil. The Shea butter oil gives the least hardness because; it has higher viscosity which lowers the cooling rate and consequently the lesser the possibility of martensite formation. In general excellent hardening properties were obtained with these vegetable local oils. It is established that surface hardening of NST 60-2 structural steel using palm kernel oil, groundnut oil, palm oil and shea butter oil can be adopted as a heat treatment process for improving its wear performance at less cost.*

Keywords: Vegetable Local Oils, Quenching, Heat-Treatment, Hardening Characteristic.
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INTRODUCTION

The distortions and cracking effects that are caused mostly by quenching components in drastic media such as brine, water, etc have necessitated the need to identify new quenching media such as vegetable local oils among some known milder quenchants to counteract the defective action of severe media (Rajan *et al*, 1992, DeGarmo et al, 1997).

Quenching of structural steel is commonly used to induce hardening effect in steels. Steels quenched are suitable for most general engineering purpose and their surfaces possess excellent resistance to wear, deformation and chipping (Wikipedia, 2014; Constructional Steelwork Association Ltd, 2011). Steel structures are unique and mostly consist of the primary phase, pearlite in ferrite matrix, eutectoids, intermetallics and secondary phases. Current research efforts are concentrated on mechanism of development of hardenability of carbon steel by some suitable quenching media. The products of this thermal treatment can be intensively used in automotive industries, manufacturing and structural applications where hardness and wear resistant are very important.

In steel, the heat treatment is generally carried out to embrace the martensitic transformation and to obtain the necessary microstructure that occurs on quenching from the austenitic start. Quenching of structural steel, involves heating steel to some temperature above the upper critical temperature, in order to convert it partially or completely to austenite, holding at this temperature for a specified period of time long enough to ensure the desired austenitization after which cooling is carried out at a rate equal to or faster than the critical cooling rate (Thelning, 1984)

Steel is an outstanding versatile engineering material. Much of the versatility of steel arises due to the fact that the properties of the steel can be controlled and changed at will (though within reasonable good limits) by heat treatment. Different heat treatment cycles bring about a wide range of properties. If the heat treatment cycle is changed, a different microstructure with ensuring different physical and mechanical properties will be obtained.

Austenitization and subsequent quenching of steels into a given quenching medium at room temperature is one of the hardening methods established in heat treatment and metal technology (Tsubuuchi *et al*, 2000). Many researchers have reported from their studies that traditionally, water and oil (especially SEA-Engine oil) are the common quenching media used when appreciable hardness is desired (Moreaux and Beek, 1981, Avner, 1984,). The mechanical properties of a quenched component are dependent on many factors such as the composition of steel, type of quenching medium, geometry of the component, tempering temperature, measurement, tolerances and variations in process equipment and operators (ASM, *2007}* . There are various quenching media for hardening namely water, oils, molten salts, molten metal, polymer solutions, aqueous solutions, gases etc. An important requirement in quenching a component is that cracking and excessive distortion must be prevented in the process of hardening.

The average viscosity and iodine value of each of the vegetable local oil been established (Aponbiede and Oyinlola, 198) that Shea butter oil has the highest viscosity value followed by groundnut oil, and then palm kernel oil. As expected, the higher the viscosity, the lower the cooling rate, and consequently the lesser the probability of martensite formation in the quenched steel. However, the degree of unsaturated fatty acids in the oil is determined by the iodine value which shows the stability of the fatty acid molecule film that forms on the metal surface. Shea butter and groundnut oil has the highest iodine values, while palm kernel has the lowest.

This work aims to properly investigate the hardening characteristics of structural steel produced in Nigeria using palm kernel oil, groundnut oil, Shea butter oil, palm oil and water as quenching media. This will suggest improvement in performance of structural steel in services.

MATERIALS AND METHODS

Materials

The NST60-2 structural steel used for this work was obtained from Oshogbo Steel Rolling Company Limited, Nigeria and its chemical composition. The experimental work was carried out in the materials laboratory of the Department of Metallurgical Engineering, Kwara State Polytechnic, Ilorin, Nigeria. The steel rods had a diameter of 10mm and a percent nominal composition of 0.35-0.42C; 0.20-0.30Si; 0.40-0.90Mn; 0.05S; 0.05P; 0.IONi; 0.02Mo; 0.28Cu; 0.03Sn; 0.10Co; 0.10Cr and the rest being Fe. The local vegetable quenching media under investigation were palm kernel oil, groundnut oil, Shea butter oil, palm oil and water obtained in Ilorin. A carboxylic heating furnace with a maximum temperature of 1200^{o}C was used to austenitize the quenched steel samples. The hardness test was carried out on LECO micro-hardness tester. After the test had been completed, the tester automatically calculated the resulting hardness values in both Hv (Vickers) and

HRc (Rockwell C) modes. All tensile tests were performed on a Hounsfield tensometer testing machine to determine the tensile strength values. A metal container of sufficient volumetric capacity was adapted as baths for quenching purpose. A metallurgical microscope with an in-built camera was used to examine and photographically record the microstructure of quenched steel samples.

Methods

For each of the local vegetable quenching media, a tensile test specimen of 5mm diameter and 20mm gauge length were machined from a 20mm diameter structural steel rod. The length of each specimen for hardness testing was chosen to be 5mm diameters and 20mm long. Six tensile test specimens were cut out to determine the tensile stress. The harness value (of structural steel also) determined with six test specimens. The test specimen were put in small graphite crucibles and packed with cast iron chips. The crucibles were covered, sealed and were heated in furnace to a temperature of 900°C. It was held at this temperature for 1hour to allow time for soaking, after which each of these austenite specimens were quenched in various local vegetable quenching media. It was ensured that the specimens were adequately submerged in the quenchants. Before subjecting the specimens to hardness testing, they were mounted in fused Bakelite powder for easy handling. The LECO micro-hardness testing machine was used to determine the hardness values across the traverse section of the quenched specimens. The tensile tests were carried out on a Hounsfield tensometer using the machined cylindrical tensile test specimens of 5mm in diameter and a gauge length of 20mm. The maximum strength (tensile stress) and hardness values were determined. The tests were carried out three times and the mean hardness valves and tensile stress were calculated. The result is shown in table 1. Micro-structural examination of samples cut from the middle of quenched structural steel specimen was carried out. Each of the samples was subjected to grinding with 240, 320, 400 and 600 grits silicon carbide abrasion paper and polished. The surface of the polished sample was etched in 2% Nital by swabbing the surface with cotton wool soaked in the etchant. The micro-structural examination of the etched surface of the specimens was made under a metallurgical microscope with an in-built camera through which the resulting microstructures were all photographically recorded. Results are shown in figures 1-6.

RESULTS

Table 1 presents the result of hardness values and tensile stress for quenched specimens in various local vegetable quenching media. Figures 1 to 6 show the micrographs developed after quenching the NST 60-2 structural steel in selected quenching media

Table 1: Mechanical Properties of Quenched Structural Steel in Various Quenching Media.

States of Structural Steels	Hardness HV test (Vicker)		Hardness HR test (Rockwell)		Tensile Stress N/mm^2	
	Hardness value	Mean Hardness value	Hardness value	Mean Hardness value	Tensile stress	Mean Tensile stress
Water Quenched	507 505 507	506.3	58 59 61	59.3	471 469 473	471
Shea Butter Oil Quenched	410 413 412	411.7	51 49 52	50.7	636 639 636	637
Palm Kernel Oil Quenched	452 454 451	452.3	55 54 57	55.3	512 515 512	513
Palm Oil Quenched	424 426 424	424.7	51 54 52	52.3	618 616 620	618
Groundnut Oil Quenched	434 432 435	433.7	53 55 53	53.7	614 610 612	612
Air Quenched (Normalized)	242 245 243	243.3	31 29 32	30.7	641 644 641	642

Figure 1: Air quenched (normalized) structure, showing fine pearlite and ferrite (x 100)

Figure 2: Water quenched structure, revealing martensite and retained austenite (x 100)

Figure 3: Palm oil quenched structure, consisting mixture of Bainite (upper) with pearlite and ferrite (x 100)

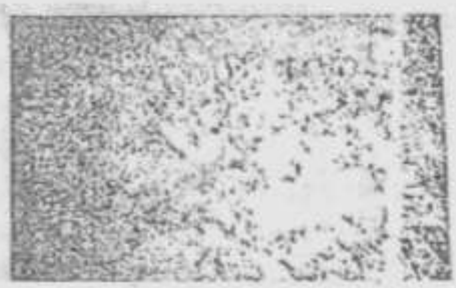
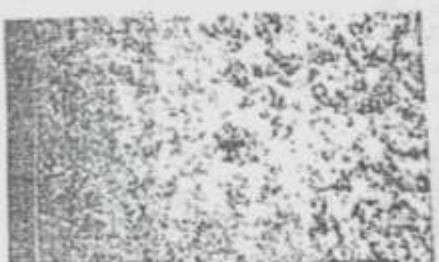


Figure 4: Groundnut oil quenched structure, showing mixture of Bainite (upper) with pearlite ferrite (x 100)



DISCUSSION

The effect of various quenchants on hardness values and tensile stress of NST 60-2 structural steel is presented in table 1. The hardness values formed the basis for comparison, from which the response of NST 60-2 structural steel quenched in vegetable local oils to surface hardening can be analyzed. Here, it is observed that higher hardness values were obtained for the entire vegetable local oil quenched specimen than the air quenched specimen normalized. The harness value of water quenched and the micrographs formed was in conformity with the expectation. Here, the harness values obtained after quenched in palm kernel oil, groundnut oil, palm oil, Shea butter oil and air are in order of 55.3HRc >53.7HRc> 52.3HRc >50.7HRc> 30.7HRc. The tensile stress obtained after quenched in palm kernel oil, groundnut oil, Palm oil Shea butter oil and air are in order of 513 < 612 < 618 < 637 < 639. The increase in harness value and decrease in tensile stress are due to variations in rate of heat extraction from the metal in these oils during the formation of bainite structure. In all the samples quenched in various oils, no crack or distortion was observed.

Metallographic studies of the air quenched (normalized) structural steel is composed of a mixture of fine pearlite in ferritic phase as shown in figure 1. As the steel specimen is water quenched, micro-examination revealed that martensite and retained austenite grains are produced and concentrated on the surface as presented in figure 2. As shown in figure 5, the specimen quenched in palm kernel oil reveals mainly bainitic structure (lower bainite). In figures 3, 4 and 6, the micrographs of the specimens quenched in palm oil, groundnut oil and Shea butter oil respectively reveal predominantly a bainitic structure with a mixture of pearlite and ferrite. The variation in the micrographs was as a result of differences in cooling rates in various quenching media used. Bainite was observed in the structure of specimens quenched in the entire groundnut oils. In essence, close examination of all microstructures revealed, were ferrite, fine pearlite and bainite.

The average viscosity of each of the local oil used has been established (Aponbiede and Oyinlola, 1998) that Shea butter oil has the highest viscosity value followed by groundnut oil, and then palm kernel oil. As usual, the higher the viscosity, the lower the cooling rate, and consequently the lesser the probability of martensite formation in the quenched steel, the structure of the vegetable local oil contains fatty acid which responsible for the molecular adhesion to the metal surface and thereby influence the quenching capability of the oils. By comparing results, it can be seen that the rate of heat extraction from the metal in the oil is related to the stability of the film thickness. It can be deduced that the thicker the film the less the rate of heat extraction. Moreover, palm kernel oil gave the best quench properties as it had the least stable film. Groundnut oil, palm oil, and Shea butter oil could be rated least effective as quenching media due to the stability of the film.

CONCLUISION

The hardening characteristics of NST 60-2 structural steel in vegetable local oils as quenchants is determined by which all the vegetable local oils responded adequately with palm kernel oil having the highest hardness value in the as quenched condition, followed by groundnut oil and palm oil, Shea butter oil gave the least quench properties. The hardness values obtained after quenched in palm kernel oil, groundnut oil, palm oil, Shea butter oil and air are in order of 55.3HRc> 53.7HRc> 52.3HRc> 50.7HRc> 30.7HRc. None of the vegetable oil caused cracking of the quenched samples, which is an indication that they all provided moderate rate of cooling. Some of the vegetable local oils gave high hardness value close to that of water; hence, if moderate hardness is required of a steel component, any of palm kernel oil, groundnut oil, palm oil and Shea butter oil may be used as a quenching medium especially if the risk of cracking and distortion is to be avoided. It appears that the structure of the vegetable local oil contains fatty acid responsible for the molecular adhesion to the metal surface and thereby influences the quenching capability of the oils. The use of vegetable local oils quenching media is seen to have promising advantages especially when the risk of quench cracking is to be avoided and wear resistance increases.

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