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# The Effect of Heat Treatment Parameters on the Service-Life of SAE 1056 Steels

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**ABSTRACT:** The relevance of heat treatment in service life performance of machines has been of immense benefit in manufacturing industries and nation's socio-economic development. Industrial machines fail as a result of inappropriate selection and treatment of materials, thereby resulting into our Nigeria's industrial economic recession. To this end, SAE 1056 Steel was treated with Snail shell and Wood Charcoal respectively at a maximum of $1100^0$C. The carburization process decreases the hardness value of samples carburized with Wood Charcoal with increase in carburizing temperature. The carburization treatment followed by the water quenching and tempering @ $350^0$C strongly influenced the Ultimate Tensile Strength and Young's Modulus of Elasticity of SAE 1056 Steels. The Optimum combination of mechanical properties was achieved with samples carburized with Wood Charcoal. It could be suggested that Samples carburized with Wood Charcoal performs better in service than samples carburized with Snail Shell when carburized at the same carburizing time and temperature. The process was supported mathematically when the ruling section *is* inversely proportional to the diffusion rate.

**Keywords:** snail shell, wood charcoal, heat treatment, carburizing temperature, carburizing time

## I. INTRODUCTION

Engineering equipment, machines and components demand materials with high mechanical strength, vi-a-vis the yield strength, Ultimate Tensile strength without failure during service life. As a result, a process which imparts such properties is highly desirable. The process demands heating, soaking and cooling (quenching or normalizing). When steel is quenched, stress which is capable of impairing the desirable properties is developed. This is due to untemper martensitic steel, while very hard, is too brittle to be useful for most applications. A method for alleviating this problem is called tempering in heat treatment process. Most applications require that quenched parts be tempered. Tempering consists of heating steels below the critical temperatures (often from 205 to $595^0$C, depending on the desire results), to impart some toughness. Higher tempering temperatures (may be up to $700^0$C, depending on the alloy and applications), are sometimes used to impart further ductility, although some yield strength is lost [1].

[2] investigated that Carburizing is a heat treatment process aimed at increasing the surface hardness and wear resistance of components which are required to perform good impact strength and resistance to wear in service. Basically, the process is based on the theory of thermal absorption and diffusion of carbon atoms into steel. The process is usually done at an elevated` temperature with a chemical agent such as solid or liquid salt that can provide adequate quantity of atomic carbon for the diffusion and absorption process.

[3] on the other hand discovered a broad range of metals that can be carburized includes steel, Nickel and alloys. Typical component that are subjected to this treatment are gears, spindles shafts, cams, levers, steering parts, distribution gears, etc. [4] concluded that this could be achieved by simply placing parts in a suitable container and covered with a thick layer of carbon powder. The process is done by packing the component in a solid carburizing compound in a suitable container and heating it slowly in a furnace to attain a temperature of $900^0$C and above. [5] opined that although it is very effective in introducing carbon, this method was exceedingly slow and as the demand for greater production grew, a development of new process was established. This includes vacuum carburizing and plasma carburizing. Another recent development in carburizing is fluidized bed furnace which can provide much faster rate of carburizing compared to the conventional process.All of these processes perform better mechanical properties and higher hardness to component than conventional carburizing. Before this, many studies were found focusing on hardness, wear resistance and microstructural properties of carburizing low carbon steel [6]. In this research, the tensile strength, hardness and microstructural analysis of the steel (SAE 1056) is studied.

[3] and [7] said that Carburizing was discovered by early blacksmiths with the aim of increasing the strength, surface hardness and enhanced wear resistance of agricultural tools such as scythes, axes and weapon such as swords. All these tools were found to have carburized layer. At that time, the process was done by *leave hot* forged in the hot coals followed by quenching in water and would harden the surface layers. Later processes involved putting such implements into cast iron boxes with charcoal and bone ash. These were heated to “red hot” (≈ $900^0$C) and left for several hours depending on the layer required. Then, they were quenched and tempered at $300^0$C.

Cooling the forged tool in water *(quenching)* forms martensite, which is due to trapped carbon atoms that do not have time to diffuse out of the crystal structure. [4] [3] [8]. In order to make the tools useful they have to be re – heated to a lower temperature than that used for forging temperature. This tempers the steel and reducing the hardness, also improves its toughness. This causes a big increase in the surface hardness, enhanced wear and fatigue resistance. Basically, the carbon content of the case and its depth is controlled by the carburizing time and temperature. Carbon and other element act as a hardening agent preventing dislocations in the iron atom crystal lattice from sliding past one another.

The amount of alloying elements and their presence in the steel can control the quality in terms of hardness ductility, and tensile strength of the resulting steel. Steel with increased carbon content can be made harder and stronger than iron, but is also more brittle .Though steel had been produced by various inefficient methods long before the *Renaissance*, its use became more common after more to trapped carbon atoms that do not have time to diffuse out of the crystal structure [4] [7] [8]. In order to make the tools useful they have to be re – heated to a lower temperature than that used for forging temperature. This tempers the steel and reducing the hardness, also improves its toughness. This causes a big increase in the surface hardness, enhanced wear and fatigue resistance. Basically, the carbon content of the case and its depth is controlled by the carburizing time and temperature.

The use of inappropriate carburizing media had led to the failure of some engineering component [8] This could be attributed to poor selection of materials, inability to determine the performance of different carburizing media on the mechanical properties of steel, inability to determine microstructure of steel, and inappropriate heat treatment process [9] [10] [11] [12]. All of these were as a result of lack of evaluating the performance of different carburizing media capable of improving the wear resistance of engineering components. Hence, this study evaluates the performance of different carburizing media on the mechanical properties of steel, determined the microstructure of the steel before and after carburizing, and as well as examined the effects of heat and mass transfer on the diffusion rate.

## II. MATERIALS

The materials used for this research work is medium carbon steel (SAE 1056, φ12mm) with the chemical composition shown in Table 1. The material was sourced from *Universal Steel Company Ogba Industrial Estate*, Ikeja Lagos).

**Table 1:** Spectrochemical analysis result of the control sample (0.56<.0.64% carbon φ12mm)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Element** | C | Si | S | P | Mn | Ni | Cr | Mo |
| % Composition | 0.6398 | 0.2003 | 0.0529 | 0.0542 | 0.3021 | 0.1168 | 0.1331 | 0.0206 |
| **Element** | V | Cu | W | As | Sn | Co | Al | Pb |
| % Composition | 0.0032 | 0.3035 | 0.0033 | 0.0055 | 0.0303 | 0.0106 | 0.0020 | 0.0012 |
| **Element** | Ca | Zn | Fe | | | | | |
| % Composition | 0.0004 | 0.0042 | 98.0159 | | | | | |

© Courtesy of Universal Steels, Industrial

## III. EXPERIMENTAL TECHNIQUES

Fourteen samples of 1056 steel were machined to standard test sample sizes of tensile test. This was done according to ASTM’s specification on standard tensile sample dimension. Twelve samples were carburized and the remaining two were reserved as a control sample. The prepared test samples were embedded in the carbonaceous material vis-à-vis Wood Charcoal and Snail Shell with small quantity of Barium Carbonate as an energizer in a steel pot which was then tightly sealed with clay cover to prevent the CO from escaping and prevent unwanted furnace gas from entering the steel pot during heating. The furnace temperature was adjusted to the required temperature (*900, 1000 and 1100$^0$C for each stage respectively*) and the loaded steel pot was charged into the furnace .When the furnace temperature reaches the required carburizing time (i.e. 2hr for $1100^0$C, 3hr for $1000^0$C and 4hr for $900^0$C for each media) Fig.1.1, it was then held at the temperature for 15 –30minute. After the material was soaked for a specified period, the steel pot was removed from the furnace and the material was quenched in water (which was initially at the ambient atmospheric temperature).

Six of the carburized test samples were then tempered at a temperature of $350^0$C for 2hrs, and then cooled in air. After the cycles of heat treatment, the test samples were subjected to tensile test, hardness test and metallographic test. Finally, the material was mounted to the microscopes which automatically examine the microstructure of the materials and the cameras attached to the microscope take the picture of the structure

## IV. DISCUSSION OF RESULTS

From Figs. 1-4, the two carbonaceous materials - Wood Charcoal and Snail Shell were observed to have a varying degree effects on the Sample. Wood Charcoal influenced the SAE 1056 to acquire a Stress Value of 500MPa below the latter with 550MPa. It was perhaps due to long hours but relatively lower carburizing temperature. This attests to the fact that Carburizing is tremendously affected by temperature via diffusion process. On the other hand, Fig. 4 showed a shoulder to shoulder performance between WC and SS. This was complimented by the uniformly distributed cementite in the cross-section at $900^0$C. Lastly, Fig. 5 revealed the effects of temperature during carburizing. With increase in temperature, the carbon atoms transported into the steel surface have the tendency to diminish towards the core.

## V. CONCLUSIONS

The service life of industrial and vehicular steel components such as cutting tools, rack and pinion, gears, crank shaft, linkages and more which required high fatigue resistance could be longer if appropriate measures are strictly adhered to. This was evident from Figs. 1-4 in the Stress variations values at specified conditions. The effectiveness of the two carburizing media compared showed that SS recorded better performance in hardness values as 607.9 HB at 4 hours.This gave interesting results when tempered at $350^0$C and as such there may not be ‘fear’ of failure under service

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**APPENDIX**

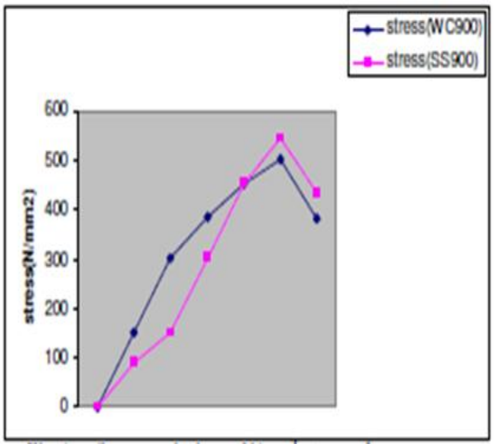


**Fig. 1:** Stress variations (N/mm$^2$) for carbonaceous materials @ 900$^0$C for 4 Hours

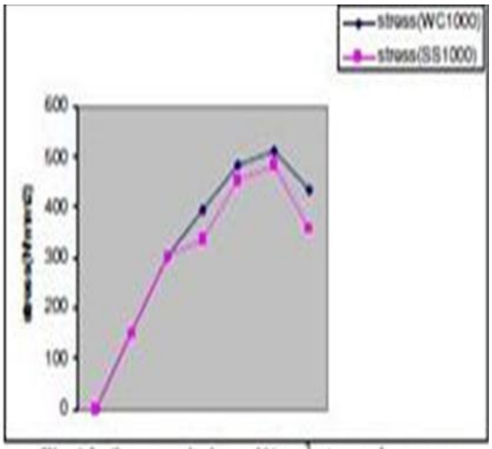


**Fig. 2:** Stress variations (N/mm$^2$) for carbonaceous materials @ 1000$^0$C for 4 Hours

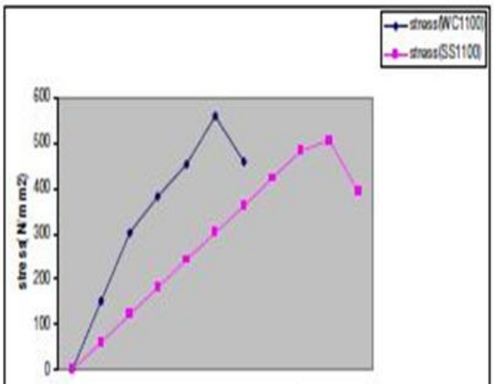


**Fig. 3:** Stress variations (N/mm$^2$) for carbonaceous materials @ 900$^0$C for 4 Hours and tempered for 2hrs

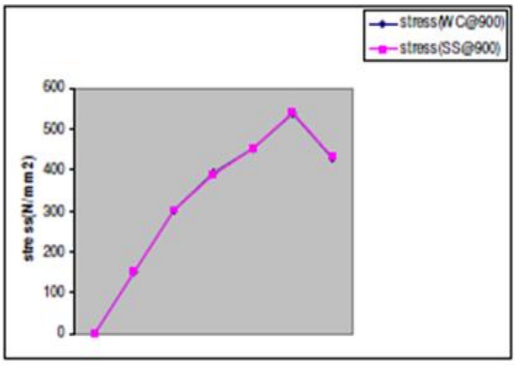


**Fig. 4:** Stress variations (N/mm$^2$) for carbonaceous materials @ 1000$^0$C for 4 Hours tempered for 2hrs

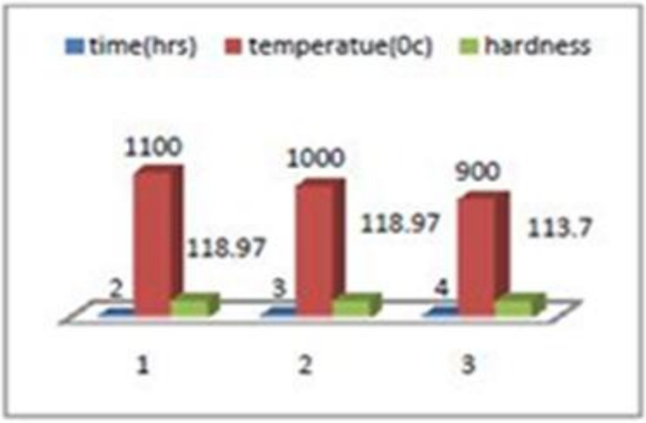


**Fig. 5:** Variation of Temperature, Hardness and Time of Carburizing SS

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