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Investigation on the Effectiveness of Sesame Oil as Austempering Medium for Grey Cast Iron; A Review

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Abstract— Many research have been carried out using different quenching media on different metals/Alloy but the use of sesame oil as quenching medium for austempering of grey cast iron have not been explored and this justified the need for the search of a more suitable , available, environmentally friendly, biodegradable and cheaper medium for austempering of grey cast iron.Nigeria is among the major exporter of sesame seeds in the world ,largest producer in Africa and third in the world, with annual production of 580,000 metric tons in 2017 mostly from Gombe, Bauchi, Adamawa, Borno , Taraba etc. despite its abundance and it usage is limited to pastry garnishing, snacks, making soup, cooking oil etc , the potential of sesame seed oil has not been investigated as medium for the austempering of grey cast iron. Based on the above-mentioned reasons therefore, the present study is geared toward the usage of hot sesame oil bath as an alternative to molten salt and molten lead baths for austempering of grey cast iron.This research will be limited to the use of Gray cast iron to evaluate the suitability of sesame oil bath as an austempering medium. The physico-chemical properties of the sesame oil, mechanical and microstructure of the gray cast iron before and after austempering would be determined.

Index Terms— Ferrous metals, Quenching, Physico-chemical, Austempering.

1. INTRODUCTION

Heat treatment is a method used to change the microstructure of substances which include metals and alloys to give the metals/alloys a property that is beneficial to the life existence of an element, for instance enhanced surface hardness, temperature resistance, ductility and strength. There are numerous kinds of heat treatment foremost ones being annealing, normalizing and hardening (Vatsayan et al., 2014). Annealing is largely a stress relieving method where substance is heated at temperature above the upper critical point temperature and is cooled in furnace itself. Normalizing is a method of grain refining operation in which substance (metals/alloys) are heated just like annealing however is cooled in still air. Hardening is a method of heating materials or metals above the upper critical point temperature after which quenching it in medium like oil and water. Tempering is a process of reheating of already hardened material to improve its toughness through heating to a temperature below critical temperature of the material and cooled in air. Materials properties is the function of the arrangement of different oriented grains and a refined arrangement of grains impart effective strength and reliability after being subjected to heat treatment. Heat treatment originated as an ancient art in man's attempt to improve the performance of materials in practical applications (Rajan et al., 1988). (Khanna, 2002a) pointed out that, in the middle of the 19^{th} century, more attention was directed to develop the art and science of producing, working and treating of metals to suit various areas of applications to improve man’s comfort. The final properties of an alloy are not only due to its chemical composition, but also due to its metallurgical history. It’s possible to use different treatments so as to change the properties of an alloy; thus, finding the easiest way of heat treatment and optimum treatment conditions is of fundamental importance in achieving the desired properties (Fracasso, 2010).

Metals and alloys develop requisite properties by heat treatment which plays a critical role in achieving appropriate microstructure that imparts the desired characteristics in a given material. Hence, the study of heat treatment is of great significance. (Rajan et al., 1988) defined heat treatment as heating and cooling operation(s) applied to metals and alloys in solid state so as to obtain the desired properties. Formation of austenite is a preliminary step for any heat treatment process for ferrous alloys. Depending on various parameters (composition of the alloy, cooling rate, section size, etc.), austenite may transform on cooling to lower temperature phases such as: ferrite, pearlite, bainite or martensite. The presence of these transformed phases and their structures are important in deciding the resultant properties in the metal/alloy (Ause, 2008). There are various types of heat treatment processes, namely; annealing, normalizing, hardening, tempering etc. In addition to these we have special heat treatments called interrupted quenching procedures which include; ausforming, martempering and austempering (Khanna, 2002a). (Ause, 2008) showed that these heat treatment processes are used to achieve the following: refine grains, soften the metal, increase hardness, remove residual stresses, improve machinability, improve toughness and increase ductility. According to (Hassan, 2009) austempering is a hardening process for metals/alloys which yields better mechanical properties including: higher ductility, resistance to shock and uniform hardness. The process consists of quenching the material from the proper austenitizing temperature directly into a hot bath at a temperature between 230 °C – 450 °C, and the bath temperature is maintained for a desired recommended time to transform the austenite into bainite.

The term "cast iron" designates an entire family of metals with a wide variety of properties. Cast iron contains more than 2% carbon present as a distinct graphite phase. In grey cast iron graphite is present as individual flakes. Grey iron is the most widely used metallic material with annual production tonnage several times the total of all other cast metals, as it offers good castability at relatively low cost (Walton, 1981) as well as good machinability. Austempered grey cast iron (AGI) is considered to be an important engineering material because of its attractive properties such as good ductility at high strengths, good wear resistance, fatigue strength and fracture toughness (Ghaderi et al., 2003; Vadiraj et al., 2010). Because of these combinations of properties, AGI is now used extensively in many structural applications in automotive industry, defence and earthmoving machineries etc. in developing and developed countries.

Austempering is a process of hardening which includes austenizing, then cooling rapidly enough for the prevention of pearlite formation to a temperature above the martensite start after which maintaining until the desired microstructure is formed. Heat treatment may be implemented to steel in order to improve on the strength, toughness or ductility so that in order to make the original coarse grain arrangement which the steel has. Austempering is one of the quenches hardening methods carried out to alloys with the intention to enhance the mechanical properties of the alloy these is possible under austempering media (Okwonna et al., 2017). In heat treatment the most preferred is usually austempering as compared to conventional method of quenching and tempering. The reason is because this type of heat treatment offers enhanced mechanical properties (typically higher ductility or notch toughness at a given high hardness). A decrease in the possibility of distortion and cracking which can occur in martensitic transformations. Lower cost than that of conventional quenching and tempering (Batra et al., 2004). Austempered grey cast iron (AGI) is subjected to an isothermal heat treatment process known as ‘‘austempering’’. In conventional austempering process, the cast iron is austenitized at a temperature range of 871–982°C (1600–1800°F) for sufficient time to get a full austenite (γ) matrix, and then quenched to an intermediate temperature range of 260–400°C (500–750°F) and it is maintained at this temperature for 20–120 min. A schematic of the conventional single-step austempering process is shown in Figure 1. During austempering reaction, austenite (γ) decomposes into ferrite (α) and high carbon or transformed austenite (YHC):

Figure1 (a). Steps of Austempering Process

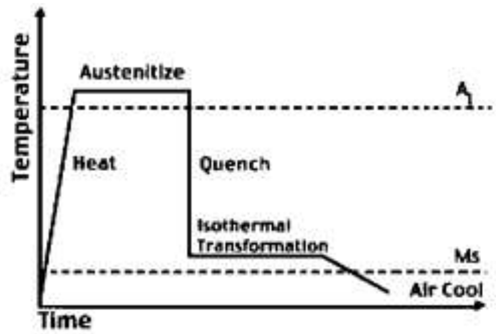


Figure 1 (b). TTT diagram

Generally, quenchants are grouped into two categories namely: those maintained at room temperature and those maintained at higher temperatures (250-450^{o}C). The room temperature quenchants are regarded as the most popular, common and conventional or traditional type of quenchants. Few examples include; water, brine, oil (mineral or vegetable), caustic soda solution, etc. Those quenchants maintained at higher temperatures are used for interrupted quenching heat treatment processes such as martempering, austempering, and ausforming. Examples of these types of quenching media are molten salt bath, molten lead bath and hot oil bath (ASM, 1978).

The mechanical properties such as ductility, toughness, strength, hardness and tensile strength can easily be modified by heat treatment of the steel to suit a particular design purpose. In some cases, the engineering material requires high hardness value to be used in situations like heavy duty activities for us to achieve that hardening is required. The hardening process involves heating the alloy to a particular temperature and holding it at that temperature then rapidly cooling in a medium. After that it eventually increases the harness of the alloy as a result of the phase transformation which is austenite and low temperature transformation (Sultana et al., 2014).

According to (Ause, 2008) for some heat treatment operations that requires hardening of components by quenching, those quenching media such as water, brine, oil, etc. may sometimes be too drastic, hence resulting to inferior mechanical properties and defects such as cracking and distortion. Such defected components are eventually rejected, resulting to economic waste. Therefore, in order to impart good mechanical properties (especially strength and toughness/ductility) and simultaneously avoid cracking and distortion, many researchers suggested that other heat treatment methods like martempering and austempering in molten salt bath or hot oil bath could be used. But unfortunately, salt bath furnace is known to be very costly.

2. MATERIALS AND EQUIPMENT

2.1 Materials

The Materials used in this work review include;

- Grey cast iron samples
- Sesame (Beniseed) oil
- Oil bath
- cotton wool, nitric acid and ethanol
- Alumina powder, water, grid papers, polishing cloth

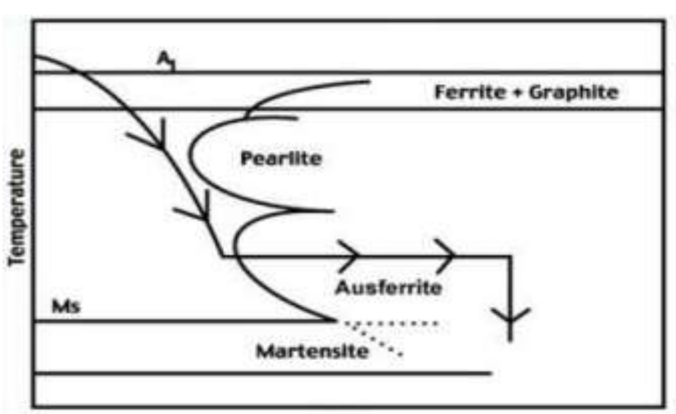
2.2 Equipment

The Equipment's used in the research work include;

- Grey cast iron samples
- Lathe machine
- Polishing machine
- Vickers hardness tester
- Hounsfield tensiometer
- Hounsfield balance impact testing machine
- Scanning Electron Microscope
- Muffle furnace
- Optical metallurgical microscope

3. MATERIAL ANALYSIS

The step by step procedure to carry out the material analysis is shown in Figure 1.



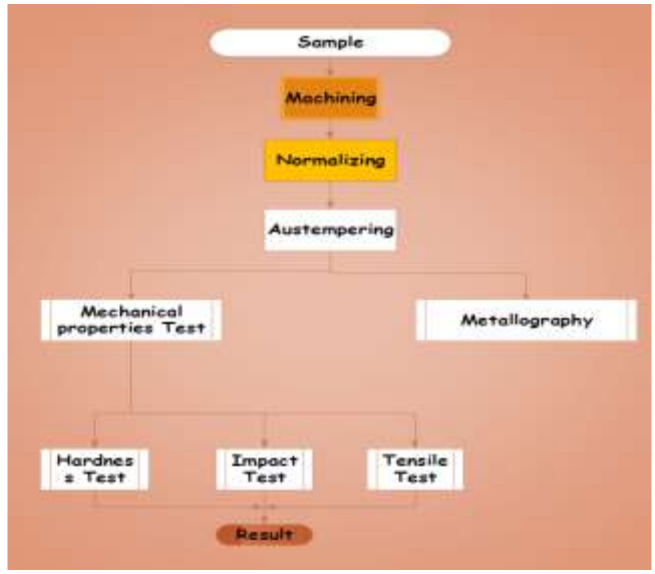


Figure 1: Block Diagram of Material Analysis.

4. AUSTEMPERING METHODS

Sample work piece is machined to required shapes for carrying out the experiment. (Normalizing) Machined work piece samples were heated to 900°C and be soaked for one hour for the necessary transformation to occur and the attainment of homogenization after which the samples was air cooled in the air. (Austempering) samples were loaded into a furnace, heated to 850°C, soaked for one hour, then removed and quenched in hot Sesame oil bath at 250°C. After one hour, the first set of samples (one for hardness, two for impact and two for tensile) was removed from the hot Sesame oil bath, cooled in air.

After three tests impact, hardness and tensile test was carried out, metallography using scanning electron microscope to analyze the microstructure.

5. EXPERIMENTAL FLOW DIAGRAM

Figure 2 shows the step by step procedure for conducting the experiments.

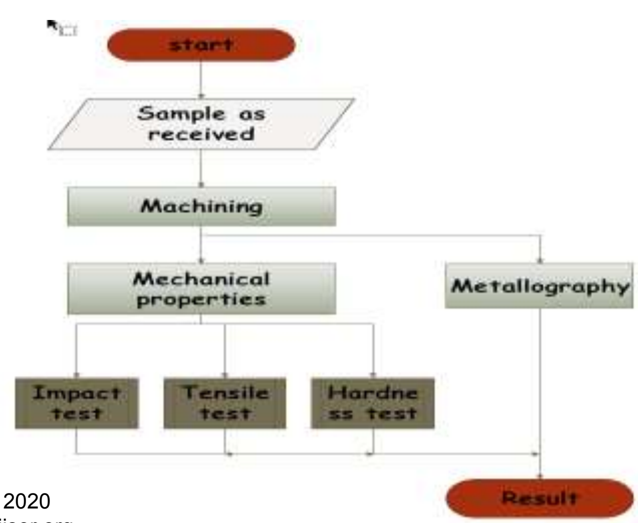


Figure 2: Experimental Flow Diagram

6. PREVIOUS WORKS

Various literatures showed that some other materials such as Sesame oil can be investigated to find their potentials in the local industries.

Evaluation of hot- bitumen bath as a Quenching medium for austempering of Steel and ductile cast iron. The investigation carried out showed that hot bitumen can be used as quenching medium in austempering process. Three ferrous alloys: Medium carbon steel (0.55%C), high carbon steel (0.75%C) and unalloyed ductile cast irons were used to evaluate the suitability of hot bitumen bath as austempering medium. Ause (2008).

Investigation of Jatropha seed oil as austempering quenchant for ductile cast iron. The result showed significant increase in tensile strength and impact energy apart from achieving an appreciable increase in hardness. The raw materials used in this study include Jatropha seed oil and ductile cast iron. Terngu and Terfa, (2014)

Effects of various quenching media on mechanical properties of annealed 0.509wt%c –0.178wt%Mn steel. The microstructure of the samples quenched in the oils under study revealed the formation of low proportions of martensite and in the case of olive oil, there was retainedAustenite.The focus was on palm kernel oil, cotton seed oil and olive oil for quenching medium carbon steel. Dauda et al., (2015).

Effect of Nigerian Neem Seed Oil as Austempering Quenchant for Locally Recycled Mild Steel. Austempering was used in this work to strengthen locally produced Nigerian steel using neem seed oil as quenchant. Neem seed oil was used as quenchant and limited to steel, only impact strength was suitable and limited to automotive gears. Nuhu (2015).

7. CONCLUSION

The following conclusions are drawn from the results of the research review above

- The Hot sesame oil bath is expected to cause the formation of ausferrite (Bainitic) microstructure after austempering.
- The physico-chemical, mechanical and microstructure of the gray cast iron before and after austempering should be determined
- The mechanical properties obtained are expected to be related to microstructure of austempered gray cast iron.

7. Recommendation

It is recommended that more research work should be undertaken to improve the properties of these material through any of the ways listed below

- Use of neem oil, shea butter, Seasame oil, sunflower oil, tung oil, jojoba oil, tonka bean oil,safflower oil, cottonseed oil, castor oil, grape seed oil, corn oil, mustard oil, palm kernel oil, hemp oil, macadamia oil, rapseed oil, mango butter, linseed oil, cherry pit oil, canola oil, borage oil, argan oil, almond oil etc.

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