The Effect of Heat Treatment on the Mechanical Properties of Grey Cast Iron in Paper Making Industries

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Abstract

Investigations were carried out to study the effect of heat treatment on the mechanical properties of grey cast iron. This study was carried out to determine a suitable heat treatment process which would give the best mechanical properties of grey cast iron and that can render it resistant to corrosion in the fluids used in paper making industries. The method used was that the cast iron was subjected to the following heat treatment processes: annealing, normalizing, stress relieving, quenching and tempering. The specimens were later immersed totally in wood pulp dissolved in water, white liquor, white liquor contaminated with 3% mercury chloride and wood pulp contaminated with 3% mercury chloride. The immersed specimens were withdrawn after four days, washed, rinsed, air dried and weighed before suspended in the solution again. The most important conclusion drawn from the results is that the annealed samples had better mechanical properties, with better tensile strength and high resistance to corrosion.

***Key words**: Annealed, Normalized, wood pulp, white liquor, Deterioration, Graphite flakes.*

INTRODUCTION

The major problem facing the paper making industries is the deterioration of their equipments by corrosion [1],[2]. They have to spend a lot in replacing and maintain their equipments. It had been discovered that wood usually caused corrosion [3]

The metals most susceptible to corrosion by wood are ferrous metals, zinc, cadmium, magnesium alloy and lead. Wood can cause corrosion of metals by direct contact and in confined spaces also by emission of corrosive vapour [3],[7].With rare exceptions, all wood are acidic, and the principal corroding agent in both types of attack is volatile acetic acid [6] Acetic acid is also known as ethonic acid. This acid when it comes in contact with iron, it forms rust.

Natural inhibitors are usually used to reduce contact corrosion. This will remove the tannins present in the wood. Even though cast iron will corrode when it is in contact with the wood, this can be prevented by some constituents that are present in its microstructure. The most important of these corrosion resistant micro-constituents are graphite, phosphates eutectic and to a lesser extent, carbide. If the cast iron is heat treated in order to promote the corrosion resistant constituents, it will therefore make it more resistant to corrosion.

The objective of this study is to determine the heat treatment process that will render grey cast iron resistant to corrosion from the fluids used in paper making industries, and determine the mechanical properties of such grey cast iron.

2.0 RESEARCH METHODOLOGY

(a) Materials and presentation.

(i) Cast iron is the major material used. It has the following compositions;

Carbon – 2.75%, silicon – 1.50%, Manganese – 0.35%, phosphorus – 0.70%, sulphur -1.0 %.(Banga, T.R; 2007)

(ii) Heat treatment processes; the cast iron was heat treated using the following processes: (a) Annealing,

(b) Normalizing, (c) Quenching, (d) Stress relieving, and (e) Tempering. The quenching medium used is standard grade SAE40 oil and it was obtained from a local dealer.

(iii) The corrosive media used are wood pulp and white liquor, which were obtained from the Nigeria Paper Mill, Jebba. The media were used as they were obtained raw and at room temperature.

(b) **EXPERIMENTAL PROCEDURE.**

The following heat treatments were carried out using a carbolite furnace:

Annealing, normalizing, stress relieving, quenching and tempering processes.

(i) **Annealing**; ten pieces of the cast Iron specimens were put inside the furnace and heated gradually up to 925^{0}C.At this temperature, the pieces were held for one hour. This is a sufficiently high temperature to ensure that fully homogenized phase is reached by all the samples according to the iron – carbon diagram.

(ii) **Normalizing**: Ten samples of the cast iron were put inside the furnace and heated gradually until it attained a temperature of 925^{0}C. This is because the normalizing temperature is usually kept above the transformation temperature range. They were held at this temperature for one hour for proper homogenization. The specimens were then brought out of the furnace to cool in still air.

(iii) **Stress Relieving**: another ten specimens were heated in the furnace for up to temperatures of 560^{0}C.These were held at this temperature for one hour. They were then removed from the furnace and allowed to cool in still air.

(iv) **Quenching**: another ten specimens were heated up to a temperature of about 870^{0}C. Immediately this temperature was reached, the samples were removed; five were quenched in oil (SAE 40), while the other five were quenched inside water held at room temperature.

(v) **Tempering:** The samples quenched in oil and water, were then removed and cleaned to make sure that they were dried and free from either oil or water. Two of each set were selected and transferred back to the furnace. These were later re-heated up to 370^{0}C, held at this temperature for 1 hour and subsequently cooled in air.

Weight loss experiment:

Four troughs were prepared. One contained the white liquor; another contained the wood pulp dissolved in water, the third contained wood pulp contaminated with 3% by weight of mercury chloride while the fourth contained white liquor contaminated with 3% by weight of mercury chloride. The surface areas of the test pieces were measured, with their initial weights before they were suspended in various solutions. The immersed samples were withdrawn after every four days. They were washed, under standard ASTM method, cleaned, air dried and weighed. Pre-exposure test was also carried out. The immersed test samples were removed later and pulled in tension to fracture to test for their tensile properties (Instrontensile testing machine was used).

3.0 RESULTS AND DISCUSSION

Visual observations: the following visual observations of the specimens were noticed when carrying out the experiments.

(i) Annealed samples –The annealed samples were covered by reddish scales, were abraded with 320 grit emery papers which had been shown [6] to produce uniform surface. The oxides scales were removed prior to experimentation.

(ii) Stress relieved specimens appeared dark-blue in color after cooling.

(iii) Tempered samples-It was observed that the oil quenched samples appeared very dark after it had been tempered while the water quenched samples had some reddish scale covering their surface after tempering.

(iv) Normalized samples- The normalized specimens were brought out of the furnace after it had been heated to 925^{0}C and held for one hour for proper homogenization. By the time the samples were brought out of the furnace, they were red hot. As they cooled rapidly in still air, a reddish scale covered the surface.

(i) Annealing Process

The samples had been softened and the internal stresses had been removed. The percentage elongation was improved. It increased from 7.5% for the as cast to 13.48% for the specimen immersed in white liquor and 10.81% for the annealed specimens immersed in wood pulp. This process also softened the grey cast iron and improved its machinability by minimizing or eliminating massive eutectic carbides.

(i) The Normalized Samples:

The result here is similar to that of the annealed component but the mechanical properties are somewhat better than the annealed component. The surface finish of the normalized specimen is better than that of annealed ones when machined, since the high ductility of the annealed makes the surface to tear.

(ii) HARDENING

Hardening is the process of heat treatment by which the cast iron is made hard by rapid cooling (quenching) from high temperature. This consists of:

(i) Water quenched; and
(ii) Oil quenched samples.
1. QUENCHING

The result of figure 5 showed that the rate of cooling in water is faster and non – uniform than the rate of cooling in oil because the specimen that was quenched in water showed a very hard structure which not fails at maximum load due to the martensitic structured that is present in the specimen. This is in agreement with the idea that martensitic structure is very hard and brittle. The hardness and brittleness of martensite is due to the fact that martensite is a super saturated solid solution of carbon trapped in a body centered tetragonal structure, which is a Meta stable condition. [5] This highly distorted lattice is the prime reason for the high hardness of martensite.

Sample showed that the oil quenched sample, exhibited both the plastic and elastic regions distinctively. This can be attributed to slow, uniform cooling which allows the formation of graphite and pearlite in its microstructure.[3] This reduces the hardness and makes it possible for the specimen to be ductile.

EFFECT OF HEAT TREATMENT ON THE PCENTAGE ELONGATION

The annealed samples have the highest percentage elongation (10. 86% to 13.48 %), while the quenching samples have the least percentage (2.50% - 2.62%) elongation.

The annealing process was applied in order to refine the structure of the cast iron. The Cast Iron was heated to just above its upper critical temperature (900^0C), so that the coarse grain structure was replaced by fine-grained austenite. On cooling, this gave rise to a structure of fine-grained ferrite and pearlite.

Effect of Corrosion on the Heat Treatment Samples.

(i) Annealing

The maximum tensile strength of the annealed specimens was obtained from the specimen that was heat treated but was not immersed in any of the corrosive fluids. This gave 322.05N/mm^2 while the highest tensile strength that was obtained from the ones immersed in white liquor is 319.59N/mm^2, this shows that the material (cast iron) has corroded. It, therefore, has a great effect on the tensile strength. The corrosion attack on the Cast Iron therefore tends to weaken the metal. It is also clear that the annealed Cast Iron is quite okay in white liquor since there is a little variation in the samples immersed in the corrosive media as compared with the Cast Iron in as- cast state.

(ii) Normalizing

Examining the normalized samples, the heat-treatment sample which was not immersed in any of the corrosive media has a tensile strength of 387.51N/mm^2 The tensile strength of the specimen dipped in the corrosive media was seriously affected to the point that the maximum tensile strength obtained is 340.4N/mm^2 in white liquor, while the least was obtained from white liquor plus mercury chloride (HgCl) ion as 270.56N/mm^2, in other words, the corrosion attack on the samples was much in white liquor with the mercury ion than in ordinary white liquor.

(iii) Stress Relieving

The effect of the heat treatment can be seen in the samples that were stress relieved. The specimen that was only stress relieved without immersing in any corrosive media has the tensile strength of 349.73N/mm^2.While the maximum tensile strength of those immersed in corrosive media (wood pulp) is 333.56N/mm^2 with percentage variation of 4.62%, and the least (white liquor plus $HgCl_2$) is 309.73N/mm^2 having the percentage variation of 11.44%. Even though the tensile strength of the stress relieved specimens were not very high compared to what was obtained from other heat treatment processes (such as annealing and normalizing), the tensile strength of the material tends to be a bit stable. This shows that the internal stresses that were relieved made the corrosion attack on the samples to be very little.

(iv) Tempering

The maximum tensile strength for tempered specimen is 296.45N/mm^2 while the minimum is 266N/mm^2. Although, the specimen that were quenched either with oil or water have a very high tensile strength than the tempered ones. Since the purpose of tempering the Grey Cast Iron is to obtain the maximum toughness.

1.0 CONCLUSIONS

Studies had been undertaken to examine the effect of heat treatment in a pulp fluid on the Mechanical properties of Grey Cast Iron. The following conclusions were drawn

From the studies carried out.

1 The tensile strength of the annealed samples (309.72N/mm^2) was less than that of the as-cast sample (327.35N/mm^2.Showing that annealing process removed the internal stresses of the Cast iron. However, the pulp fluid reduces the tensile strength of the material but with a higher elongation.

2 The rate of corrosion attack increased with the cooling rate. This is the reason why corrosion was less in the annealed samples, which was slow cooled in the furnace, than other heat treated samples that were cooled rapidly either in still air or quenching media.

It is therefore concluded that annealed grey cast iron could be used to construct metals and equipment, machines and other part in paper making industries with possible minimum repairs/ maintenance This is because the effect of the pulp fluid in the mechanical properties is minimal with the annealed cast iron.This effect becomes mentioned when mercury chloride present in the solution.

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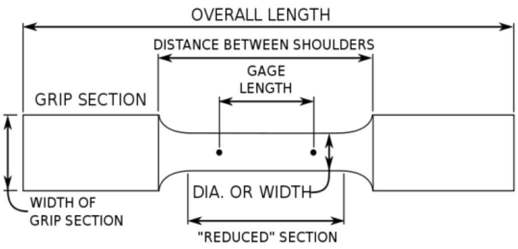

FIG 1. Typical sample of instron tensile testing machine (Davis et al, 1983).

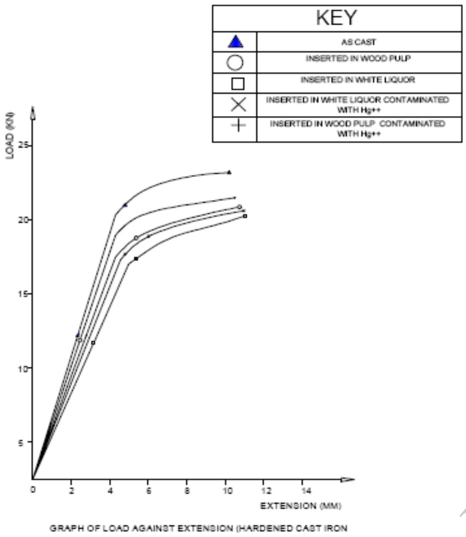

Figure2 Graph of load against extension of Normalized Cast Iron

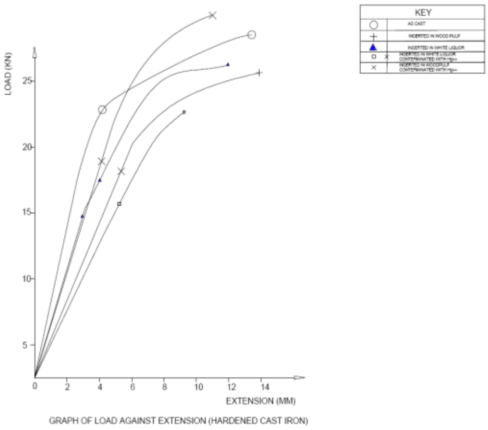

Figure3 Graph of load against extension for the annealed specimen

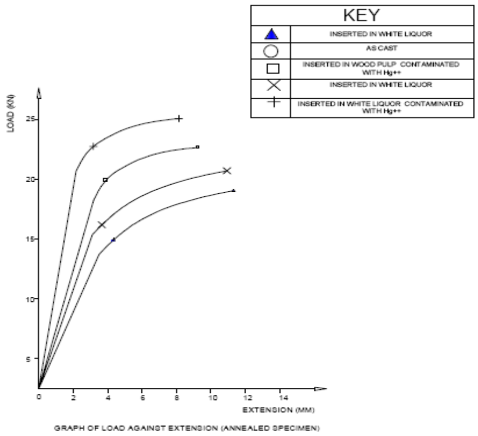

Figure 4 Graph of load against extension water and oil quenched specimen

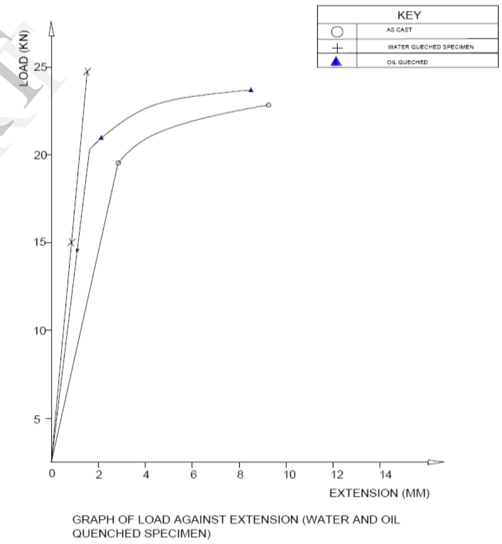

Figure 5 Graph of load against extension of Hardened Cast Iron