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Effect of Austempering Time on the Mechanical Properties 0f Ductile Iron, Austempered in Rubber Seed Oil

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Abstract:-. Austempering is a high performance isothermal heat treatment that imparts superior performance to ferrous metals. Salt bath has been recognized as the conventional quenching medium for austempering. This study investigated the effect of austempering time on the mechanical properties of ductile cast iron austempered in rubber seed oil at 250 ^{0}C. Test samples were austenitized at 950 ^{0}C; socked for 1hr; austempered for varying periods of 1, 2, 3, 4 and 5hrs. The result showed significant increase in tensile strength and impact energy apart from achieving an appreciable increase in hardness, implying that rubber seed oil can be used as hot bath for the austempering of ductile cast iron.
Keywords: - ustempering, austenitized, ausferrite, socked, matrix rubber seed oil

I. INTRODUCTION

Ductile cast iron, frequently referred to as nodular or spheroid graphite iron is a recent member of the family of cast irons. It contains spheroid graphite in the as cast condition, through the addition of nucleating agents such as cerium or magnesium to the liquid iron, [1]. The graphite spheroids are dispersed in a matrix similar to that of steel with the graphite spheroids exerting only a minor influence on the mechanical properties in contrast to the effect of graphite flakes in gray cast iron, [2]. The matrix structure then has the greatest effect on the properties of the iron. Ductile irons are therefore a family of alloys, which combine the advantages of gray cast iron (low melting point, good fluidity and castability, excellent machinability, and good wear resistance) with the engineering advantages of steel (high strength, toughness, ductility, hot workability and hardenability), [3].

Austempering is a high performance isothermal heat treatment that imparts superior performance to ferrous metals. It is a multi-step process that includes austenitizing, followed by cooling rapidly enough to avoid the formation of pearlite to a temperature above the martensite start (Ms) and then holding until the desired microstructure is formed and then air cooled. The metallurgical phase obtained is called ausferrite. It is composed of acicular ferrite and residual austenite saturated by carbon atoms. The proportion of phase changes with the chemical composition and heat treatment makes it possible to produce a family of ADIs. The presence of retained austenite in ADI exhibit excellent combination of strength and ductility together with good fatigue and wear properties,[4] The The high silicon content of ductile iron suppresses the formation of carbides which are normally associated with bainitic reactions, allowing the rejected carbon to austenite surrounding the formed ferrite platelets during transformation,[5]. The carbon content in austenite is enriched and makes it thermally stable to retain even well below room temperature. During austempering ductile iron undergoes two-stage transformation. In stage I, two step reaction take place which has an important effect on mechanical properties. The austenite (Υ) decomposes into ferrite (α) and high carbon austenite (Υ_{HC}):

$$\Upsilon \rightarrow \alpha + \Upsilon_{HC} \qquad \text{(stage I)}$$

If the sample is held at the austempering temperature for too long, then a next reaction (stage II) takes place where high carbon austenite further decomposes into ferrite and carbide:

$$\Upsilon_{HC} \rightarrow \alpha + \text{carbide} \qquad \text{(stage II)}$$

The product of this second reaction is undesirable because it results to embrittlement of the material and degrades the mechanical properties. Therefore, this reaction should be avoided during heat-treatment. [6]. Austenizing temperature and time are factors that affect the final properties of ADI, [7] and [8]. Braka confirmed this when investigating effect of austenizing temperature on austempering Kinetics of alloyed ductile iron. He studied the morphology of the matrix after austempering at 350^{0}c for 60,120, 240, 360, 480 min and after austenizing at 850^{0}c, 900^{0}c and 930^{0}c for 120 min. In all cases the microstructure consists of an austenite matrix and upper banite with relatively coarse ferrite needles. The microstructure of the specimen austenized at 850^{0}c consists of different proportions of procutectoid ferrite and banitic ferrite. This depends on the austenizing temperature and austempering time. A coarser structure is produce at high austempering temperature which has lower tensile strength. With lower austempering temperatures a structure that is finer, with more strength, hardness and wear resistance can be obtained. T he time at the austempering temperature is also important: too short a time resulst in unstable austenite which is readily more brittle [9]. A small amount of fine martensite can be beneficial in improving both the wear and the fatigue resistance.

Austempered ductile iron has been long recognized for its high tensile strength, ductility, wear resistance and toughness making it a possible replacement for forged steels in many applications [10]. Strength to weight ratio is more than that of aluminium, so ADI can replace aluminium also, where strength of the component is to be considered for minimum weight.

Salt bath has been the conventional quenching medium for austempering heat treatment of steels and cast iron. However, oils are among the quenching media of industrial significance, [11]. Oils of mineral and vegetable origins have been used as quenchant. The use of oils of mineral origin is however compromised by the film or nucleate boiling heat transfer they exhibit, resulting to lower-temperature cooling rates. This characteristic is absent in vegetable oils, where heat transfer is dominated by convective cooling, [11] The cooling rate for vegetable oils is faster than that of comparable quenchants, making them suitable for austempering heat treatment. The cooling time-temperature and cooling-rate curves obtained show that the cooling properties of series of vegetable oils appear to be comparable to each other.

This research work investigated the potential of rubber seed oil as austempering quenchant for ductile cast iron. The development of a quenchant from locally source raw materials is expected to be a significant contribution to the foundry industry. Rubber seed oil is non consumable vegetable oil which has little or no application in human nutrition

II. METHODOLOGY

The raw materials used in this study include rubber seed oil and ductile cast iron. Rubber seeds oil while ductile cast iron was produced in a commercial foundry (Nasir Foundries Jos, Plateau State. Nigeria).
Fifteen Y-blocks were produced using open ladle treatment method for this study. The chemical composition (in wt. %) of castings was as follows: 3.63C, 2.60Si, 0.35Mn, 0.02S, 0.03P, 0.03Mg, the balance was Fe. Samples for tensile tests and charpy impact tests were machined from the blocks. Screw-type samples (ASTM.A370-68) with 10mm diameter and 75mm gauge length were used for tensile tests. All tensile tests were performed at room temperature at a strain rate 1.3x10-3s-1. The dimensions of the notched charpy samples (ASTM E 23-93a) were 10x10x50mm. Impact tests were also performed at room temperature applying 300J impact energy. Prior to testing samples were austenitised at 950^{0}C for 1h and then austempered in hot rubber seed oil bath at 250 ^{0}C for varying periods of 1hr, 2hrs, 3hrs, 4hrs and 5hrs. After austempering samples were air cooled, after which they were washed with kerosene. Samples were tested in the as cast and austempered condition. A minimum of three samples were tested for each heat-treatment condition.

III. RESULT AND DISCUSSION

The results obtained from this research work are displayed in form of graphs in Figures 1 -3. Fig. 1 shows the effect of austempering time on the tensile and yield strength of ductile cast iron specimens austenised at 950 ^{0}C and austempered in hot rubber seed oil bath maintained at 250 ^{0}C. The tensile strength reached a maximum at 4 hrs then decreased. This increase in tensile strength is attributed to the formation of ausferrite in the matrix of the ductile cast iron. At the austempering period of 5 hrs a drop in tensile strength was noticed, indicating that the reaction crossed from toughening stage to embrittlement. Stage I reaction $\Upsilon_H \rightarrow \alpha + \Upsilon_{HC}$ (toughening); Sage II reaction $\Upsilon_{HC} \rightarrow \alpha + \varepsilon$ – carbides (embrittlement).[7]. There was a corresponding increase in the yield strength of the tested specimen as shown on Figure 1.

Figure 2, shows percentage elongation and reduction in area of the austempered ductile cast iron increasing with austempering time. This is also in agreement with the stage I austempering reaction shown above. Figure3 shows the effect of austempering time on the hardness and impact strength of ductile cast iron specimens austempered in rubber seed oil bath. It is evident that as the austempering time increased the hardness values of the austempered specimens decreased to minimum values of 286 BHN, 269 BHN, and 256 BHN. The drop in hardness at 2hrs, 3 hrs, 4 hrs and 5hrs austempering periods shows transformation of the matrix to stabilized austenite and ferrite structure. The impact energy also increased progressively with austempering time. This indicates a progression in the stage 1 reaction, increasing the stability of austenite in the ferrite matrix of the cast iron. This is in agreement with [8]. The highest impact energy value of austempered ductile iron for this study was 69J in hot rubber seed oil bath at 4hrs austempering period.

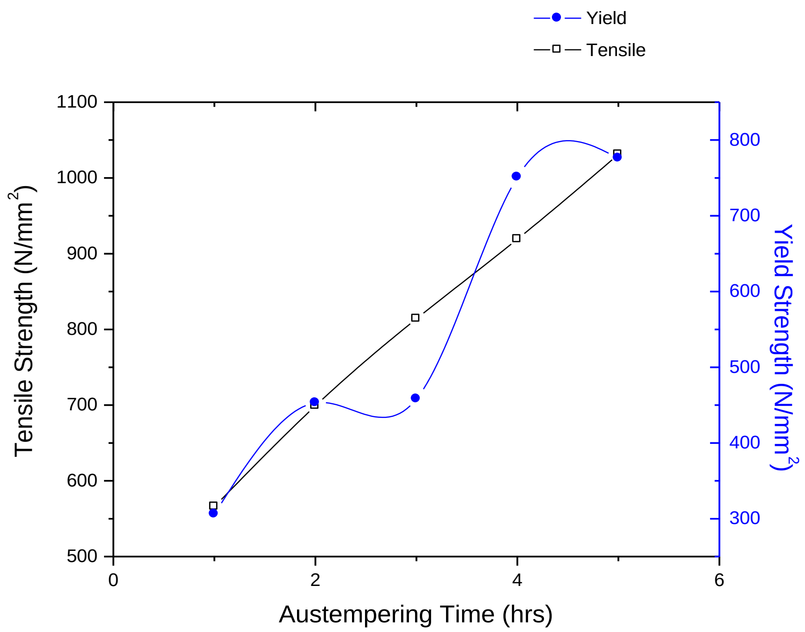

Fig. 1: Effect of austempering time on the tensile and yield strength of ductile cast iron austenitized at 9500C and austempered in hot rubber seed oil at 2500C for varying periods

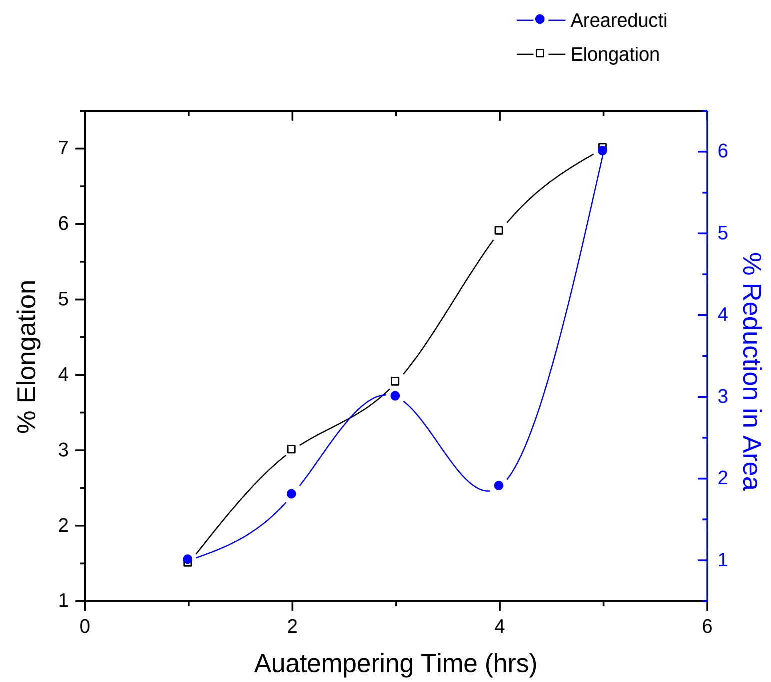

Fig. 2: Effect of austempering time on elongation and contraction of ductile cast iron austenitized at 950^0C and austempered in hot rubber seed oil at 250^0C for varying periods

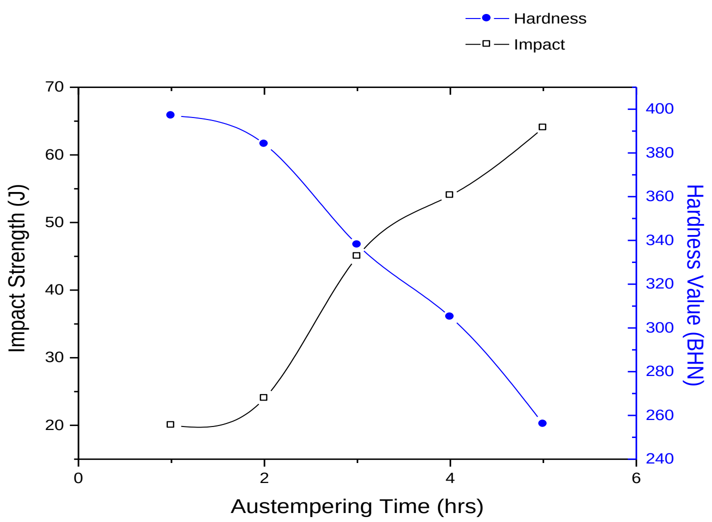

Fig. 3: Effect of austempering time on Hardness superimposed on Impact energy values of ductile cast iron austenitized at 950^0C and austempered in hot rubber seed oil at 250^0C for varying periods

IV. CONCLUSION

This research work investigated the potential of rubber seed oil as austempering medium for ductile cast iron. From the observations and analysis of the results obtained, it can be deduced that; rubber seed oil was able to cause the formation of 'ausferrite' structure at 250^0C in the ductile cast iron. There is appreciable improvement in mechanical properties of ductile cast iron when austempered in the rubber seed oil. The as-cast tensile, hardness and impact energy values of 570 N/mm^2; 196 BHN and 31 J increased to 962 N/mm^2; 349 BHN and 47 J. The optimum combination of mechanical properties was obtained at austempering time of 4hrs.for the austempering temperatures studied. The variation in the properties with the bainitic level reveals the relationship between mechanical properties and bainitic ferrite and retained austenite contents. The tensile strength values are increased with increasing bainitic level in the matrix structure. The impact strength and hardness values are also influenced significantly by the matrix microstructure.

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