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Production And Commercialization Of Austempered Ductile Iron

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Abstract:
The research work is on the production of Austempered Ductile Iron (ADI) and its commercialization. The materials used include a scrap of grey cast iron, graphite and ferrosilicon magnesium which was used as inoculants. The methodology applied is green sand moulding and casting. The scrap of the grey cast iron was melted in the rotary furnace and poured into the ladle before the inoculants were added. The molten metal was later poured in to the mold and later removed and felted .Machining was done and the product austenitized and salt bathed with Potassium Chloride, Sodium Chloride and Barium Chloride at 8500C. It was later austempered and salt bathed in 500g each of potassium nitrate and sodium nitrate at 4200C.The specimens were later subjected to mechanical testing and the micro-examinations were carried out using optical machine. The results of the test showed that the material is austempered ductile cast iron according to literature. The metal can be produced enemas for commercialization.

Key words*: Austempering, austenitization, Green sand mold, ferrite, microstructure and micro-examination.*

1.Introduction

In recent years, Austempered Ductile Iron (ADI) has attracted considerable interest because of its excellent properties, such as resistance to fatigue (Dorazil,1991), good wear, high strength with good ductility and rolling contact resistance. The manufacturing cost of ADI is also substantially lower than wrought or forged steel according to Olivera, et al 2006, Okazaki, et al (1991); Shiokawa (1978)and Adewuyi(2002). Furthermore, the density of ADI is lower than steel (Riposan et al (2002);. Thus, ADI has the advantage of higher specific strength than steel (Raymond (1996). Due to all the stated properties of ADI above, it is considered a very promising engineering material and an economical substitute for wrought or forged steel in several structural applications in the automotive industry, (Olivera et al (2006). It is these attractive properties that are currently placing ADI as a material for crankshaft manufacture.

The mechanical properties of ADI can be tailored to suit particular applications by adjusting heat treatment parameters or material compositions (Olivera et al 2006). This can aid the proportion of the phases present in the microstructure.

The process involved the production of a ductile iron casting, austenitization and salt bathed at (850^0C), then quenching and salt bathed to a temperature of 420^0C. (Adewuyi, 2002). Donald , 2008 recently, pointed out that it is possible to produce both compacted graphite irons and ductile iron from the same base iron (Riposan et al 2002), using cored wire containing a high ferrosilicon magnesium. Results showed (Donald,2008) that it was possible to use such a magnesium treated ductile iron with low residual Magnesium (Mg) levels (0.025 to 0.04 percent) but with an addition of “fresh” sulphur. The sulphur addition was in the form of a rapid dissolving iron sulphide briquette (Olivera et al 2006). Less than 0.02 weight percent sulphur was needed to “de nodulize” the iron. Thus, it was possible to have the same furnace melt chemistry and have a controlled transition from ductile iron to compacted graphite iron in the same campaign (Riposan et al 2002).

2.Experimental Procedure

The scraps of the grey cast iron used to be in lumps. They were broken into pieces for easy charging into the furnace. 55kg of the grey cast iron was measured and charged into the furnace. 4kg of graphite was added while 0.338kg of ferrosilicon magnesium were later added as inoculants ssssbased on our calculator.

The chemical composition of the materials charged into the furnace is as stated below: Grey Cast Iron; Carbon – 4.32%, Silicon – 2.20%, Manganese – 0.79%, Phosphorus – 0.077%, Sulphur – 0.199%, Magnesium 0.0039%

- **Pattern making**
  A simple pattern which was cylindrical in shape was made from wood, having a dimension of 20mm in diameter by 500mm in length. Five of such wooden patterns were made and placed in the cope to form the mould. They were used to generate the casting.
- **Green Sand Moulding**
  Green sand moulding may be explained as a plastic mixture of sand grains, clay, water and other materials which can be used for moulding and casting processes. The sand is called "green" because of the moisture present and thus distinguished it from dry sand. Here silicate, clay, betonies, coal dust and water were mixed to form the green sand moulding that was used.
- **Preparation of the green sand moulding**
  The moulding requires the ramming of sand around the pattern. The wooden box cope was placed on a flat floor, some sand was packed inside while the patterns were placed erect inside it and sand was packed, and the ramming of the sand was done. As the sand was packed, and rammed, it developed strength and become rigid. Ramming was done using a small wood. No spruce was made but gating system was made at the top of the cavity for easy pouring of the molten metal.
- **Furnace Pre-heating.**
  The Rotary furnace was fired using engine oil and blower. The fire was raised to the highest and this was maintained for a complete one hour. During this time nothing was charged in to the furnace. This is called the pre-heating period for the furnace, after which the furnace was ready for charging. The temperature of the rotary furnace was about 800^0C.
- **Materials charged in to the Furnace**
  The already measured grey cast iron 55kg, 4kg of graphite were then charged in to the furnace. The furnace was then fired and this continued until the temperature of the furnace reached $1{,}500^0$C. This temperature was attained after the furnace had been fired for one hour thirty minutes (1hr 30mins).The metal was continuously checked until it was ascertained that it had become molten.
- **Ladle Pre-heating**
  Before the cast iron became a molten metal, the ladle was pre-heated. It was heated to a temperature well above 500^0C. It was maintained at this high temperature until the molten metal was about to be poured into it.
- **Tapping of Metal in to Ladle for treatment.**
  The Rotary furnace was rotated to a point where there was a small opening. The already pre-heated ladle was brought near and the molten metal was poured into the ladle. The Ferrosilicon magnesium and the Ferrosilicon powered already measured down were just dropped inside the molten metal in the ladle. For late inoculation. The two salts melted almost immediately because of the high temperature of the molten metal.
- **Pouring of molten metal into the mould.**
  The ladle was lifted and then the molten metal was poured into the already prepared mould. As the moulds were filled with the molten metal the remaining melt was quickly poured out of the ladle.
- **Removal and Felting**
  The cast metal was left to cool inside the mould overnight. The mould was broken and the cast rods were removed, picked and cleaned one after another. They were felted using wire brush to remove both sand and unwanted metal attaching to the cast metal.
- **Machining of the samples for mechanical testing.**
  The test samples were then machined one after another. The tensile strength specimens were machined to the standard test see.. About 20 specimens were machined and prepared for further tests. Another set were machined for impact tests.
- **Heat treatment**
  Austempered Ductile Iron (ADI) was produced by an Isothermal heat treatment called austempering. The process of austempering heat treatment consists of the following:
  - Austenitizing process: Each set of melt was charged into the furnace one after another. The ductile iron was salt bathed with the mixture of sodium chloride, potassium chloride and barium chloride in a ratio of 3: 2:1 respectively at 8300C. The heating was done slowly. It took the furnace two (2) hours to attain to this temperature.
  - The specimens were then withheld for one hour for proper homogenization.
  - The specimens were quickly removed and transferred to a container that contained the mixture of 500grams each of Sodium Nitrate and Potassium Nitrate salts. The salts were then heated to a temperature of 4500C. Thus the samples were austempered.
  - After this, the specimens were removed from the furnace and allowed to cool in still air.(at room temperature). Other melts were later carried out following the above process.
  - A multi-meter tester AVD890C (thermocouple) was used to monitor and measured the salt bath temperature.
- **Mechanical Test**
  Metals are tested in order to know their mechanical properties which will enable it withstand certain service conditions. These properties include: Hardness, strength, toughness, stiffness, ductility and malleability among others. The values of these proportions vary greatly from metal to metal and are dependent upon the metallurgical condition of the material (Usman 2009).

The tensile strength test was carried out from the universal testing machine, whereby the specimens were fractured and the result was recorded in table1 of the appendix. The impact test was also carried out using notch-bar impact test (the izod machine) the result is as shown on table2. The hardness was also taken using the hardness testing machine.

- **Microscopic Examination**
  Specimen Preparation
  Specimen of 20mm diameter and 10mm thickness were cut for microscopic examination. The specimens were mounted in certain thermoplastic (phenolic materials) using mounting press. The phenolic powder materials mould at 100^0C – 140^0C which is usually at low temperature to avoid structural changes in the specimen The specimen was placed in a small cylindrical steel mould containing the phenol powder which was heated by an electric heater to 100^0C. A press given a pressure of $25N/mm^2$ was used to compress the mould contents during heating after reaching 140^0C temperature. The heater was replaced by a water-cooled coil and the specimen was ejected after cooling.
  Other process like grinding, polishing and etching were carried out on each specimen before the photomicrographs were taking (see photo plates 1=3 in the appendix.)

3.Results And Discussion

The formation of nodules were achieved by the addition of nodulerizing elements which is magnesium was used. Magnesium boils at 1100^0C and Iron melts at 1500^0C because of this; magnesium is usually added in the ladle just before pouring in to the molds.

3.1.Metallurgy

The metallurgical structure of austempered ductile iron (ADI) was controlled through heat treatment and it was changed or manipulated based on what properties that was needed. Austenite was obtained due to the high temperature at which it was heat treated. The graphite in the ductile iron due to the nodulerization changed to spheroid shape while the ferrite and pearlite were controlled through alloying of the iron. Base on the ratio of the ferrite to pearlite, the tensile strength, yield strength and the elongation can be easily manipulated to produce the needed grade of the iron.

The photo plate of the microstructure is shown below contained spheroidal nodules. This shows that the material is nodular ductile iron. This was subjected to austenization and austempering heat treatment which had transformed the nodular ductile iron to austempered ductile iron. Looking at the structure, one can clearly see the austenite and ferrites. The austenite contained the spheroidal nodules. The auetempering process produced a matrix microstructure that is substantially ausferrite (a mix of high carbon austenite and acicular ferrite).figure 2

3.2.Application Of The Austempered Ductile Iron

The potential of Austempered Ductile Iron (ADI) and its application is very vast because of its properties, cost and flexibility. The following are its application;

- It is used for the production of agricultural implements because of its excellent resistance to soil wear.
- It is used for the production of grinding, mixing, pelletizing food and feed milling.
- Austempered ductile irons are also used to produce gears because of its wear resistance and better vibration damping than steel.
- It is used for the production of Industrial machines, because its components will be wear resistance.
- It is also used to make diggers, grab teeth because of its high strength and wear resistance.
- It can be used to produce pumps (e g oil well pumps) and pipes (call ductile iron pipes) use for water and sewer lines. It is used instead of polypropylene and polymeric materials such as PVC, HDPE and LDPE (which are all much lighter than steel or ductile iron).
- ADI is used to produce automotive components where higher strength than aluminum is required.
- It is used for the production of agricultural tractors and off high way diesel trucks.
- ADI is used to produce crank shafts according to Chatteley et al (1998) and cam shafts.

4.Conclusion And Recommendtion

The main objective of this research work was to produce austempered ductile iron and to commercialize it. This was achieved through the casting that was done which is ductile cast iron. The ductile cast iron was austenitized and austempered to produce the expected austempered ductile iron. The microstructure actually proved this. Also from the applications of the austempered ductile iron that were stated earlier in this work, it had shown how vast the usefulness of the metal is. So metallurgist and designers can easily commercialize the metal. In the areas where forged steel is too expensive and the tensile strength of aluminum is insufficient ADI can be used.

4.1.Recommendations

The following recommendation can be made on this research;

- To get different mechanical properties, the chemistry of the work can be manipulated. The percentage by weight of the following elements can be altered; carbon, silicon, manganese, sulphur and magnesium.

- The heat treatment to which the ductile iron is subjected matters a lot. The temperature can also be manipulated so that one can obtain different properties.
- The amount of inoculation and the time to which it is added can also alter the properties of the ductile iron.
- Apart from the austenitization and austempering of the ductile iron, further heat treatment processes can be used; e.g. annealing, normalizing and tempering processes can be carried out depending on what we want.

5.References

1. Rebasa, N. Dommarco, R; Sikora, J. (2004): 'Wear resistance of high nodule count ductile iron' 253 , (T -8), Hokongghub,Elsevier hokongghub. Elsevier.com/retrieve/pi.
2. Dorazil, E (1991), 'High strength Austempered Ductile Cast Iron', first edition, Ellis Horwood, London.
3. Banga, T.R; Agarwal, R.l and Manghnani, T. (2007), ' Foundry Engineering' Fifth reprint, Khanna Publishers, 2-B. Nath Market, Nai Sarak, Delhi – 110006.
4. Olivera, E; Dragan, R;Slavica, Z; Lepoava,S; and Milan, T. J;(2006),'Microstructure and fracture of alloyed austempered Ductile Iron', Institute of Nuclear Science "Vinica", Beldrade,Serbia and Montenegra.
5. Okazaki, K; Asai, H, Tokuyoshi, M; Kusonoki, H. & Sakahara, H. (1991):'Spheroidal graphite cast iron' Proceeding World Conference on Austempered Ductile Iron, Bloomingdale II, pg 271 (4).
6. Shiokawa, T. (1978):' Effect of graphite nodules on crack growth behavior of austempered ductile cast iron (ADI)' 59th Japan Ductile Cast Iron. Association Conference, Tokyo, Japan, 1978 pp 138-150.
7. Adewuyi, B.O. (2002): Effect of Austempering temperature in the fatigue Strength of Ductile Iron, PhD Thesis, Federal University of Technology, Akure.
8. Riposan, I; Chisamera, M; Stan, St; Sparkman, D; Kelley, D. and Barstow, M. (2002): "Experience producing compacted Graphite Cast Irons by Sulfur Addition after Magnesium Treatment", American Ferrous Society Transactions, Vol. 110 pp 851-859.
9. Karl, M.P, Niels, S.T (2007), ' Graphite Nodule Count and size distribution in thin – walled ductile cast iron' Department of Manufacturing Engineering and Management, Technical University of Denmark, Produktionshopvet, DK – 2800kgs. Lyngby, Denmark.
10. Imasogie, B; Afonja, A; Ali, J.A. (1995): 'Cast Iron in the light of recent Research (Conference proceedings.) Nigerian Metallurgical Society, 20-30.
11. Raymond A. Higgins (1996): 'Engineering metallurgy, part 1, sixth edition, Arnold, London pp 363-364.
12. Donald B. Wagner (2008), 'Science and Civilization in china' volume 5, Chemistry and chemical Technology, Part III, Ferrous Metallurgy; Cambridge University Press pg 159 – 169 ISBN 978 – 0 – 521 – 87566 – 0
13. Usman, A.W. (2009): 'Introduction to some mechanical test' – Training Papers on mechanical testing, metallographic, techniques and corrosion in the oil and gas industries held in National Metallurgical Development Centre (NMDC) plots No BPG 179, Zaria road, Jos.
14. Chatterley, T. and Murrel, P. (1998): 'ADI Crankshafts – An Appraisal of their production potential, SAE Technical Paper Series, No 980686, SAE Congress, Detroit, Michigan, U.S.A.,

Appendix

Specimen identification	Diameter (mm)	Tensile strength N/mm^2	Ultimate tensile strength (UTS) N/mm^2	Original length (mm)	New length (mm)	Extension (mm)	Percentage Elongation (%)
C_1 (As cast)	20.00	292	395	145.00	149.79	4.79	3.30
C_2	20.00	467	606	145.00	159.50	14.50	10.00
C_3	20.00	458	610	145.00	155.88	10.88	7.50
C_4	20.00	448	590	145.00	156.60	11.60	8.00

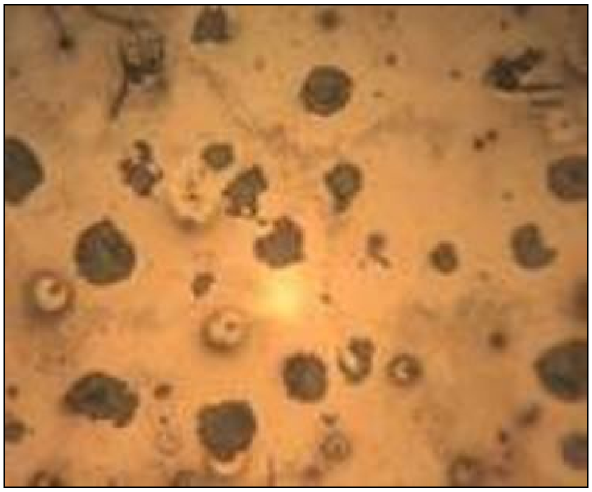
Table 1: Tensile Properties For The Austempered Ductile Iron

Key; C1 As Cast, C2, C3, C4 Are Specimen From The Austempered Ductile Iron Which Was Austempered At 420^0C.

Specimen Identification	Test I	Test II	Test III	Average (HRC)
As cast	40.00	45.0	39.0	41.3
C_1	38.0	30.0	40.0	36.0
C_2	33.0	31.0	34.0	32.7
C_3	31.8	31.5	30.0	31.1

Table 2: Hardness Test For Austempered Ductile Iron

Key; C1 As Cast, C2, C3, C4 Are Specimen From The Austempered Ductile Iron Which Was Austempered At 420^0C.



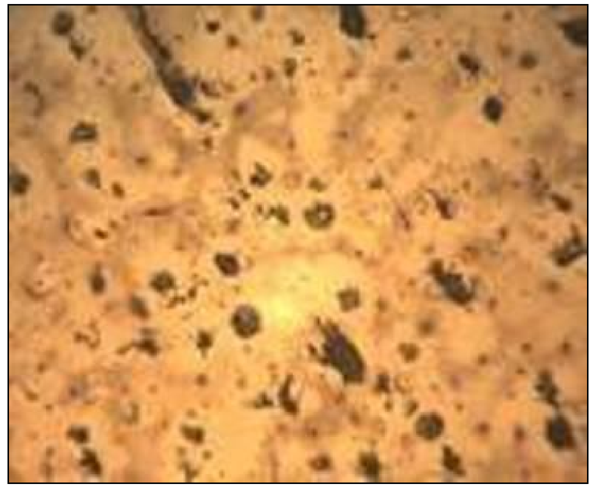


Figure 1: Photomicrograph Of Ferrite Ductile Iron
Figure 2: Photomicrograph Ofductile Iron Showing The Nodles

Figure 3: Photomicrograph Of Pearlitic Ductile Iron