# Fabrication of ADI Using S.G Cast Iron

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### ABSTRACT

Austempered Ductile Iron (ADI) is a type of graphite cast iron produced by an isothermal heat treatment process. It is an alternative to traditional steel castings and forgings and even aluminium due to the exceptional mechanical properties such as high strength, good toughness and excellent machinability. Tempering is an effective method to increase the mechanical properties of SG Cast Iron by modifying its microstructure. In the present research, the transformation of SG Cast iron after applying various tempering temperatures was investigated. Mechanical properties of SG Cast Iron before and after heat treatment at various tempering temperatures were measured. The mechanical properties of SG Cast iron after heat treatment were enhanced and the resulting metal formed can be called as ADI (Austempered Ductile Iron). Thus the tempering temperatures must be carefully selected so that excellent properties of ADI are achieved.

Keywords- ADI, tempering, microstructure, mechanical properties

### I. .INTRODUCTION

Austempered Ductile Iron (ADI) has recently received significant attention owing to the excellent combination of mechanical properties such as high strength together with good ductility, good wear resistance and higher fatigue strength to make th material a successful substitute for forge steel or aluminium alloys. The remarkable properties of ADI are attributed with the unique microstructural constituents such as bainitic ferrite and high carbon enriched retained austenite. The austempering heat treatment process was first developed and applied to steels in the 1930's. This consists of heating a material into the austenite phase field and then quenching it to a lower temperature (the austempering temperature) and holding at this temperature to allow the austenite to transform isothermally to an acicular ferrite phase containing carbides known as bainite. Early trials to austemper ductile iron were undertaken [2] in the 1950's, soon after the development of ductile iron.

### A) SG Cast Iron-

SG Iron is also known as Ductile Cast Iron, Nodular Cast Iron, Spheroidal Graphite Iron and Spherulitic Cast Iron. This grade of Iron was developed over 60 years ago and in the USA. As the name Ductile Iron suggests this grade of Cast Iron has a degree of ductility. The main characteristic of this material is the structure of the graphite. In SG Cast Iron the graphite is in the form of spherical nodules (hence the name Spheroidal Graphite) rather than flakes as in Grey Iron. This nodular graphite structure inhibits the creation of linear cracks hence the ability to withstand distortion.As with Grey Iron, there are many grades of SG Iron that can be specified offering the engineers varying degrees of tensile strength and elongation. The various grades are achieved through a combination of alloy additions and heat treatment.

The SG Cast Iron in this experiment was obtained in the form of a 50x10 cm rod and then cut into 20 pieces for testing as samples.

### 1) Chemical composition:

For common cast iron, the main elements of the chemical composition are carbon and silicon. High carbon content increases the amount of graphite or Fe3C. High carbon and silicon contents increase the graphitization potential of the iron as well as its castability. The manganese content varies as a function of the desired matrix. Typically, it can be as low as 0.1% for ferrule irons and as high as 1.2% for pearlitic irons, because manganese is a strong pearlite promoter. From the minor elements,

ISSN: 2233-7857 IJFGCN Copyright ©2020 SERSC phosphorus and sulfur are the most common and are always present in the composition. They can be as high as 0.15% for low-quality iron and are considerably less for high-quality iron, such as ductile iron or compacted graphite iron.

The main effect of chemical composition in nodular (ductile) iron is on graphite morphology. The carbon equivalent has only a mild influence on the properties and structure of ductile iron, because it affects graphite shape considerably less than in the case of gray iron.

Nevertheless, to prevent excessive shrinkage, high chilling tendency, graphite flotation or a high impact transition temperature, optimum amounts of carbon and silicon must be selected. Minor elements can significantly alter the structure in terms of graphite morphology, chilling tendency, and matrix structure. Minor elements can promote the spheroidization of graphite or can have an adverse effect on graphite shape.

### 2) Production of SG Cast iron:

SG Irons are produced directly by the solidification of a melt containing sufficient silicon to ensure graphite formation, after careful removal of Sulphur and oxygen. Magnesium additions to the bath tie up Sulphur and oxygen and radically change the graphite growth morphology. Magnesium reacts with the oxygen to form highly stable MgO, which floats to the surface and can be skimmed off. The oxygen content is reduced from typical levels of 90-135ppm to about15-35ppm. Magnesium also reacts with the Sulphur to produce MgS which again floats to the bath surface, but less stable than the oxide. Since magnesium has low solubility in the metal and is volatile, the reactions can become reversible if losses are too great. Silicon in the form of Ferro silicon is generally added to provide additional deoxidation. Other elements from groups 1A, 11A and 111A can be also being employed to tie up oxygen and Sulphur. In particular cerium forms highly stable oxides and sulphides and less volatile than magnesium, with which it is used in combination. Some of the inclusions formed by the inoculants act as nuclei for the graphite and are found at the center of the nodules. The simplest explanation of the spherodising effect of inoculants such as magnesium is that oxygen and Sulphur are absorbed preferentially on the hexagonal planes of graphite, leading to the lamellar morphology. The removal of Sulphur and oxygen by the inoculants allows more isotropic growth. A careful choice of alloying additions is used to appropriately adjust the deoxidation, graphitizing and nucleation effects.



Fig 1.Mirostructure of ductile iron (a) unetched (b) nital etched.

### B) Austempered Ductile Iron

The austempering process was first developed in the early 1930's as a result of the work that bains, etal was conducting on the isothermal transformation of steel. In the early 1940's flinn applied this heat treatment cast iron namely gray iron. In the 1950's both the material ductile iron, and the austempering process had been developed.

### Process

1) Heat castings in a molten salt bath to austenitizing temperature (815-927Oc)



Fig.2. Austempering process

2) Hold at austenitizing temperature to dissolve carbon in austenite.

3) Quench quickly to avoid pearlite.

4) Hold at austempering temperature (232-4000C) in molten salt bath for isothermal transformation to ausferrite.

Consistent control of times and temperatures throughout the entire process

1) Initial austenitizing times and temperatures ( $1550^{\circ}$  to  $1700^{\circ}$  F.) are controlled to ensure formation of fine grain austenite and uniform carbon content in the matrix. The precise temperature is grade dependant.



Fig.3 Control of time and temperature on the process

2) Quench time must be controlled within a few seconds, to avoid formation of pearlite around the carbon nodules, which would reduce mechanical properties. Quench temperatures ( $450^{\circ}$  to  $750^{\circ}$  F.) must stay above the point of martensite formation.

3) In the austempering step which follows austenitizing, the temperature of the final salt bath must also be closely controlled. The austempering step is also precisely time-controlled, to avoid over- or under-processing. By the end of this step, the desired ADI ausferrite structure has developed.

#### **II. EXPERIMENTAL PROCEDURE**

SN

C.I sample

3.985

0.188

A) Chemical composition

	CHEMICAL	L COM	IPOSIT	ION C	JF TH	E SAM	PLE (	JSED	
r. 0.	Sample Identification	Chemical Composition, %							
		С	Mn	Si	Ni	Mo	W	Cu	Fe

1.724

0.289

0.307

0.141 0.673

91.825

 TABLE I

 CHEMICAL COMPOSITION OF THE SAMPLE USED

## B) Heat Treatment Process

The original samples were cut from bars into cubes with dimensions 30x30x30 mm. The original microstructure of as cast ductile iron has graphite nodules uniformly surrounded by pearlite. An austenizing temperature of 900°C was selected based on previous research. The ductile iron samples were austenized in a salt bath for 25 min. Then the samples were rapidly transferred to another preheated salt bath furnace for an austempering process at 276°C,321°C,and 373°C for 30 min, and then cooled in air to room temperature. The ADI samples were then subjected to a tempering process at various temperatures for 60 min in an electric furnace and cooled by water quenching to room temperature. A schematic of the heat treatment process utilized in this research is shown in Fig 4



Fig 4. a) Austenizing and austempering processes. b) Tempering process carried out for 60 min on ADI samples

### **II.** RESULTS

### A) Hardness measurement (Rockwell C)

A Rockwell hardness tester was used to measure the hardness of the ADI samples. In Fig.5, it can be seen that the hardness of the ADI samples decreases with increasing austempering temperature at the same holding time. This may be due to a decrease in martensite in the matrix and more austenite being transformed into ausferrite. In addition, the hardness also decreases with increasing tempering temperature for each austempering condition.



Fig.5 Hardness measurements for ADI samples for each tempering temperature

### B) Microstructure analysis

Figs. 6-8 show the microstructure of the ductile iron samples obtained from different austempering and tempering temperatures. The ADI samples austempered at 373°C have thick feather-like

ISSN: 2233-7857 IJFGCN Copyright ©2020 SERSC ausferrite, but thin needle-like ferrite is formed for 276°C and 321°C austempering temperatures. This is because the diffusion rate of carbon atoms is faster under higher

austempering temperatures and the growth rate of nucleated ferrite platelets increases. After applying the tempering process, the ferrite and high carbon content austenite gradually vanish, and particles are formed in the matrix. These particles are likely cementite. The main microstructural constituents of the ductile iron samples for each heat treatment condition are reported in Table 1. For the samples austempered at 276°C and 321°C, the characteristic ausferritic structure still exists along with tempered martensite when the tempering temperatures are lower than 538°C. The formation of cementite particles becomes obvious for 538°C or higher tempering temperatures. For the samples austempered at 373°C, the ausferritic structure is no longer present after tempering at 482°C or higher temperatures. Wen et al suggested that a tempering temperature of 200°C had insignificant effects on ausferrite structure, but was effective in producing tempered martensite. As a result, the uniform ADI matrix with martensite has been transformed into tempered martensite and cementite. Moreover, the microstructure of samples after being austempered at 276°C with a tempering process of 321°C without tempering.



Fig.6 Microstructure photos of samples at various tempering temperatures

### **IV. CONCLUSIONS**

1) As the austempering temperature is increasing hardness and tensile strength are decreasing and elongation is increasing.

2) As the austempering time is increasing tensile strength, hardness and elongation are increasing.

3) In microstructure austenite is increasing with increasing austempering temperature and ferrite is increasing with increasing austempering time.

4) The samples which are autempered at higher temperatures having upper bainitic structure and the samples which are austempered at lower temperatures are having lower bainitic structure.

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