EFFECT OF HEAT TREATMENT PROCESSES ON DUCTILE CAST IRON MECHANICAL PROPERTIES - AN EXPERIMENTAL APPROACH

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ABSTRACT

Ductile cast iron is the most important material which is used in many industrial and automobile applications. In the present work the effects of austempering, normalizing and annealing heat treatment processes on Ductile Iron specimen are studied. Various temperatures and holding times are used in the present work. Maximum hardness is observed in austempered (at 860ºC) ductile iron specimen and minimum hardness value is observed in annealed (at 900ºC). Tensile strength is observed maximum in normalized (at 925ºC) specimen and minimum value observed in annealed (at 860ºC) ductile iron specimen.

Keywords: Ductile Iron, Austempering, Normalizing, Annealing, Tensile Strength, Hardness.

I. INTRODUCTION

Ductile iron is one form of cast iron which is ductile and it offers the designer a unique combination of high strength, wear resistance, fatigue resistance, toughness and ductility in addition to good cast ability, machinability and damping properties. Unfortunately these properties of SG (Spheroidal Graphite) cast iron are not widely well known because of the misconception about its brittle behavior. It was seen that by adding magnesium caused the graphite to form nodules rather than flakes [1]. This resulted in a new material, with excellent tensile strength and ductility. Adding these mechanical properties of this material to the advantages already offered by cast iron soon led to it finding its way into virtually every mainstream area of engineering, in many cases replacing existing steel castings or forgings due to achievable cost savings. SG iron is an alloy of iron and carbon having nodules or spheroids of graphite embedded in a Ferrite-pearlitic matrix. The nodules are compact spheres and are sharp and regular [2]. The graphite occupies about 10-15% of the total material volume and because graphite has negligible tensile strength, the main effect of its presence is to reduce the effective cross-sectional area, which means that ductile iron has tensile strength, modulus of elasticity and impact strength proportionally lower than that of a carbon steel of otherwise similar matrix structure. The matrix may vary from a soft ductile ferritic structure through a hard and higher strength pearlitic structure to a hard higher and comparatively tough martensitic structure. General engineering grades of ductile iron commonly have the structures which are ferritic, ferritic/pearlitic or pearltic [3]. Controlled processing of the molten iron precipitates graphite as spheroids rather than flakes. The round shape of the graphite eliminates the material's tendency to crack and helps prevent cracks from spreading. The properties of SG iron are affected by elements like Si, Mn, Cu, Ni etc. Experiments have shown that heat treatment operations can improve the properties of

SG iron to such an extent that it may overcome the properties shown by steels. Today austempered ductile iron is considered a bright prospect having a good combination of properties [4]. Combining the tensile strength, ductility, fracture toughness and wear resistance of steel with production of economics of a conventional ductile iron, ADI offers the designer a great opportunity to create superior components at reduced cost [5]. The aim of the present study is to find out the effect of various heat treatment processes such as annealing, normalizing and austempering on ductile cast iron mechanical properties. All experimental results correlated with optical microstructures.

II. EXPERIMENTAL DETAILS

2.1 Processing of Ductile Iron

Ductile Iron casting is prepared in the shape of a rectangular block.The composition used was given in the table 1. Ductile iron was produced in a batch of 100 kg. The pouring temperature was about 1400ºC.The melt was poured into the mold cavities with 50 kg ladle.

Table 1 Composition of SGCI Used In the Present Study

C%	Si%	Mn%	S%	P%	Cr%	Ni%	Cu%
3.61	2.83	0.38	0.02	0.02	0.04	0.05	0.56

2.2 Specimen Preparation

Specimens for the tensile strength are prepared as per ASTM standards.

Gauge length: 60 mm

Gauge diameter: 12 mm

Total length: 90 mm

Grip diameter: 18 mm

2.3 Heat Treatment

Following heat treatment processes are conducted on the ductile iron specimens.

2.3.1 Austempering

Austempering is heat treatment that is applied to ferrous metals, most notably steel and ductile iron. In steel it produces a bainite microstructure whereas in cast irons it produces a structure of acicular ferrite and high carbon, stabilized austenite known as ausferrite. In the present work

austempering process was done at 860°C. In Austemperingthe specimen was heated in the furnace to the temperature of 860^{0}C. The specimen then quenched in the water and cooled.Austempering involves the nucleation and growth of acicular ferrite within austenite, where carbon is rejected into the austenite. The resulting microstructure of acicular ferrite in carbon-enriched austenite is called ausferrite. Even though austenite in austempered ductile iron is thermodynamically stable, it can undergo strain-induced transformation to martensite when locally stressed. The result is islands of hard martensite that enhance wear properties.

2.3.2 Annealing

Thespecimen was heated in the furnace to the temperature of 900^{0}C. The specimen then cooled in the furnace itself. Due to annealing process the mechanical properties of ductile iron will improved. The stresses developed during machining processes can be relieved and the original mechanical properties will regained by the material with the help of annealing process.

2.3.3 Normalizing

Normalizingis this process which is similar to annealing and is carried out to avoid excessive softness in thematerial. The material is heated above austenitic phase and then cooled in air. This gives relatively faster cooling and hence enhanced hardness and less ductility. In this process austenite is decomposed in ferrite and carbide at relatively lower temperature and fine pearlite is produced.In the present work the specimen was heated in the furnace to the temperature of 925^{0}C. Then the specimen cooled in the air.

III. RESULTS AND DISCUSSION

By conducting these experiments, it is observed that the maximum hardness is observed in austempered heat treatment process and low hardness is observed in annealing process [Table 2]. This is mainly due to the cooling rate differences. The high tensile strengthis observed in normalizing process and low tensile strength observed in austempered process. But these hardness and tensile strengths are greater than as cast specimens.

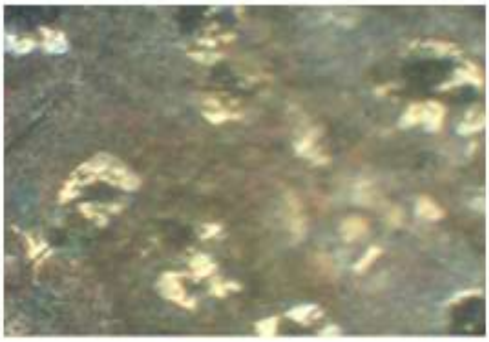

Figure 1 Microstructure of Graphite Nodules in Ferrite and Pearlite Matrix 40x (As Cast)

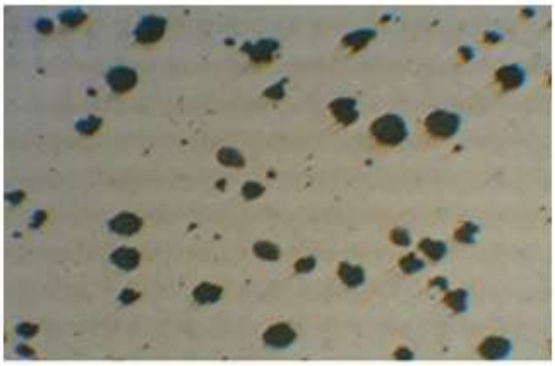

Figure 2 Optical microstructure of of SG Iron specimen 20x(as cast)

Figure 3 SG Iron specimens (at 860^{0}c Austempered)

Figure 4 SG Iron specimens (at 900^{0}c Annealed)

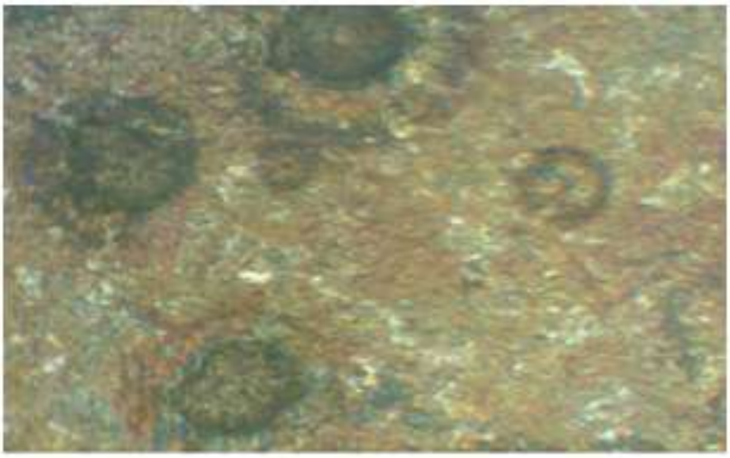

Figure 5 SG Iron specimens (at 925^{0}c Normalized)

Table 2 Mechanical Properties of Specimens

Specimen	Hardness (HRC)avg	Tensile strength (N/mm^2)	Yield strength (N/mm^2)
As cast	45	485	380
Austempered (At 860^{0}C)	58	490	386
Annealed (At 900^{0}C)	43	530	423
Normalised (At 925 ^{0}C)	49	655	507

Table 3Microstructure Nodularity Analysis of Unheated Treated S G Cast Iron Specimen

Parameter	**Value**
Nodularity (%)	69.6
Nodule Area (%)	7.0413
Nodules (mm$^{2)}$	63
Avg size (µm)	30.0502
Min size(µm)	5.1607
Max size (µm)	76.756

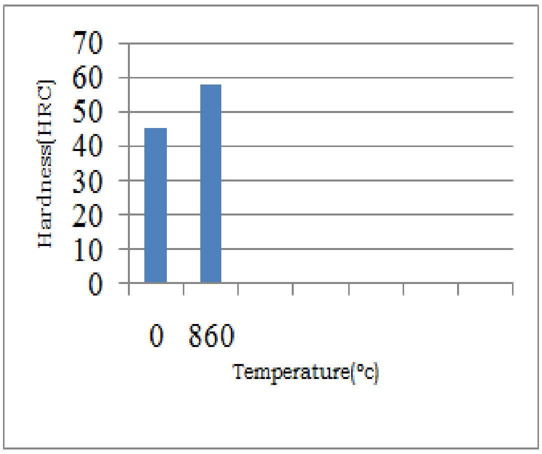

Figure 6 Hardness Related To Austempering (At 860^0C)

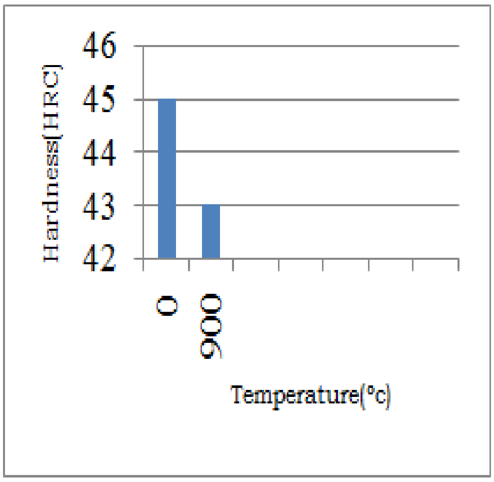

Figure 7 Hardness Related To Annealing (At 900^0C)

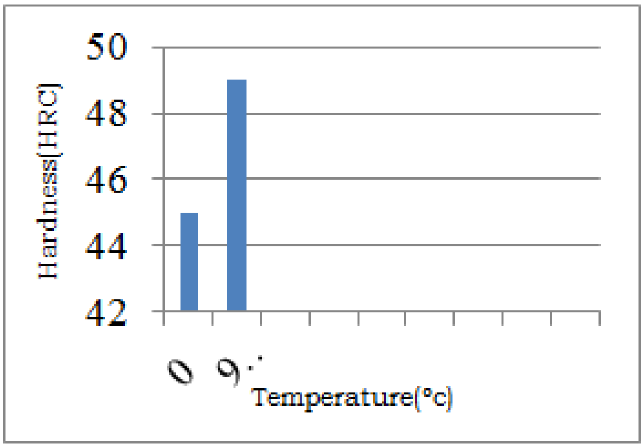

Figure 8Hardness Related To Normalizing (At 925^0C)

Nodularity is decreased due to heat treatments. Low nodularity observed in austempered heat treated specimens [Table 3]. And also the nodules count is reduced. In annealed process more elongation is observed. It is observed that cooling rate has high effects on mechanical properties of Spheroidal Graphite cast iron.

Volume fraction analysis shows that pearlite has maximum in unheated specimen.

Graphite nodules observed in tempered martensite matrix.

IV. CONCLUSION

In this study S G cast iron specimens were heat treated by using three different heat treatment processes namely austempering, annealed and normalizing. S G cast iron specimen shows maximum hardness in austempered process, this may be due to fast cooling rate results in more amount of treated martensite at room temperature in microstructure. In annealed and normalizing specimen hardness values used majorly lower as compared to austempered specimen, this may be due to compaction of course of grains at high temperature and slowly cooling rate is also correlated with their microstructure.

Tensile strength is improved maximum by normalizing process. In annealed specimen the number of nodules is equal 30 which are more than other two specimens due to slowly cooling rate. The annealed S G cast iron specimen shows maximum elongation that is 11.04%.

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