# Fractographic Study of Ductile Iron

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**Abstract -** Ductile iron is a kind of iron that belongs to the family of cast. The quality of cast iron that differ this iron from other iron are its ductile property while other iron are having brittle property. The application of ductile iron is mainly in industries because of its strength and its ductile nature. This iron is having its ductile nature because of the spheroidal graphite which is present in it at microstructure level. Cracks are usual in all the industries, field of functions and research of cracks currently it is essential for the advancement of the life cycle of the product. Present research are concentrated on analyzing, crack properties of ductile iron are used in different method of processing.

***Key Words***: As-cast ductile iron, Annealing, Hardening and Tempering, Microstructure, Tension test.

## 1. INTRODUCTION

Rounded graphite iron are also called as ductile iron. It is gaining through composing slight adding of the changer like magnesium or cerium into the molten iron. Different flaky graphite in grey cast iron, rounded graphite will not weaken the matrix significantly. Because of this purpose, the physical properties of SG iron are better as compared to grey iron. Ductile iron have excellent moisten property and effect toughness. Due to its physical properties, ductile iron has wide applications in different industries' apparatus. Necessary properties can be transmit in ductile iron through method of processing such as annealing etc. Different method of processing are performed to impart necessary matrix/stage inside the sample. Various matrix has various physical properties. Existence of the stages are assured through microstructures which are detected in metallurgical optical microscope. Austempered and toughened ductile iron has improved needed physical properties as compared to ductile iron. Because of extensive area of uses, valuation of ADI get substance. Fractographic investigation is also one of the technique of classification of material.

Tempering enhanced the ductility at the cost of toughness through converting the parent matrix in complete ferritic, while higher be toughness can be get through destruction the sample into the salt bath (austempering) from the austenitizing temperature consequence in formation of above or below bainitic structure which is depend on the cooling amount . Mechanical properties of the ductile cast iron, such as UTS and toughness enhanced with enhance in pearlite content and at the same time ferritic matrix cause rise in ductility and impact strength.

## 2. MATERIALS & METHODS

### 2.1 Material

The material used in the present research work is Ductile Iron.

### 2.2 Methods

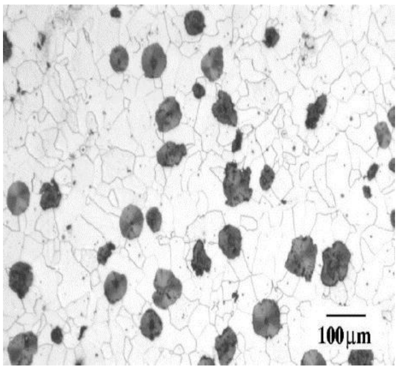
Ductile iron is a special type of cast iron family which differs from other cast iron in the manner of ductility since others are brittle in nature. Ductile iron (DI) is gaining its popularity in many industrial applications due to its strength and considerable amount of ductility which is because of the presence of spheroidal graphite in microstructure. Fracture is very common in almost every industry and field of application and analysis of fracture now-a-days has become essential for optimizing the product life span.

The current study is focused on investigating the mechanical properties and fracture characteristics of ductile iron subjected to various heat treatment processes. Tensile and impact specimens are machined from a test block according to ASTM E8 and ASTM D256 standards respectively. Specimens are austenitized at 1000°C, followed by different rate of cooling and quenching. The austenitizing time being 90minutes and quenching media are mineral oil, air and salt bath for tempering, normalizing and austempering processes respectively. Isothermal annealing is also carried out in some specimens to have comparison between mechanical properties and behavior of the material. The tempering and austempering temperature is 500°C and time being 2 hrs and 4 hrs respectively. Tensile test has been performed using INSTRON-1195 and Izod Impact test is performed using Izod impact tester. Vickers's hardness is determined by application of 20 kg with 10sec. dwell time using Vickers's Hardness Tester. Fracture surfaces of each heat treated and as-cast specimens, after tension and impact test are observed under Scanning Electron Microscope. Tensile strength is found to be maximum for tempered and hardened specimen whereas annealed specimen is having more ductility at the expense of strength. The annealed specimen is found to be ductile in nature whereas the tempered and hardened and normalized specimens have showed mixed mode of failure.

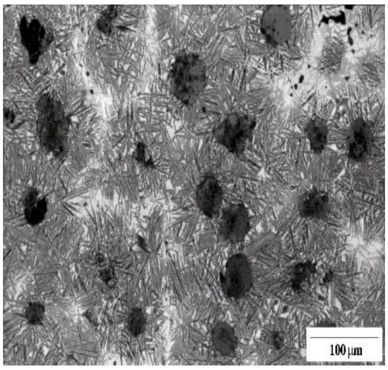
## 3. RESULTS

### Metallographic Analysis

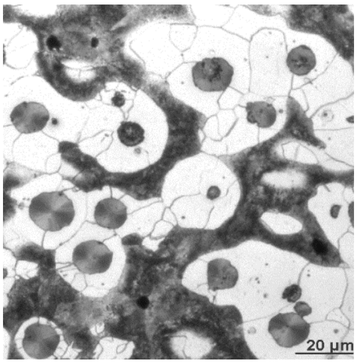
The quantitative metallographic investigation had conducted on every of the treated as compared to as-cast sample and are shown in the picture below



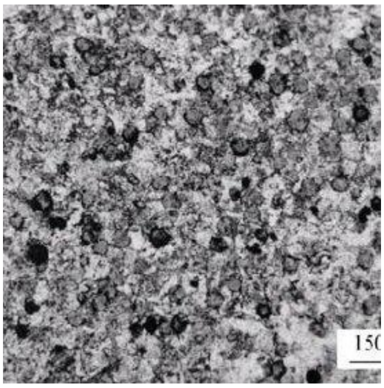

**(A)** As-Cast



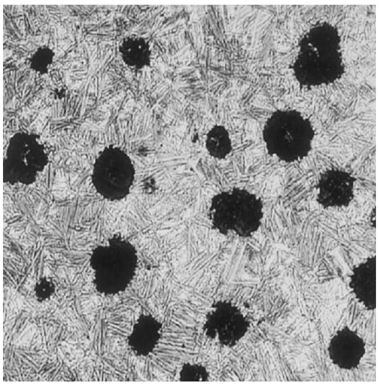
**(B)** Hardened and Tempered




**(C)** Annealed



**(D)** Normalized



**(E)** Austempered

### XRD Analysis

| Specimen | planes | Crystal size (nm) | Crystal structure | Residual strain (%) |
|---|---|---|---|---|
| Tempering | (110),(200),(211) | 225 | BCC | 0.342 |
| Annealing | (110),(200),(211) | 123 | BCC | 0.164 |
| Austempering | (110),(200),(211) | 97 | BCC | 0.323 |
| As-cast | (110),(200),(211) | 42 | BCC | 0.205 |
| normalizing | (110),(200),(211) | 31 | BCC | 0.249 |

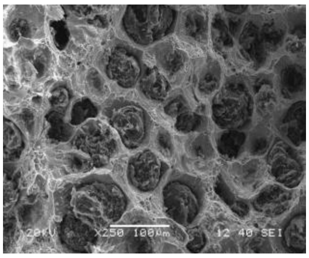
## Mechanical Properties

The result of all the Mechanical Properties tested for different heating treatment process are displayed in the table below

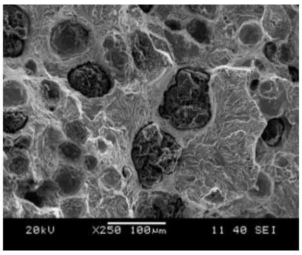
| Sample ID | Mechanical Properties | | | | |
|---|---|---|---|---|---|
| | UTS (MPa) | 0.2% YS (MPa) | % Elongation | Hardness (HV20) | Impact Energy (J) |
| As- Cast | 359.96 | 160.63 | 32.22 | 277 | ------- |
| Annealed | 336.1 | 159.7 | 31.89 | 220 | ------- |
| Normalized | 691.2 | 245.6 | 11.90 | 508 | 7.63 |
| Hardened & Tempering | 1054 | 722.9 | 12.73 | 610 | 9.149 |
| Austempering | 842.5 | 356.7 | 14.11 | 445 | 10.15 |

### FRACTOGRAPHIC ANALYSIS

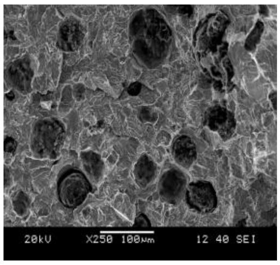
Fracture surface of both the samples, thermal process and as cast samples are detected in the Scanning Electron Microscope at 50X, 250X and 500 X magnifications and as shown in the figure.



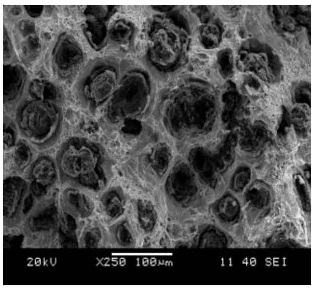

As Cast at 250x



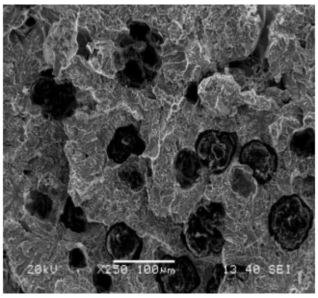

Hardened & Tempered at 250x



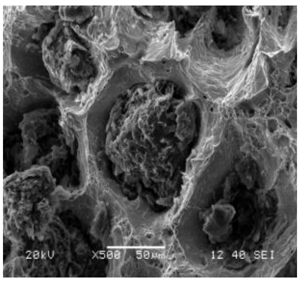

Normalized at 250x



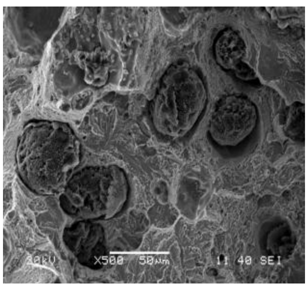

Annealed at 250x



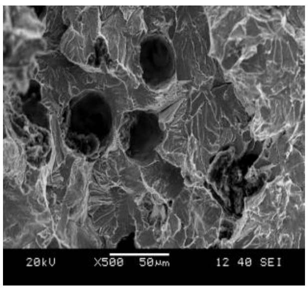

Austempered at 250x




As Cast at 500X




Hardened & Tempered at 500X




Normalized at 500X

## 4. CONCLUSIONS

Various conclusions which are reported during this study are:

- The maximum and minimum thermal conductivity are 0.715 W/m K and 0.609 W/m K when ϕ = 1.50% at t = 50°C and ϕ = 0.25% at t = 25°C, respectively by using nanofluid whereas The maximum and minimum enhancement in thermal conductivity ratio are 13.3% and 0.83% when ϕ = 1.50% at t = 50°C and ϕ = 0.25% at t = 25°C, respectively in comparison to water.
- The maximum and minimum viscosity are 1.11 mPa.s and 0.58 mPa.s when ϕ = 1.50% at t = 25°C and ϕ = 0.25% at t = 50°C, respectively by using nanofluid whereas the maximum and minimum enhancement in viscosity ratio are 40.50% and 11.53% when ϕ = 1.50% at t = 25°C and ϕ = 0.25% at t = 50°C, respectively in comparison to water.
- The maximum and minimum density are 1058 Kg/$m^3$ and 1001 Kg/$m^3$ when ϕ = 1.50% at t = 25°C and ϕ = 0.25% at t = 50°C, respectively by using nanofluid whereas the maximum and minimum enhancement in density ratio are 6.11% and 1.31% when ϕ = 1.50% at t = 25°C and ϕ = 0.25% at t = 50°C, respectively in comparison to water.
- The maximum and minimum specific heat are 4032 J/Kg K and 3699 J/Kg K when ϕ = 0.25% at t = 50°C and ϕ = 1.50% at t = 25°C, respectively by using nanofluid whereas The maximum and minimum decrement in specific heat ratio are 11.50% and 3.56% when ϕ = 1.50% at t = 25°C and ϕ = 0.25% at t = 50°C, respectively in comparison to water.

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