Study on Fractographic Property of Ductile Iron

Dharmendra Pratap Singh[1] Karunakar Singh[2] Shiv Kumar[3]

[1]M. Tech, Department of Mechanical Engineering, G.I.T.M, Lucknow, Uttar Pradesh.
[2]Assistant Professor & Head of Department, Department of Mechanical engineering, R.I.T.M Lucknow.
[3]Assistant Professor and Head of Department, Department of Mechanical Engineering, G.I.T.M, Lucknow.

Abstract: **Cast iron is a group of iron-carbon alloys with a carbon content more than 2%. Its usefulness derives from its relatively low melting temperature. The alloy constituents affect its color when fractured: white cast iron has carbide impurities which allow cracks to pass straight through, grey cast iron has graphite flakes which deflect a passing crack and initiate countless new cracks as the material breaks, and ductile cast iron has spherical graphite "nodules" which stop the crack from further progressing. In this research work after the preparation of sample they are subjected for machined testing such as tensile and impact as per international standard. The prepared sample are further subjected for heat treatments such as hardening and tempering, annealing etc. And then followed by cooling and quenching. These heating treatment are done in order to analyses the mechanical properties and its behavior. Austempering of the sample is done for certain time at a temperature of 500º C further more yielding and impact testing were also performed. Crack exterior of every method of processing, as-cast sample, later stress and collision test was analysed Scanning Electron Microscopy. Fracture toughness is at the highest for annealed sample while the annealing sample will have more ductility at the cost of toughness. The annealed sample which are obtained are ductile in nature while the annealed, toughened samples specimens have displayed the mixture of the failing.**

Index Terms: **As-cast ductile iron, Annealing, Hardening and Tempering, Microstructure, Tension test, Vickers hardness, Austenitizing temperature, Nodularity, Graphite Area Fraction**

I. INTRODUCTION

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. 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. Percentage of carbon usually varies between 3.0 to 4.0 percent. Although the much practiced carbon percentage range between 3.4 and 3.8 percent. Castability, which can be enhanced by enhancing flexibility, is part of the essential specification which have changed if there is change in carbon percentage. Interdendritic reduction is the reason caused during the last phase of solidification. The interdendritic reduction can be resolve huge proportion by rising carbon percentage. Mechanical properties are low controlled through the different carbon percentage in the obtained range of rounded Iron. UTS of rounded Iron can be decreased approximate 2.48 MPa per 0.1% rise of carbon span important depletion in the hardness. Toughness can be lesser approximate 5 numbers per 0.15% by adding carbon while percentage expansion or ductility enhance more usually in the case of as-cast sample. Modulus of elasticity of specimen is impacted through the carbon percentage in proportion to volume of carbon in the matrix. Silicon is used as graphitizer and it enhance the spheroids which are available in the matrix of the rounded Iron. It enhance the ferrite area fraction by decreasing main carbides and pearlite. Physical properties of the SG Iron are considerably affected through silicon substance. For every 0.25% silicon added, at 0.18% manganese, enhance 21 MPa in UTS of Spheroid graphite Iron by enhanced ferrite matrix whereas decreasing percentage elongation in annealed ferritized microstructure. Silicon content and temperature, controls the impact resistance. Enhanced in silicon or less temperature will decrease the impact value. 2.25% silicon content provide complete ductility in the temperature -100C while when it is monitored to 1.4%, the substantial can be malleable as low as -600C temperature. Generally, silicon content is highest 2.4% while less than 2.25% when impact has considering much significant. Silicon more the normal range promotes good heat resistant features. Silicon performed as a inoculants in the manufacturing of SG Iron. To provide least possible carbides in as-cast specimen, 0.6 to 0.8% silicon, as a consequence of inoculation with Ferro-silicon, have important role.

II. MATERIALS & METHODS

Materials

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

Methods

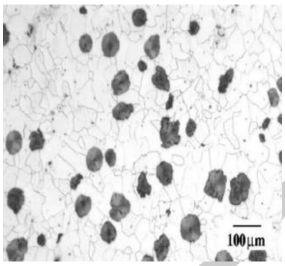
Ductile iron is a special type of cast iron family which differs from other cast iron in the manner of ductility since others are brittle in nature. Ductile iron (DI) is gaining its popularity in many industrial applications due to its strength and considerable amount of ductility which is because of 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.

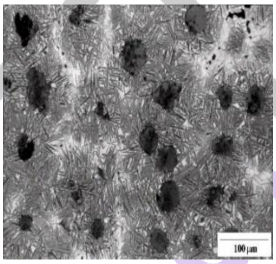
III. RESULTS

Metallographic Analysis

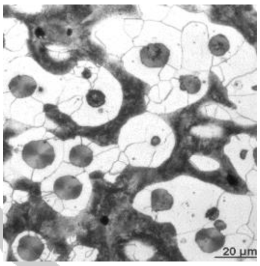
The quantitative metallographic investigation had conducted on every of the treated as compared to as-cast sample and are shown in the picture below



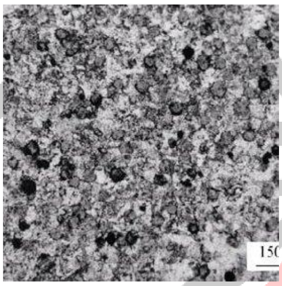
(A) As-Cast



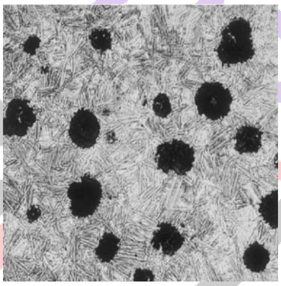
(B) Hardened and Tempered



(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

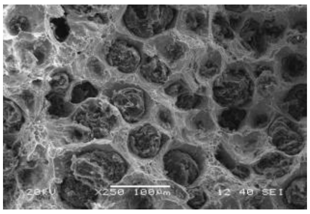
Mechanical Properties

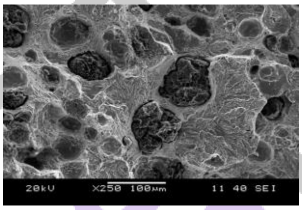
The result of all the Mechanical Properties tested for different heating treatment process are displayed in the table below

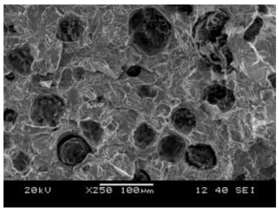
Sample ID	Mechanical Properties				
	UTS (MPa)	0.2% YS (MPa)	% Elongation	Hardness (HV20)	Impact Energy (J)
As- Cast	359.96	160.63	32.22	277	-------
Annealed	336.1	159.7	31.89	220	-------
Normalized	691.2	245.6	11.90	508	7.63
Hardened & Tempering	1054	722.9	12.73	610	9.149
Austempering	842.5	356.7	14.11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

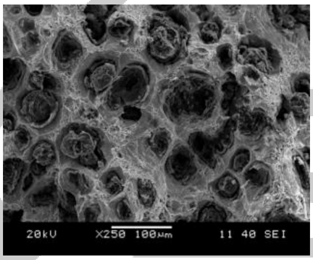
FRACTOGRAPHIC ANALYSIS

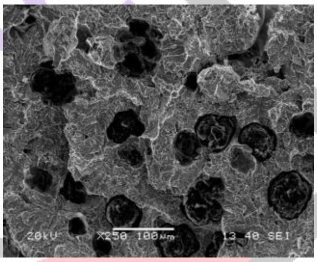
Fracture surface of both the samples, thermal process and as cast samples are detected in the Scanning Electron Microscope at 50X, 250X and 500 X magnifications and as shown in the figure.

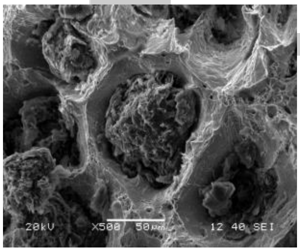

As Cast at 250x

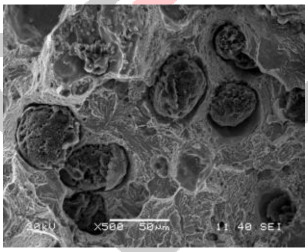

Hardened & Tempered at 250x

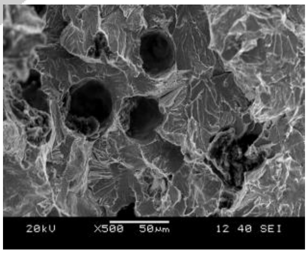

Normalized at 250x


Annealed at 250x


Austempered at 250x


As Cast at 500x


Hardened & Tempered at 500x


Normalized at 500x

IV. CONCLUSIONS

Ductile iron samples are subjected to various thermal processes are succeeded by the physical properties, microstructural and fractographic characterization investigation. As a result which are drawn from latest analysis:

- Annealed thermal process causes homogeneity in the matrix, thus enhancing nodularity, percentage expansion and impact energy at the cost of UTS and toughness.

- Toughened and annealed samples have maximum UTS and toughened with fine cost of flexibility.
- The UTS and toughened value for normalising and austempered samples are central tempered and toughened & annealed samples with less cost of flexibility for normalized sample because of hard pearlitic matrix.
- X-ray diffraction investigation assured BCC crystal structure for as-cast as in comparison with heat treated samples.
- With the modification in matrix heat treatment of ductile iron will also increase the quantitative metallographic aspect like nodularity and nodule count.
- As-cast and annealed sample along with complete ferritic matrix show complete ductile fracture characterised by micro void coalescence and dimple rupture phenomena.
- The toughened & annealed samples noticed to have both river marking and shallow dimples show blende mode fracture.
- Normalizing and austempered sample have river marking in comparison to cleavage plane, charactering less energy brittle fracture.

REFERENCES

[1] Rajan T.V., Sharma C.P., Sharma Ashok. Heat Treatment Principles and Techniques. India, Prentice-Hall India, Jan, 2004

[2] Gulcan Toktas, Mustafa Tayanc, Alaaddin Toktas, Effect of matrix structure on the impact properties of an alloyed ductile iron, Materials Characterization 57 (2006), p290–299.

[3] Cheng-Hsun Hsu, Kuan-Ting Lin, A study on microstructure and toughness of copper alloyed and austempered ductile irons, Materials Science and Engineering A 528 (2011), p 5706–5712.

[4] US patent 2485760, Keith Millis, “Cast Ferrous Alloy”, issued 1949-10-25

[5] Higgins.R.A., Engineering Metallurgy Applied Physical Metallurgy.London,Edward Arnold,Sixth edition 1993

[6] Gandhi. R.N.“Engineering Properties and Applications of Spheroidal Graphite Iron”.Proceedings of A Seminar Held in Bombay 21-22nd Feb,1970, Pub.:Institute of Indian Foundrymen, 1971, p.129

[7] Da.Sheng, Yongping Zheng, ” A study of the microstructure and properties of continuous casting rare earth ductile iron pipes”. *Journal of Alloys and Compounds, 207/208* (1994) 383-385, *JALCOM 3063*

[8] Konoplyuk*S, Abe T, Uchimoto. T, Takagi. T, Kurosawa. M,” Characterization of ductile cast iron by eddy current method”, NDT&E International 38 (2005) 623–626

[9] Chaengkham. Pongsak, Srichandr. Panya, “Continuously cast ductile iron: Processing,structures, and properties”. Journal of Materials Processing Technology 211 (2011) 1372–1378.

[10] Konoplyuk S, “Estimation of pearlite fraction in ductile cast irons by eddy current method”. NDT&E International 43 (2010) 360–364

[11] Shaker M.A., “A note on the effect of nodularization characteristics on the workability of quenchhardened and tempered cast irons”. Journal of Materials Processing Technology, 32 (1992) 545-552

[12] Dommarco R.C. ,Sousa M.E., Sikora J.A., “Abrasion resistance of high nodule count ductile iron with different matrix microstructures”. Wear 257 (2004) 1185–1192

[13] Rashidi Ali M , Moshrefi-Torbati M, “Effect of tempering conditions on the mechanical properties of ductile cast iron with dual matrix structure (DMS)”. Materials Letters 45(2000) 203–207.

[14] Wen D.C., Lei T.S., “Influence of Tempering on the Mechanical Properties of Austempered Ductile Iron”. Materials Transactions, JIM, Vol.40, No. 9(1999), 980-988.

[15] Konečná R., Nicoletto G, Bubenko L., Fintová S., “A comparative study of the fatigue behavior of two heat-treated nodular cast Irons”. Engineering Fracture Mechanics, EFM 4054, S0013-7944(13)00183-5

[16] Batra Uma, Tandon Pankaj, Kaur Kulbir, “A study of austenitization of SG iron”. Bul.Mater.Sci., Vol. 23, No. 5, October 2000, 393-398

[17] Karsay. S.I., Anderson.J.V., “Production of S.G.Iron”,1996

[18] A guide to mechanical properties of ductile iron, Mid-Atlantic Casting service.

[19] ASM Handbook, Formerly 9th edition, Metal Handbook, vol.12, Fractography, Page no-3.

[20] Cullity B D "Elements of X-ray diffraction". Reading, MA: Addison Wesley Publishing Company, Inc. 1956