Effect Of Basic Chemical Element In Sgi (Ductile Iron)

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Abstract

The basic chemical element such as carbon, silicon, manganese, magnesium, copper etc. plays an important role in SGI (Spheroidal Graphite Iron) castings process. The behaviour of these elements in molten metal of the ductile iron plays a different role because of their different mechanical and chemical properties. If we govern such composition that will be optimal by virtue of its study of effects on castings. As we know, there is small change in the chemical composition, the wide effects on the mechanical properties and their microstructure. The chemical compositions in ductile iron are always considered in the range. So that it is difficult to achieve the targeted mechanical properties and the microstructure as per the given specification it always affects in the end use of the product.

Keywords:-chemical element, ductile iron, effect, mechanical properties.

1. Introduction

SGI CASTING (DUCTILE IRON)

S.G Cast iron is defined as a high carbon containing, iron based alloy in which the graphite is present in compact, spherical shapes rather than in the shape of flakes, the latter being typical of gray cast iron As nodular or spheroid cal graphite cast iron, sometimes referred to as ductile iron, constitutes a family of cast irons in which the graphite is present in a nodular or spheroid cal form. The graphite nodules are small and constitute only small areas of weakness in a steel-like matrix. Because of this the mechanical properties of ductile irons related directly to the strength and ductility of the matrix present—as is the case of steels. One reason for the phenomenal growth in the use of Ductile Iron castings is the high ratio of performance to cost that they offer the designer and end user. This high value results from many factors, one of which is the control of microstructure and properties that can be achieved in the as cast condition, enabling a high percentage of ferritic and pearlitic structure.

PROPERTIES OF SG CAST IRON

A number of properties such as mechanical, physical and service properties are of important in assessing materials suitably for any application. The mechanical properties of interest are tensile strength proof stress, elongation, hardness, impact strength, elastic modulus, and fatigue strength, notch sensitivity while the physical properties of interest are damping capacity, machinability and conductivity. The service properties generally involved are wear resistance, heat resistance, corrosion resistance.

- Easy to cast
- The high fluidity of the metal in its molten state makes it ideal for the casting process
- Strength
- Tensile strengths of up to 900N/mm2 (ADI gives the option of higher strengths).
- Ductility
- Elongations of in excess of 20% (Lower grades only)
- Excellent Corrosion Resistance when compared to other ferrous metals.
- Ease of Machining Free graphite in the structure also lends itself to machining (chip formation).
- Cost per Unit Strength
- Significantly cheaper than most materials.

APPLICATIONS

The possible applications of S.G Iron are very wide. The properties are such as to extend the field of usefulness of Cast Iron and enable it, for some purpose, to replace steel casting, malleable Cast Iron, and non-ferrous alloys .But S.G Iron is not recommended as a replacement for all castings
at present made in flake graphite Irons, sometimes the inherent properties of the flake graphite Iron are

adequate for the purpose of exiting designs. The use of S.G Iron is suggested where improved properties are dictate a replacement of other material or where the use of S.G Iron will permit an improvement in the design. Some popular uses of S.G Iron for various engineering application are for,

- Support bracket for agricultural tractor.
- Tractor life arm.
- Check beam for lifting track.
- Mine cage guide brackets.
- Gear wheel and pinion blanks and brake drum.
- Machines worm steel.
- Flywheel.
- Thrust bearing.
- Frame for high speed diesel engine.
- Four throw crankshaft.
- Fully machined piston for large marine diesel engine.
- Bevel wheel.
- Hydraulic clutch on diesel engine for heavy vehicle.
- Fittings overhead electric transmission lines.
- Boiler mountings, etc.

STANDARD GRADES OF SGI CAST IRON

□Ταβλε 1.Στανδαρδ Γραδεσ οφ ΣΓ Ιρον ΙΣΟ 1083 (87)□

S. N.	SPECIFICATION	TENSILE STRENGTH	ELONGATION	BRINELL HARDNESS
1	ISO 1083 (87) – 350/22	350	22	150 HB MAX
2	ISO 1083 (87) – 400/15	400	15	130 – 180 HB
3	ISO 1083 (87) – 400/18	400	18	130 – 180 HB
4	ISO 1083 (87) – 450/10	450	10	160 – 210 HB
5	ISO 1083 (87) – 500/7	500	7	170 – 230 HB
6	ISO 1083 (87) – 600/3	600	3	190 – 270 HB
7	ISO 1083 (87) – 700/2	700	2	225 – 305 HB
8	ISO 1083 (87) – 800/2	800	2	245 – 335 HB
9	ISO 1083 (87) – 900/2	900	2	280 – 360 HB

ROLE OF CHEMICAL ELEMENT IN SGI CAST IRON

- **Manganese**

As it is a mild pearlite promoter, with some required properties like proof stress and hardness to a small extent. As Mn retards the onset of the eutectoid transformation, decreases the rate of diffusion of C in ferrite and stabilize cementite (Fe_3C).But the problem here is the embrittlement caused by it, so the limiting range would be 0.3-1.0 1).

- **Silicon**

As the Si in the ductile iron matrix provides the ferritic matrix with the pearlitic one. Silicon enhances the performance of ductile iron at elevated temperature by stabilizing the ferritic matrix and forming the silicon reach surface layer, which inhibits the oxidation The potentially objectionable influences of increasing silicon content are:_ 1). Reduced impact test energy. 2). Increased impact transition temperature. 3). Decreased thermal conductivity. Si is used to promote ferrite and to strengthen ferrite. So Si is generally held below 2.2% when producing the ferritic grades and between 2.5% and 2.8% when producing pearlitic grades

- **Copper**

It is a strong pearlite promoter. It increases the proof stress with also the tensile strength and hardness with no embrittlement in matrix. So in the pearlitic grade of the ductile iron the copper is kept between 0.4-0.8% and is a contaminant in the ferritic grade.

- **Nickel**

As it helps in increasing the U.T.S without affecting the impact values .So it can be in the range of 0.5-2.0. It strengthens ferrite, but has much less effect than Silicon in reducing ductility. But there is the danger of embrittlement with the large additions; in excess of 2%.Due to the high cost it is generally present as traces in the matrix.

- **Molybdenum**

It is a mild pearlite promoter. Forms intercellular carbides especially in heavy sections. Increases proof stress and hardness. Danger of embrittlement, giving low tensile strength and elongation value. And it also improves elevated temperature properties.

- **Chromium**

As it prevents the corrosion by forming the layer of chromium oxide on the surface and stops the further exposition of the surface to the atmosphere. But as it is a strong carbide former so not required in carbide free structure and <1% required in the grade of GGG-50 .it is kept around 0.05% Maximum. 12

- **Sulphur and Phosphorus**

As ‘P’ is kept intentionally very low, as it is not required because it causes cold shortness and so the property of ductile iron will be ruined. But the addition of S is done for better machinability, but it is kept around 0.009 and maximum 0.015%.As the larger additions of Sulphur may cause the hot (red) shortness.

AIMS & OBJECTIVES

- Optimization of composition of basic elements for targeted mechanical properties.
- To minimize the number of experiments for to achieve targeted values
- To increase profit by minimizing rejection % by optimum composition for targeted properties.
- To satisfy the end user of the product by getting whatever properties required.
- To set the optimal composition for the standard grade.

METHODOLOGY :-

STEPS IN PRODUCTION OF S.G IRON

- **Desulphurisation**

Sulphur helps to form graphite as flakes . Thus, the raw material for producing S.G Iron should have low sulphur (less than 0.1%), or remove sulphur from iron during melting, or by mixing iron with a desulphurising agent such as calcium carbide, or soda ash (sodium carbonate).

- **Nodule rising**

Magnesium is added to remove sulphur and oxygen still present in the liquid alloy and provides a residual 0.04% magnesium, which causes growth of graphite to be spheroidcal, probably the interface energy becomes high to have a dihedral angle of 180 degree,(in simple term the graphite does not wet the liquid alloy.). Magnesium treatment desulphurises the iron to below 0.02% S, Before alloying it. Magnesium and such elements have strong affinity for sulphur and thus scavenge sulphur from the molten alloy as an initial stage for producing S.G Iron. These additions are expensive to increase the cost of S.G Iron produced. Thus sulphur of molten alloy (or the raw material used), before nodulising, should be kept low. Magnesium is added when melt is near 1500 degree centigrade, but magnesium vaporizes at 1150 degree centigrade. Magnesium being lighter floats on the top of the bath, and being reactive burn off at the surface. In such cases magnesium is added as Ni-Mg, Ni-Si-Mg alloy or magnesium coke to reduce the violence of the reaction and to have saving in Mg.

- **Inoculation**

As magnesium is carbide former, ferrosilicon is added immediately as innoculant. Remelting causes reversion to flake graphite due to loss of magnesium. Stirring of molten alloy after addition of nodulising element evolves a lot of gas, which gets dissolved in liquid alloy, and forms blow-holes in solid casting. The contraction during solidification of nodular cast iron castings is much greater than that of gray iron castings, which needs careful design of moulds to avoid shrinkage cavities in solidified castings.

3.2 MAGNESIUM TREATMENT

Why magnesium:_ Research work has shown that on a laboratory scale additions of a number of elements are capable of producing spheroidal graphite structures in the cast irons. These elements include magnesium, cerium, calcium and yttrium. However, owing to a number of factors the application of these elements on a production scale has been restricted to the element magnesium, although it is claimed that in Japan calcium based alloys are used for producing ductile iron castings. It is generally supposed that magnesium removes impurities such as Sulphur and oxygen, which may tend to segregate to free surfaces of molten metal, thereby lowering surface tension. Similarly, these impurities lower the interfacial tension between the graphite and metal. When they are removed, this interfacial tension rises to a higher value and it is often presumed that it constrains the graphite to reduce its surface area per unit volume, which it does by assuming a spherical shape. The use of cerium results in nodular graphite structures, with certain type of metal compositions, but these restrictions and the general inconsistency of the process again makes it unsuitable for large-scale application. However, the benefits of including a small amount of cerium in the nodularising process in order to offset the subversive nature of contaminating elements such as lead, antimony and titanium are well known, and the majority of ductile iron is produced using the ceriumbearing magnesium alloys

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STANDARD COMPOSITION RANGE IN SG IRON GRADE

“Ταβλε 2.Στανδαρδ Χομποσιτιον Ρανγε ιν ΣΓ Ιρον γραδε□

S. N.	SPECIFICATION	C %	Si %	Mn %	S %	P %	Mg %	Cu %
1	350/22	3.75-3.85	2.50-2.75	0.15	0.02 max	0.03 max	0.035 - 0.045	--
2	400/15	3.65-3.75	2.60-2.70	0.20	0.02 max	0.03 max	0.035 - 0.045	--
3	400/18	3.65-3.75	2.60-2.70	0.20	0.02 max	0.03 max	0.035 - 0.045	--
4	450/10	3.65-3.75	2.60-2.70	0.20	0.02 max	0.03 max	0.035 - 0.045	--
5	500/7	3.75-3.85	2.60-2.70	0.30	0.02 max	0.03 max	0.035 - 0.045	0.40-0.50
6	600/3	3.60-3.70	2.20-2.45	0.40	0.02 max	0.03 max	0.035 - 0.045	0.50-0.60
7	700/2	3.60-3.70	2.30-2.45	0.30	0.02 max	0.03 max	0.035 - 0.045	0.60-0.70
8	800/2	3.55-3.65	2.20-2.30	0.35	0.02 max	0.03 max	0.035 - 0.045	0.70-0.80
9	900/2	3.45-3.55	2.10-2.20	0.35	0.02 max	0.03 max	0.035 - 0.045	0.80-0.90

COMPOSITION FOR DUCTILE IRON ISO 1083 (87) 500/7:For the experiment we take a composition of 500/7 grade.

“Table 3.Composition for ductile iron IS0 1083 (87) 500/7”

S. N.	LEVEL	C %	Si %	Mn %	Mg %	Cu %
		I	II	III	IV	V
1	I	3.75	2.60	0.25	0.035	0.40
2	II	3.80	2.65	0.30	0.040	0.45
3	II	3.85	2.70	0.35	0.045	0.50

STUDY OF EFFECT OF BASIC CHEMICAL ELEMENTS IN SGI CAST IRON

MECHANICAL PROPERTIES

- **Tensile Strength**

Tensile properties indicate how the material will react to forces being applied in tension. A tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, reduction in area, tensile strength, yield point, yield strength and other tensile properties

The main product of a tensile test is a load versus elongation curve which is then converted into a stress versus strain curve. Since both the engineering stress and the engineering strain are obtained by dividing the load and elongation by constant values (specimen geometry information), the load-elongation curve will have the same shape as the engineering stress-strain curve. The stress-strain curve relates the applied stress to the resulting strain and each material has its own unique stress-strain curve. A typical engineering stress-strain curve is shown below. If the true stress, based on the actual cross-sectional area of the specimen, is used, it is found that the stress-strain curve increases continuously up to fracture.

- **Elongation**

Elongation is defined as the permanent increase in length, expressed as a percentage of a specified gage length marked in a tensile test bar, which is produced when the bar is tested to failure. Elongation is used widely as the primary indication of tensile ductility and is included in many Ductile Iron specifications. Elongation also includes the localized deformation that occurs prior to fracture. However, because the localized deformation occurs in a very limited part of the gage length, its contribution to the total elongation of a correctly proportioned bar is very small. Brittle materials such as Gray Iron can fail in tension without any significant elongation, but ferritic Ductile Irons can exhibit elongation of over 25%. Austempered Ductile Irons exhibit the best combination of strength and elongation.

- **Brinell Hardness Number**

The Brinell hardness test is commonly used to determine the hardness of materials like metals and alloys.

The test is achieved by applying a known load to the surface of the tested material through a hardened steel ball of known diameter. The diameter of the resulting permanent impression in the tested metal is measured and the Brinell Hardness Number is calculated as

Change Equation

Select an equation to solve for a different unknown

$BHN = \frac{2P}{\pi D\left[D - \sqrt{D^2 - d^2}\right]}$	Brinell Hardness Number
$P = \frac{BHN \times \pi D\left[D - \sqrt{D^2 - d^2}\right]}{2}$	load
$d = \sqrt{D^2 - \left(D - \frac{2P}{BHN \times \pi D}\right)^2}$	depression diameter

$BHN = 2P / (\pi D (D - (D^2 - d^2)^{1/2}))$
Where,
BHN = Brinell Hardness Number
P = load on the indenting tool (kg)
D = diameter of steel ball (mm)
d = measure diameter at the rim of the impression (mm)

MICROSTRUCTURE

In addition to the effects of elements in stabilizing pearlite or retarding transformation (which facilitates heat treatment to change matrix structure and properties), certain aspects of composition have an important influence on some properties. Silicon hardens and strengthens ferrite and raises its impact transition temperature; therefore, silicon content should be kept low as practical, even below 2%, to achieve maximum ductility and toughness. Nickel also strengthens ferrite, but has much less effect than silicon in reducing ductility. When producing as-cast grades of iron requiring fairly ductility and strength such as ISO GRADE 500/7, it is necessary to keep silicon low to obtain high ductility, but it may also be necessary to add some nickel to strengthen the iron sufficiently to obtain the required tensile strength. Almost all elements present in trace amounts combine to reduce ferrite formation, and high-purity charges must be used for irons to be produced in the ferritic as cast-condition. Similarly, all carbide forming elements and manganese must be kept low to achieve maximum ductility and low hardness. Silicon is added to avoid carbides and to promote ferrite as-cast in thin sections. The electrical, magnetic, and thermal properties of Ductile irons are influenced by the by the composition of the matrix. In general, as the amount of alloying elements increases and thermal conductivity decreases.

RESULTS & DISCUSSION

- ✓ Small addition of carbon increases the Brinell hardness number.
- ✓ Variations in silicon percentages vary the hardness and tensile strength and elongation also.
- ✓ Increase in copper % increase in tensile strength.
- ✓ Residual magnesium variations effects on microstructure of the SG Iron.
- ✓ To increase in the manganese % increase in the Brinell hardness number.

CONCLUSION

- ➢ To minimize the number of experiments to achieve the targeted mechanical properties in SGI casting, it is important to find the optimal chemical composition.
- ➢ It is very helpful to the designer of the product for getting targeted mechanical properties required for the end use.
- ➢ It is optimal solution for the product where very precise calculated mechanical properties are required.

REFERENCES

1. Indian Foundry Journal Vol.57 No. 1, 2011
2. M.A.Kenawy Mechanical and Structural Properties of Ductile Cast Iron Egypt. J. Sol., Vol. (24), No. (2), (2001)
3. Source Book on Ductile CI, ASM, 1977
4.www.**iso**.org/**iso**/**iso**_catalogue/...tc/catalogue_detail.htm
5. Zamba J, Sumandi M, Materials and Design Vol 25 august 2004
6. D. P. Kanicki, "Marketing of Ductile Iron," Modern Casting, April, 1988
7."NCMS Study Reveals DI Castings May Mean Cost Savings." Modem Casting, May, 1990, p 12.
8. Indian Foundry Journal Vol.57 No. 8, 2011.