Introduction –

S. G. Iron consists of family of cast iron in which the graphite is present in nodular or spheroidal form.

The spheroidal shape of graphite helps “arresting crack”, resulting in high tensile strength and good Ductility as compared to grey C.I.

Types of S. G. Iron –

1. Ferrite S.G. Iron (More Ductile)
2. Pearlite Ferrite S. G. Iron
3. Pearlite S.G. Iron (More Brittle)

Equipment used in Foundry –

1. Furnace capacity 100 – 1000 Kg for medium sized foundry with 350 – 650 KW input
2. Pyrometer to measure temp of metal before and after treatment.
3. C.E. Meter for base metal composition for C%, Si% and C.E.V.
4. Spectrometer for chemical Analysis before and after treatment.
5. Micrometer and BHN machine to observe metallurgical and mechanical properties.

Row Material –

1. Small variations in raw material quality would detrimental to casting quality.
2. Cast iron are in near eutectic Fe-C-Si alloy.
3. Addition of si – 1) Increased Equilibrium eutectic temperature (TEG)

2) Decrease metastable eutectic temperature (TEC)

3) Moves eutectic point towards lower carbon content.

1. TEG – Equilibrium (graphite) Eutectic temperature.

TEC – Metastable (carbide) Eutectic temperature.

TAL – Austenite Liquidous Temperature.

TGL – Graphite Liquidous Temperature.

1. Addition of Ni and Mo in combination for corrosion resistance, high strength, high temperature application.
2. Since raw material contain S and O elements it is necessary to remove these from melts.

Charging material –

1. CRCA Scrap (Cold Rolled Closed Annealed) –

Carbon – 0.20 to 0.30 %

Silicon – 0.05 to 0.25 %

Manganese – 0.30 max %

Phosphorus – 0.05 max %

Sulphur – 0.020 max %

Chromium – < 0.04 %

CRCA must be rust free, non-oily, free from hollow pipes, painted scrap etc. for good quality of melt.

1. Silicon Steel Scrap –

Carbon – 0.30 %

Silicon – 1.7 to 3.0 %

Manganese – 0.40 %

1. Pig Iron –

Carbon – 3.5

1. Sorel Iron –
2. Copper Scrap –   
   Cu content must be 95% min, free from varnish or paint.
3. Tin –

Sn is ten times strong pearlite stabilizer than copper, to used with care.

Melting –

Ductile cast iron requires tighter control with raw materials and processes but good properties and it is avoiding long heat treatment.

Alloy composition, casting design and production are important factors for performance of final product.

Shape of graphite and growth depends on melts chemical composition.

After treatment, residual Mg should be in range 0.03 - 0.05%.

Mg addition should be calculated from

Mg = 0.75% s + residual mg (0.03 – 0.05 %) / expected mg yield

The expected yield depends on local process condition in foundry, it is very sensitive to melt temperature and time pasted after melt treatment.

Magnesium Treatment –

* In 1940, it was demonstrated that ductile cast iron could be made by adding Mg to liquid metal.
* Addition of Mg change shape of graphite from lamellar to nodular.
* As graphite shape is changed, nodules are embedded in a coherent austenite matrix.
* After melting, base metal undergoes a cleaning process which also called magnesium treatment.
* A liquid metal poured over a Ni-Mg or Fe-Si alloy which contain 3-10% Mg.
* During this process, Mg reacts with Oxygen and Sulphur reducing melts content of these elements.

Question – Why Magnesium?

Research work has shown that on a laboratory scale addition of a number of elements are capable of producing S. G. Iron, like Magnesium, Ce, Ca and Yttrium.

We will restrict ourselves to Fe–Si–Mg Alloy with Cerium Misch Metal. (TRE up to 2% Max)

* Additions of Mg, Ce and La change shape of graphite from Lamellar to nodular.
* Nodules are embedded in coherent austenite matrix.
* Cast iron characterized by their carbon equivalent (CEV)

CEV = %C + (%S + %P)/3 [P = Phosphorus]

* For Ductile Cast Iron – 3.0 to 4.3% C and 1.8 to 2.8% Si and 3.6 to 4.9 CEV
* Eutectic point is at CEV = 4.3%
* During solidification graphite expands and compensate shrinkage.
* If initial eutectic undercooling is too large, metastable carbides may form instead of graphite.

Solidification of Ductile Cast Iron –

* Raw materials in industries contain a range of trace elements, particularly Sulphur and Oxygen.
* To remove it, melt undergoes cleaning process aka ‘magnesium process’.
* Liquid metal poured over Ni – Mg or Fe – Si which contain 3 – 10 % Mg and in some cases rare earth elements.
* During this process, Mg reacts with O and S reduce these elements.
* After treatment remain Mg should be in 0.03 % to 0.05 %.
* Mg additions may be calculated from –

Few treatment process for S.G. Iron using Fe – Si – Mg alloy.

1. Direct pouring techniques.
2. Sandwich process.
3. The tundish cover process.
4. In mold process.

Few treatment processes for S.G Iron using Pure Mg –

1. Plunging or submerging techniques
2. Wire feed technique.
3. GF converter.

The choice of treatment method depends upon –

1. The demand rate of metal in foundry.
2. The weight and number of casting to be produced.
3. The melting and holding system.
4. The metal handling and distribution system.
5. Specification requirements.
6. Environmental requirements.
7. Space availability.
8. Cost.

Inoculation –

Inoculation is a means to control and improve the microstructure and mechanical properties of cast iron.

The inoculation process will provide sufficient nucleation sites for the dissolved carbon to precipitate as graphite rather than iron carbides.

The most common inoculant is a ferrosilicon based alloy with small and defined quantities of either Ca, Ba, Zr, rare earths and Al.

Inoculation also reduces the tendency for solidification shrinkage formation.

Ductile Iron Inoculation –

In ductile iron the nodularizing treatment will influence inoculation efficiency and therefore it is important to select the correct treatment process and magnesium bearing material.

1. During nodularizing numerous inclusions are formed with a sulphide care and an outer shell containing complex magnesium silicates.
2. Such micro-inclusions will however not provide effective nucleation of graphite because the crystal lattice structure of magnesium silicates does note match well with the lattice structure of graphite.
3. After inoculation with a ferrosilicon alloy containing Ca, Ba or Sr the surface of the Mg silicate micro-Particles with be modified and other complex Ca, Ba or Sr silicate layers will be produced.
4. Such silicates have the same hexagonal crystal lattice structure as graphite and due to very food lattice much ceil therefore act as effective nucleation sites for graphite nodules to grow from during solidification.

Inoculant elements –

1. Aluminum –

Typical 0.5 to 4.5 %

1. Calcium –

Typical 0.5 to 2.0%

Ca + Al total of 2.5 %

Known as inoculating grade Fe Si

First commercially used Fe Si inoculant.

1. Manganese –

Typical 3 to 10 %

Used in combination with other elements Ba, Zr Forms Lower melting point phases.

1. Zirconium –

Typical 1.5 to 4.5 %

aids fade resistance in combination with other inoculants.

1. Barium –

Typical 1.0 to 11.0%

Minimize chill formation in combination with other elements.

Good fade resistance.

1. Rare earths –

Typical up to 10%

Combinations of Ce/La

1. Bismuth –

Typical up to 1.5 %

Combination with 0.5% RE

Effective in thin section ductile iron

1. Strontium –

Typical 0.6 to 1.0%

Combination with 0.1 % Ca and 0.5 % Al maximum

Good chill reduction

Lower shrinkage tendencies

Low S grey irons and ductile irons treated with high RE FSM reduce effectiveness.

1. Remedy –

0.3% addition of ladle inoculant Fe Si + 1.5% Al + 1% Ca.

Inoculation Methods –

1. Ladle Inoculation –
2. Gravity Feeding
3. Air Assisted Injection
4. Injection of cored wire
5. Late/ Post Inoculation –
6. In-stream Inoculation during pouring into mold.

1) Air Assisted Injection of inoculant.

2) Gravity feeding of Inoculation.

1. Wire injection in the pouring siphon of pressurized holding furnace.
2. In the mold inoculation.
3. Inoculation in the runner.

1) Solid insert placed into the sprue well.

2) Inoculant placed into the filter.

1. Inoculation in the pouring basin.
2. Inoculant block placed into the pouring basin.
3. Floating inoculant in the pouring basin.

The purpose of inoculation –

1. Control of graphite structure.
2. Elimination or reduction of chill/ carbide.
3. Reduction of casting section sensitivity.
4. To maintain good nodules shape.

Effect of inoculation on ductile iron –

1. Optimum nodule shape.
2. Degree of nodularity.
3. Improve nodule count.
4. Prevention of formation of carbides.
5. Increases ferrite content.
6. Improve strength.
7. Reduces hardness.

Defects –

* Initially solid nucleates near boundary and solidification toward center. Solid will also nucleates somewhere in liquid and moves towards primary dendrite. As the solidification not uni-directional, the place where primary and secondary dendrites meets there will be micro voids which cannot be compensate by riser is called dendritic growth.
* To avoid this, chills are used. Chills are made of same material and are kept all round the mould. Due to rapid heat transfer, primary dendrites not give chance to form secondary dendrites but this create Hot tear defect.

1. Hot tear :- Due to rapid solidification towards center, contraction stress developed, as a result cracking appear at last in center.
2. Misrun :- Incomplete cavity filling due to inadequate metal supply or too low melt temperature or improve design of gates. When liquid metal flow from thin areas it solidify due to more heat loss before reach end of cavity.
3. Cold shut :- when two metal streams meet without complete fusion. It may occurs at center
4. Shift :- A misalignment between two halves of mould or core. This defects called mould shift or core shift.
5. Penetraction :- If mould surface is soft or poros, liquid metal may flow between sand particles resulting rough surface.
6. Gas defects :- It mould wet and molten metal poured in it then created gas trapped into liquid metal and from blow holes, pin holes.
7. Shrinkage Cavity:- Improper riser form this defects i.e. volume contraction during solidification. This affect on appearance and performance.
8. Structural defects (Graphite and Matrix)
9. Rat tail Defects.
10. Drop.
11. Inclusions (Dross, slag, Fluid Slag, etc.)
12. Dirt.
13. Buckle.
14. Swell

Dross Effect and its causes.

1. Man :-

1)Slow Pouring, 2) Unskilled worker, 3) Improper Slag removal, 4) Incorrect charge mix.

1. Material :-

1)C. E. value > 4.5, 2) High Al % 0.03, 3) Faulty filter used, 4) Base S% > 0.025,

5)High S coal dust for molding, 6) Incorrect tapping temperature, 7) To high residual Mg.

1. Methods :-

1)No filter Used, 2) Incorrect Methoding, 3) Depay in Metal handling, 4) Depay in Pouring,

5)No cover for ladle, 6) Incorrect filter placement.

1. Equipment :- 1) Faulty C.E. meter, 2) Unclean Ladle.

Properties of Ductile Iron –

1. Due to Mg treatment –
2. Avoid long heat treatment.
3. High and low temperature strength.
4. More ductility with less corrosive.
5. Easy to cast complex shapes.
6. Fatigue strength and Fatigue toughness.
7. Good fluidity.
8. Due to inoculation treatment –
9. Improved “Strength: Weight” ratio.
10. More strength per unit cost.
11. Reduced component weight.
12. Good dimensional accuracy.
13. Good machinability.

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