Influences of the Formation of Cast Iron with Nodular Graphite Using Magnesium Treatment Processes

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Abstract - The magnesium role is significant for the development of tiny ball like structure (spheroids) of graphite in cast iron. The mechanical properties of casting materials not only found by the matrix alone but also metallurgical things(shape, type, and distribution) of the incorporated graphite. The incorporated graphite affected the material's properties, due to nodular graphite formation and causing the notch effect. The purpose of this study how magnesium responsible to achieve nodular graphite in cast iron. From several theories, to discover the form nodular graphite-:Cementite theory, Austenite theory, Melt-theory, Bubble theory, and graphite-morphology. The introduction of magnesium into the melt is a plunging method and the section metallographic specimens were prepared by using Microscope Olympus with an integrated camera. Chemical composition analysis was conducted by using the Optical emission spectrometer SPECTROMAX.A photo of the microstructure. The spheroid graphite is surrounded by a bright ferrite matrix that encircles the graphite and dark pearlite. The properties of graphite have been shown to decrease as the quantity of magnesium increase. According to the findings, the smaller the graphite generated in nodular cast iron the higher the magnesium content. The size of the pearlite will increase, causing additional cementite to form. Nodular cast iron will grow stronger, harder and stiffer as a result. The sulfur content of the treated cast iron has been a critical criterion for evaluating the desulfurization process and the degree of magnesium assimilation.

Key Words: Bubble Theory, Desulfurization Process, Graphite-Morphology, Melt Theory, Nodular Graphite.

1. INTRODUCTION

Crystal growth is one of the most measured problems in metal science. The problem in an iron formation is the graphite that arises in the melt. Sharp graphite flakes occur due to nodular graphite is present in an iron carbon alloy, creating stress concentration in the metal matrix. Many technologies for producing iron with nodular graphite developed have been explored to improve flexibility. According to specific research, rapid cooling and super cooling are additional criteria for nodular graphite production. Magnesium nodular graphite was created in hug casting (Up to 10 tons) in green sand moulds using alloyed irons containing 0.05 percent. In which eutectic crystallization occurs for at least 5 hours. The drop in crystallization temperature should not be confused with super cooling, which is required to generate nodular graphite. The microstructure of flake graphite, which becomes nodular graphite in iron alloyed with magnesium [2]. Carbon monoxide - CO and magnesium efficiently react with oxygen – is the gas that leads to the production of nodular graphite in ductile cast iron [8]. Vacuum is formed in several locations of the liquid iron when two gaseous entities form two solid bodies with high strength and melting point [8]. The initial magnesium bubbles shrank from 2 mm to 2–3 m, and graphite growth occurred from the periphery to the center [2]. When ductile irons are inoculated with magnesium, bubble production of graphite nodular shaped inclusions occurs [8]. The research focuses on the behavior of magnesium in the melt during the production of cast iron with nodular graphite.

2. MATERIALS AND EXPERIMENTAL PROCEDURE

2.1. Metallurgical and Material Reagent

The Matrix of EN-GJS-500 consists of a mixture of pearlite and ferrite. The melt can differ within a component depending on wall thickness and cooling rate, leading to variations in the hardness of the material Table.1. Shows the chemical composition of the cast iron starting components

Iron designation	C	Si	Mn	P	S	Mg
A	3.65	2.20	0.30	0.035	0.003	0.030
B	3.85	2.16	0.13	0.058	0.028	….
C	4.48	0.68	0.12	0.057	0.001	…..

Table.1.Chemical composition of starting material of cast iron used, Mass% [3]

Nodular cast iron is made from iron A, and desulphurized pig iron is used to make nodular cast iron. Grey cast iron with flake graphite (C, Fe-Si alloy, and a trace of iron sulphide) [3]. The cast iron has about 7.20 g/cm3 density, and magnesium has roughly 1.78 g/cm3 density, and these causes melt [13]. There have been numerous methods for adding magnesium or magnesium containing master alloys into cast iron [12].

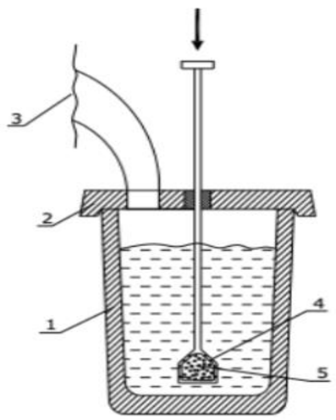


Fig.1. Schematic Diagram of Introducing Magnesium into Melt [11], Plunging Method, 1- Ladle Containing Molten Cast Iron; 2-Cover; 3- Gas exhauster; 4- Plunger; 5- Master Magnesium.

The Plunging method is one of the most extensively used ductile iron manufacturing procedures. In this process, Mg – Master alloys are plunging into the iron melt. The Cast iron has heated at a pouring temperature of 1550 °C. The degree of saturation SC ≈1.0 and carbon equivalent value CEV ≈4.3 (near eutectic iron-carbon-silicon casting alloy) and melt volume of 50 kg with approximately 38 kg raw iron and approximately 10.5 kg iron scrap use in the furnace. The Addition of pure carbon C99.8 (200 g) because of melting loss and inoculation condition is ladle inoculation with 0.3 % FeSi75 (200 g), desulphurization and de-oxidation by the plunging method has been performed using the master alloy FeMn82 (180 g) and the magnesium treatment using the using the plunger with a master alloy of 1.2% FeSiMg5 (650 g). It has contained basic elements in the following amounts: Si, Mg, Ca, Ce, and Fe according to the give **Table.2.**

METALS	C	Si	Mn	P	Cu	S	Mg
GJS	3.5-3.8	2.1-2.3	0.30 - 0.35	<0.2	<0.25	<0.01	0.04 - 0.25

Table.2. Chemical composition in %.

This case's spheroidization process was volcanic, with several metal flashes and a huge amount of smoke emitted [12]. The cast iron was graphitized in stream after it had been spheroidized.

2.2 METHODS AND EQUIPMENT

The Metallographic studies were examined using an Olympus BX51M microscope with an integrated camera. The Progress GRYPHAX Aktur of the company Jenoptik AG and the Software Stream Motion by Olympus. Automatic grinder and polisher TegraPol-31 of the used. A deep-etching procedure with 3 percent HNO3(Nital) was used to detect the texture of graphite nodules on polished samples. The following equipment was used to analyse the melting process-:Casting samples: tubes of L50 mm x Ø10 mm, Platelet samples: 30mm^3 x 30mm^3 x 5 mm^3 for chemical composition Medium-frequency crucible induction furnace induced by Göllingen GmbH (60 kg). The chemical composition of the melt was investigated using the SPECTROMAXx Optical emission spectrometer from SPECTRO Analytical Instruments GmbH andCarbon/Sulfur Analyzer from LECO Corporation CS744 Series.company Struers GmbH.

3. RESULTS OF THE STUDY

The following parameter was discovered and established due to the conducted research on light reflected on the Microscope Olympus BX51M. As per the result, we get to know some influence about magnesium. The photo of a microstructure in Fig. 1, It seems that the spheroid graphite nearby the bright ferrite. The matrix encircles graphite and black pearlite. The lower the proportion of Mg, the less likely graphite will be visible. Solidification in nodular cast iron begins with forming austenite from liquid cast iron. This occurrence was accompanied by a drop in liquid temperature below the eutectic temperature (under-cooling) and a rise in carbon content in the remaining liquid to the eutectic point. Under eutectic temperature, a minor quantity of crystallization core will cause under-cooling. Just at a monitoring period, quite so much energy consumed for melting is released as free energy. The temperature will rise again as this energy is released till it approaches the eutectic temperature. Aside from austenite, eutectic graphite develops together in the same state (called eutectic cells). The percentage of carbons in the alloy is reduced due to graphite development. Between both the austenite grains converted into pearlite, spherical graphite will exist. The iron carbide that creates pearlite can become graphite in thick-walled casting or due to slow cooling; therefore, there will be a ferrite structure in addition to pearlite from around spherical graphite. This percentage of perlite ferrite determines nodular cast iron's hardness, stiffness, and toughness. Because of the increased magnesium content, there is a propensity for yield and tensile strength to increase. This occurs as the magnesium content rises, causing the size of the graphite and ferrite surrounded by spheroid graphite to shrink and the magnesium content added to it. The impact energy required to break nodular cast iron tends to decrease with high Mg content. The variation in the magnesium content will change the Graphite size, Graphite shape, Graphite nodularity, Graphite form, Total numbers of particles per mm^2, and Number of nodular particles per mm. As per table 1, we see the two different materials with different magnesium contain and result.

Effect of magnesium content in graphite

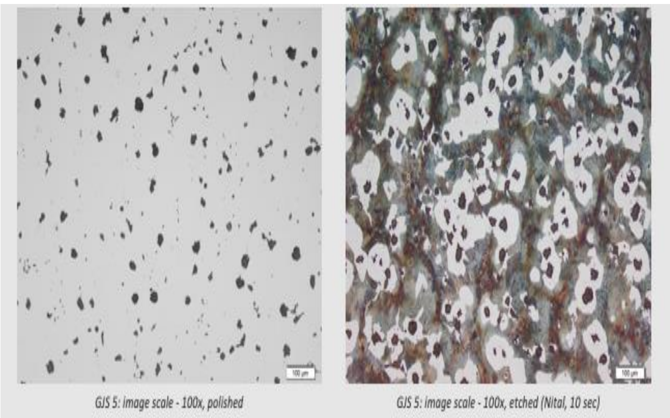


Fig.2. Reference sample -GJS-5, Entire sample area- 19.57mm^2, etched sample.

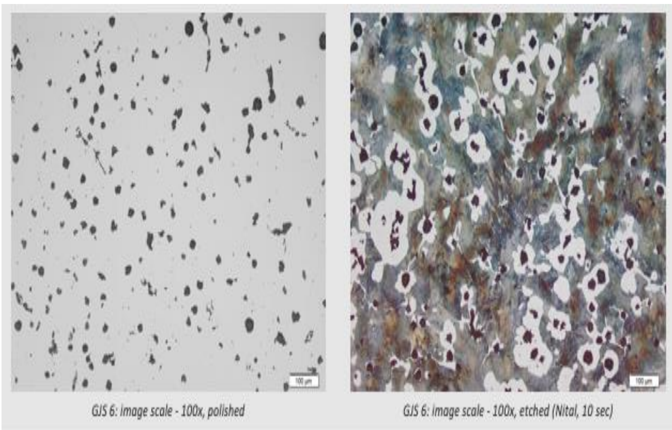


Fig.3. Reference sample -GJS-6, Entire sample area- 19.57 mm^2, etched sample.

Sample result	Reference sample	
	GJS-5	GJS-6
Graphite Size	4.8%	5.4%
Graphite Shape	7	7
Graphite Nodularity	58.8%	38.5%
Graphite Form	V(58%),II(32%), IV(9%)	V(49%),II(31%) ,
Total Number of Particle Per mm^2	776.476	737.029
Number of Nodular Particle Per mm^2	136.328	120.079

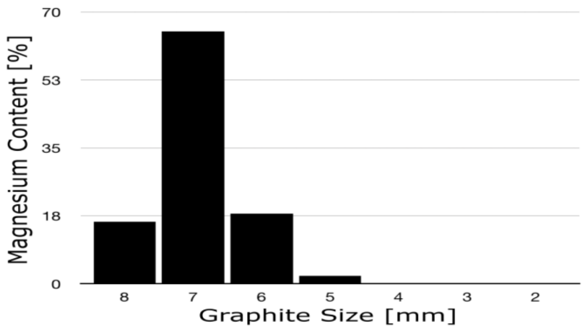
Table.3. Result of the Experiment.

4. DISCUSSION OF RESULT

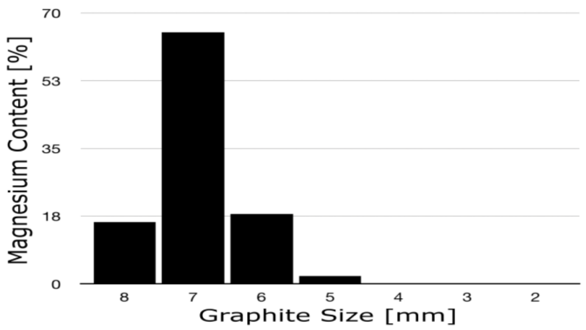
The observed facts and the sound-known features of magnesium as a common spheroidizers and one of the strongest deoxidizer allow the following process of nodular-shaped graphite creation to be proposed because of the reaction's intense interaction of magnesium with carbon monoxide.

$$2Mg\,(L) + C(S) = Mg_2O(S) + CO\,(G)$$

This reaction causes a gas bubble to erupt and a whole chain to form, the base of which has been hexagonal graphite with a hollow in the centre. The meta-stable magnesium sub-oxide makes up the bubble shell and supply channel [8]. Carbon monoxide and other gases can diffuse in liquid cast iron because all three components are closely linked and form part of a coherent system. For example, when magnesium reacts with carbon monoxide, a unified system is produced, and gaseous phase diffusion occurs, resulting in so-called nodular graphite. As per the result, we differentiate that result into three categories graphite size, graphite form, and graphite nodularity. Material is varied with the graphite contained. However, as we saw in graph 1, in a comparison of both material GJS-5 and GJS-6, the graphite maximum (7) and minimum (5) size is the same means magnesium does not affect the graphite size.

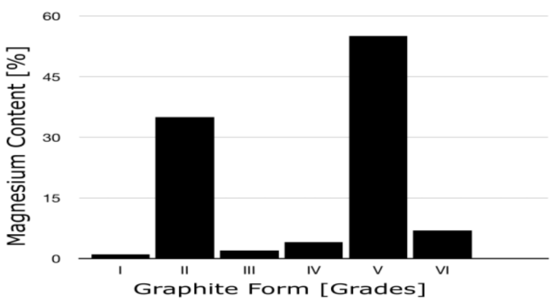


Graph.1.A . Graphite size of GJS 5.

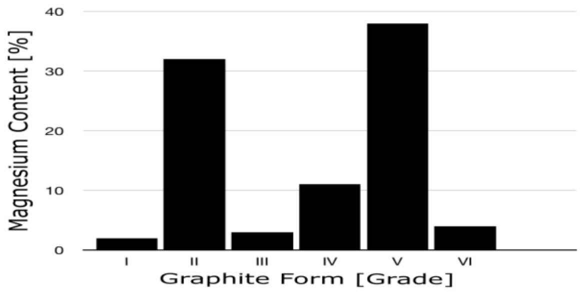


Graph.1.B . Graphite size of GJS 6.

But in the case of a graphite form in graph 2, Graphite forms are distributed in various grades as per European standards. The roman numbers determination of the shape and the percentage should be determined utilizing which the graphite particles approximate the size. In GJS-5 the graphite form is V(63%),II(24%),IV(13%) and in GJS-6 graphite form is V(69%),II(31%). As we see, the form factor in the graphite is changes with a change in magnesium composition.

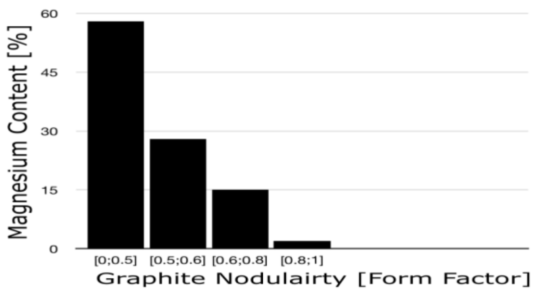


Graph..2.A.Graphite form of GJS 5.

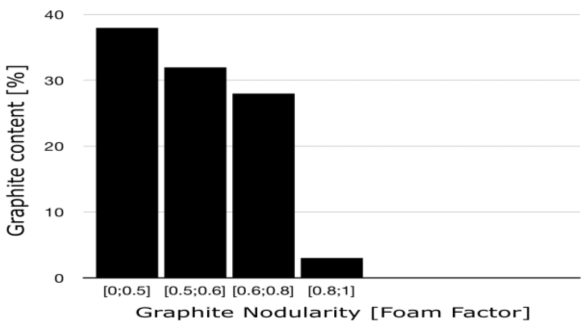


Graph..2.B. Graphite form of GJS 6.

Another aspect, we focused on graphite nodularity in graph 3. The proportion of graphite particles in cast iron is determined by graphite nodularity. As per the result, the material has minute graphite nodularity stimulation between GJS-5 (49.8%) and GJS-6 (49.5%). Graphite nodularity is means a change in mechanical strength and toughness. So that both materials have different nodularity means different mechanical strength and toughness.



Graph.3.A.Graphite Nodularity of GJS 5.



Graph.3.B.Graphite Nodularity of GJS 6.

5. CONCLUSION

The study found that the thinner the graphite produced, the higher the magnesium content in nodular cast iron. Pearlite will be more significant, resulting in more cementite formation. Nodular cast iron's cementite effect will grow more robust, more challenging, and stiffer. The resulting sulfur content plays a significant factor in developing the desulphurization process. The yield of magnesium refers to the amount of magnesium incorporated into the treated cast iron. As per the research, magnesium content can be affected graphite -size, sample, form, and nodularity according to those properties of the material will change hence magnesium influences forming graphite and will be affected on mechanical properties its toughness. Graphite positively impacts mechanical qualities such as high strength, long fatigue life, and ductility. The improving mechanical property will easily replace steel.

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