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Study of microstructure of thick wall ductile iron castings

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Abstract : Ductile Iron castings with section thickness 60mm, 70mm & 80mm were produced using manufacturing process in which the chemical composition was adjusted to guarantee the formation of spheroidal graphite during solidification. Simultaneously other parameters like carbon equivalent, tapping temperature, inoculation and magnesium residuals were monitored. Microstructure and its constituents of these thick wall castings were characterized using an image analyzer. Matrix structure and graphite forms were investigated as a function of section thickness. Pearlite content, nodule count and nodularity decreases with increasing section thickness where as nodule size increases.

Keywords : Microstructure, Spheroidal graphite iron, Manufacturing process.

INTRODUCTION

The use of ductile iron casting (DI) has been increasing constantly all over the world. In the recent years there has been increasing interest in solidification of both thin and thick wall ductile iron casting. Most of the work on this subject has been based on metallurgical examination after solidification and cooling to room temperature, which also involves a phase transformation during cooling process.

The microstructure of typical commercial spheroidal graphite irons in as cast condition consists of graphite nodules embedded in a ferrite shell and of pearlite. This so called bull's eye structure. For determining mechanical properties, the control of microstructural constituents is of practical importance[1].

The alloy first undergoes the stable eutectoid reaction in which austenite decomposes to give ferrite and graphite. Ferrite nucleated at the graphite/austenite interface and then grows symmetrically around the nodules. This reaction is here after called the ferritic reaction. This growth is controlled by diffusion of carbon through the ferrite shell, which makes it quite a slow process. Therefore the temperature of the metastable ectectoid could be reached before the complete transformation of austenite. Once the metastable reaction is initiated, also named the pearlite reaction proceeds quickly because of the cooperative growth of ferrite and bainite. This latter transformation is similar to the pearlitic reaction[2].

Several studies were carried out in order to improve the production process of spheroidal graphite iron and to identify the characteristics of the microstructure and the final mechanical properties[3]. The current paper presents the results of microstructural characterization of thick wall ductile iron castings.

EXPERIMENTAL PROCEDURE

Melting and casting

Three melts of spheroidal graphite iron were produced using the tundish tea pot ladle treatment

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method for this study. Charges consisting of 250kg SG iron returns, 200kg steel scraps, 50kg pig iron and 17kg coconut charcoal were melted in a 500kg capacity coreless induction furnace. The manufacture analysis of pig iron and steel scrap is listed in Table 1.

Table 1 : Showing the composition of pig iron and steel scrap.

Sample	C%	Si%	Mn%	S%	P%	Fe%	Rest elements
Pig iron	4.19	1.72	0.08	0.014	0.051	93.28	Balance
Steel scrap	0.036	0.027	0.112	0.0027	0.0129	99.70	Balance

The carbon percentage in coconut charcoal was found 54.2% by analyzing with strolein apparatus. The liquid metal was tapped at 1450^{o}C to a preheated ladle containing 6kg of 5.5% Mg-Fe-Si, 2kg of 75% foundry grade ferrosilicon (size 2-6mm). 1kg of 75% ferrosilicon was used for post inoculation by treating with open ladle and argon gas purging was carried out for proper mixing. Upon completion of treatment, slag was removed from the metal surface in order to avoid defects in casting and final sample was taken for chemical analysis by spectro M-9 model and the result was given in Table 2 . The treated iron was poured into dry sand mold bonded with resin and catalyst. During pouring (at temperature 1380^{o}C), in stream inoculation was carried out.

Table 2 : Showing the chemical analysis result of the sample under study.

Sample	C%	Si%	Mn%	S%	P%	Cr%	Ni%	Mg%	Fe%	Rest elements
H1	3.62	2.14	0.146	0.009	0.024	0.025	0.120	0.042	93.20	Balance
H2	3.60	2.12	0.148	0.009	0.025	0.026	0.119	0.040	93.62	Balance
H3	3.61	2.13	0.149	0.010	0.023	0.028	0.117	0.038	93.45	Balance

Similar procedure was conducted for other two heats and for each heat, two molds were poured. The test castings were approximately 250x60x50mm size (2nos for H1), 250x70x50m (2nos for H2), 250x80x50mm (2nos for H3).After pouring of twenty four hours, the metallographic sample preparation was carried out by using standard technique. The sample was taken from the centre of the casting. The specimens were mounted, ground and polished using the conventional metallographic techniques. Metallographic etching was performed with 2% nital for microstructure analysis and the reagent $Na_2S_2O_5$ +Picric acid was used for carbide content. The matrix structure, nodule count, nodule size values were measured by using both the ASTMA247 standard and images were acquired at a magnification of 100x & 400x. Five fields of view per sample were analyzed. The basic features measured were area fraction, area, percentage of ferrite and pearlite.

RESULTS

The microstructural analysis and characterization is represented in different Figures for three melts of H1, H2 and H3. Fig. 1.1, 1.2 and Table 3 exhibits the microstructure.

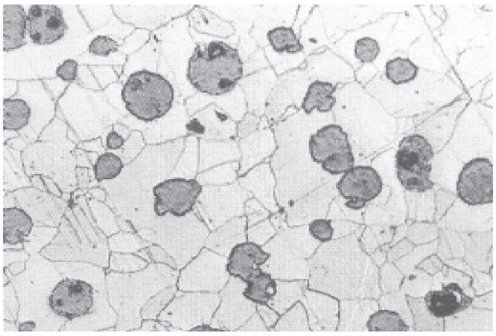

Fig. 1.1

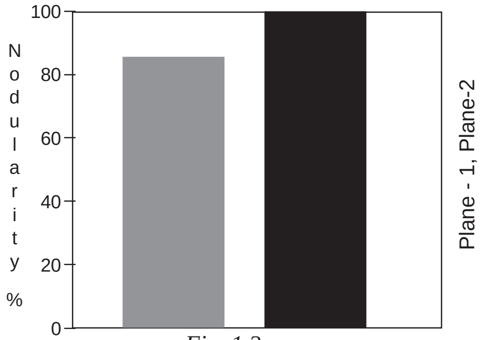

Fig. 1.2

Table 3 : Showing the data of microstructure analysis.

SID:C9811	Frame Area (mm²)	Nodularity (%)	Nod. Count	Nod Count/mm²	Nodularity (%)	Nod. Count
Frame - 1	0.2751	71.622	53	192	100.000	1
Frame - 2	0.2751	62.712	37	134	100.000	1
Frame - 3	0.2751	80.702	46	167	100.000	1
Frame - 4	0.2751	67.647	46	167	100.000	1
Average	0.2751	70.543	45	165	100.000	1

Nodularity and area fraction. Fig 1.1 shows the graphite nodules in compacted graphite form embedded in the ferrite matrix. The percentage of nodularity and nodule count is found to be 100 and 165 as shown in Fig. 1.2 as determined by image analyser. Fig. 2.1, 2.2 and Table 4 exhibits the microstructure of melt H2.

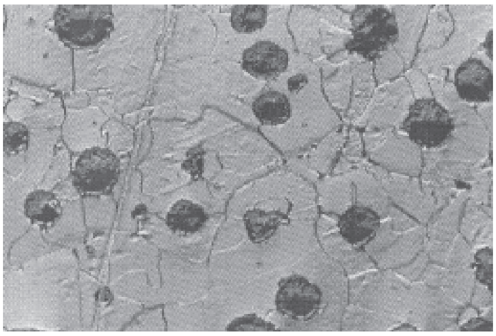

Fig. 2.1

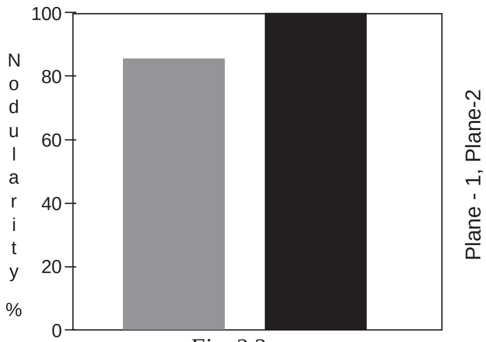

Fig. 2.2

Table 4 : Showing the data of mcirostructure analysis (melt H_2)

SID:SL-02	Frame Area (mm²)	Nodularity (%)	Nod. Count	Nod Count/mm²	Nodularity (%)	Nod. Count
Frame - 1	0.2751	86.207	50	181	100.000	1
Frame - 2	0.2751	88.889	48	174	100.000	1
Frame - 3	0.2751	86.538	45	163	100.000	1
Frame - 4	0.2751	86.792	46	167	100.000	1
Frame - 5	0.2751	90.385	47	170	100.000	1
Average	0.2751	87.732	47	171	100.000	1

Low nodule count and exploded graphite are found in the structure. Similarly Fig. 3.1, 3.2 and Table 5 shows the distribution of nodules in the matrix and their characteristics.

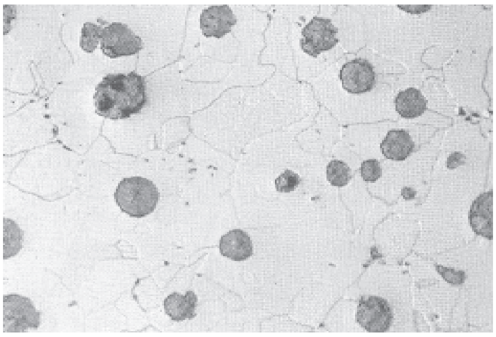

Fig. 3.1

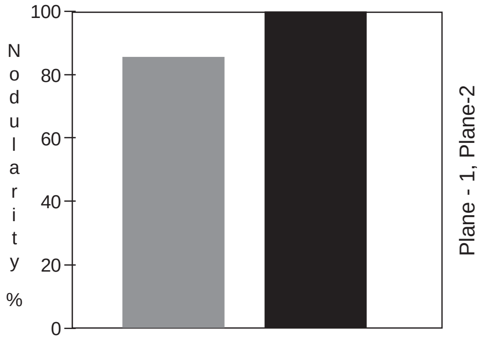

Fig. 3.2

Table 5 :

SID:SL-74	Frame Area (mm^2)	Nodularity (%)	Nod. Count	Nod Count/mm^2	Nodularity (%)	Nod. Count
Frame - 1	0.2751	72.222	26	94	100.000	1
Frame - 2	0.2751	62.162	23	83	100.000	1
Frame - 3	0.2751	77.083	37	134	100.000	1
Frame - 4	0.2751	80.952	34	123	100.000	1
Frame - 5	0.2751	82.222	37	134	100.000	1
Average	0.2751	75.481	31	114	100.000	1

Graphite flotation and spiky graphite are found. Fig. 3.1 shows a classic case of nodule alignment. This is caused by large dendrites growing during the solidification with the nodules being precipitated between the dendrite arms. Thus the nodules appear to be aligned. Graphite flotation is due to low density graphite nodules and is found during the solidification of thick section or otherwise slow cooling castings. Due to the presence of small amount of rare earth elements, spiky forms of graphites are observed. The nodule count and nodularity are shown in Table 5. No massive carbides were revealed on the metallographic samples of casting of H1, H2 and H3 by using different etchants. Graphite content varied from sample to sample. For H1 amount of graphite is 12-18%, 8-14% in H2 and 8-12% in H3. Graphite content decreases with increase in casting thickness. Again also nodule count decreased from sample H1 to H3.

CONCLUSION

Three heats were produced using the same procedure but there is variation in casting thickness. Pearlite content of microstructure varies with thickness of castings. In general pearlite content decreases with increasing thickness of casting. Microstructure of ductile iron castings with section size 60, 70 and 80mm were characterized quantitatively. The number of graphite nodules decreases as the casting thickness increases. Graphite nodules are generally in bigger size in thick sections. Nodularity is generally above 95% in all samples. All the samples examined were carbide free.

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