

Post inoculation in the structural control of ductile cast iron

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Abstract : Ductile Cast Iron, a relatively new engineering material has been the subject of intensive investigations in recent years. It is essential to have an improved understanding of the mechanism of nodule formation, economical methods of processing and mechanical properties of commercial ductile cast irons. The present study deals with the beneficial effects of Post-Inoculation on the as-cast structure and properties of ductile iron. Post-inoculation process was carried out on ductile iron melts and tensile test, charpy impact test, chemical composition and microstructure analysis were performed for evaluation.

Keywords : Post-inoculation practice, mechanical properties, analysis of microstructure.

INTRODUCTION

Ductile iron developed in 1943, found that by adding magnesium before pouring caused the graphite to form nodules rather than flakes. This resulted in a new material, with excellent tensile strength and ductility^[1-15]. Adding these mechanical properties of this material to the advantages already offered by cast iron soon led to finding its way into virtually every mainstream area of engineering. In many cases existing steel casting or forgings were replaced due to achievable cost savings.

The US transportation industry is faced with three major challenges: reduce emissions, improve fuel economy and lower cost. One method of improving fuel economy is to reduce vehicle weight and provide the transportation industry with a means of weight reduction at little or no cost penalty^[16-18]. The cast iron and steel industries have undertaken major product improvement programs e.g. thin wall iron casting technology. The ductile iron offers the possibility of obtaining a broad range of mechanical properties starting from a general spheroidal graphite cast iron melt and applying specific heat treatments. Also it has a lower manufacturing cost and the capacity of obtaining complex shape components as it is a cast material.

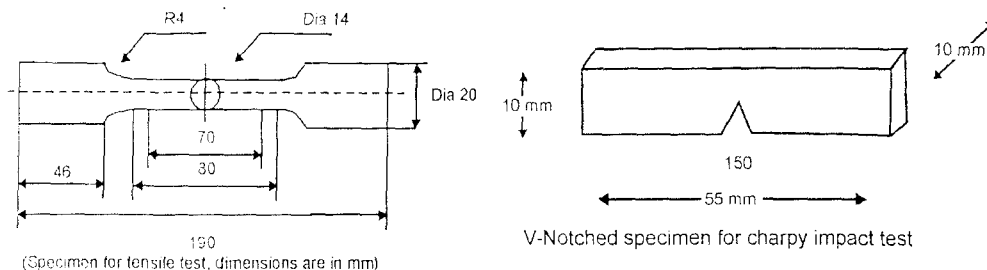
In order to achieve the optimum properties in ductile iron castings, the proper post-inoculation of ductile iron is just as important in producing high quality ductile iron castings. Post-inoculation practice in ductile cast iron provides nucleation centres for graphite precipitation. Providing these centers makes graphite precipitation easier during solidification. Without proper nucleation, carbides can be present in the as cast ductile iron castings. This will result in castings with inferior ductility and mechanical properties. Suitable post-inoculation normally prevents the tendency for carbides to form during solidification. Actually, if as-cast ductile iron is to be readily achieved, proper and adequate post-inoculation is of prime importance. Therefore post-inoculation is a key to structural control in ductile cast iron.

The present work focuses on the study of the influence of Post-Inoculation on the mechanical and microstructural properties of ductile iron casting in as-cast condition.

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EXPERIMENTAL PROCEDURE

Melting and Casting : Three melts of nodular iron were produced using open ladle treatment method for this study. Charges consisting 50kg pig iron (C=4.17%, Si=1.66%, Mn=0.138%, S=0.024%, P=0.060%), 100kg S.G return (C=3.62%, Si=2.12%, Mn=1.19%, S=0.010%, P=0.026%) and 150kg steel scrap (C=0.038%, Si=0.037%, Mn=0.135%, S=0.005%, P=0.015%) were melted in 250kg capacity coreless medium frequency induction furnace. The molten metal was tapped in a preheated ladle containing ferro silicon magnesium alloy of size 15-25mm (Si=45.50%, Mg=5.85%, Ca=1.08%, Al=0.91%) at the bottom covered with steel scrap. The tapping temperature of molten metal was 1450°C. Commercial argon gas was punched through steel pipe to the melt for proper mixing with addition of 1% ferro silicon inoculant (3.5kg) of size 2-6mm (Si=73.52%, Al=1.06%, P=0.035%, S=0.004%, Ca=0.19%, Ba=2.00%). At this time the sample was taken from the melt for final chemical analysis. The treated iron was poured into furan resin sand molds (keel block specimen of size 230x140x125mm) bonded with epoxy resin and catalyst. The pouring temperature was 1380°C. Similarly other two melts were prepared among them one was not post inoculated and the other was post inoculated with 0.5% addition of 70.52% Ferrosilicon. Tensile testing specimens were made from casting obtained from keel Block and their tensile strength, yield strength and elongation were measured using Universal Testing Machine (model- UTE 100, max.capacity-1000 KN, Make-Fuel Instruments & Engineers pvt.ltd, Maharashtra, India). Hardness tests were also performed on each sample using Brinell Hardness Tester. Average values were obtained based on 5 measurements. Charpy impact test at -20°C in a Shimadru pendulum of 300j maximum capacity was performed with notched specimen (10x10x55mm, BSEN 10045-2-1993) cooled in a bath for 5 minutes containing methanol and dry ice for temperature down to -20°C. The impact values were calculated taking average results of three specimens.



The samples for microstructural observation were taken from the centre of the casting. The microstructures of the samples were observed using Image Analyzer (Make-Correct Tokyo, Seiwa optical) after polishing and etching using 2% Nital solution. The chemistry of each melt was determined by using Spectrometer (Spectro lab, M-9 model, Jerman make).

RESULTS AND DISCUSSION

Table 1 shows the chemical composition of three of the irons tested. The iron number DI-1 was post inoculated with 1% addition of 73.52% ferrosilicon. The iron number DI-2 was post inoculated with 0.5% addition of 73.52% ferrosilicon and iron number DI-3 was not post inoculated.

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Table 1 : Showing the chemical composition of three test samples

Iron no.	C%	Si%	Mn%	S%	P%	Cr%	Ni%	Mg%	C.E
DI-1	3.59	2.31	0.18	0.009	0.026	0.015	0.034	0.047	4.36
DI-2	3.55	2.24	0.17	0.010	0.025	0.018	0.032	0.045	4.29
DI-3	3.58	2.18	0.17	0.009	0.027	0.017	0.035	0.046	4.30

Table 2 shows the mechanical tests performed on test bars taken from keel block castings. It was observed from the test result that there is a little difference in tensile strength and yield strength but there is considerable difference in hardness and ductility characteristics.

Table 2 : Showing the result of mechanical test of the three samples

Iron no.	UTS (Mpa)	Y.S. (Mpa)	EL%	R.A.%	BHN (Avj.)	Impact (J)	P.I
DI-1	440	322	21	25	154	15	1.0% PI
DI-2	461	338	17	20	163	12	0.5% PI
DI-3	412	330	11	7	179	9	None

P.I=Post Inoculant

Fig. 1 represents the microstructure of DI-2 which was properly post inoculated with 1% addition of 73.52% of ferrosilicon. This microstructure is very ideal and convenient. The matrix shows >90% ferrite and high nodule count. The graphite nodules are well formed and uniformly distributed in the ferritic matrix. Due to high ferritic content, the tensile strength is low and ductility is high. If the silicon and manganese contents of DI-2 were higher, the tensile strength would be higher and the ductility lower even though the matrix was still ferritic, because of the solid solution strengthening effect of these elements

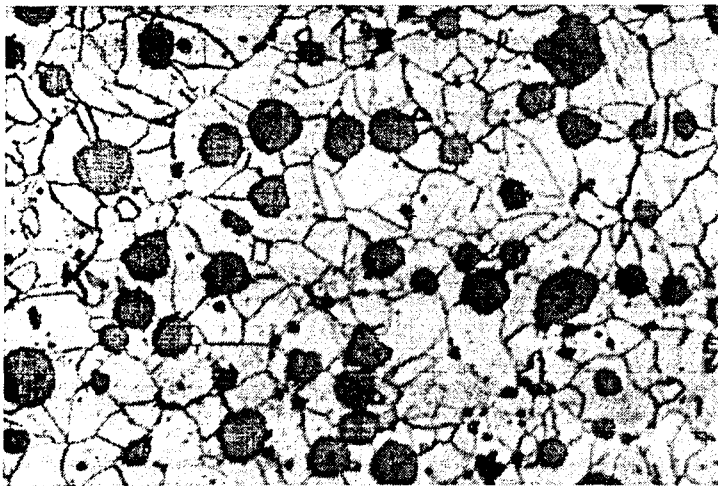


Fig. 1: 1% addition of PI, 100X magnification, 2% nital etched, high nodule count and low pearlite content

Fig. 2 represents the as-cast microstructure of DI-2 which was post inoculated with 0.5% addition of 70.52% ferrosilicon. The structure shows well formed graphite nodules in a ferritic matrix consisting of 6% pearlite. The nodule count is lower than DI-1 and percentage of pearlite is higher. This fact is only due to greater post inoculant in DI-1. This difference in metallography reflects in mechanical properties in Table 2.

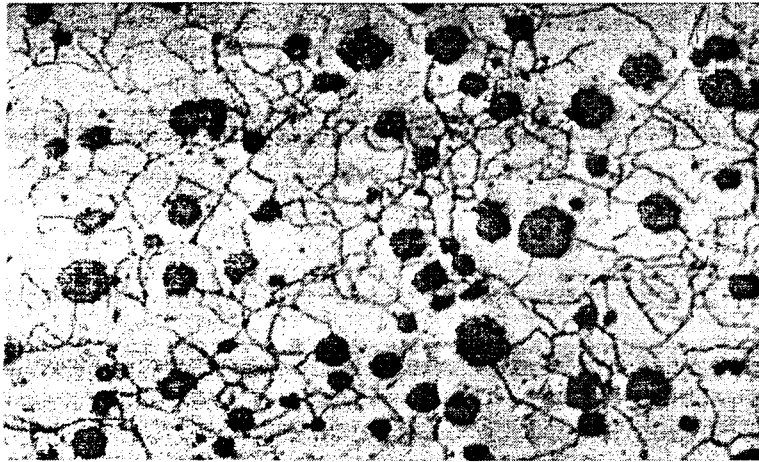


Fig. 2 : 0.5% addition of PI, 100X magnification, 2% nital etched

Iron number DI-2 has higher hardness, higher tensile and yield strength, but lower ductility and impact energies than DI-1. This indicates that DI-2 was inadequately post inoculated. The mechanical properties and machinability would be unsatisfactory for most application.

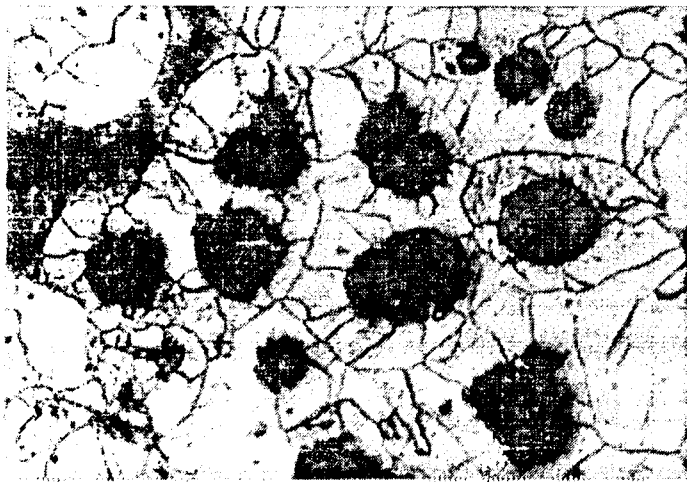


Fig. 3 : 100 X magnifications, 2% nital etched, poor graphite structure

From the analysis of Fig. 3 with the help of Image Analyzer, we observe poor graphite structure and lower nodule count in DI-3 which was not post inoculated. Carbides were present in substantial quantities. The mechanical properties from Table 2 reflect that DI-3 shows lower tensile and yield strength, lower elongation, lower impact values and higher hardness. This again reveals the benefits and need for proper and adequate post inoculation of ductile iron.

CONCLUSIONS

Post inoculation practice of ductile iron is carried out for at least three reasons :

- i) To provide sufficient nucleation centers for proper graphite precipitation.
- ii) To obtain optimum mechanical properties in the casting in as-cast condition.
- iii) To make possible the production of as-cast ductile iron castings.

Post inoculation of ductile iron is an important step in the structural control of ductile iron. It is especially important in the production of as-cast ductile iron castings. There are many precautions several are necessary in order to realize the maximum benefits from inoculation. One of the most important is the consistency of the inoculating practice. In order to achieve consistent results, it is necessary to have a controlled and consistent inoculating practice.

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