USE OF SILICON CARBIDE AS AN INOCULANT IN DUCTILE IRON CASTING TO REDUCE THE COST WITH KEEPING THE PROPERTIES

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Abstract

Ductile iron is one of most applicable material in automotive industry. This metal is usually used for manufacturing the crankshafts and axles. Inoculation step of these parts is very important and sensitive, also is effective on microstructure and mechanical properties. In present work, the effect of silicon carbide (SiC) as an inoculant on the structure and properties of the suspension arm of Peugeout 405 automobile was evaluated. The aim of this research was the obtaining a method to use SiC and optimization the amount of SiC. In order to obtain this target, the percentage of ferrite and pearlite and the count and nodularity of graphite were examined. Furthermore some mechanical properties such as tensile strength and hardness were tested. The results showed that SiC is an appropriate replacement for conventional inolculant (FeSi) because SiC has a lower cost in comparing to FeSi while the properties are same.

Keywords: Silicon carbide, Ductile iron, Inoculant.

1. INTRODUCTION

Today some of the steel parts in the automotive industry have been replaced by ductile iron due to weight loss and to reduce production cost [1]. Ductile iron is considered as a Composite that some spherical graphite has distributed in iron matrix. The structure of spherical graphite cast iron, lead to increase ductility in this type of iron composition. mechanical properties of ductile iron depends on the structure that is formed during freezing[2]. published Literatures indicate, ductile iron metal matrix is determined by cooling rate, composition, pouring temperature, rare earth material in melt and pig iron in charge. Among these cases, type of inoculant, inoculant values and adding step is very important for achieving best microstructure without carbide. Indeed inoculating aids to reduce adverse changing composition effect on microstructure and properties of ductile iron. To achieve maximum yield, content of inoculants must be select optimum. Over inoculating or loss is not proper[3,4]. Adjustment adequate method for inoculating treatment is critical. Inoculants material must be dissolved homogenous in melt. In general, inoculants is used to control properties and microstructure of ductile iron by reducing cooling rate and increasing primary crystals during solidification [1, 5]. Traditionally, inoculants based on graphite, ferrosilicon or silicide and calcium. Today, the most common inoculants are ferrosilicon material which contains small amounts of zirconium, cerium, calcium, barium and aluminum [6, 7, 8]. There are many research related to improving the chemical composition of ferrosilicon or replacing with lower cost inoculants [9]. In recent works, effect of different combinations such as silicon carbide, crystalline graphite, mixed silicon carbide and ferrosilicon has investigated. All of them have performed as pre inoculating process in melting furnace. The results showed that adding of SiC has positive effect on nodule count of cast iron, accordingly increase number of graphitic nodules. In addition SiC, supplies Si and C of cast iron melt. It also reduces possibility of carbide formation. Casting technology articles regularly recommended adding of SiC to melt because of its special effect on pre inoculating. It has been well documented in the gray cast iron[10 , 11].

There are different trends in the iron-making small and large plants for adding inoculants. But it’s said, microstructure and mechanical properties will be improved, whatever, addition of inoculant steps increase [12].

In this work, Adding silicon carbide and optimizing its value in the final inoculation step has been studied. Moreover, the structure and mechanical properties of it with ZIRCINOC inoculants that commonly used in Iran's factories was compared. Finally, Economic evaluation of the use of silicon carbide instead of conventional insemination in large scale was examined.

2. MATERIALS AND EXPERIMENTAL PROCEDURE

In order to investigate the influence of silicon carbide and comparison with commonly ZIRCINOC inoculant, samples with different content of SiC and ZIRCINOC inoculants has been prepared by 3-ton induction furnace (table1). chemical composition of ZIRCINOC is given in table2.

Tab. 1 Specification of different compositions in various step

	Step1		Step2
N-Sample	% SiC	% ZIRCINOC	% ZIRCINOC
1	0.3	0	0
2	0.3	0	0.15
3	0.25	0	0.15
4	0.2	0	0.15
5	0.15	0	0.15
6	0	0.3	0.15

Tab. 2 Chemical analysis of ZIRCINOC inoculants

Elements	Si	Zr	Ca	Ba	Mn	Al	Fe
% wt	65	4.7	1.2	0.8	4.7	0.9	Res

Experiments are done on car parts with standard analysis (GGG40) according to Table 3, In order to investigate the potential of silicon carbide as inoculants.

Tab. 3 Chemical composition range of car part(GGG40)

%Fe	%C	%Si	%Mn	%P	%S	%Mg
Res	3.50-3.60	2.45-2.56	0.251≤	≤0.015	≤0.015	0.035-0.07

The furnace charge contains 40% steel scrap and 60% ductile return. After melting charge, spheroidizing is done into 800 kg ladle. Zircon-ferrosilicon inoculant is added to melt in two stage ladle to ladle (0.3 %wt) and during pouring melt (o.15 %wt). due to unknown behavior of silicon carbide as final inoculants, it has been test in two different situation. First one, it was added 0.3%wt value in ladle to ladle stage. But due to lack of solution silicon carbide into melt it was not proper. Second it was added with ferrosilicon magnesium in ductile making ladle. Ductile making temperature was 1480±10 º C and pouring temperature was 1420±10 º C. all of microstructure samples have cut of car part that molding by green sand (JOLT SQUEEZ Machine).

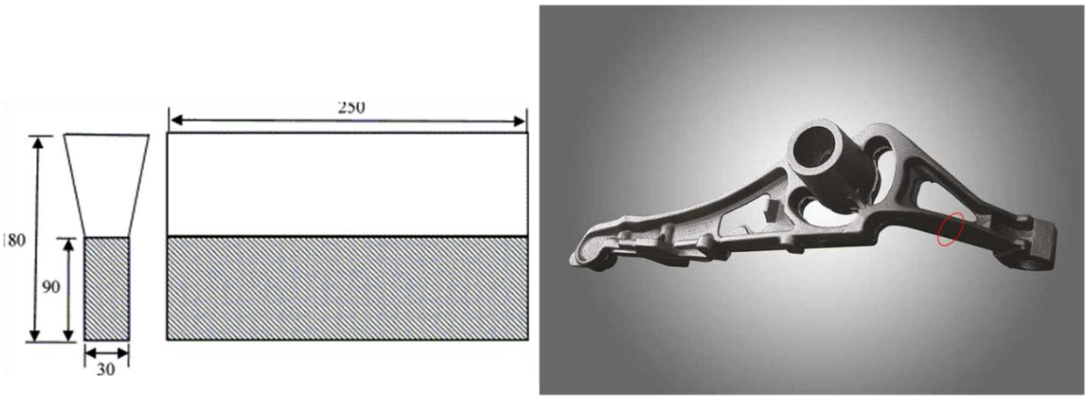


Fig. 1 dimension of Y-Block sample and car part picture under studied (respectively left and right).

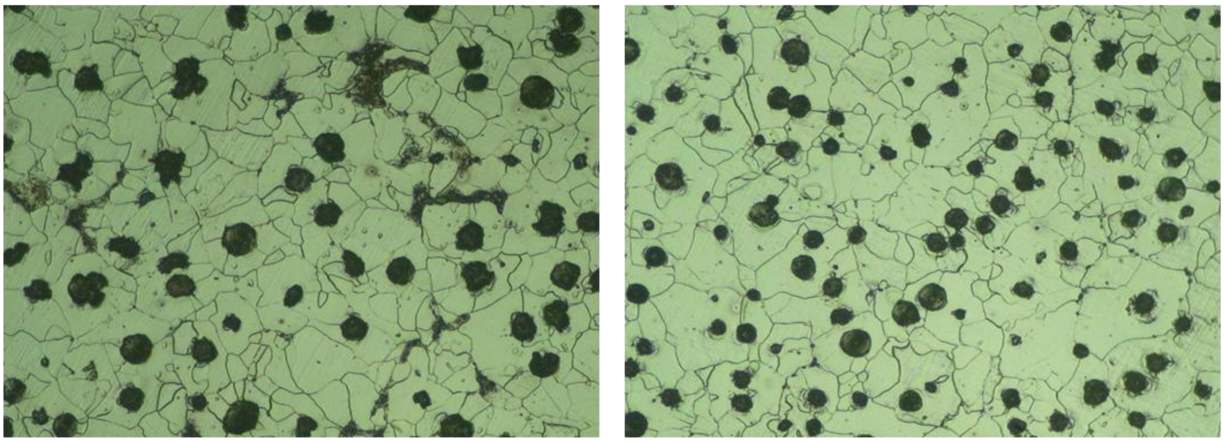
After experiments and preparing sample, effect of inoculating such as nodule count, graphitic spheroid size and microstructure evaluated by optical microscope in 100× magnification. Quantitative analysis of microstructure was done by image analyzer software.

To study the mechanical properties such as yield strength and tensile strength (according to standard E8) Y Block samples was casted(Fig.1). Moreover, Brinell hardness test was performed on samples.

3. RESULT AND DISCUSSION

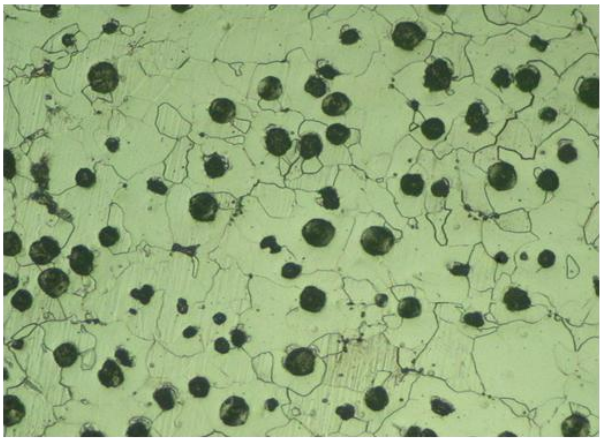
3.1 Microstructure

Figure2 qualitatively shows shape and distribution of spherical graphite, ferrite and pearlite phase with different inoculants value. The metallographic samples were provided of a part with 5mm thickness. Nodule count and pearlite phase content in microstructure with various SiC and ZRSINOC inoculants have been shown in diagram3.

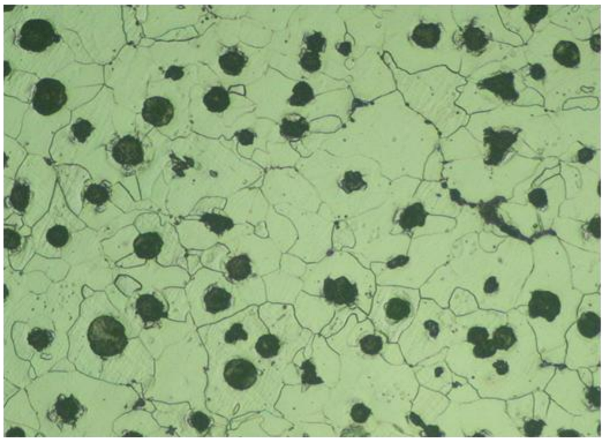


a) Microstructure with 0.3 wt% SiC

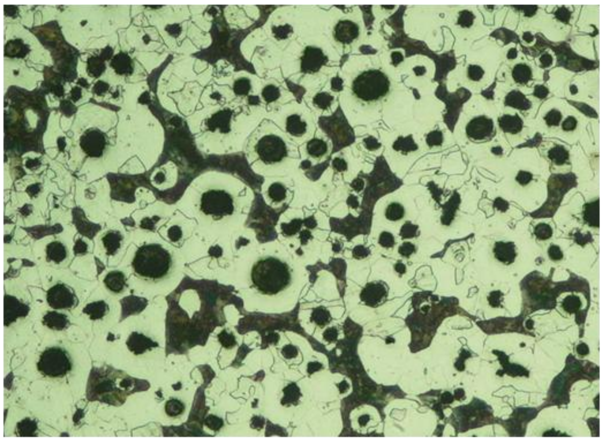
b) Microstructure with 0.3 wt% SiC+ 0.15%wt ZIRCINOC



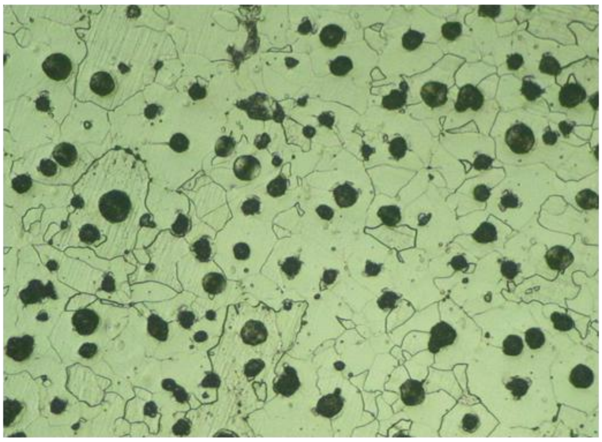
c) Microstructure with 0.25 wt% SiC+ 0.15%wt ZIRCINOC



d) Microstructure with 0.2 wt% SiC+ 0.15%wt ZIRCINOC



e) Microstructure with 0.15 wt% SiC+ 0.15%wt ZIRCINOC



f) Microstructure with 0.45%wt ZIRCINOC

Fig. 2 Microstructures show ferritic ductile iron under different value of inoculants(100X.

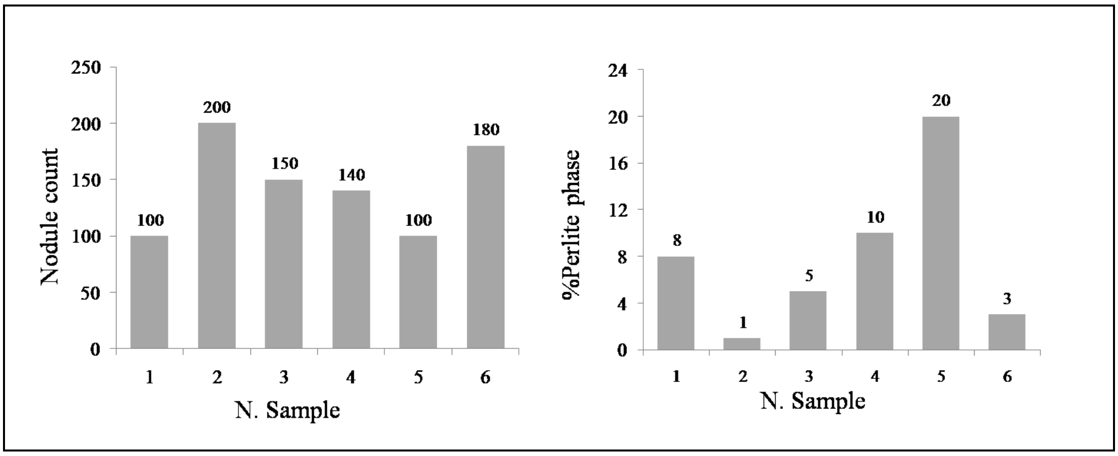


Fig. 3 % pearlite phase and nodule count for different values of inoculants (respectively right and left)

It can be concluded by Quantitative analysis of microstructure of Figure 2, reducing of SiC at first inoculating step to progress pearlite phase. So that is observed, there are most pearlite phase in microstructure with 0.15%wt SiC and 0.15%wt ZIRCINOC. In addition, Figure 3 shows that by reducing the amount of silicon carbide, nodule count decreases. This is probably due to reduced graphite nucleation in melt.

3.2 Mechanical properties

Uni-axial tensile tests and hardness results are illustrated in Figure 4. As it can be observed, hardness, yield and tensile strength properties significantly increased for sample No. 5 with lower inoculants than the other samples.
According to Fig.2 Increasing these values can be attributed to the higher percentage of pearlite phase than the other sample with lower.

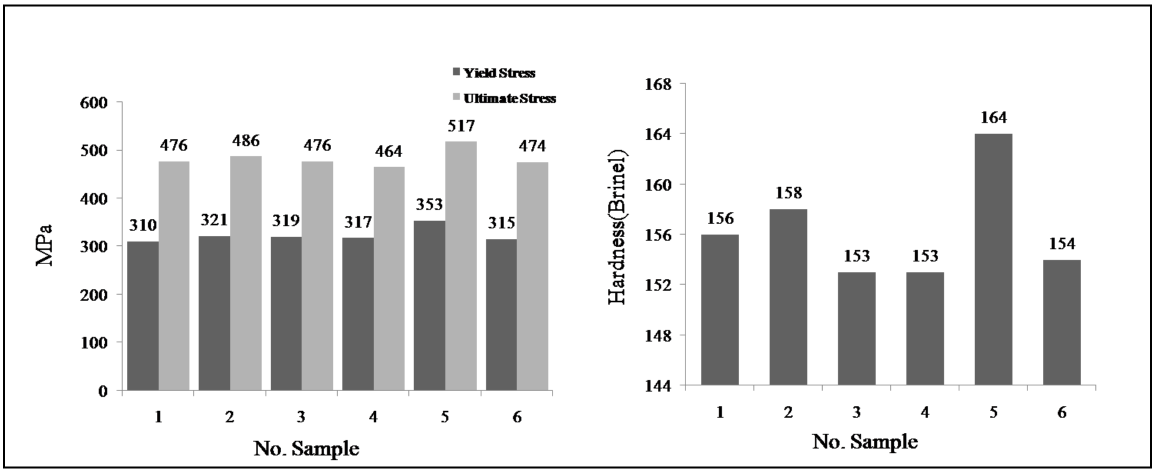


Fig. 4 changes hardness (left graph), yield strength and tensile (right chart) for different values of SiC and ZIRCINOC inoculants.

4. ECONOMIC EVALUATION OF USED SIC AND ZIRCINOC IN INOCULATING PROCESS

After evaluation of microstructure and investigation of mechanical properties, sample with 0.3 % wt SiC and 0.15% wt ZIRSINOC on pouring stage are optimized conditions of inoculating process. of spheroidizing, nodule count and microstructure, this sample(No.2) is comparable with inoculated 0.45%wt ZIRCINOC sample.Thus this inoculant can be replaced by SiC. Moreover, standard requirements for mechanical properties such as yield strength and tensile and hardness are met simultaneously. According to tests, the price is the only difference between two inoculants, so that silicon carbide is almost half the price of ZIRCINOC. The cost reduction associated with inoculants in large foundry with 150 ton melt daily has shown in table.4.

Tab. 4 Raw material costs associated with ZIRCINOC and mixed silicon carbide with ZIRCINOC inoculants

Inoculants	ZIRCINOC	Mixed SiC and ZIRCINOC ratio 3:1	Reduced cost($)
The price per kilogram (U.S. $)	2.67	1.79	0.88
Price per 1 ton melting ductile iron(U.S. $)	12.5	8	4.5
Cost of melting 150 tons per day(U.S. $)	1875	1200	675
Monthly cost per ton melted 4500 (U.S. $)	56250	36000	20250

The economic assessment shows that the use of silicon carbide in the massive production, Costs related to the inoculating operations reduced by 36%.

5. CONCLUSION

The results of the evaluation of silicon carbide as latest inoculants shows that decreased the amount of silicon carbide to 0.15%wt, increased Percent pearlite phase. Subsequently It leads to increased hardness and strength. Compare the structure and mechanical properties of samples, has been inoculated by silicon carbide and ZIRCINOC indicate that SiC is suitable for replacing ZIRCINOC. The studies also show that the optimal amount of of silicon carbide as inoculants is 0.3 wt%. In addition, the 0.15 wt% ZIRCINOC during the pouring melt for achieving the appropriate spherical graphite structure is essential. Using of SiC instead of

ZIRCINOC, reduce the costs of inoculating about 36%. Especially in large scale production it's very considerable.

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