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# Fusion crust characteristic of additional SiC particle in cast iron

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**Abstract.** There have been many researches about improving the properties of materials by adding SiC particle in cast iron in recent years. However, researches on the appearance change, action mechanism, etc. of SiC particle in cast iron have not been deepened. We mainly study the appearance change characteristics of additional SiC particle in cast iron melt and its improvement effect in the paper. The results show that additional SiC particle reacts in cast iron solution, and its size decreases. The phenomenon is summarized as fusion crust characteristic of SiC particle in cast iron. The reaction product of SiC particle fusion crust process can be used as additional nucleation of graphite precipitated core during solidification and the reduced SiC particle after reaction also can be used as additional nucleation of nucleation center for graphite and austenite. Meanwhile, SiC is distributed in a scattered mode, and pin inhibits grain growth in grain boundary.

**Keywords:** SiC; gray cast iron; fusion crust characteristic.

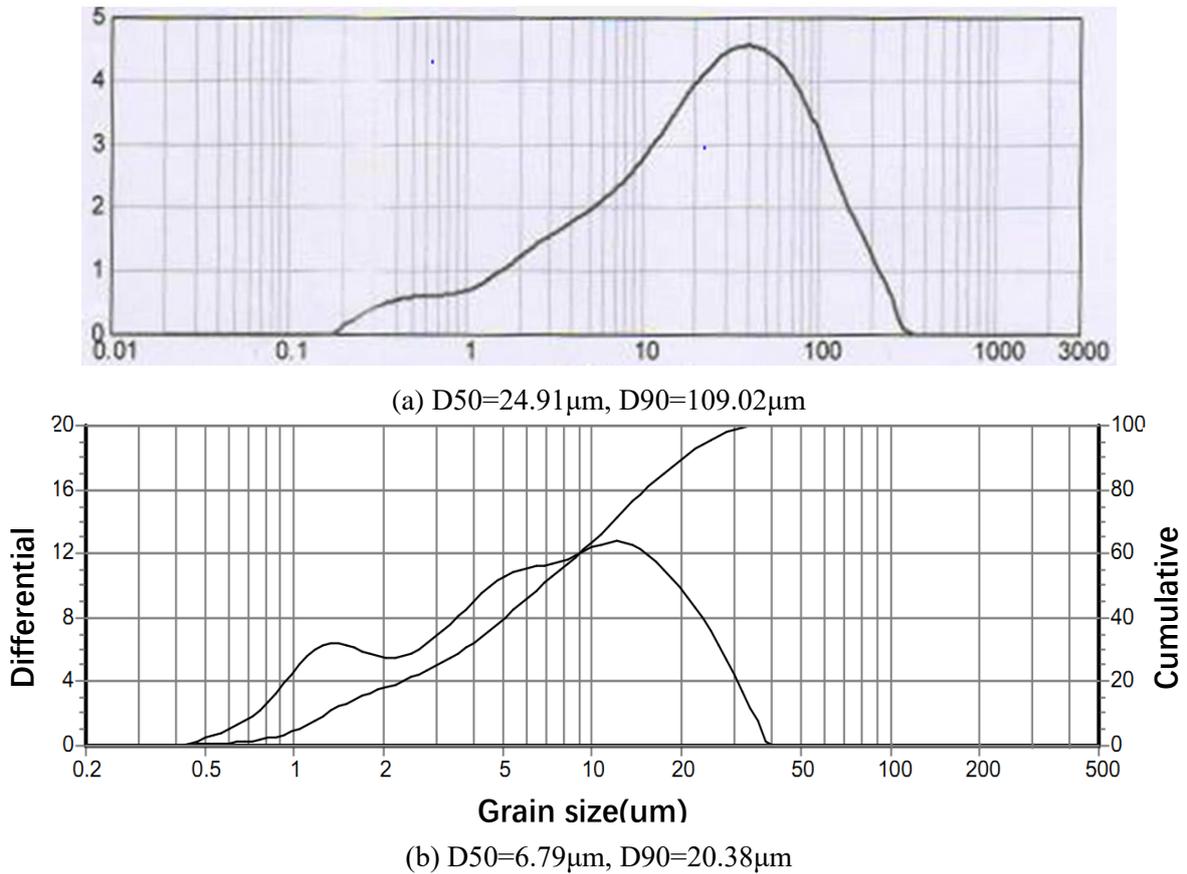
## 1. Introduction

There have been many researches about improving the properties of materials by adding SiC particle in cast iron in recent years. Literature [1-2] belongs to the research result of Russia, wherein the research of literature [1] shows that the addition of trace modified SiC particle can increase the content of pearlite and improve the graphite morphology. Literature [2] shows that the grain size in the tissue of grey cast iron, carbon steel and copper can be significantly reduced by adding a small amount of additional particles such as SiC, etc., thereby improving their mechanical properties. There are also many domestic researches on the issue. Dalian Jiaotong University made a lot of researches in the aspect. Studies in literature [3-6] show that additional SiC particle can improve the mechanical and wear resistance of cast iron. The influence of additional SiC particle on microstructure and hardness of Q235 steel is described in literature [7]. Although certain progress and achievements have been made in the research of additional SiC particle on improving the organization and characteristics of cast iron. However, the research on the appearance change, action mechanism, etc. of SiC particle in cast iron is still not thorough. In the paper, the appearance changes, distribution and other properties of additional SiC particles in cast iron melt and their influence on materials are investigated mainly in the paper.

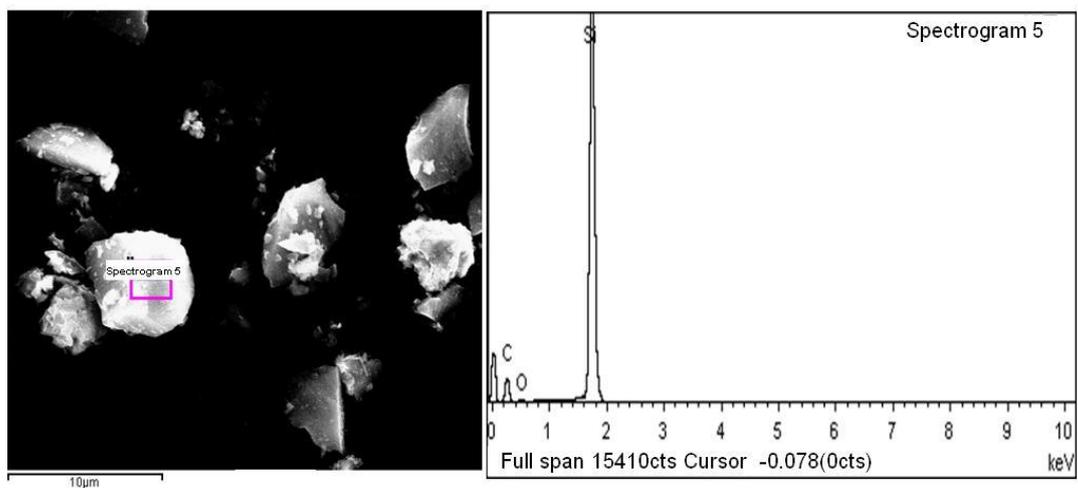


**2. Experimental Procedure**

Two SiC samples with the same raw material, the same manufacturing process and different particle size distributions were selected for the test in order to verify the appearance change of additional SiC in the melt, which were respectively recorded as 1# and 2#. The particle size distribution curves of 1# and 2#SiC were tested as shown in figure 1.



**Figure 1.** SiCp granularity distribution diagram



**Figure 2.** SEM micrograph of modified fine SiC particles

Intermediate frequency melting furnace is used for dosing according to the proportion of 60wt% steel scrap +40wt%recirculated iron. Five elements are dosed according to table 1. Silicon-Calcium-Barium nucleating agent is selected for inoculation. The addition is 0.3wt%. Coupon with diameter of 30mm is cast according to addition of 0.2wt%SiCp.

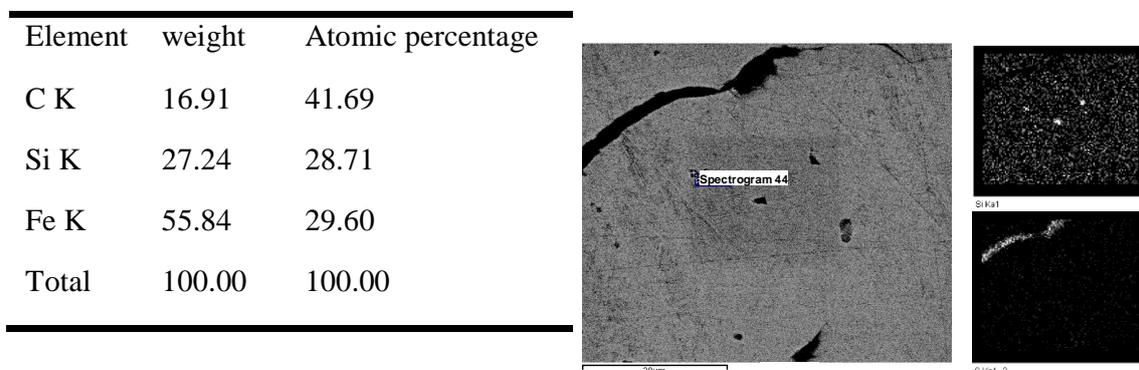
**Table 1.** Main molten iron composition

Element name	C	Si (original)	Si (final)	Mn	P	S
Target value /wt%	3.15-3.25	1.75-1.85	1.9-2.0	0.75-0.85	≤0.06	0.06-0.1

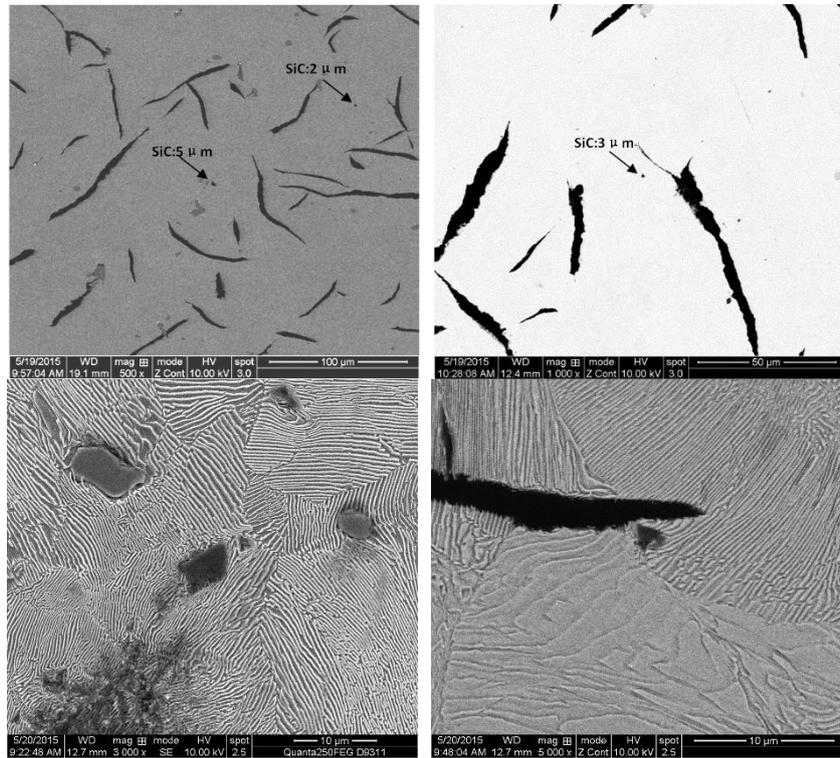
Phase analysis is conducted before and after SiCp treatment by using Empyrean PW1710 X-ray diffractometer. SEM observation is conducted with QUANTA FEG250 scanning electron microscope from FEI company. EDS analysis is conducted with OXFORD. Particle size distribution law of SiC particle was observed and counted by SEM photographs. Graphite morphology and eutectic group are observed by Axio Observer, Dlm inverted metallographic microscope from ZEISS company.

### 3. Results

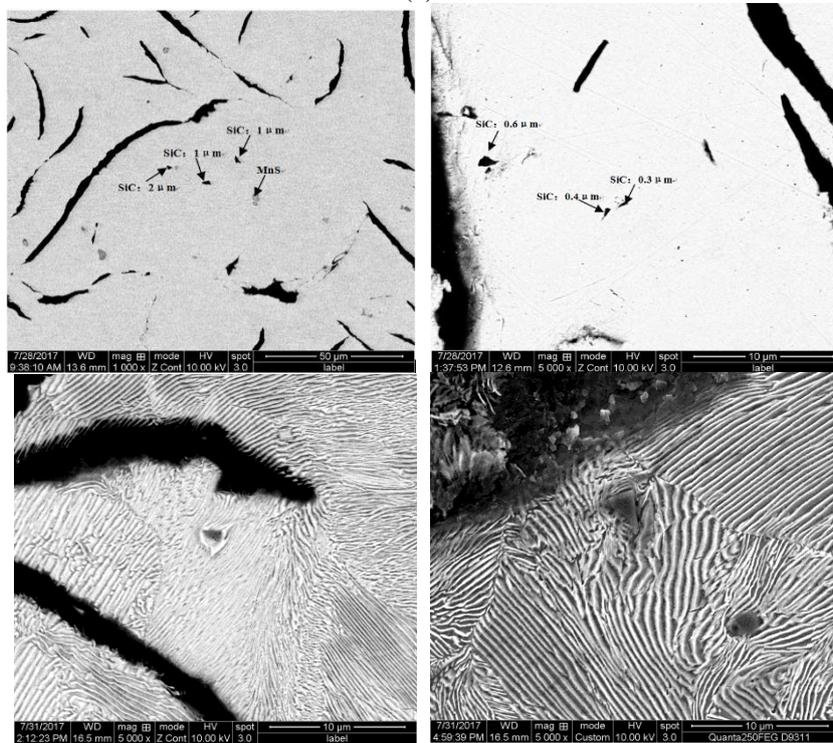
EDS and surface scanning of figure 3 show that three black particles are SiC with particle size of about 3 $\mu$ m. Figure 4 shows that 1# and 2#SiCp are distributed within or at the boundary of the pearlite cluster in the melt. There is no obvious change in the shape of SiC compared with that before the melt is added. The observed grain size is all below 5 $\mu$ m. Table 2 shows the particle size distribution of 1# and 2#SiCp observed by SEM in the random section of four samples of the two plans and the comparison with the particle size distribution before the addition of melt. There are 22 SEM photos in 1# and 41 SEM photos in 2#. It can be seen from table 2 that D50 of 1# and 2# SiCp is 24.91  $\mu$ m and 6.79  $\mu$ m respectively before the addition of melt. The proportion of observed SiC particle size larger than 5 $\mu$ m is always 0.00% after addition of melt. The large size particle that should easily discovered before addition of melt is not found. It is obvious that SiC with large particle size is probably decreased after addition of melt. In addition, it can be seen from table 2 that the particle size distribution of 1#SiCp with large particle size before the addition of melt is mainly 3-5 $\mu$ m after addition of melt, which accounts for 58.33%, while the particle size smaller than 1 $\mu$ m is 0.00%. The particle size of 2#SiCp is mainly in the range of 1-2  $\mu$ m after the addition of melt, which accounts for 52.08%. The proportion of those smaller than 1 $\mu$ m is 20.83%. 2#SiCp is obviously smaller than 1#SiCp in particle size before the addition of melt. However, the decreasing phenomena of SiCp size is more prominent after the addition of melt, thereby indicating that the decreasing speed of SiCp with larger particle size is faster in melt.



**Figure 3.** SiCp EDS and surface scanning



(a)



(b)

**Figure 4.** SiCp distribution and size

**Table 2.** SiC<sub>p</sub> size distribution in SEM

Plan	Before addition of melt		After addition of melt			
	D50	D90	< 1μm	[1-2]μm	[3-5]μm	> 5μm
1#SiC <sub>p</sub>	24.91μm	109.02μm	0.00%	41.67%	58.33%	0.00%
2#SiC <sub>p</sub>	6.79μm	20.38μm	20.83%	52.08%	27.08%	0.00%

#### 4. Discussion

The sizes of 1# and 2#SiC were reduced when they are added into cast iron solution according to the test results. It is obvious that SiC reacted in cast iron solution. The following reactions occur since carbon and silicon are soluble in cast iron solution although SiC does not decompose at cast iron melting temperature under standard state:



$$\Delta G^0 = 3887 + 92.4T \quad (2)$$

Since  $\Delta G^0 \gg 0$ , reaction can be conducted spontaneously to the left, SiC can be decomposed into [Si] and [C] in the iron solution. Meanwhile it is shown that SiC particle observed in figure 3-4 is additionally mixed, since the reaction cannot be carried out spontaneously to the right rather than generation due to internal reaction.

In addition, SiC is inherently unstable in cast iron solution:



$$\Delta G^0 = 9900 - 9.14T \quad (4)$$

The reaction can be spontaneously carried out to the right when  $T > 1083\text{K}$  occurs. The reaction is always carried out in cast iron solution at the casting iron melting temperature [8].

It can be seen that the SiC particle size is gradually decreased since the reaction (1) and (3) occur in cast iron solution.

**Table 3.** Relationship between lattice matching mismatch and capability of nucleation [9]

Mismatch ( $\delta$ )	< 6%	6~12%	> 12%
Nucleation capability	Strong nucleation capability	Nucleation capability	Weak nucleation capability

The SiC particle size reduction in cast iron solution is obviously beneficial to cast iron materials.

Firstly, the small particle after reaction can be used as the center of nucleation to increase the number of nucleation and refine grain. It is calculated that the mismatch degree of SiC and graphite is 8.1%. It can be seen from table 3 that SiC has the ability to be the core of graphite. Literature [10] shows that the heterogeneous crystal nucleus precipitated out of graphite has a size  $< 5\mu\text{m}$ , and it is generally  $0.4\text{-}2\mu\text{m}$ . The SiC particle after reaction in Figure 4 and Table 2 is in line with conditions.

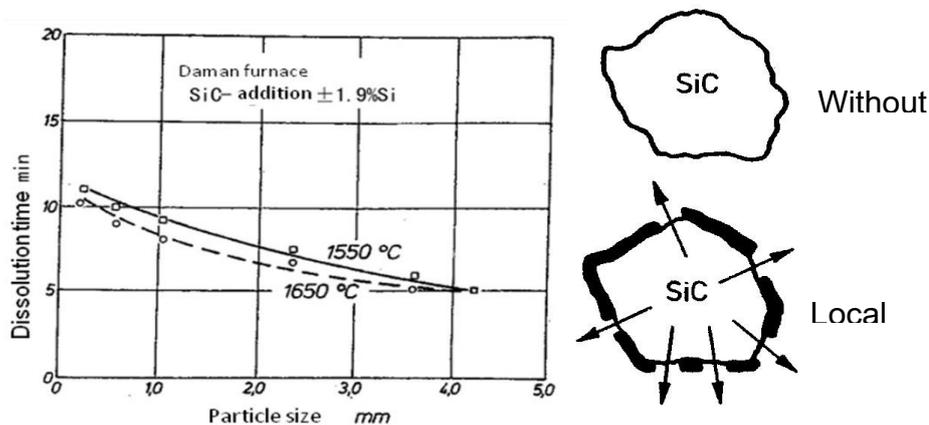
Secondly, C generated by reaction (3) makes C element in cast iron solution unevenly distributed, C element is too high locally, and 'carbon peak' appears in the microregion. The precipitated graphite belongs to non-equilibrium graphite [11], which is the best core of the precipitation.

Thirdly, SiC is diffused in melt, and it can nail grain boundary.

In summary, the reaction size of SiC particle decreases in cast iron solution. The phenomenon is summarized as fusion crust characteristic. It can be inferred that the characteristic also exists in cast steel solution according to fusion crust condition. SiC's fusion crust process and smaller particle after fusion

crust can play a role in grain refinement. The effect of grain refinement can be seen from literature [2][8]. Grain refinement will further improve the corresponding properties of materials.

It can be seen that 1#SiC with large particle size has a faster reaction rate and larger size change in the molten iron than 2#SiC with small particle size according to the comparison of the size distribution of 1# and 2#SiC before addition of melt in table 2. Figure 5 shows the relationship of dissolution time of SiC and particle size, dissolution time is reduced with the increase of particle diameter, the dissolution rate is increased because the epidermis of each SiC particle (in micron level range) is wrapped by the reaction product  $\text{SiO}_2$ ,  $\text{SiO}_2$  hinders the contact of molten iron and SiC. The dissolution rate of a large particle size core is faster than that of a few particles with small diameter. Figure 6 shows that SiC without artificial oxidation treatment uniformly covers the surface of SiC particle on the surface  $\text{SiO}_2$  layer, thereby hindering SiC from precipitating into molten solution. Cracks are formed after oxidation treatment, and the internal SiC can be precipitated through the cracks with controllable change, thereby reaching a slow and timely nucleation action. SiC particle gradually dissolves into iron solution in local regions, especially those rich in Si and C in terms of kinetics. Moreover, low SiC component is objectively allowed to exert the role due to the high solubility of Si and low solubility of C [12].



**Figure 5.** Relationship of SiC dissolution time and particle size in molten iron Figure 6 SiC control

## 5. Conclusion

The morphology change, distribution and other characteristics of additional SiC particle in cast iron melt, and their influence on material are studied in the paper, and the conclusion is shown as follows:

SiC's reaction size decreases in cast iron solution. The phenomenon is summarized as fusion crust characteristic, which also exists in cast steel solution.

2) SiC particle product during fusion crust process in the steel solution and the final small SiC particle play a role in refining the grain. Therefore, fusion crust characteristic is beneficial for improving the performance of steel materials.

3) SiC has a faster reaction speed in casting iron solution with large particle size than small particle size. The speed can be decelerated after oxidation treatment, thereby playing the role of inoculating nucleation timely.

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