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The Effect of Heat Removal from the Casting Mould on the Crystallization High Silicon Cast Iron

M. Stawarz *, M. Gromczyk, J. Szajnar
Silesian University of Technology, Foundry Department, Towarowa 7, 44-100 Gliwice, PL
*Corresponding author. E-mail address: Marcin.Stawarz@polsl.pl

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Abstract

Silicon cast iron with high chemical resistance, which is the biggest advantage of this material, did not have any competition for a long time. It was popular on the market of metal materials because of its low price. However, the production of this material requires special attention and precautions, which is a barrier for foundry. The article presents the results of research of high silicon cast iron crystallization based on thermal derivative analysis (which has identified characteristic temperatures of the investigated alloy crystallization process basis on the part of Fe – Si phase diagram and process analysis using calculations made in Thermo – Calc software) and metallographic analysis of the structure.

Key words: Thermal derivative analysis, Intermetallic phases, High silicon cast iron, Crystallization

1. Introduction

High silicon cast iron is the material representing the group of acid-resistant alloys. It is a ferrous and silicon alloy with another components such as C, Mn, P, S. High silicon cast iron contains 11.5 to 18.0% Si. This material is heat resistant, it can work in conditions up to 1100˚C [1] and it is also wear resistant. The most important advantage of high silicon cast iron is its acid-proofness [2]:

- the alloy with 14.5% Si content – resistance to 30% sulfuric acid;
- the alloy with 16.5% Si content – resistance to sulfuric and nitric acid of any concentration;
- the alloy with 17% Si content – resistance to the copper and chlorine solution.

Unfortunately, this type of cast iron has also got many disadvantages, which limits the production and application of this material. High silicon cast iron can be characterized by [2]:

- low resistance to basis corrosion;
- higher content of Si in the alloy increases its brittleness;
- high casting contraction;
- low mechanical properties;
- tendency to form contraction cavity;
- high tendency to absorb gases.

Carbon has significant influence on technological, mechanical and founding properties of high silicon cast. For each of the silicon content in the alloy there is the optimal scope of C [1]. The carbon content in high silicon cast iron should be decreased while increasing the silicon content in alloy. The influence of carbon can be different on properties of cast iron and it can affect them in negative or positive way.

Benefits resulting from the presence of carbon in high silicon cast iron may are:

- reduction of casting contraction;
- improving machinability of the material;
- reducing brittleness.

However, too high carbon content can lead to decrease of mechanical properties and leakproofness of castings.

This article focuses on the research conducted on silicon cast iron with silicon content increased to 19%. The presented results refer to a series of melts for the specific content of Si. They are the chosen part of studies [3-7] conducted on this material in Foundry Department of Silesian University of Technology.

2. Experimental part

For the experimental melt two kinds of moulds were prepared [3, 8]. Theese moulds were adapted to perform the measurement of temperature changes in time. First mould was made of sand with bentonite and in this mould the metal should cool in conditions close to typical. Whereas in second mould the sibral insert was placed inside, which slowed down the heat transfer from the mould [3]. In each of moulds the thermoelement was in quartz coat. Thermoelements were connected to multichannel converter, which enabled registration of temperature changes in time during the crystallization of the cast iron in moulds.

To the melt of cast iron with 19% silicon content the metal charge made of steel scrap, ferroalloy FeSi75 and carburizer was properly prepared [9]. After melting the charge the molten alloy was poured into heated up casting ladle. Moulds were flooded in sequence: a mould with sibral insole and then the mould without an insert.

Registered changes of temperature in time and calculated values of the first derivative corresponding to them were shown in Figures 1 and 2.

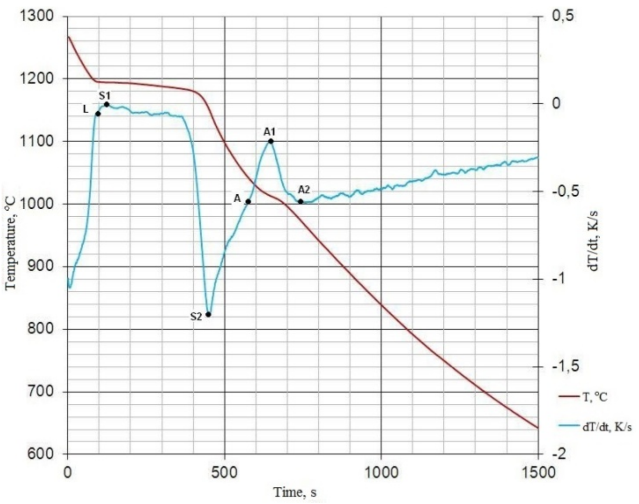

Fig. 1. TDA diagram of high silicon cast iron (19% Si) in sand mould with the sibral insert [7]

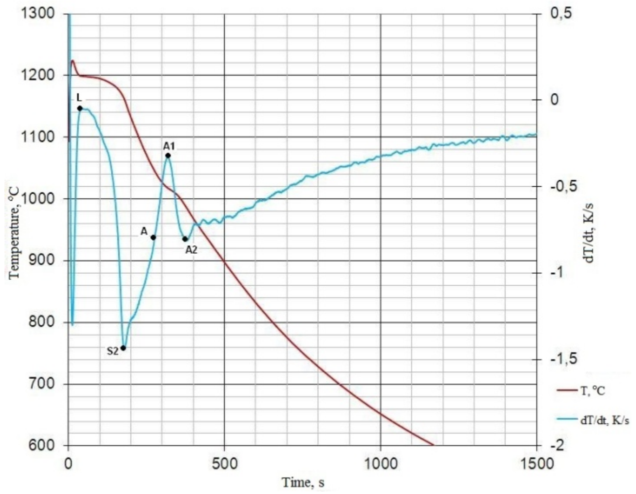

Fig. 2. TDA diagram of high silicon cast iron (19% Si) in sand mould [7]

The use of sibral insert helped to slow down the crystallization process. Analysis of the experiment results for the examined alloy was focused on observation of the thermal effects of crystallization process at liquid and solid state. Based on visible characteristic points on the crystallization curve (first derivative of temperature change in time) the characteristic temperatures of crystallization process were designated. Significant temperatures were determined using the part of Fe – Si phase diagram (Fig. 3) and based on the calculations made in Thermo – Calc software (Fig. 4).

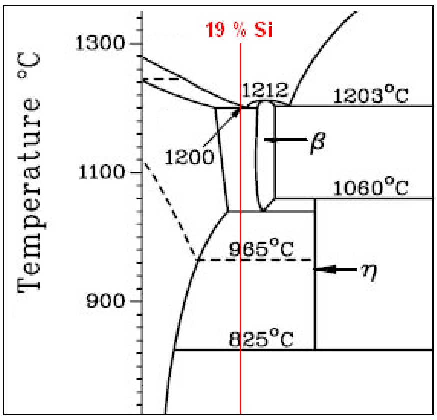

Fig. 3. Part of the Fe – Si phase diagram [10]

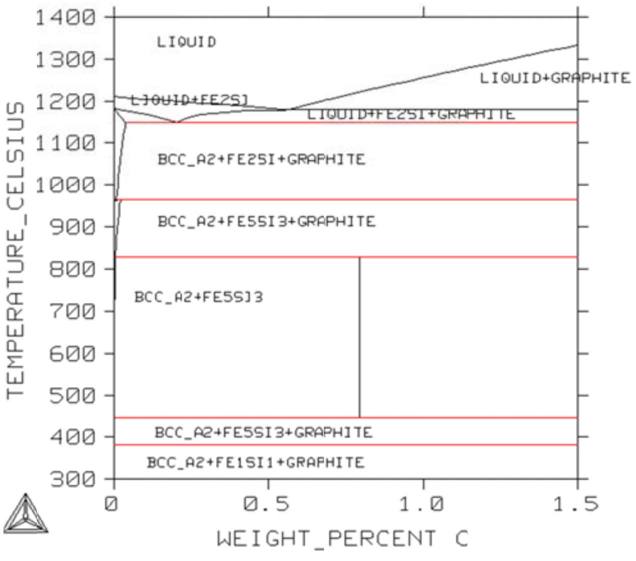

Fig. 4. Thermo Calc analysis

The L point projected onto the cooling curve determines the start temperature of primary crystallization TL (liquidus), the S1 point projected onto the cooling curve is associated with the maximum thermal effect of eutectic crystallization in temperature TS1. The S2 point projected onto the temperature curve determines the end of the primary crystallization temperature TS2 (solidus). The TA temperature at point A defines the start of Fe_2Si phase transition to Fe_5Si_3 phase. The temperature of the maximum thermal effect of this transition TA1 was determined by projecting the A1 point on the cooling curve. Based on the A2 point the finish temperature of Fe_2Si to Fe_5Si_3 phase transition TA2 was estimated. Characteristic temperatures obtained from the graphs analysis (Fig. 1-2) were summarized in Table 1.

Table 1.
Characteristic temperatures of crystallization process for the different conditions of heat transfer from mould

	TL, °C	TS1, °C	TS2, °C	TA, °C	TA1, °C	TA2, °C
Sibral	1205	1195	1155	1040	1015	970
Sand	1205	1205	1150	1040	1025	985

Pictures of examined cast iron microstructure were presented on Figures 5-6. The large amount of Fe_5Si_3 phase precipitations (dark area) and graphite in silicon-ferrite matrix (bright area) can be seen. In matrix the needle longitudinal elements of the structure which were classified as primary Fe_2Si phase crystallizing directly from the liquid can also be noticed, they are indicated with arrows in microstructure pictures.

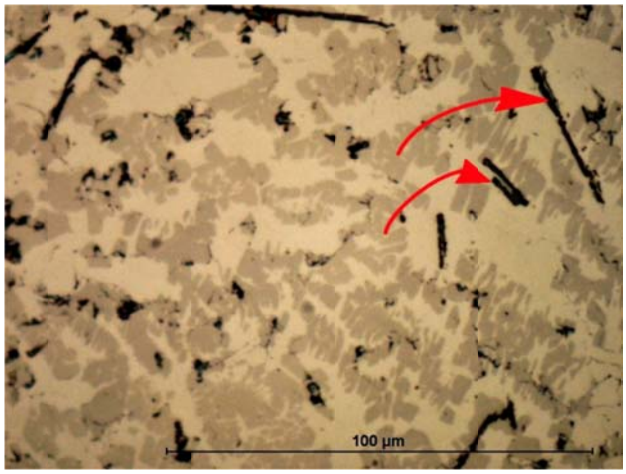

Fig. 5. Microstructure of high silicon cast iron with 19% Si content cast into a sand mould

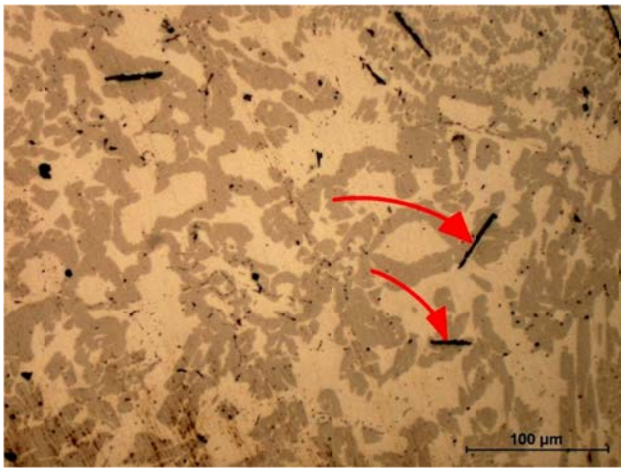

Fig. 6. Microstructure of high silicon cast iron with 19% Si content cast into a mould with sibral insert

Analysing the metallography of the alloy it may be noted that the amount of graphite visible in pictures is quite low, which is consistent with the recommended low carbon content for the alloy with silicon content of 19%. From chemical analysis (using the analyser C and S LECO) that the carbon content in examined alloy was 0.52%.

A greater amount of primary Fe_2Si phase precipitations was observed in the microstructure of the alloy solidifying in the mould without the insert of sibral. The quantitative analysis was conducted using a computer image analyser from Nicon with NIS – Elements BR software.

3. Conclusions

In matrix of silicon cast iron with 19% Si content two kinds of intermetallics appeared – Fe_2Si phase in the form of needle longitudinal precipitates (Fig. 5 – 6), which was classified based on the calculation in Thermo – Calc (Fig. 4) and the analysis of the Fe-Si phase diagram (Fig. 3) as a primary precipitation crystallizing directly from the liquid and the Fe_5Si_3 phase. Slowing crystallization process resulted in decrease of primary Fe_2Si phase precipitations amount. The thermal effect of the crystallization of Fe_2Si phase was not identified on the registered curves (Fig. 1-2).

The use of two different conditions of heat transfer from the casting mould affects the recorded value of characteristic temperatures of crystallization process and morphology of microstructures.

The lower value of recorded temperature (about 10°C for the mould with sibral insert) was observed for S1 point associated with maximum thermal effect of eutectic crystallization. The analogical differences were noticed for A1 point, which describes the maximum thermal effect of transition Fe_2Si phase to Fe_5Si_3 while the temperature describing the end of this transition was lower for about 15°C.

For both analysed cases, there was no difference in the liquidus temperature TL (1205°C) and for the start of Fe_2Si to Fe_5Si_3 transition in point A (1040°C).

The higher temperature (about 5°C) for S2 point was registered for the alloy solidifying in the mould with sibral insert.

In the next stage of the research it is planned to execute the phase analysis of components of alloy matrix and statistical connection of results received from TDA analysis and metallographic examinations.

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