CRYSTALLIZATION PROCESS OF INTERMETALLIC PHASES IN HIGH SILICON CAST IRON

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Abstract

Presented research focused on high silicon cast iron with 19% silicon content. The studies were conducted in two steps. In the first step the crystallization process analysis using TDA method was executed, metallographic examination on optical microscope was made and calculations in Thermo - Calc were performed. Two different intermetallic phases were noticed in cast alloy: Fe_5Si_3 and probably Fe_2Si. In the second step the EDS analysis on scanning electron microscope was conducted, which has proven the occurrence of primary Fe_2Si precipitation. These phases significantly affect the quality of high silicon cast iron.

Keywords: Intermetallic phases, silicon cast iron

1. INTRODUCTION

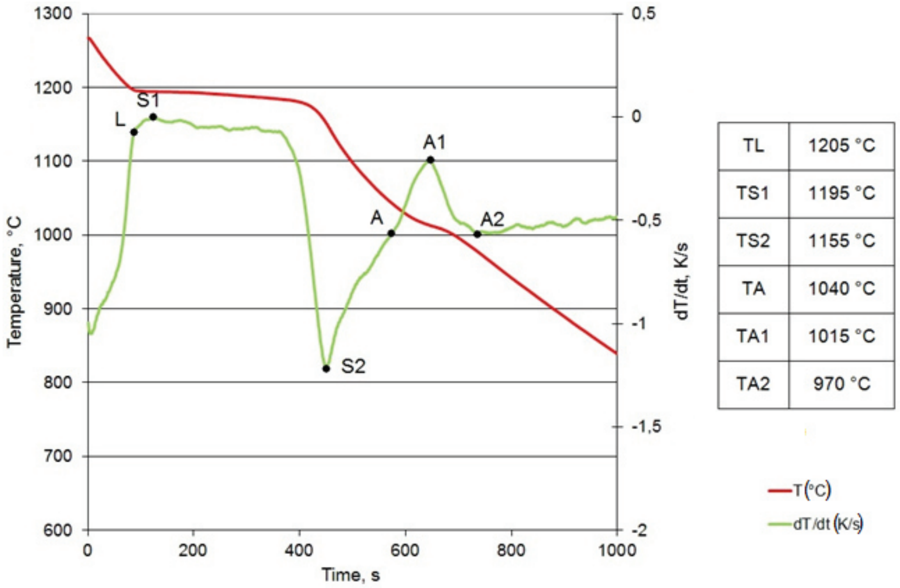
The execution of appropriate casting for industry poses many challenges for engineer. Most of castings are used for work in specific conditions. Of course, entrepreneurs are looking for material, which has got very good properties and low cost at the same time but it often does not go hand-in-hand. Undoubted advantage of high silicon cast iron is its low price in relation to properties which this material can achieve [1-7]. However, HSCI production entails many difficulties like internal stresses, porosity, cracks and finally defective products. For this reason the attention to detail of mould technology and casting process are very important. High silicon cast iron is usually applied for castings working in acid environment [8-10] (equipment for sulphuric acids, reaction apparatus, compressors) but because of its high hardness value the wear resistant of material is also good and it can be used in abrasion conditions [11]. Nevertheless the high hardness value is reason for low impact strength and high brittleness at the same time. Through the appropriate control of crystallization process the formation of preferential phases [12] is possible, which affects the properties and quality of high silicon cast iron. The most used HSCI are with 14-16 % Si content, this studies focused on cast iron with silicon content increased to 19%. In this alloy two different intermetallic phases Fe_5Si_3 and Fe_2Si appeared, which can affect the properties in many ways.

2. EXPERIMENTAL PART

Presented work is a part of studies conducted on high silicon cast iron in Foundry Engineering Department of Silesian University of Technology [13]. The studies were made in two steps. In the first step the TDA analysis were executed, metallographic examination using optical microscope was made and calculations in Thermo - Calc were perform. In the next step the EDS analysis on scanning microscope was done. The experiment was executed on material with 19% of silicon casted into TDA - Is tester. Analysis of crystallization process was conducted using TDA method supported by calculations made in Thermo - Calc software [14].

2.1. Crystallization analysis

Silicon cast iron was melted using electric induction furnace with the capacity of 20kg with corundum brickwork. Charge for melt consisted of steel scrap, ferroalloy FeSi75 and carburizer Ranco. Preliminary carburizing of alloy was applied [15]. The charge materials were casted using double melting technique and appropriate deoxidation [12]. Chemical Analysis on LECO analyser revealed 0.52% content of carbon. Crystallization analysis was conducted in TDA - Is probe with Sibral insulating insert. **Figure 1** presents recorded and calculated cooling and crystallization curves for HSCI 19.



TL	1205 °C
TS1	1195 °C
TS2	1155 °C
TA	1040 °C
TA1	1015 °C
TA2	970 °C

Figure 1 ATD curves with characteristic points of crystallization

On crystallization curve there is clearly visible peak during crystallization in solid state. It is thermal effect of F_2Si to Fe_5Si_3 phase transition. Characteristic points related with Fe_5Si_3 hard phase crystallization were marked on graph by points A, A1, A2. Those points projected onto cooling curve define temperatures of: the start of F_2Si to Fe_5Si_3 phase transition (TA), maximum thermal effect (TA1) and the end of this transition (TA2). Points L, S1 and S2 projected onto cooling curve define the liquidus temperature (TL), the maximum thermal effect of eutectic crystallization (TS1) and temperature of the end of primary crystallization (TS2).

2.2. Metallographic examination

Samples for metallographic examinations were cut from place near the thermocouple. Samples have been properly prepared by multi-stage surface grinding and polishing to execute metallographic examination. During the observation of microstructure two kinds of intermetallic phases have been noticed. The microstructure of HSCI 19 with marked two types of precipitation were presented in **Figure 2.** Furthermore, the analysis from Thermo Calc software was shown (**Figure 2**) and referred to selected phases.

These analysis allows to detect the presence of silicide phase (Fe_5Si_3) and primary precipitates of

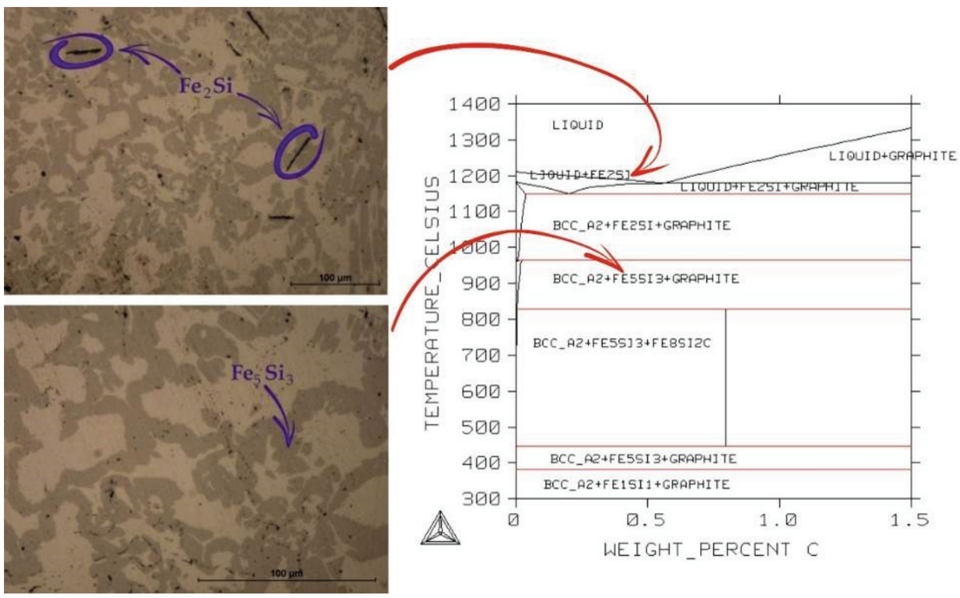


Figure 2 Microstructure and Thermo Calc analysis for HSCI 19

Fe_2Si crystallizing directly from the liquid. From literature is known significant influence of Fe_5Si_3 phase to corrosion resistance of high silicon cast iron. They may also affect the wear resistance because of their high hardness. However, the appearance of primary precipitates may result in increased brittleness and deterioration of impact strength of the alloy.

2.3. SEM analysis

In the second step of experiment the EDS analysis on scanning electron microscope was conducted to confirm the presence of primary phase in alloy and to verify the microstructure of the examined precipitates. The analysis was performed on the fracture of HSCI 19 sample using Phenom ProX SEM. In **Figure 3** the testing sample in macro scale was presented and in **Figure 4** the microstructure of fracture was shown.

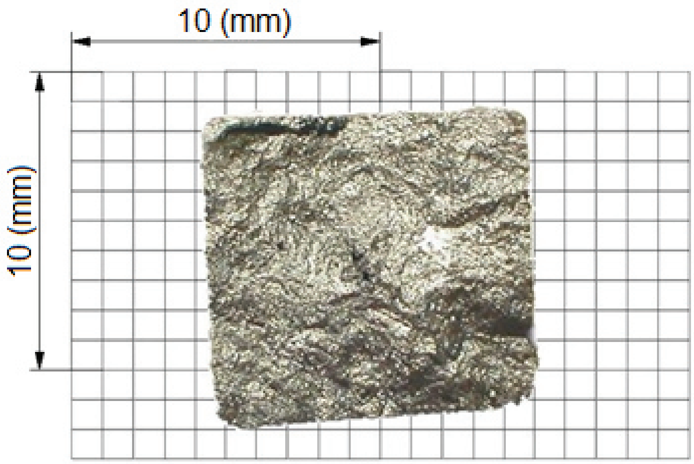


Figure 3 Fracture of HSCI 19 sample in macro scale

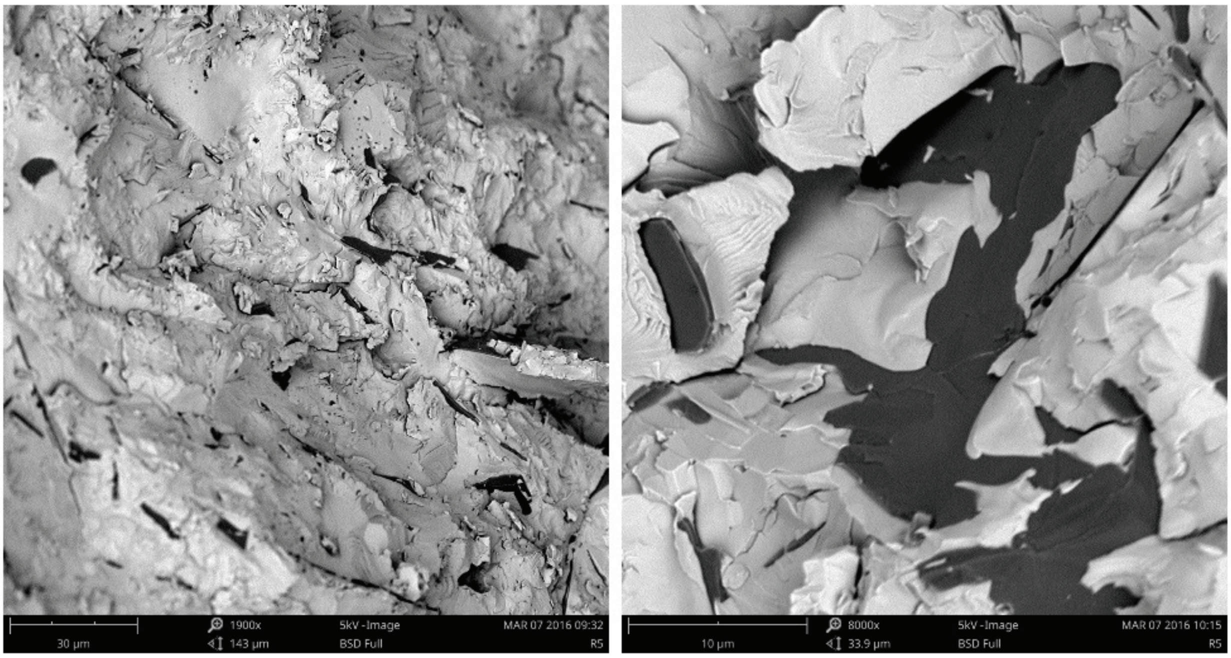
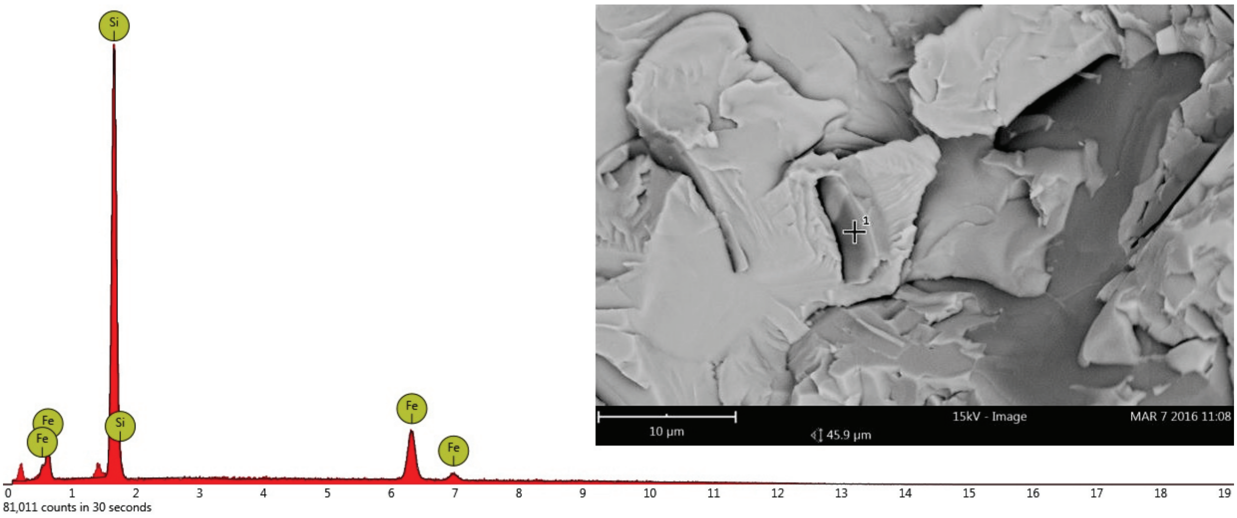


Figure 4 Microstructure on SEM

In photos from scanning microscope the large and longitudinal precipitates of Fe_2Si primary phase (dark places) are also clearly visible. Most of them have a shape of flat plate-like precipitates.

In **Figure 5** the results of EDS analysis were presented with pictures with markings of testing places.



Element Number	Element Symbol	Element Name	Weight Concentration	Error
14	Si	Silicon	60.1	0.0
26	Fe	Iron	39.9	0.1

Figure 5 EDS analysis on SEM

The EDS analysis showed the presence of iron and silicon in indicated place, which confirmed that the analyzed precipitates were Fe_2Si phase crystallized from a liquid.

3. CONCLUSION

Based on conducted studies and obtained results the following conclusions were drawn:

- TDA analysis and metallographic examinations of high silicon cast iron revealed the presence of large amounts of Fe_5Si_3 phase in matrix for 19% silicon content,
- the other intermetallic phases and the EDS analysis showed the presence of iron and silicon in indicated place, which confirmed that the analyzed precipitates were Fe_2Si phase crystallized from liquid,
- Fe_5Si_3 phase has a significant influence on corrosion resistance of high silicon cast iron, it may also increase the wear resistance by its high hardness,
- the appearance of primary precipitates may result in increased brittleness and decrease of impact strength of the alloy,
- appearance of different intermetallic phases may be related to the pouring point and cooling rate.

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