ANALYSIS OF THE HIGH SILICON CAST IRON CRYSTALLIZATION PROCESS WITH TDA METHOD

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Abstract

The high silicon cast iron is a very attractive material because of its corrosion and abrasion resistance and also the ability to work at high temperature. The additional advantage of this material is the low production cost. Unfortunately, the material, despite the attractive properties, makes considerable inconveniences during the manufacturing process [1, 2]. The applications, these days, are limited to corrosion resistance. It has for example a high resistance for sulphuric acid. But also as electrode for cathodic corrosion resistance, it is still very popular [3]. This material is back slowly for industrial applications but still missing detailed knowledge, for example about the influence of technological parameters on the quality of the alloy, etc. In this paper the research results of crystallization process of alloyed cast iron with high silicon content were presented. Two alloys with a silicon content at 17 and 19% were chosen to research. The results of crystallization process were based on thermal derivative analysis TDA [4, 5]. Using the recorded data a derivative of the temperature variation was calculated, what allowed to determine the characteristic points of the crystallization process. The results made possible to identify the phase transitions in the studied alloys and to describe phases that were shown during the metallographic examination.

Keywords: Silicon cast iron, crystallization, thermal derivative analysis, intermetallic phases

1. INTRODUCTION

The main subject of the work is to use the thermal derivative analysis method to study the crystallization process of high silicon cast iron with the variable silicon content in alloy. In the article the hard Fe_5Si_3 phase precipitates were also included. The evaluation of the effectiveness of used method and the quality assessment of resulting alloys were the aim of the research. Huge competitiveness on foundry market forces producers to shorten the manufacturing process while ensuring high quality castings and their affordable price. During the casting process the casting microstructure directly affects the mechanical and technological properties of the final products. An important factor, which leads to the improvement of the quality of the castings, is the right application of knowledge about mechanisms of crystallization. That enables easy control of the crystallization kinetics during the manufacture of casting for the optimization of the resulting microstructure and properties. This knowledge can be very useful in the production of high silicon cast iron which makes a lot of difficulties in manufacturing process. High silicon cast iron is a brittle and low thermal shock resistant material. It requires special precautions during the manufacturing process [1, 2] and the proper preparation of charge materials [6].

2. EXPERIMENTAL PART

During the experimental studies the test stand described in paper [5] was used. Charge materials were prepared, melting process was performed and additions were added to the melt [6-14]. The experiment was performed for two alloys with high silicon content 17% and 19% respectively. Samples were cast into sand moulds with the addition of bentonite (TDA tester), which were shown in paper [4].

2.1. TDA analysis

Temperature changes over time registered during the experiment and calculated values of first derivative were shown on **Fig. 1** and **2**. To identify the characteristic temperatures of crystallization process the analysis made in ThermoCalc and Fe - Si phase diagram were used. The L point projected onto a cooling curve determines the start temperature of primary crystallization TL (liquidus), which is also associated with the maximum thermal effect of eutectic crystallization. The S point projected onto the temperature curve determines the end of the primary crystallization temperature TS (solidus).

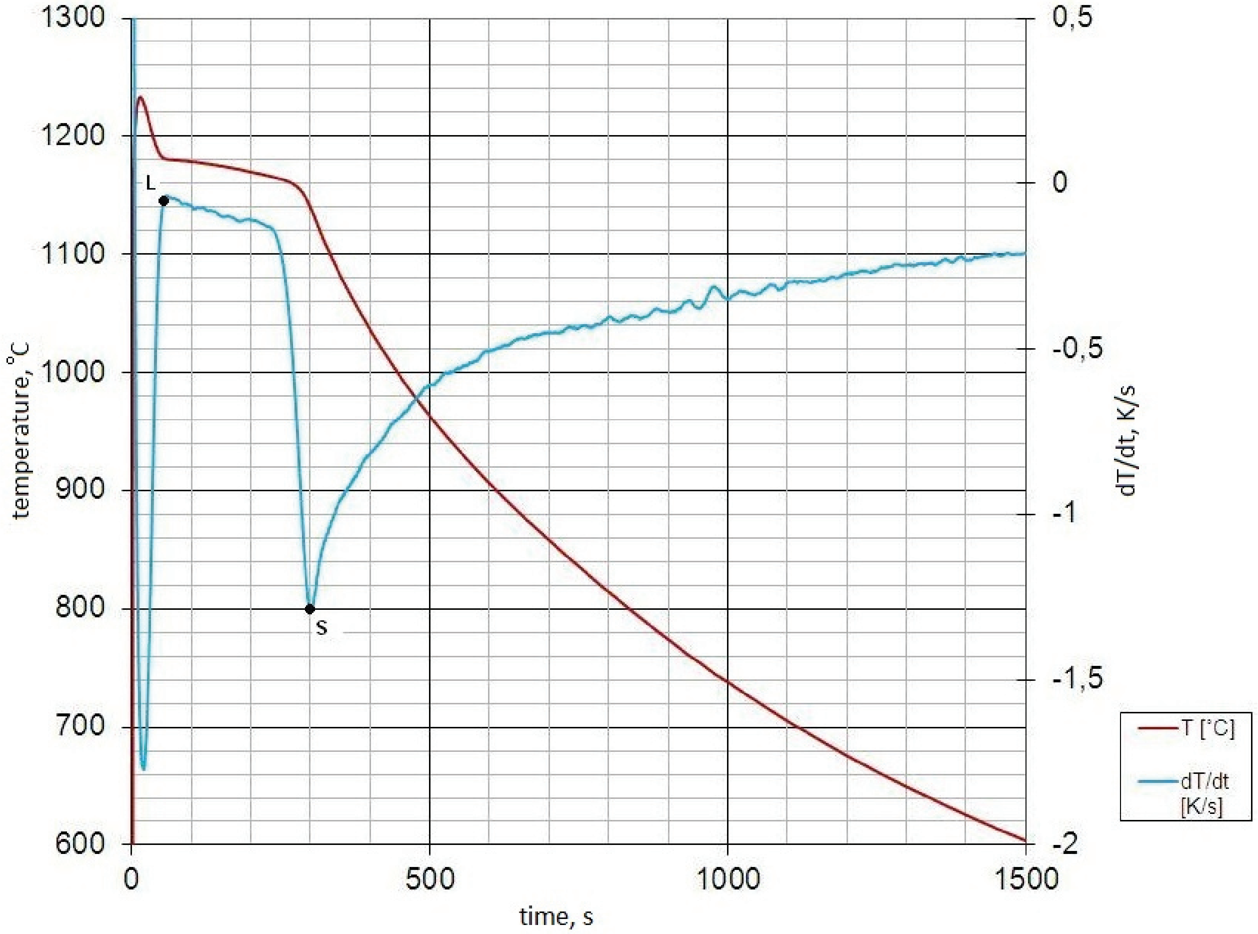

Fig. 1 TDA curves with the characteristic points,silicon content 17 %

Based on the recorded data the significant thermal effects in the solid state which may be comparable with the Fe - Si phase diagram were not detected. The maximum temperature recorded on the graph is 1233 °C. During the analysis made for cast iron with 19% silicon content it was possible to obtain more informations about solid state transitions wich can be observed on **Fig. 2**.

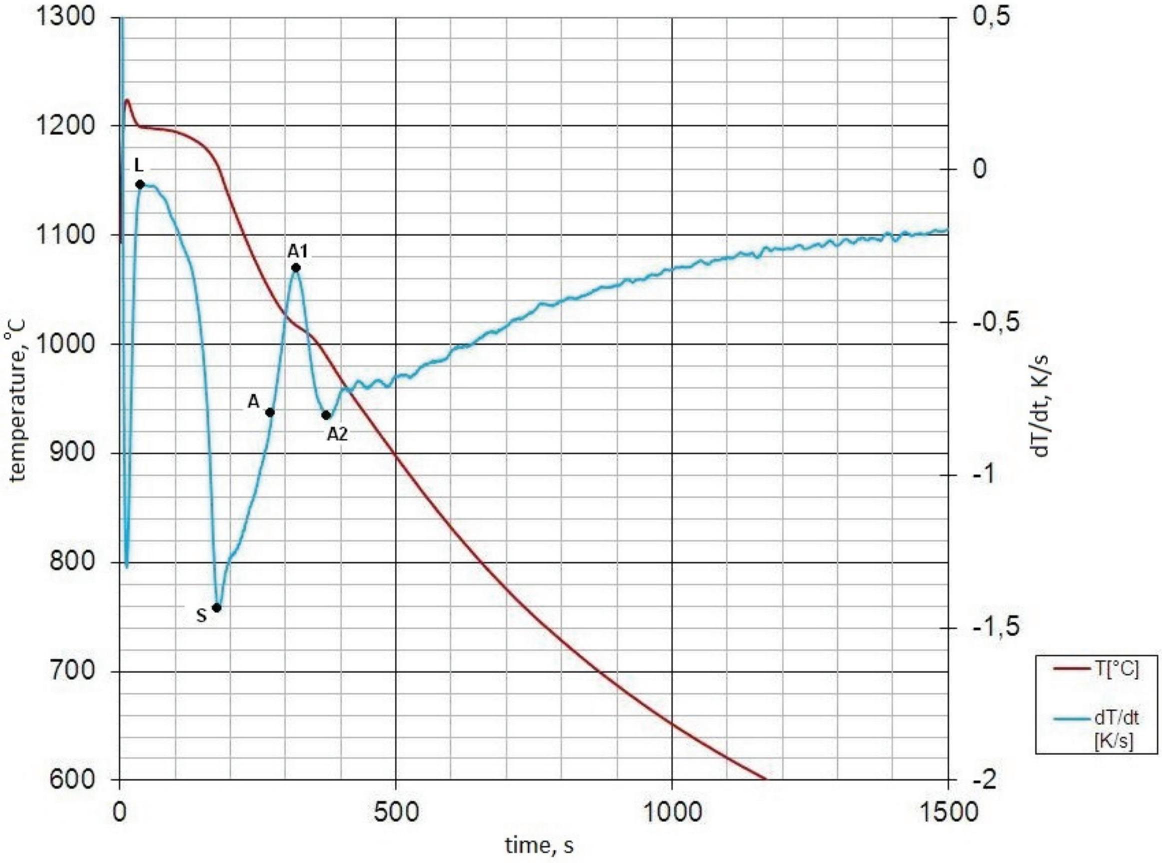

Fig. 2 TDA curves with the characteristic points, silicon content 19 % [15]

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 was estimated. Characteristic temperatures obtained from the graphs analysis (**Fig. 1** and **2**) were summarized in **Table 1**.

Table 1 Characteristic temperatures of TDA analysis

	TL, ˚C	TS, ˚C	TA, ˚C	TA1, ˚C	TA2, ˚C
17%Si	1190	1150	-----	-----	-----
19%Si	1205	1150	1040	1025	985

2.2. Metallographic analysis

Samples for metallographic examination were taken from castings made in moulds to TDA analysis. They were cut from the place where thermocouple was located. Pictures of microstructure were presented on **Figs. 3 - 5**.

On the microstructure presented on **Fig. 3** the precipitates of nodular graphite can be seen. Despite the high silicon content in the alloy, the amount of silicide phase is small, which is in accordance with the results obtained from the TDA analysis and the numerical calculations by ThermoCalc.

On pictures of microstructure (**Fig. 4**) the precipitates of Fe_5Si_3 in silicon-ferrite matrix can be seen. It can be also noticed the needle longitudinal elements of the structure which were classified as primary Fe_2Si phase (**Fig. 5**).

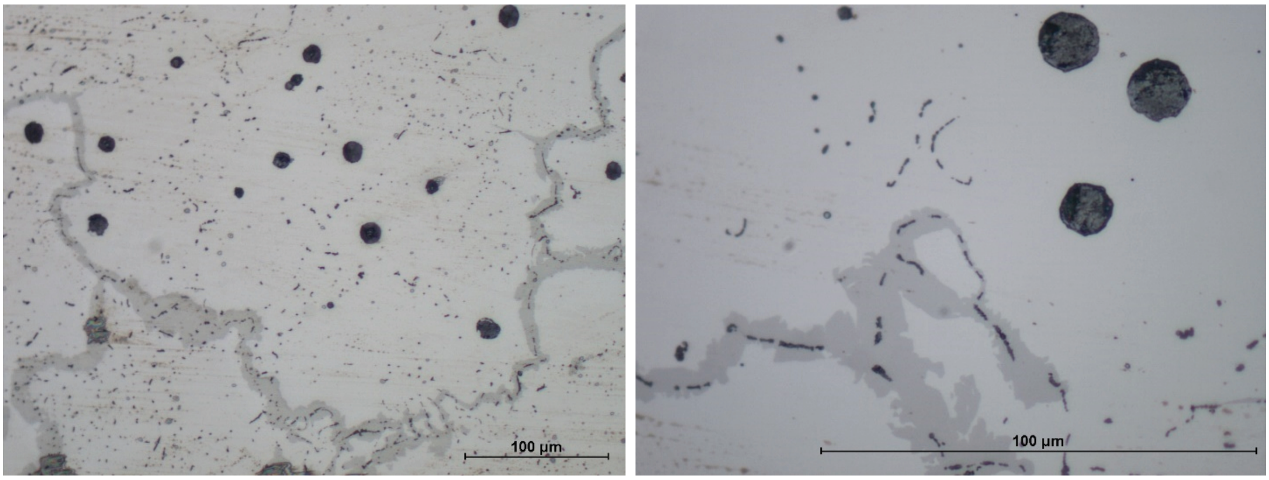

Fig. 3 Microstructures of silicon cast iron, silicon content 17 %

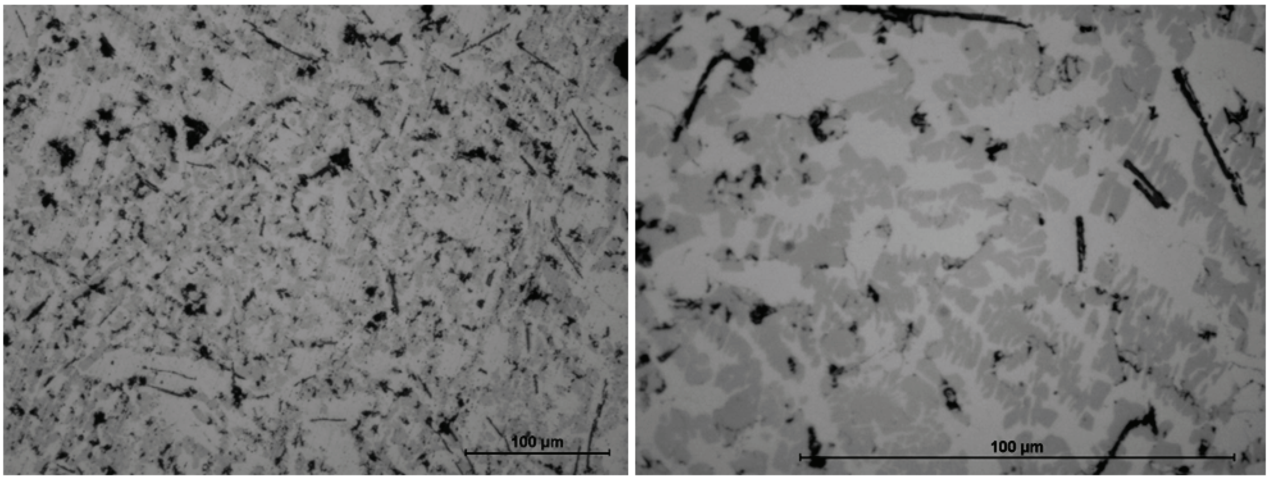

Fig. 4 Microstructures of silicon cast iron, silicon content 19 %

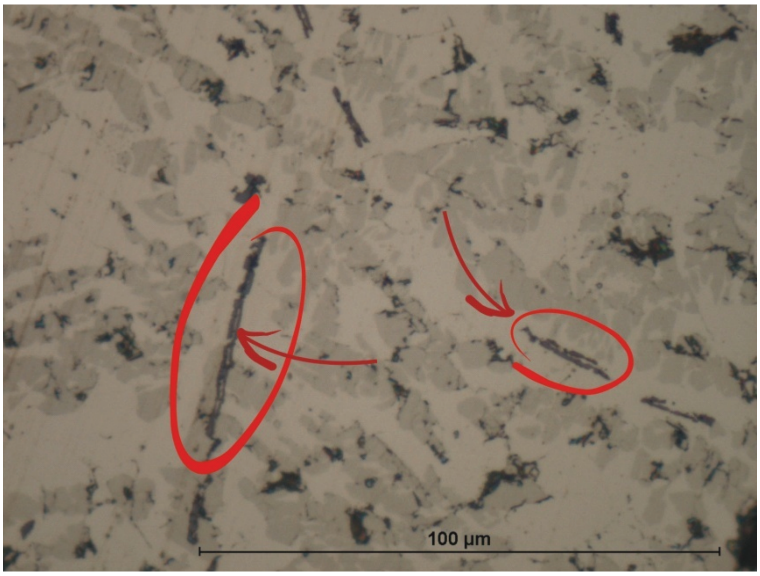

Fig. 5 Primary precipitates of Fe_2Si phase, silicon content 19 % [15]

3. CONCLUSIONS

Based on the conducted studies the thermal effect in solid state (Fe_2Si phase transition to Fe_5Si_3 phase) was not observed on the TDA graph (**Fig. 1**) for the casting with silicon content at 17 %. On pictures of microstructure (**Fig. 3**) the silicide phase is clearly seen but the amount of it is quite small, which is in accordance with the results obtained from the TDA analysis and the numerical calculations by ThermoCalc. Accordingly, it is presumed that the thermal effect generated from the silicide phase crystallization was to small and the testing equipment could not register it.

In matrix of alloy with 19 % silicon content two kinds of intermetallics appeared - Fe_2Si phase in the form of needle longitudinal precipitates (**Fig. 5**), wich was classifided based on the calculation in ThermoCalc and the analysis of the Fe-Si phase diagram as a primary precipitate crystallizing directly from the liquid and the Fe_5Si_3 phase. The thermal effect from the crystallization of Fe_2Si phase was not identified on the registered curves (**Fig. 2**). The thermal effect from the transition of Fe_2Si to Fe_5Si_3 phase is clearly visible on the TDA diagram. Some of the conducted analyzes should be confirmed by the other research. However, significant results were achieved and they can be used in the realization of further considerations on the analysis of high silicon cast iron quality. Despite the increasing silicon content in the alloy, which has a significant effect on the corrosion resistance of this alloy, there was not observed any large decrease of durability of castings poduced from this material while the hardness was incrased (relatively to the cast iron with 15% Si content [4]).

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