ANALYSIS OF AlSi9Mg ALLOY CRYSTALLIZATION WITH USE OF ATND METHOD

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Summary

The paper discusses crystallization research aluminum-silicon casting alloy (AlSi9Mg) with use of Thermal-Voltage-Derivative Analysis method (ATND). Method of analysis of non-ferrous metals crystallization assures comprehensive image of formed structural components of the alloy. Below are shown results of crystallization analysis of ATND method in graphic form (crystallization diagrams). In the crystallization diagrams of the AlSi9Mg alloy are presented thermal and voltage curves with their derivative. Individual structural constituents crystallizable in the investigated alloy are reflected on curves of the method in form of characteristic peaks. Moreover, the paper presents structures of the investigated alloy together with marked structural constituents which were identified with use of X-ray microanalysis.

Keywords: fundamentals of foundry processes, crystallization, structural constituent, ATND method

Analiza krystalizacji stopu AlSi9Mg metodą ATND

Streszczenie

W pracy przedstawiono wyniki badań procesu krystalizacji stopu AlSi9Mg metodą Analizy Termiczno-Napięciowo-Derywacyjnej (ATND). Metoda ATND daje pełny obraz powstających składników strukturalnych stopu. Wyniki analizy krystalizacji przedstawiono w postaci graficznej (wykresów krystalizacji). Wykresy krystalizacji stopu AlSi9Mg obejmują krzywą termiczną wraz z jej pochodną oraz krzywą napięciową i jej pochodną. Krystalizujące składniki strukturalne w badanym stopie są odzwierciedlone na krzywych metody ATND w postaci charakterystycznych pików. Wykonano badania mikrostruktury stopu i określono jej składniki fazowe identyfikowane metodą mikroanalizy rentgenowskiej.

Słowa kluczowe: podstawy procesów odlewniczych, krystalizacja, struktura stopu, metoda ATND

1. Introduction

Cast alloys of aluminum, except main alloying components as silicon, magnesium, copper, nickel and manganese comprise also other elementary substances like iron, zinc, tin, lead, etc, which are considered as impurities. During crystallization of alloy are formed the main phases and eutectic mixtures, and also the phases originated from impurities present in the alloy. Knowledge

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about process of crystallization of alloys constitutes a source of much information for cognitive reasons, to develop a new technologies of preparation of liquid metal and to control of alloy melting process in the industry. A Thermal-Derivative Analysis method (ATD) has been implemented in last years for investigation of the processes of crystallization. Investigations of crystallization processes with use of a new method – Thermal-Voltage-Derivative Analysis (ATND) are being conducted in the Laboratory of Chipless Forming Technology. This method has been developed as a combination of ATD method and a method of measurement of electric voltage generated during solidification of alloy. Arisen phases and eutectic mixtures can be determined with use of ATND method and any attempts can be made to estimate their quantity and character [1, 2].

2. Research methodology

EN AC-43000 (AlSi9Mg) alloy is rated among hypo-eutectic alloys, because content of silicon is smaller than eutectic content (12,5% of Si). During investigations the alloy was melted in electric resistance furnace. Investigations of the crystallization process were carried out with alloy in crude form, i.e. melted from pig sows without any metallurgical treatments. Such approach was taken because AlSi9Mg alloy in form of pig sows is partially modified. That alloy belongs to the most prevalent alloys used in the industry, and therefore it is reasonable not to perform any refining or modification treatments. Chemical composition of the discussed alloy was investigated in the Foundry Research Institute Krakow and it is shown in the Table 1.

Table 1. Chemical composition of AlSi9Mg alloy

Al – 89,04%	**Zr** – 0,001%	**Si** – 9,18%	**Fe** – 0,792%	**Cu** – 0,187%
Mg – 0,313%	**Mn** – 0,310%	**Zn** – 0,08%	**Cr** – 0,0156%	**Ni** – 0,007%
Ti – 0,007%	**V** – 0,004%	**Pb** – 0,040%	**Sb** ≤0,000%	**Sn** – 0,010%
Ca – 0,0099%	**Na** ≤0,0001%	**Li** ≤0,0001%	**P** – 0,0005%	**Sr** ≤0,005%

Mechanical properties of the hypo-eutectic alloys are similar to properties of the hyper-eutectic alloys. In last years they were not often used in building of machines from two reasons. Firstly, long and expensive thermal processing for obtainment suitable mechanical properties is necessary. Secondly, melting process has to be led in closely defined technological conditions. Melting point of the alloy has to have such value which to be lowest and simultaneously it gives best fluidity [3, 4].

The AlSi9Mg silumin marks high plasticity and strength. This alloy demonstrates a structure consisting mainly of $\alpha + \mathrm{Si}$ eutectic mixture and α

dendritic crystals of solid solution. Allowable impurity of the alloy in form of iron or manganese effects in presence of Al(FeMn)Si phase. Magnesium in the alloy is a important constituent specified by the standard. Presence of the magnesium enables heat treatment of the alloy aimed at improvement of mechanical and technological properties.

3. Results of the investigations

In the Fig. 1 and 2 crystallization curves of the AlSi9Mg alloy obtained by use of ATND method are presented. The points shown in the diagram illustrate characteristic thermal and voltage effects arisen during crystallization process. These effects are reflection of formation of individual phases and eutectic mixtures, as well as phase transition of already existing phases. First big, visible voltage effect arisen in temperature of 643°C is a reflection of formation of Al(FeMn)Si phase [2, 5, 6]. The next point, sharply visible in temperature of 595°C is a reflection of formation of Mg_2Si compound [2, 5, 6], whereas the point with temperature of 594°C reflects formation of α phase crystals. It constitutes a clearly visible thermal and voltage effect. The next point with temperature of 586°C represents a thermal and voltage effect of crystallization of $L + FeAl_3 \rightarrow Al + Mg_2Si + Fe_2SiAl_8$ phase compounds. In temperature of 568°C an effect arisen due to crystallization of „main" eutectic mixture of α+Si alloy is seen. The point which is present in temperature of 554°C reflects formation of $Mg_2Si + FeMg_3Si_6Al_8$ phases.

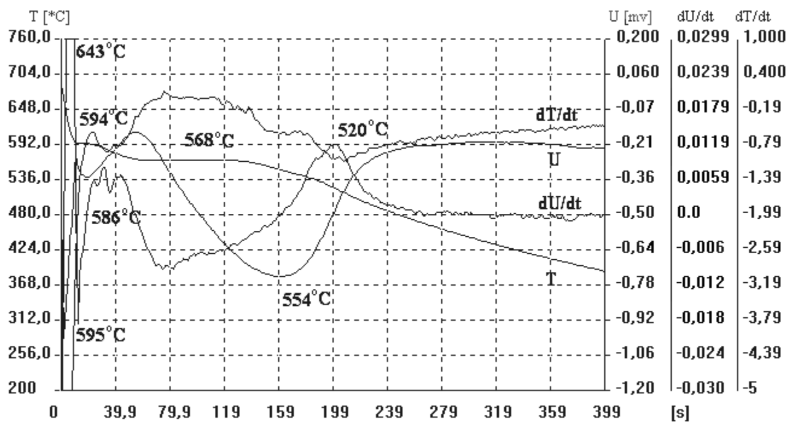

Fig. 1. Crystallization curve of crude AlSi9Mg alloy obtained with use of ATND method

Many researches [5-8] also specify crystallization temperature of these phases as 554°C. Whereas, the point occurring in temperature of 520°C specifies formation of quadruple Al_2Cu + $Mn_3Si_2Al_{15}$ + Si eutectic mixture. Together with drop of alloy's temperature, solubility of individual alloying components in α solid solution also considerably decreases, in ambient temperature the solubility in nearly at zero level.

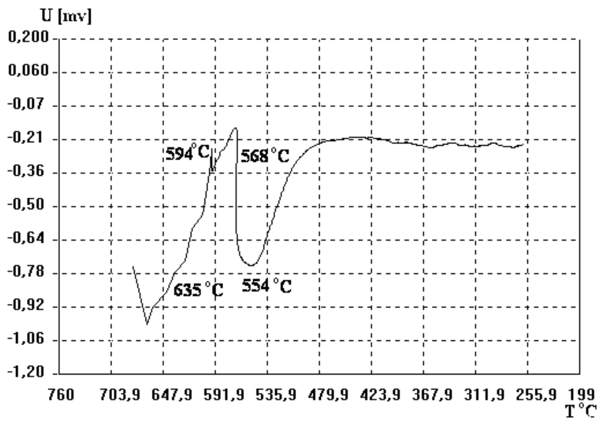

Fig. 2. Crystallization curve of crude AlSi9Mg alloy

In the Fig. 3 metallographic photos of AlSi9Mg silumin are shown. Moreover, in the Fig. 4 the main structural constituents, which next were undergone X-ray microanalysis are marked. Individual phases were identified on base of energetic spectra of individual structural constituents. The research has confirmed presence of phases recorded with use of ATND method during

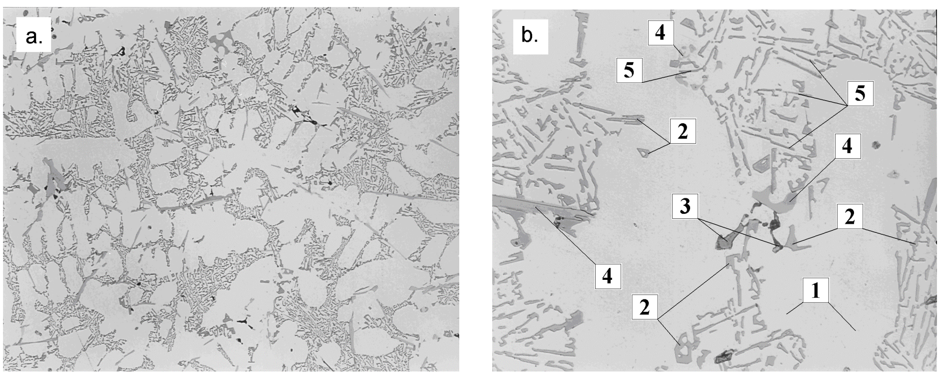

Fig. 3. Microstructure of crude AlSi9Mg alloy: a) magnification 100×, b) magnification 400×: 1 – α phase, 2 – Si phase, 3 – Mg_2Si phase (Al – matrix), 4 – AlFeSi phase, 5 – Al(FeMn)Si phase

crystallization of crude AlSi9Mg alloy. Recorded temperatures of formation of individual phases from crystallization curves are slightly different from crystallization temperature of these phases cited in Polish and foreign literature [5-8].

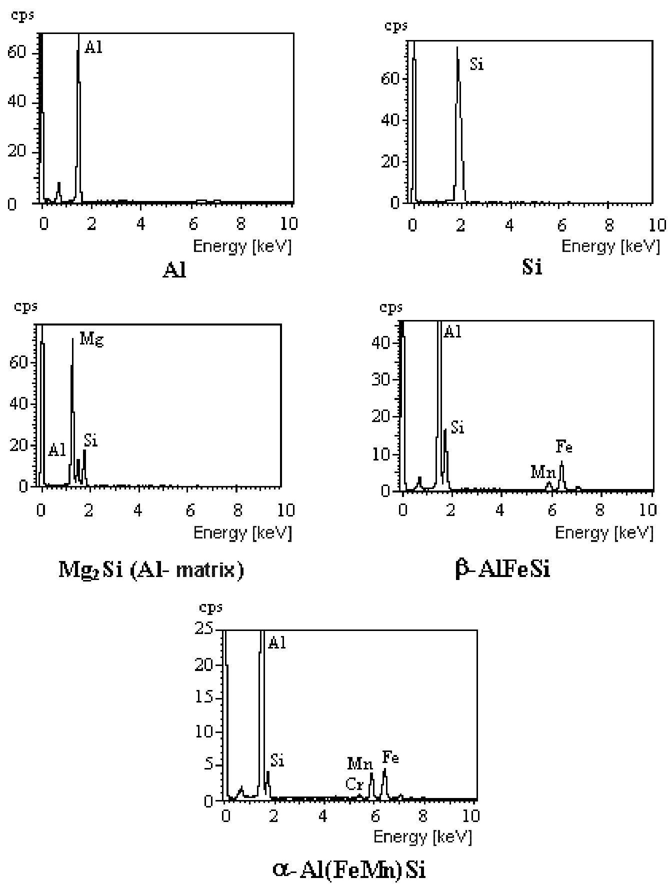

Fig. 4. Energetic spectra of identified structural components of crude AlSi9Mg alloy

4. Conclusions

Method of Thermal-Voltage-Derivative Analysis (ATND) due to simultaneous measurement of melting temperature of a solidifying alloy and generated difference of electric potential on measuring probes enables:

- identification of physical-chemical phenomena occurring in course of melting and crystallization of investigated alloys,

• identification of individual structural components, thanks to the peaks seen on plotted curves, what was confirmed by X-ray analysis of the investigated alloy,

• determination of dissolution temperature, releases of alloying elements in solid state and determination of phase transitions which are not accompanied by thermal effect.

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