

Derivative thermo analysis of the near eutectic Al-Si-Cu alloy

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Abstract

For determining of the dependence between cooling Speer, chemical composition and structure of the Al-Si-Cu aluminium cast alloy the thermo-analysis was carried out, using the UMMA device (Universal Metallurgical Simulator and Analyzer), next the optical and electron scanning microscopy was used for investigation of the structure, phase and chemical composition of the AC- AlSi7Cu3Mg grade Al cast alloy also using the EDS microanalysis as well the EBSD technique.

Keywords: Aluminium alloy; derivative thermo-analysis; UMMA

1. Introduction

Castings from aluminium alloys are widely used in production of machines and car engine elements made in the technological processes. Aluminium alloys are especially preferred in designs thanks to their good mechanical properties and possibility to make very complicated castings with high service properties. Thanks to the contemporary casting and heat treatment technologies, castings from the aluminium alloys have the suitably high mechanical properties and simultaneously decrease the part weight. Therefore, there are more and more frequently used in the means of transport industry [1-11].

Properly choose technological factors have influence on the crystallization kinetics of the aluminium alloys, involving such elements like the mould diameter, as well the casting temperature which decreases together with the crystallization rate of the castings and the alloy overcooling grade, this causes in this way a prolongation of the crystallization time [12-14].

A important investigation factor is the application of derivative thermo analysis. It is more and more usable in the

industrial practice for investigation of crystallization kinetic. The derivative thermo analysis makes it possible to determine the kinetic and dynamic of thermal the processes proceeding during the crystallization process of the alloys. This makes it possible to work out the statistical interdependence between the characteristic values of the ATD diagram curves, chemical composition, cooling speed rate of the alloy, parameters describing the structure as well mechanical properties [15].

The investigated Al-Si-Cu alloys are near eutectic Al-Si alloys with two main solidification stages, formation of aluminium reach (α -Al) dendrites followed by development of two phase eutectic (α -Al-Si). However, the additional alloying elements like as: Cu, as well as impurities like as: Fe, Mn leads to more complex solidification reaction.

2. Material and experimental procedure

For statement of the interdependence between the chemical composition and the structure of the AC- AlSi7Cu3Mg

(EN 1706:2001) aluminium cast alloy (Table 1), cooled with different cooling speed, followed investigations were made:

- Alloy structure using MEF4A optical microscope supplied by Leica together with the image analysis software as well electron scanning microscope using Zeiss Supra 25 device within high resolution mode,
- phase composition using EBSD and chemical composition of the Al alloy using qualitative and quantitative X-Ray analysis, as well EDS microanalysis,
- derivative thermo analysis using the UMSA thermo simulator (Fig. 1).

Table 1.

Chemical composition of AC- AlSi7Cu3Mg aluminum alloy

Mass fraction of the element, %							
Si	Cu	Mg	Mn	Fe	Ti	Zn	Ni
6,5-8	3-4	0,3-0,6	0,2-0,65	$\leq 0,8$	$\leq 0,25$	$\leq 0,65$	$\leq 0,3$

Thermo analysis of the investigated alloy was carried out using UMSA device [16]. The heating and cooling system, location of the thermo element, the size of the sample, as well the cylinder sampler isolation are presented on Figure 2. For generating of suitable cooling speed, the samples were cooled using compressed gas supplied through the nozzles present in the heating inductor. The gas flowing rate for sample cooling will be regulated and controlled using a rotameter. The compressed gas flow rate was regulated for achieving of the following cooling speed:

- $\approx 0,2$ °C/s, furnace cooled sample,
- $\approx 1,4$ °C/s. compressed gas cooled sample.

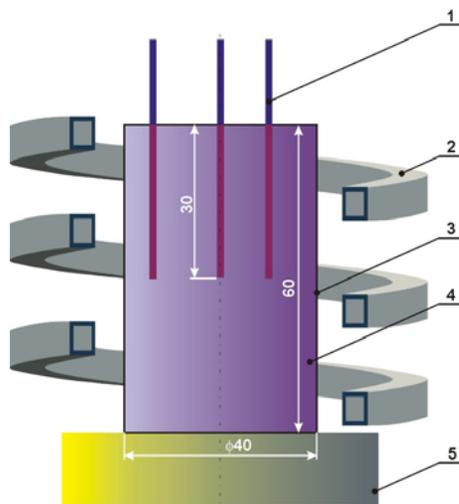


Fig. 2. Scheme of the heating and cooling system of the UMSA device, location of the thermo elements, as well size of the samples for thermo analysis: 1 – thermocouple, 2 – heating inductor – cooling nozzles, 3 – steel foil, 4 – sample, 5 – sampler isolation

For measurement and recording of the temperature changes a K-type (chromo–alumel) thermocouples was used. Tests were

performed several times for each cooling speed for statistical estimation of the investigation results.



Fig. 1. UMSA device used for the thermal derivative analysis

3. Discussion of the experimental results

Metallographic investigation results performed on the optical and electron scanning microscope aloud to conclude, that the AC- AlSi7Cu3Mg aluminium cast alloy is characterized by structure consisted of α solid solution (#1) as the alloy matrix as well a non continuously β -Si phase (#2) (Fig. 3) which build the eutectic grains $\alpha+\beta$, whereof the morphology is depending on the cooling speed rate. The investigated alloy is also characterized with an occurrence of the β -Si phase in form of big irregular plates with sharp edges and corners, non uniformly distributed in the matrix, as well big interphase space. The boundaries are characterized with sharp edges (Fig. 4). In the structure of the investigated alloys occur the precipitation of the $\text{Al}_{15}(\text{FeMn})_3\text{Si}_2$ (3) phase (Fig. 3, 4), which are present mostly near the $\alpha+\text{Al}_2\text{Cu}+\beta$ (#4) eutectics. Changes in the cooling rate influence mainly the morphology of precipitation in the investigated alloys, particularly the β phase morphology change.

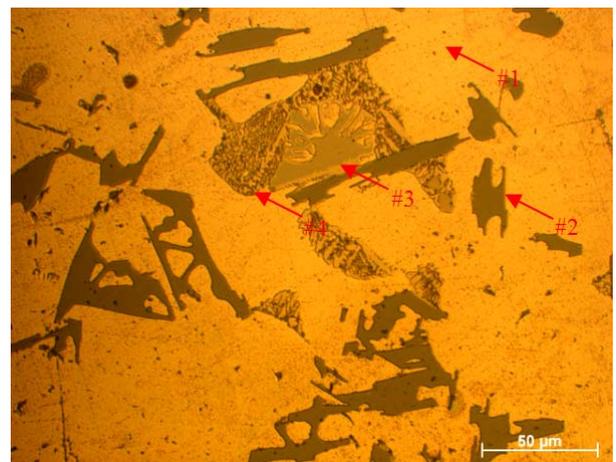


Fig. 3. Microstructure of the AC- AlSi7Cu3Mg alloy, cooled with cooling rate of $0,2$ °C/s

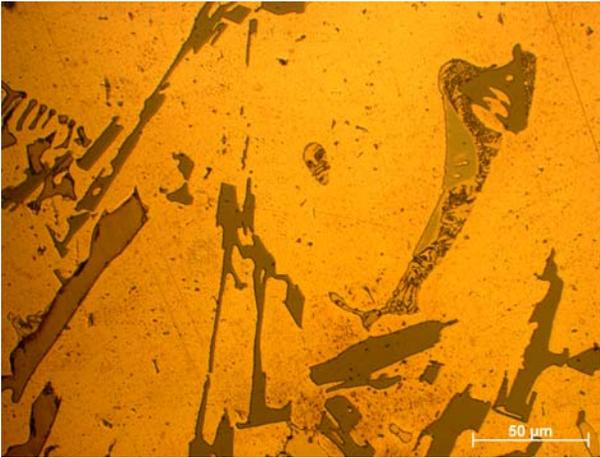


Fig. 4. Microstructure of the AC-AlSi7Cu3Mg alloy, cooled with cooling rate of 0,2°C/s

Microstructure observation performed using the scanning electron microscope as well quantitative X-ray analysis confirm the occurrence of $\alpha+\beta$ eutectic in the investigated alloys, as well aloud to suppose that in the investigated alloys occurs also ternary eutectic $\alpha+Al_2Cu+\beta$ present in the phase equilibrium diagram and also $Al_{15}(FeMn)_3Si_2$ phase (Fig. 5, 6).

As a result of the carried out investigations, particularly EDS area distribution of the elements and quantitative point-wise analysis, performed using the EDS microanalysis, the occurrence of the main alloying additives was confirmed (Fig. 7) Si, Cu, Mn, and Fe, which are components of the Al-Si-Cu cast alloy cooled with the cooling rate assumed in the experiment.

As a result of the investigation information about mass and atomic concentration of the elements in the investigated micro regions of the matrix and particles were achieved.

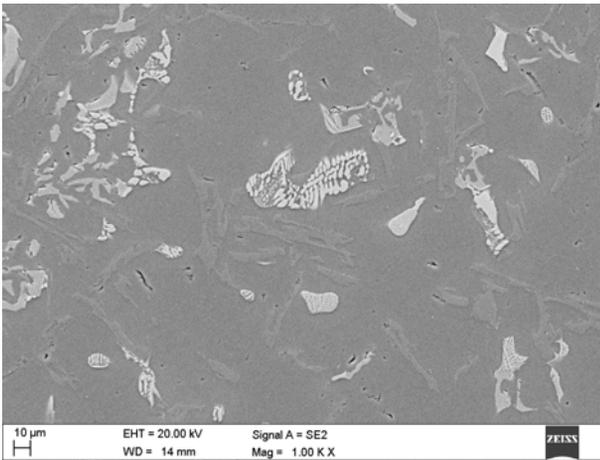


Fig. 5. SEM microstructure of the AC-AlSi7Cu3Mg alloy, cooled with 1,4°C/s cooling rate

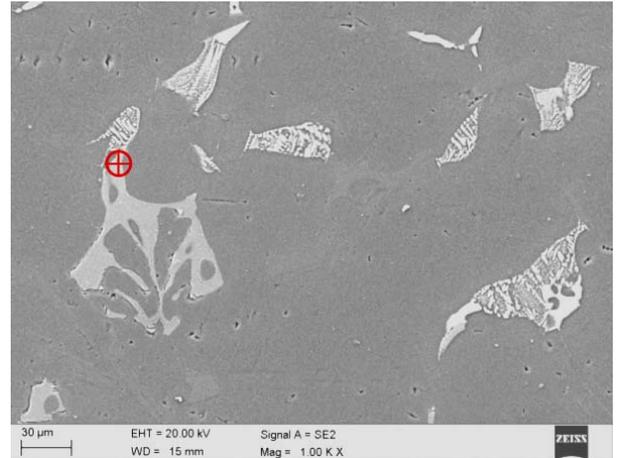


Fig. 6. SEM microstructure of the AC-AlSi7Cu3Mg alloy, cooled with 0,2°C/s cooling rate

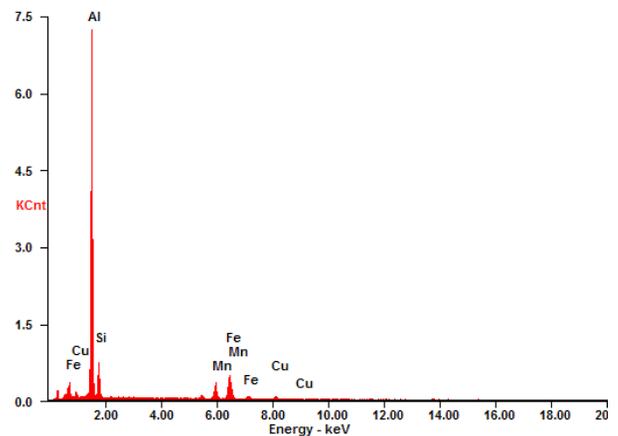


Fig. 7. Point-wise EDS microanalysis of the marked place presented on Figure 6

During the derivative thermo analysis points were determined describing the thermal processes during crystallization of the investigated alloy, The points of big importance for the thermal process define values of temperature and time of the thermal derivative analysis curves. A representative diagram of the thermo derivative analysis together with the marked points described the thermal processes occurred during the crystallization process is presented on Figure 8.

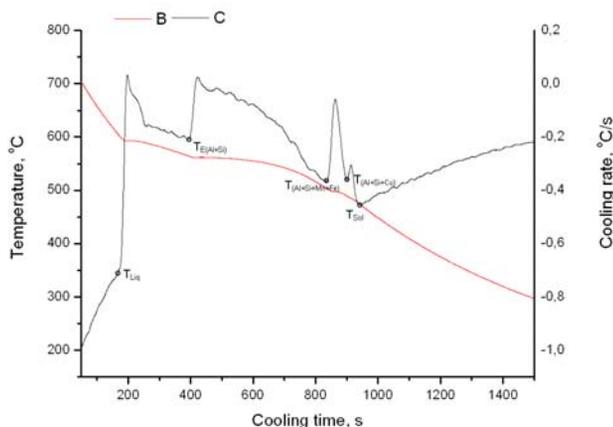


Fig. 8. Temperature and cooling rate of the investigated sample, B cooling diagram, C – derivative analysis curve dT/dt

4. Conclusions

Crystallization of the hypoeutectic Al-Si-Cu alloy starts with the crystallization of:

1. α -Al,
2. $\text{Liq} \rightarrow \alpha\text{-Al} + \text{Al}_{15}(\text{FeMn})_3\text{Si}_2$,
3. $\text{Liq} \rightarrow \alpha\text{-Al} + \text{Al}_2\text{Cu} + \text{Si}$.

The change of the cooling rate influence mainly the morphology change of the precipitation occurred in the investigated alloys, particularly the β phase morphology. Change of the cooling rate of the AC- AlSi7Cu3Mg alloy is also responsible for structure refining.

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