ANALYSIS OF Al-Mg CASTING ALLOYS CRYSTALLIZATION WITH USE OF ATND METHOD

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S u m m a r y

The paper presents results of non-ferrous metals crystallization tests performed with use of the ATND method. Method of analysis of non-ferrous metals crystallization gives complete picture of arisen structural components of alloys. Particular structural components of alloys investigated with use of the ATND method were verified in x-ray microanalysis, what unequivocally confirmed their presence. Below are presented in graphical form (crystallization diagrams) results of crystallization process obtained from the ATND method. In crystallization diagrams of AG10 and AG51 alloys are shown curves (thermal curve and its derivative, voltage curve and its derivative). Crystallizable individual structural components of the investigated alloys are reflected on curves of the method in form of characteristic peaks. The tests were performed with AG10 and AG51 aluminum-magnesium casting alloys. Moreover, the paper presents structures of the investigated alloys with marked structural components identified with use of x-ray microanalysis.

Keywords: theoretical fundamentals of casting processes, crystallization, structural component, structural constituent, ATD, ATND

Analiza krystalizacji odlewniczych stopów Al-Mg metodą ATND

S t r e s z c z e n i e

W pracy przedstawiono analizę wyników badań metodą ATND procesu krystalizacji stopów metali nieżelaznych. Analiza procesu krystalizacji tych stopów umożliwia charakterystykę powstających składników fazowych ich mikrostruktury. Składniki fazowe mikrostruktury badanych stopów określone metodą ATND zweryfikowano metodą mikroanalizy rentgenowskiej. Przedstawiono krzywe krystalizacji stopów magnezu AG10 i AG51 w zależności od temperatury i czasu, określono efekty cieplne
i napięciowe. Ustalone wartości temperatury i napięcia użyto w obliczeniach matematycznych, w analizie regresji w celu określenia wartości temperatury krystalizacji składników fazowych badanych stopów. Wykonano badania mikroskopowe stopów AG10 i AG51.

Słowa kluczowe: analiza ATD, ATND, analiza krystalizacji, krystalizacja stopów

1. Introduction

AlMg10 and AlMg5Si1 casting alloys are classified to group of casting alloys of aluminum. Castings from magnesium alloys are about 20-30% lighter

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than aluminum alloys and 50-75% lighter than iron alloys castings, and what is why these alloys are used in aircraft and rocket structures, and everywhere mass of products manufactured from these alloys has essential significance for conditions of their operation. Alloys with magnesium begin to be more and more frequently used in foundry industry because they feature lower density and higher corrosion resistance comparing with typical silumins. They feature good vibration damping properties and high strength (also in increased temperatures). In the past these alloys were less implemented in production due to two reasons. In case of these alloys there exists a need of long-lasting and expensive heat treatment necessary to assure satisfactory mechanical properties. Very strict technological regime which needs to be observed in process of melting of the alloy is the second difficulty. These alloys should be melted in protective atmosphere or under protecting coating, because magnesium oxidizes easily. Melting temperature should be selected to be the lowest possible, but still assuring demanded castability of the alloy.

Components made from magnesium alloys are usually produced in various foundry processes, to the most often methods belong high-pressure die-casting and gravity casting, especially sand casting and casting in metal moulds. Other technologies connected are: Squeeze Casting, Thixocasting and Thixomolding [1].

During crystallization of an alloy are generated main structural constituents and eutectic mixtures, as well as structural constituents originated from impurities being in the alloy. Knowledge on crystallization processes is a source of much information to cognitive purposes, to development of new technologies of preparation of liquid alloy and to control of melting processes within industry. Obtaining suitable structure of material, what determines its usage to a given requirements becomes possible owing to implementation of crystallization process theory to control of technological processes. That is why there were implemented methods based on analysis of temperature changes (thermal – ATD, DTA), electric conductivity changes (electric – AED) and thermal-voltage-derivative analysis (ATND).

The ATMD method has come into being as a mix of ATD method and measurement of electric voltage arisen during solidification of alloy. Generated structural constituents and eutectic mixtures can be determined with use of the ATND method; moreover one can make attempts to estimate their quantity and character.

2. Methodology

The paper presents test results of crystallization process of AG10 and AG51 alloys with use of the ATND method. In the tests there were used commercial alloys of magnesium. The alloys were melted in electric resistance furnace in

temperature of 760ºC. The tests were carried out on not-modified alloys. Results of chemical constitution of the tested alloys are specified in the Tables 1, 2.

Magnesium casting alloys feature microstructure consisting from α solid solution, α+Mg$_2$Si eutectic mixture and Al$_3$Mg$_2$ structural constituent. In the Fig. 1 and 2 are shown crystallization curves of AG10 and AG51 alloys registered with use of the ATND method.

Table 1. Chemical constitution of AG10 alloy

Al – 93,78%	**Mg** – 3,803%	**Fe** – 0,361%	**Zn** – 0,034%	**Na** – 0,002%
Mn – 0,295%	**Ti** – 0,004%	**Ni** – 0,041%	**Bi** – 0,002%	**Pb** – 0,006%
Sn – 0,019%	**Cu** – 0,036%	**Be** ≤0,000%	**Cr** – 0,006%	**Si** – 1,608%

Table 2. Chemical constitution of **AG51** alloy

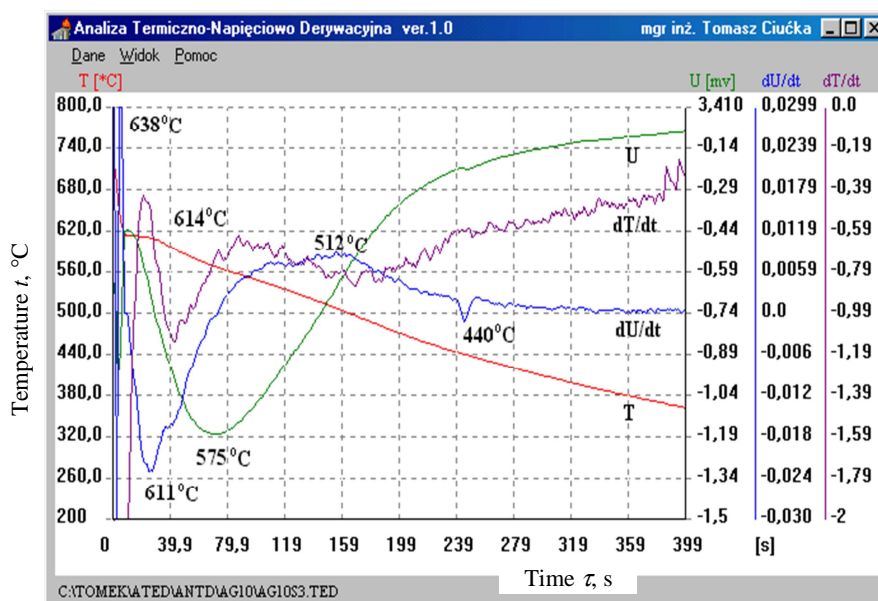| **Al** – 90,94%	**Mg** – 7,505%	**Cr** – 0,005%	**Ni** – 0,528%	**Zn** – 0,146%
Mn – 0,018%	**Ti** – 0,007%	**Pb** – 0,014%	**Ga** – 0,011%	**Sb** ≥ 0,066%
Sn – 0,053%	**Bi** – 0,002%	**Li** – 0,000%	**Na** – 0,0022%	**Ca** – 0,001%
Be – 0,000%	**P** ≥ 0,0200%	**V** – 0,010%	**Zr** – 0,005%	
Sr – 0,001%	**Si** – 0,412%	**Fe** – 0,217%	**Cu** – 0,027%	

Fig. 1. Crystallization curves of AG10 alloy from ATND method

In thermal and voltage curves seen in diagram of the analysis one can notice individual peaks occurring during crystallization of individual structural components of the investigated alloy [2-4]. Height of the peaks can be transferred into quantity of constituents arisen in the solidifying alloy. In the characteristic points of the crystallization curves there are plotted readout temperatures of solidifying specimen. In the next stage of the work these temperatures shall be used to identification of individual structural constituents and eutectic mixtures arisen in the solidifying alloy [5-10].
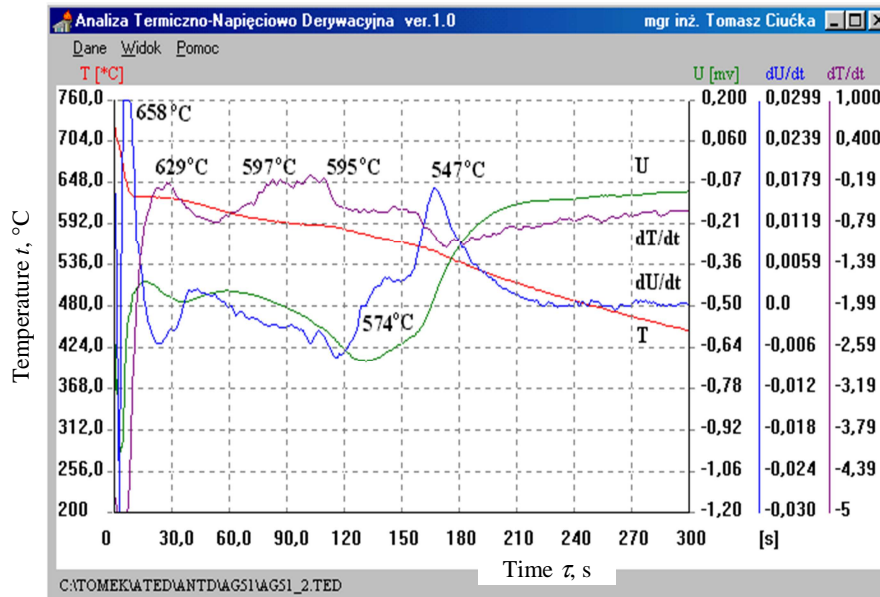

Fig. 2. Crystallization curves of AG51 alloy from ATND method

In the point occurring at temperature of 638°C is seen the first big voltage effect resulted from crystallization of high melting – ferric (L+Al$_3$Fe → Al + Fe$_2$SiAl$_8$) structural constituent. In the point showing temperature of 614°C (AG10) and 629°C (AG51) is seen the maximal thermal effect, originated from crystallization of dendrites of α solid solution. The next visible point is the point present in temperature of 575°C (AG10) and 597°C (AG51). According to [1, 6, 7] it is temperature of crystallization of Al(FeMn)Si constituent. Subsequently, Al$_3$Mg structural constituent crystallizes in the interdendic spaces. In temperature of 440°C (AG10) is marked a slight voltage effect of crystallization of residual quantity of α + Al$_{12}$Mg$_{17}$ eutectic mixture. Temperature of that transition cited in literature [1] amounts to 437°C. In such supersaturated liquid, concentration of individual elementary substances has grown to such extent that

generation of that structural constituent was possible. In the Fig. 3 are shown photos of AG10 and AG51 alloy structure. In the Fig. 3 are marked identified structural constituents by EDS method (Fig. 4).
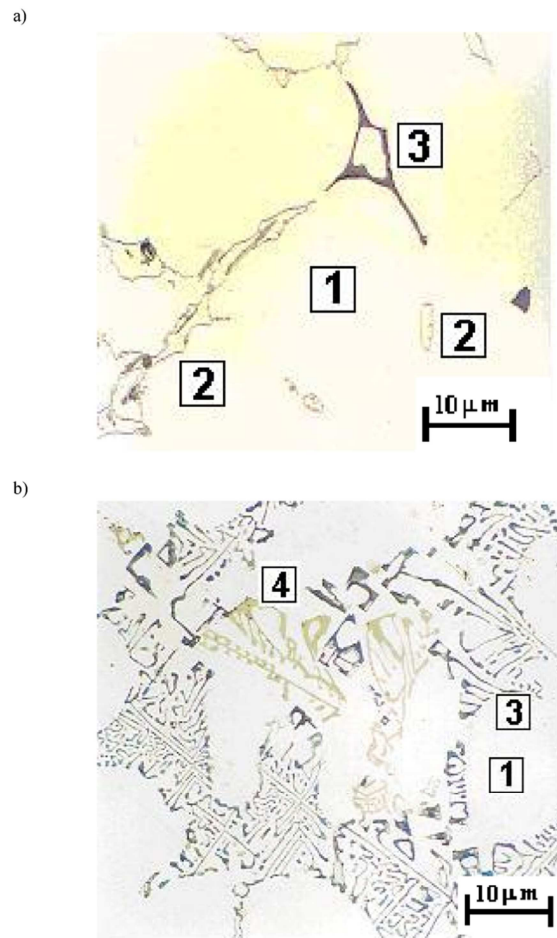
a)

b)

Fig. 3. Microstructure of AG10 alloy, with marked phase components (a), microstructure of AG51 alloy, with marked phase components (b): 1 – Al(α)matrix, 2 – Al$_3$Mg$_2$ phase, 3 – Mg$_2$Si phase, 4 – Al(FeMn)Si phase

In the Fig. 5 is shown a set of crystallization curves of AG10 alloy. Visible, repeatable character of individual measurements testifies for lack of randomness in the crystallization process and its registration with use of the ATND method. Repeatability of measurements constitutes a fundamental feature of a testing method to investigate crystallization process of alloys. In the presented work,
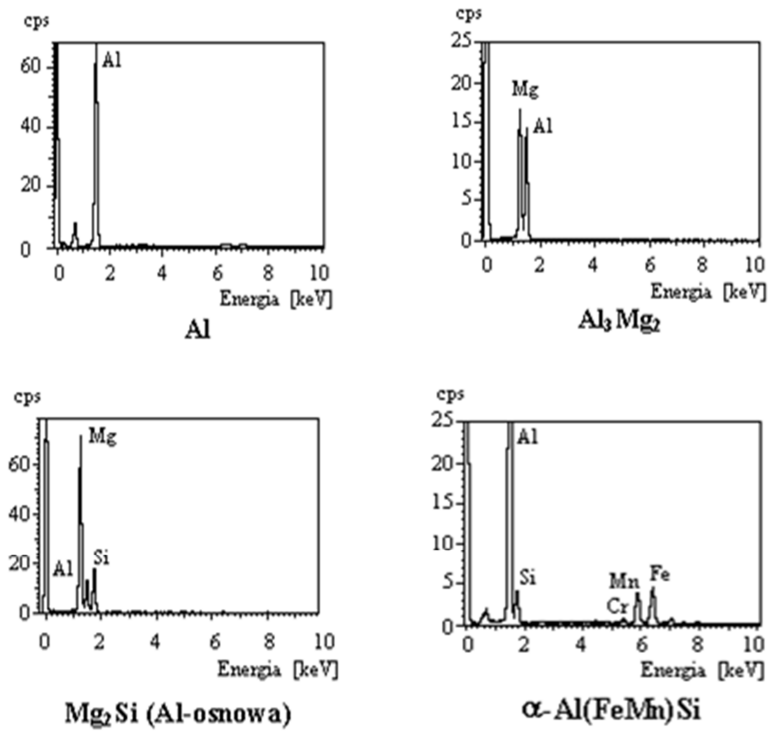
Fig. 4. Energetic spectra of identified microstructural components of AG10 and AG51 alloys:
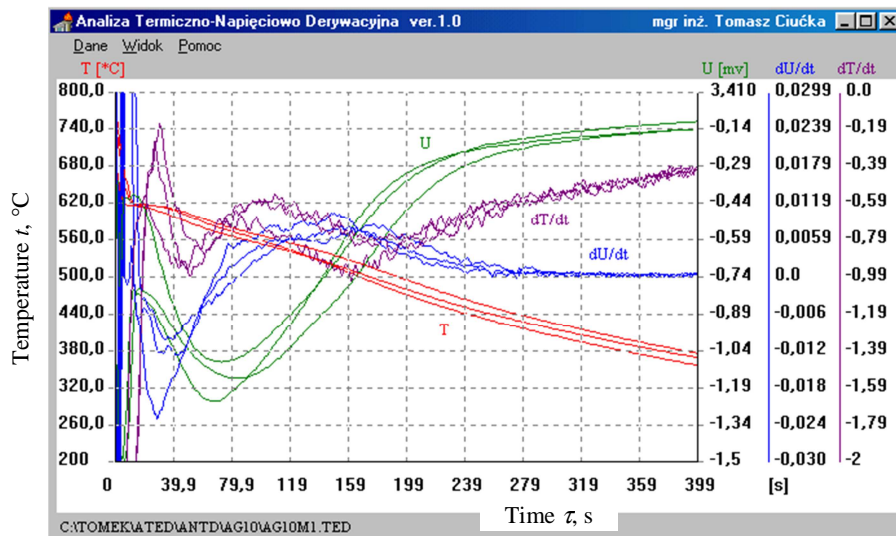a) Al, b) Al$_3$Mg$_2$, c) Mg$_2$Si and d) α-Al(FeMn)Si

Fig. 5. Set of crystallization curves of AG10 alloy obtained from ATND method

repeatability of individual tests of investigated alloys is high. It is worth to be mentioned that production process of machinery components, like foundry industry is, from its nature is the process with low repeatability. Probability of crystallization of identical structural constituents having identical dimensions in the same locations is very low in case of various castings. In spite of production of the same castings, from the same alloy, each such casting is different. Visible repeatability of the ATND method in this case is satisfactory.

3. Conclusions

The ATND method, simultaneous measurement of temperature of solidifying alloy and electric potential difference measured on probes reveals temperatures of crystallization of individual alloying components:

- thermal and voltage curves show at physical-chemical phenomena occurring during crystallization of alloy,

- formation of structural constituents and eutectic mixtures, peaks visible on curves of the method, were confirmed during x-ray microanalysis of structural components present in the tested alloys,

- can be useful during determination of temperatures of dissolution of individual components, release of structural constituents from supersaturated solutions in solid state and in determination of phase transitions where thermal effect is present,

- characteristic parameters (temperatures) of heat treatment of investigated alloys are possible to determination with use of the ATND method.

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