Achievements in Mechanical and Materials Engineering

COMMENT Worldwide Congress on Materials and Manufacturing Engineering and Technology
16th - 19th May 2005 Gliwice-Wisła, Poland

COMMITTEE OF MATERIALS SCIENCE OF THE POLISH ACADEMY OF SCIENCES, KATOWICE, POLAND
INSTITUTE OF ENGINEERING MATERIALS AND BIOMATERIALS OF THE SILESIAN UNIVERSITY OF TECHNOLOGY, GLIWICE, POLAND
ASSOCIATION OF THE ALUMNI OF THE SILESIAN UNIVERSITY OF TECHNOLOGY, MATERIALS ENGINEERING CIRCLE, GLIWICE, POLAND

13th INTERNATIONAL SCIENTIFIC CONFERENCE ON ACHIEVEMENTS IN MECHANICAL AND MATERIALS ENGINEERING

Applications of the derivation analysis for assessment of the ACAlSi7Cu alloy crystallization process cooled with different cooling rate

L.A. Dobrzański[a], , W. Kasprzak[b], J Sokołowski[b], R. Maniara[a], M. Krupiński[a]

[a] Institute of Engineering Materials and Biomaterials, Silesian University of Technology, Konarskiego 18a, 44-100 Gliwice, Poland, email: mariusz@krupinski@polsl.pl

[b] NSCER/Ford/University of Windsor, Windsor, Onatario, Canada

Abstract: In this work the derivation analysis techniques is applied for the preparation of ACAlSi7Cu alloy thermal characteristic, and assessed influence of cooling rate for characteristic transformations during the crystallizations. Alloys were cooled with three cooling rate: 0,2 °C/s, 0,5°C/s and 1 °C/s.

Rise of the cooling rate is influenced on a α dendrite phase nucleation point what have an effect on a solid fraction. In this case alloys are much more uniform. The changes of crystallization temperature on the end of the process are not observed during the rise of the cooling rate.

Keywords: Derivation analysis, Thermal modification, Quantities assessment of the crystallization process

1. Introduction

At present the aluminum alloys have a good mechanical property, low-density, good thermal and electric conductivity. Mainly for these reasons, aluminum alloys have a widespread application in the motor vehicle and aircraft industries as well as in household and office equipments.

At present in the word occurs the tendency to decrease both the mass of the constructions and the production cost. In this case it is very important precise fix a parameters of the production.

Mainly parameter of the technological process, which has influence on the mechanical properties, is a heat treatment temperature. Precise heat treatment is based on a quantity of the phases precipitate (i.e. Al_2Cu, Mg_2Si, $Al_4CuMg_5Si_4$ [3, 9]) and precise fix of the temperature of the multicomponent eutectic crystallization.

The simplest and very effective method, which makes it possible to determine a curve of the crystallization process – the cool curve $T = f(t)$, is the thermal analysis. This coolling curve gives information about the metal crystallization process with continuous cooling rate.

Extension of the thermal analysis is the derivation analysis. This method determines the derivative of the cool curve – crystallization curve $T' = \frac{dT}{dt} = f'(t)$. T' gives particularly temperature changes during the alloy crystallization. These changes come from internal heat source – phase transformations and size of the changes is proportional to amount of the phases

precipitate. Metal cool process is described by means of the hypothetical curve (base line). The total crystallization heat is proportional to the areas between the base lines and the crystallization curve.

Based on the literature [1, 7, 9] equation 1 describes the general function of the crystallization:

$$\frac{dT}{dt} = \frac{1}{V\rho C_p}\left(\frac{dQ_L}{dt} - hA(T - T_0)\right) \tag{1}$$

.where:

V – volume of the metal test sample, ρ – density of the metal test sample, C_p – specific heat of the metal test sample, T – temperature, t – time, h – thermal conductivity coefficient, A – crystallization area , T_0 – ambient temperature, Q_L – latent heat oh crystallization.

The method of base line calculations for the aluminum alloys is described in the literature [10].

For solve of the general crystallization function (1) it is necessary to find the elementary functions of the crystals growth and function of the nucleation. Based on the Tammana and Chworinowa theory and assumption that the growth of the nucleus and growth rate of the solidify layer in time is described by the Gauss law [1, 10].

The knowledge of the curse of the nucleation function, crystals growth function and assumption that the crystallizations heat is proportional to the quantity of the precipitated phase make possible to evaluate of the mount proportion of the crystallization phases.

2. EXPERIMENTAL PROCEDURE

The object of the research was an ACAlSi7Cu alloy designed for car block engaging. The chemical composition of the analysed alloy is shown in Table 1

Table 1.
Chemical composition of the ACAlSi7Cu alloy in wt-%

Components concentrations, in wt %									
Si	Ni	Cu	Fe	Sn	Zr	Mn	Zn	Ti	Sb
7,1	0,006	0,99	0,990	0,990	0,003	0,11	0,04	0,08	0,009

The ACAlSi7Cu is made in the NSCER/Ford/University of Windsor in Canada laboratory. In the first step all components are melted in the electrical resistance furnace with the ceramic crucible. The melted process is made in the 850°C temperature. During processing, the melt is covered with a protective argon gas atmosphere to prevent oxygen and hydrogen contamination and before casting, liquid metal was degassed by 20 min. Temperature is checked by the thermocouples.

Samples for the thermal analysis are cast to the thin well steel crucibles.

The average mass of the samples is 330 ±30. In these samples are drilled concentric holes. The diameter of these holes is 2 mm and length is 25 mm measured from the top of the cast. Thermal analysis is made by the UMSA device. Chemical composition is examined by optical spectrometer.

In the next step of the investigations the samples are remelted in the steel crucible by the UMSA device in the 750°C temperature and cooled with the three cooling rate 0,2 °C/s, 0,5 °C/s, 1°C/s. The cooling rate is forced by a suitable air fallow

3. RESULTS DISCUSSION

Assessment of the cooling rate on the phase transformations in the ACAlSi7Cu is made by crystallizations curves. The crystallizations curves are based on the data captured during the thermal analysis. Samples are cooled with different cooling rate. The crystallizations curves are shown in figure 1

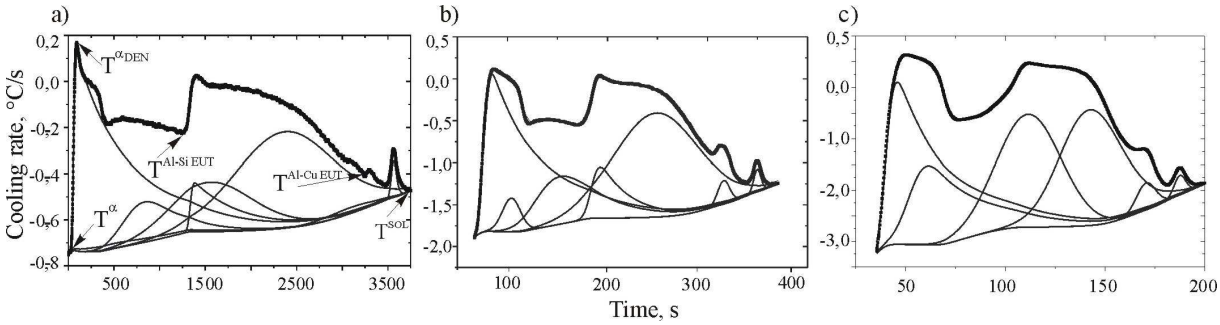

Figure 1. Derivate curves with peak fitting for cooling rate: a) 0,2 °C/s, b) 0,5 °C/s, c) 1 °C/s

According to the showed derivation curve in figure 1, the α phase network nucleation is begun in the T^{α} temperature. Decreasing of the temperature to $T^{\alpha DEN}$ the α phase network is become coherence. During continuing of the temperature decreasing dendrite crystallizations front drop out free silicon atoms directly to the liquid.

Crystallization of the coherent dendrites is gone on to the $T^{Al\text{-}Si\ EUT}$ temperature. In this temperature Al-Si eutectic crystallization is began in effect supersaturations rest of the liquid. Eutectic crystallizations end is in the $T^{Al\text{-}Cu\ EUT}$ temperature. Then $Al+Al_2Cu+Si$ ternary eutectics are begun. Ternary eutectic crystallization end is in the T^{SOL} temperature. During crystallization of the ternary eutectic in alloy precipitated rich in Cu and Fe phases.

The figure 2 show influence of the cooling rate on the nucleation temperature of the α phases - T^{α}, Al-Si eutectic crystallization start point - $T^{Al\text{-}Si\ EUT}$, $Al+Al_2Cu+Si$ ternary eutectic crystallization start point - $T^{Al\text{-}Cu\ EUT}$ and crystallization finish - T^{SOL}.

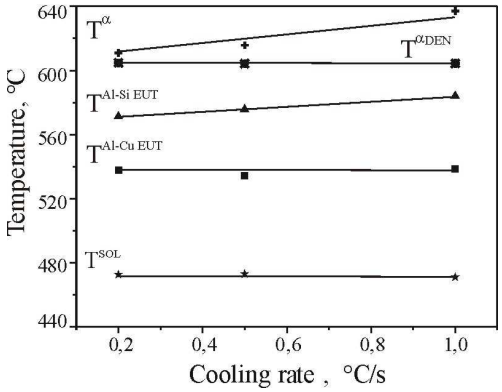

Figure 2. Influence of the cooling rate on the temperature: T^{α}, $T^{\alpha DEN}$, $T^{Al\text{-}Si\ EUT}$, $T^{Al\text{-}Cu\ EUT}$ T^{SOL}

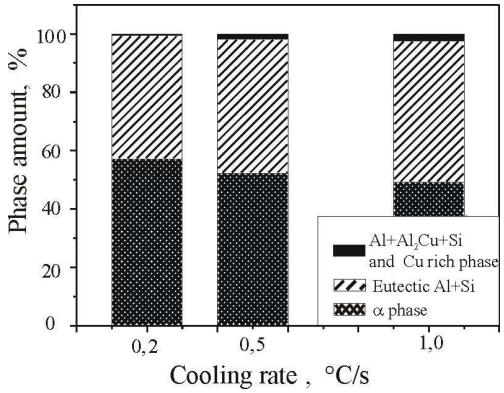

Figure 3. Influence of the cooling rate on the phases amount

When the cooling rate is increased, then the temperature α phase nucleation is increased from 610°C for the 0,2°C/s cooling rate to 637°C for 1°C/s cooling rate. Coherent dendrite point temperature is 604 °C and is constant for the all cooling rate. When the cooling rate is increased then the Al+Si eutectic start crystallization temperature is increased too. Temperature of the $Al+Al_2Cu+Si$ ternary eutectic crystallization start point is constant for all cooling rate.

Changes of solidus temperature is not observed during the examination, this temperature is constant for all cooling rate and is even 474°C. When the cooling rate is increased, the solidification range is increased form 138°C for the 0,2°C/s cooling rate to 166°C for 1°C/s cooling rate. Quantity of the crystallization phases is calculated by decompresses of crystallization function on the elementary functions. Sheddage crystallization function is shown fig 1. Comparison of the phase amount during chilled with different cooling rate are shown in figure 3. When the cooling rate is increased the amount of Cu rich phase is increased and the amount α phase is decreased.

4. CONCLUSION

The subject of the research is conducted with the evaluation of the influence of the crystallization cooling rate on the phase crystallization temperature in ACAlSi7Cu alloy.

The investigations show that the derivation analysis is an efficient tool for calculation of the changes in the crystallization process. The derivation analysis marks the crystallization range of the phases very precisely.

The results of the analyses can be summarized in the following conclusions:

1. Increase of the cooling rate has influence on the increasing α phase nucleation temperature and Al-Si eutectic start point; this has an influence on the quality of the alloy.
2. Increase of the cooling rate influences the amount of the Cu rich phases formed during the crystallization process what have an influence on the mechanical properties after the heat treatment.
3. The derivation analysis can be use for the quantitative analyses of the crystallization phases in industrial investigations.

REFERENCE

1. K.G. Upadhaya, D.M. Stefanescu, K. Lieu, D.P. Yeager: Computer aided cooling curve analysis: Principles and applications in Metal casting, AFS Transactions, vol 97, 1989,
2. D.M. Stefanescu, K.G. Upadhaya, D. Bandyopaadhyay: Heat Transfer-Solidification Kinetics Modeling of Solidification of Casting, Metallurgical Transactions A, vol. 2A, 1990,
3. I.J. Polmear: Light alloys metallurgy of the light metals, GB 1993
4. S. Piotrowski R. Władysiak, Ocena krystalizacji siluminów podeutektycznych syntetycznych metoda ATD, Krzepniecie Metali i Stopów, PAN – Oddzial w Katowicach, komisja odlewnictwa, z 22, 1995,
5. Y.F. Chen, S.H. Jong and W.S. Hwang, "The effect of cooling rate on the latent heat released mode for near pure aluminum and aluminum silicon alloy," Modeling of Casting, Welding and Advanced Solidification Processes VII, Edition by M. Cross and J. Campbell; The Minerals, Metals and Materials Society 1995,
6. S. Jura, Z. Jura: Teoria metody ATD w badaniach stopów Al, Krzepnięcie metali i stopów, PAN-Oddział w Katowicach, Komisja Odlewnictwa, z. 28, 1996,
7. M.B. Djurdjevic, W.T. Kierkus, G.E. Byczynski, T.J. Stockwell, J.H. Sokolowski: Modeling of fraction solid for 319 aluminium alloy, AFS Transactions, 1997,
8. J.M. Boileau, J.W. Zindel and J.E. Allison, The effect of solidification time on the mechanical properties in a cast A356-T6 aluminum alloy, Society of Automotive Engineers, Inc., 1997,
9. S. Pietrowski: Siluminy, Wydawnictwo Politechniki Łódzkiej, Łódz, 2001
10. W.T. Kierkus, J.H. Sokolowski: Recent Advance In CCA: A New Method Of Determining Baseline Equation, AFS Transactions, 2001,