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Effect of dispersion hardening process on elongation of EN AB-43200 silumin

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Abstract

Aluminum alloys belong to the second, after ferrous alloys, group of material having the biggest application in technology. Mass of metal structures is of important value, what involves lightweight mass of materials used in a given structure. Lightweight metals are used more and more often in metal structures, whereas aluminum and its alloys are the most widespread. Mechanical and technological properties of castings produced from Al-Si alloys depend on correct melting and pouring process, design of the castings and moulds and their heat treatments. Reduction of production costs requires selection of optimal parameters of the heat treatment (temperatures and durations of the treatments).

The paper describes implementation of the ATD method to determination of hyperquenching and ageing treatments of EN AB-43200 (AK9) silumin. Investigated alloy was melted in electric resistance furnace. In the next stage the alloy underwent the treatment of refining and modification. Course of crystallization is presented with use of thermal-derivative analysis (ATD). That method was also used to determination of temperature range of heat treatments of the alloy. Obtained results apply to solidification curves recorded with use of the ATD method, light microscopy, strength tests and determination of an effect of heat treatment parameters on A_5 elongation of the investigated alloy. On base of the performed tests of heat treated alloys there was determined an effect of selected parameters on obtained elongation (A_5).

Key words: Mechanical properties, Crystallization, Dispersion hardening, ATD

1. Introduction

The most widespread group among aluminum alloys found in foundry industry are technical alloys of aluminum with silicon - called as silumins - where silicon is the main alloying constituent [1].

The main structural components of silumins are: solution of silicon in aluminum – structural constituent α (Al), which can be more or less plastic depending on possible alloying components and implemented heat treatment, as well as silicon - β(Si) which is distinguished by hardness and brittleness To obtain correct mechanical properties of silumins, except alloying components there are used changes in their structures due to modification and possible heat treatment process [2-6].

Properly performed process of modification of the alloy facilitates processes of coalescence and coagulation of silicon, what directly impacts on improvement of mechanical properties of silumins, enabling reduction of hyperquenching and ageing times.

Heat treatment is performed in order to increase mechanical and plastic properties of the alloy. The heat treatment consists on hyperquenching (holding at a temperature below temperature of eutectic process in order to solubilize Mg_2Si releases, to homogenize concentration of elementary substances of dendritic crystals' section of α structural constituent, to change morphology of silicon releases [4], and ageing (soaking of supersaturated alloy in order to precipitate a strengthening phases from supersaturated solid solution – in silumins containing magnesium or copper only, precipitate strengthening is obtained in result of precipitation of Mg_2Si, Al_2CuMg and Al_2Cu) structural constituents) [2].

Nowadays, to control crystallization of alloys the following methods are used: Thermal Analysis (AT), Thermal-Differential Analysis (DTA) and Thermal-Derivative Analysis (ATD) [4-7].

The ATD method, based on analysis of temperature change run, enables registration of phenomena arisen in result of melting and solution heat treatment processes of alloys [8 - 12]. It is especially important from point of view of possibility of making use of obtained diagrams to determination of temperature ranges for solution heat treatment and ageing treatment.

2. Methodology of the research

EN AB-43200 (AK9) alloy is rated among hypoeutectic alloys. It features very good casting properties and is destined for castings having complicated shapes and high strength. Presence of magnesium additive enables implementation of heat treatment (Mg_2Si structural constituent).

Investigated alloy was refined with Rafal in quantity of 0,5% of mass of the charge, and next, modified with strontium in quantity of 0,06% of mass of the charge.

The Fig.1 shows structure of AK9 alloy after refining and modification.

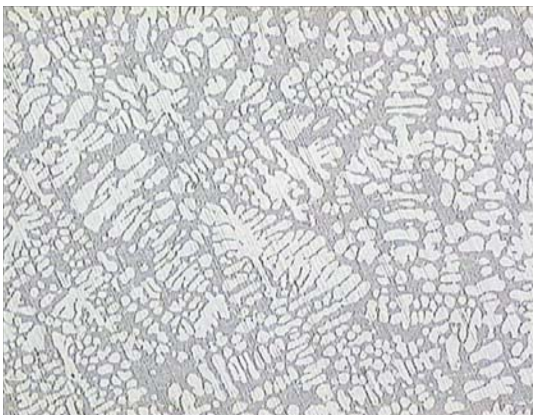


Fig. 1. Microstructure of refined and modified AK9 alloy, magnification 300x

Process of solidification and melting of the alloy was registered with use of fully automated Crystaldimat device, which enables obtaining ATD curves for solidification and melting processes of the investigated alloy. Test pieces of the investigated material featured diameter of 16 mm and length of 22mm

The heat treatment was performed for the alloy modified with respect to shape of eutectic mixture, what significantly influences susceptibility of eutectic silicon to coalescence and rounding during process of the heat treatment [13].

In the Table 1 below are shown parameters of the heat treatment performed for the investigated alloy.

Table 1.
Heat treatment parameters of the alloy

Solution heat treatment temperature [°C]	Solution heat treatment time [h]	Ageing temperature[°C]	Ageing time [h]
t_{p1} - 520	0,5	t_{s1} - 180	2
t_{p2} - 545	1,5	t_{s2} – 235	5
t_{p3} - 560	3	t_{s3} - 310	8

Temperatures of solution heat treatment and ageing treatment were chosen on base of analysis ATD curves (Fig. 2) obtained for refined and modified AK9 alloy.

Tensile test was performed with use of ZD-10 universal testing machine, utilizing testing pieces produced according to PN-88/H-88002 standard.

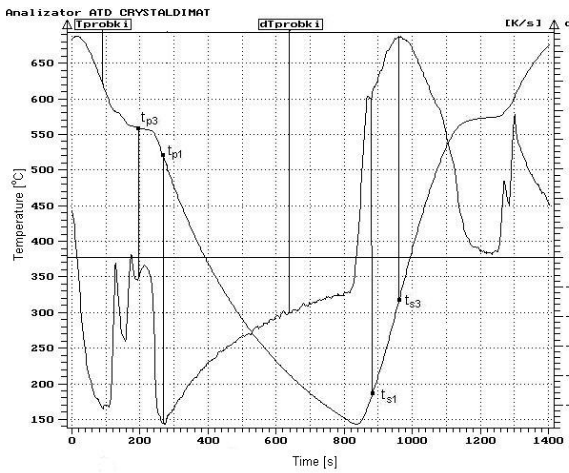


Fig. 2. The ATD method of modified AK9 alloy

3. Description of obtained results

Elongation (A_5) of refined and modified alloy amounted from 7,4% to 10%. After performed heat treatment, the elongation (A_5) for the investigated alloy amounted from 3,7% to 18 %.

In the Fig. 3 is shown the effect of performed treatments on change of elongation of the alloy.

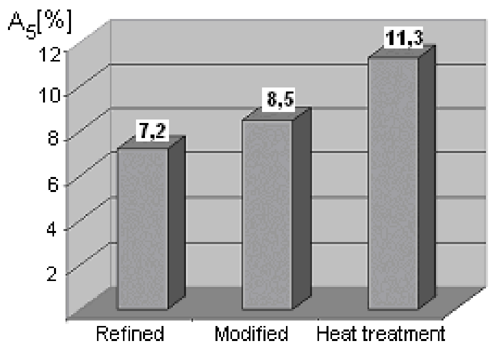


Fig. 3. Effect of performed heat treatments of AK9 alloy

Structure of the alloy, with characteristic shape of silicon precipitation, has direct effect on elongation of the alloy after the heat treatment (Fig. 4).

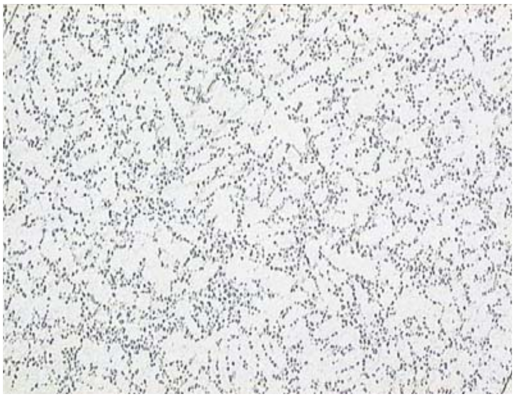
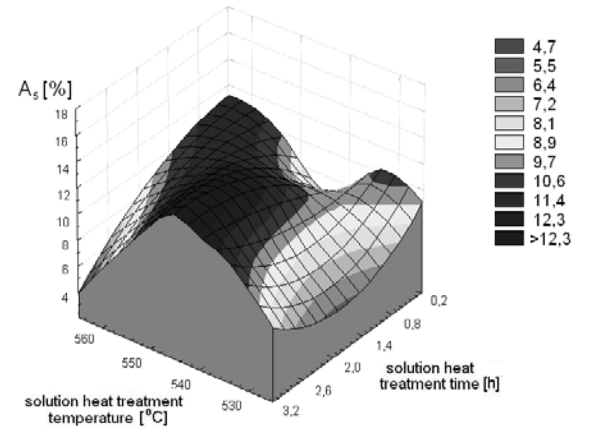


Fig. 4. Microstructure of AK9 alloy after dispersion hardening, magnification 300x

Basing on three stage plan of the research, obtained results are shown in form of three-dimensional diagrams illustrating effect of selected parameters of the heat treatment of AK9 silumin on change of its A_5 elongation (Figs. 5-6).

a)



b)

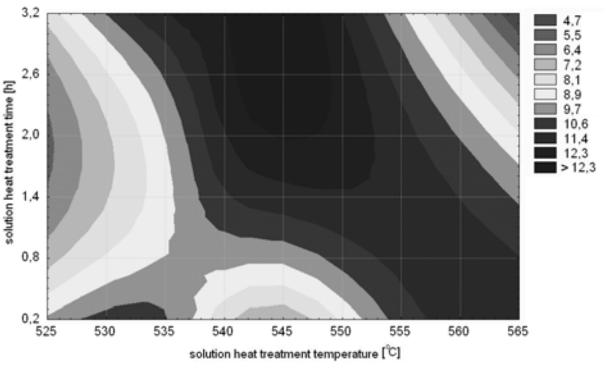
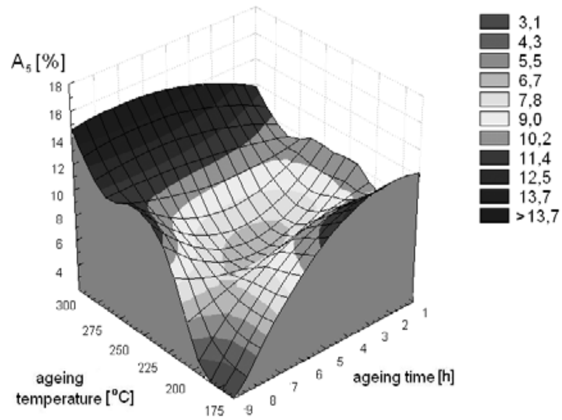


Fig. 5. Effect of temperature and duration of solution heat treatment on A_5 elongation of AK9 alloy: a) three-dimensional diagram, b) isohypse diagram

a)



b)

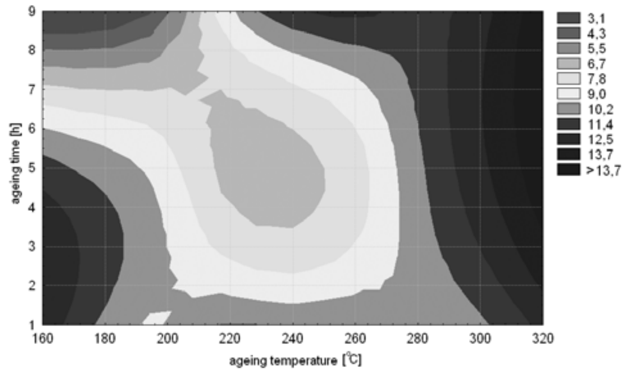


Fig. 6. Effect of temperature and duration of ageing treatment on A_5 elongation of AK9 alloy: a) three-dimensional diagram, b) isohypse diagram

4. Conclusions

On base of obtained results one can state that the heat treatment has effect on growth of elongation of AK9 alloy.

The highest values of the A_5 elongation were obtained for the following parameters:

a) solution heat treatment temperature – 540 - 550 °C,

b) ageing heat treatment duration – 1,5 do 3 hours,

c) ageing temperature - above 275 °C,

d) ageing duration - 3 to 9 hours.

The highest value of the elongation, A_5 = 18%, was obtained for the test pieces from material which was solution heat treated in temperature of 560 °C during 1,5 h and ageing in temperature of 310 °C during 5 hours.

Performance of further research is connected with determination of dispersion hardening parameters of AK9 silumin, which are necessary to obtain optimal combination of mechanical and plastic properties of the alloy.

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