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Effect of T6 heat treatment on mechanical properties and microstructure of EN AB-42000 alloy modified with strontium

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Abstract

Process of silumin properties perfection in scope of classic (simple and cheap) methods is connected with change of morphology of silumin precipitations through: process of alloy modification, maintaining suitable temperature of superheating treatment and pouring into moulds, as well as perfection of heat treatment operations. In the paper are presented results of a tests aimed at investigation of an effects of performed heat treatment operations on change of tensile strength of EN AC-42000 silumin modified with strontium. Investigated alloy was melted in electric resistance furnace. Course of crystallization process was recorded with use of thermal-derivative analysis (ATD), and on base of this analysis one determined temperatures range of heat treatment operations of the alloy. Performed heat treatment operation resulted in change of mechanical properties (R_m, A_5) of the investigated alloy, whereas performed tests enabled determination of temperature and duration of solutioning and ageing treatments, which condition improvement of its mechanical properties.

Keywords: modification, heat treatment, ATD, mechanical properties

1. Introduction

Contemporary technical knowledge and production technology have enforced introduction of new methods of smelting, founding and heat treatment of casting alloys, enabling reduction of materials consumption through improvement of their mechanical and technological properties.

Silumins, i.e. alloys of Al-Si system, belong to the most widespread casting alloys based on aluminum [1]. It is connected with a series of operational and technological advantages of this group of alloys, such as: low specific gravity, relatively low melting point, good thermal conductivity, good corrosion resistance, satisfactory strength in normal and increased temperature, good machinability, good castability and small solidification shrinkage among others [1-5].

Usage of these alloys as material for cast machinery parts is connected with control of morphology of silicon precipitations, what can be accomplished through thermal changes in solid state and/or modification of alloy.

In practice, obtainment of suitable structure of silumins is connected with processes of its refining and modification [1-3, 5-12]. Alloys based on equilibrium state of Al-Si – containing additional alloy-forming elements like (e.g.: Mg, Cu) – except modification can be heat treated.

ATD method has been used for many years; both for the purpose of research work and in control process within industrial environment, to make assessment of quality of alloys, resulting in considerable extend from course of its solidification process [13-18]. Implementation of the ATD method also enables determination of temperature ranges of solutioning and ageing treatments for process of dispersion hardening with soaking of the alloy in temperature close to solidus curve [19-21]. It is especially important, taking into consideration necessity to guarantee a suitable initial structure of material – destined for heat treated castings – characterized by dispergated precipitations of eutectic silumin, which in great measure facilitates processes of its coalescence and spheroidization [3,5].

2. Methodology of the research

The first stage of the investigations consisted in testing of crystallization course of the alloy produced from pig sows.

In the next stage one performed treatment of refining with Rafal 1 preparation in quantity of 0,6% mass of charge, in temperature of 730 °C. When the refining was terminated (60 minutes), one removed oxides and slag from the metal-level and performed treatment of modification with strontium, using AlSr10 master alloy in quantity of 0,4% mass of charge (0,04% Sr).

Test pieces to the strength tests were poured in metal mould heated to temperature of 250 °C, and were prepared in compliance with PN-88/H-88002 standard. Static strength tests were performed with use of ZD-20 testing machine.

Process of solidification and melting of the alloy was recorded with use of fully automated Crystaldimat analyser.

Chemical constitution of the investigated alloy is collated in the Table 1. Analysis of the chemical constitution was performed with use of spectrometry method (emission spectrometer with glow-type excitation of GDS 850A type).

Table. 1. Chemical constitution of the investigated alloy

EN AB-42000	Si	Cu	Zn	Fe	Mg	Ti	Mn	Ni	Cr	Pb	Sr	Al
	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
from pig sow	7,1	0,4	0,15	0,628	0,4	0,1	0,3	0,04	0,06	0,04	0,01	reszta
refined	7,2	0,25	0,3	0,75	0,35	0,10	0,30	0,12	0,07	0,03	0,01	reszta
modified	7,5	0,27	0,3	0,65	0,30	0,04	0,27	0,04	0,07	0,025	0,03	reszta

In the Fig. 1 are presented recorded curves of heating (melting) and crystallization process of refined and modified alloy, recorded with used of ATD method.

On the thermal curve are marked temperatures of solutioning and ageing treatments of the investigated alloy.

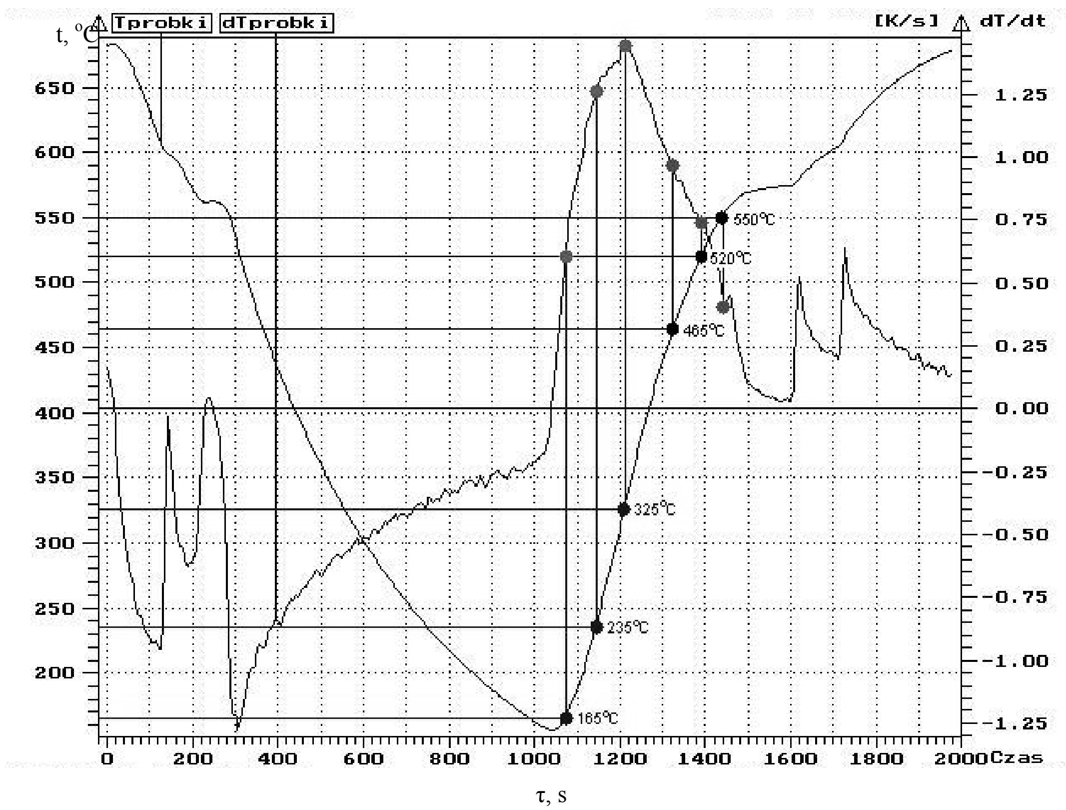


Fig. 1. Curves from the ATD method for refined and modified EN AB-42000 alloy

In the Table 2 are shown parameters of heat treatment operations for three-stage plan of testing with four variables. In the accepted plan of the investigations, number of configurations amounts to 27.

Table. 2. Heat treatment parameters of the alloy

temperatura przesycania t_p [^oC]	czas przesycania τ_p [h]	temperatura starzenia t_s [^oC]	czas starzenia τ_s [h]
t_{p1} - 465	0,5	t_{s1} - 165	2
t_{p2} - 520	1,5	t_{s1} - 235	5
t_{p3} - 550	3	t_{s1} - 325	8

Temperatures of solutioning and ageing treatments were selected on base of values of points on the ATD melting curves (Fig.1).

3. Description of obtained results

To the heat treatment one used refined and modified alloy. In the Fig. 2 are presented average values of tensile strength R_m of the EN AB-42000 alloy after heat treatment, referenced to values obtained for the alloy without heat treatment.

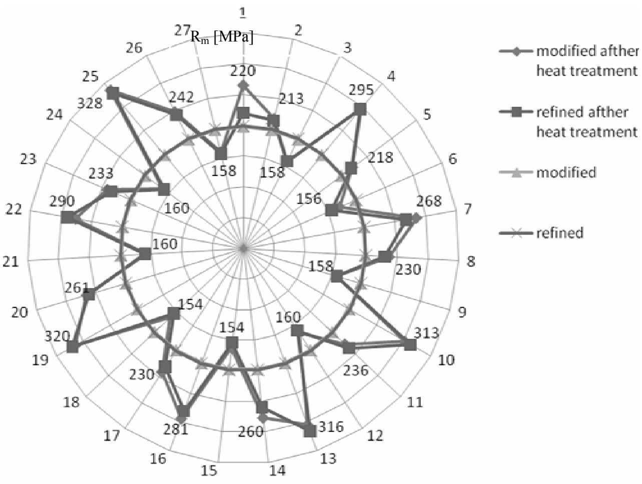


Fig. 2. Change of tensile strength R_m of the investigated alloy for individual configurations of the investigations plan

Tensile strength value obtained in case of refined alloy amounted from 190 to 201 MPa. A slight change of the tensile strength, R_m, (196÷207 MPa) is seen after the modification. After performed heat treatment the tensile strength R_m was included in range of 154 ÷ 328 MPa.

In the Fig. 3 is presented a microstructure of refined and modified alloy prior the heat treatment.

The microstructure is characterized by clearly refined eutectic mixture within interdendritic space of phase α.

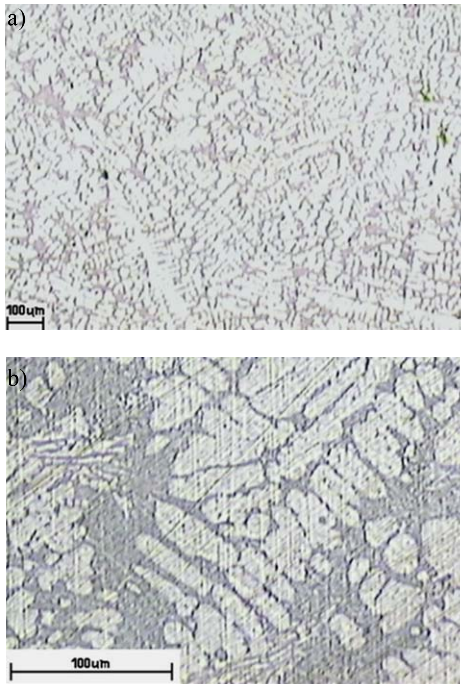


Fig. 3. Microstructure of modified alloy:
a) magnification 100x, b) magnification 500x

The Fig. 4 illustrates structure of EN AB-42000 alloy after heat treatment.

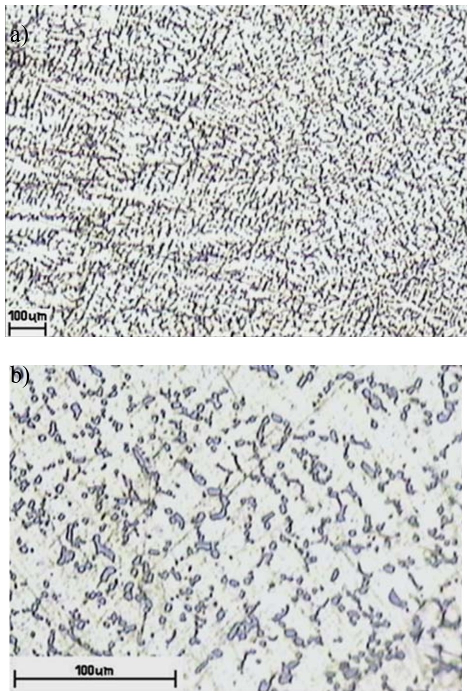
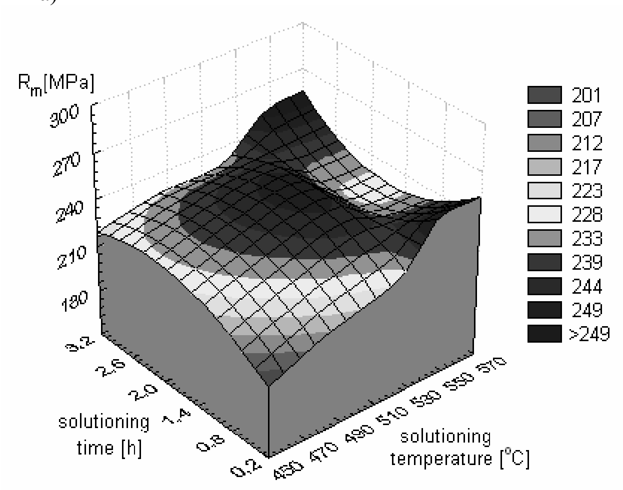


Fig. 4. Microstructure of alloy after heat treatment:
a) magnification 100x, b) magnification 500x

Change of microstructure of the alloy after solutioning and ageing treatments (Fig. 4) can be characterized by uniform, spherical precipitations of eutectic silicon on background of metallic matrix (α - solid solution). Making comparison of obtained average values of parameters from the test of the alloy after heat treatment and the alloy without heat treatment, it was found a growth of the tensile strength R_m up to 163% (configuration no. 25, Fig. 2) comparing to modified alloy without heat treatment. The highest value of tensile strength R_m= 328 MPa was obtained for: solutioning temperature of 550 ^oC, solutioning time of 3 h, ageing temperature of 165 ^oC and ageing time of 8 h.

In the Figs. 5-6 are presented spacial diagrams, showing effect of temperature and duration of solutioning and ageing treatments on change of tensile strength R_m of the investigated alloy.

a)



b)

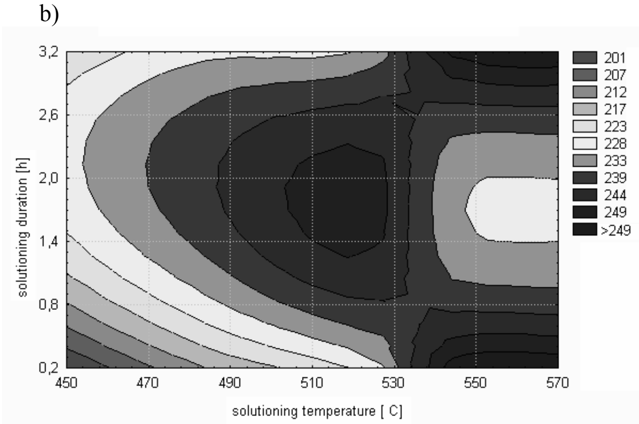


Fig. 5. Effect of temperature and duration of solutioning treatment on tensile strength R_m of EN AB-42000 alloy: a) spacial diagram, b) isohypse diagram

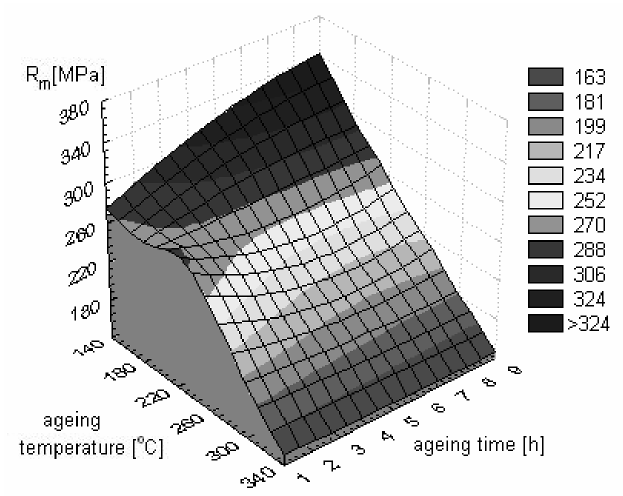
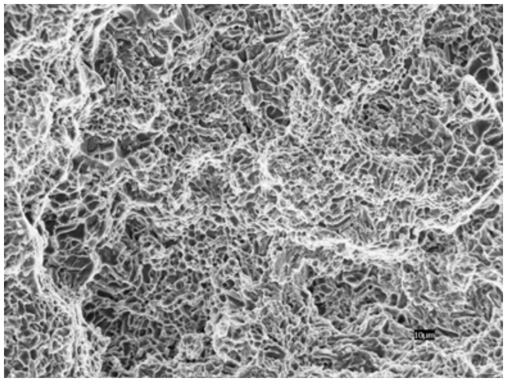


Fig. 6. Effect of temperature and duration of solutioning treatment on tensile strength R_m of EN AB-42000 alloy

In the Fig. 7 are presented photos of fracture's surface of the test piece which is characterized by the lowest and the highest tensile strength R_m after heat treatment.

a)



b)

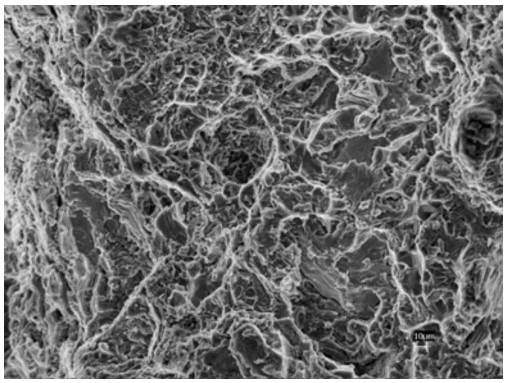


Fig. 7. Photos of fracture of the alloy after heat treatment, magnification 1000x: a) alloy with the lowest tensile strength R_m, b) alloy with the highest tensile strength R_m

In the Fig. 7a is seen a spacial transcrystalline fraction with considerably developed surface, with strips of plastically broken links. Whereas in the Fig. 7b are seen a zones of cleavage fracture with cracking front through diversified planes of cleavaging and plastically broken links.

In the Fig. 8 are shown average values of elongation A_5 of the EN AB-42000 alloy after heat treatment in relation to values obtained for the alloy without heat treatment.

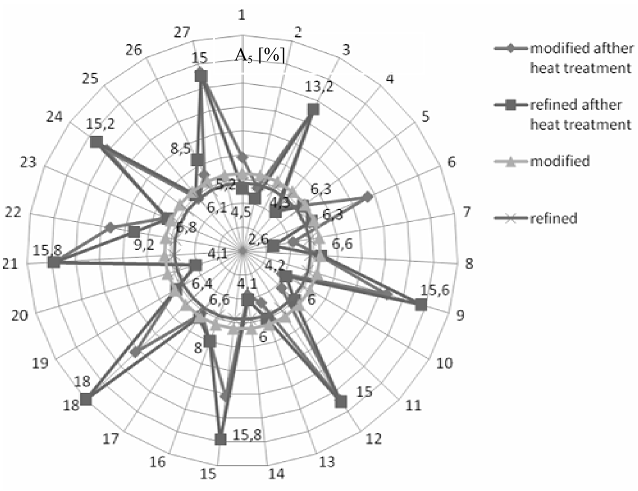


Fig. 8. Change of elongation A_5 of the investigated alloy for individual configurations of the investigations plan

Elongation A_5 obtained for the refined alloy amounted from 5,5 to 5,9 %. After modification occurred a slight increase of the elongation (6 – 7,2 %). After performed heat treatment, the elongation of the alloy amounted from 2,6 to 18%.

Making comparison of obtained average values of the parameters from the test for the alloy after heat treatment and the alloy without heat treatment it has been confirmed a threefold growth of the elongation A_5 (configuration no. 18, Fig. 8) comparing with the alloy modified, without heat treatment.

The highest elongation A_5= 18% was obtained for: solutioning temperature of 520 ^{o}C, solutioning time of 3 h,, ageing temperature of 325 ^{o}C and time of ageing of 5 h.

In case of the elongation, its increase is connected, first of all, with high temperature of ageing of the alloy.

In the Fig. 9 are presented spatial and isohypse diagrams depicting effect of temperatures and durations of solutioning treatment of EN AB-42000 alloy on change of its elongation A_5.

In the Fig. 10 is presented a spacial diagram depicting effect of temperature and duration of ageing treatment of EN AB-42000 silumin on its elongation A_5.

In the Fig. 10 is presented a spacial diagram depicting effect of temperature and duration of ageing treatment of EN AB-42000 silumin on its elongation A_5.

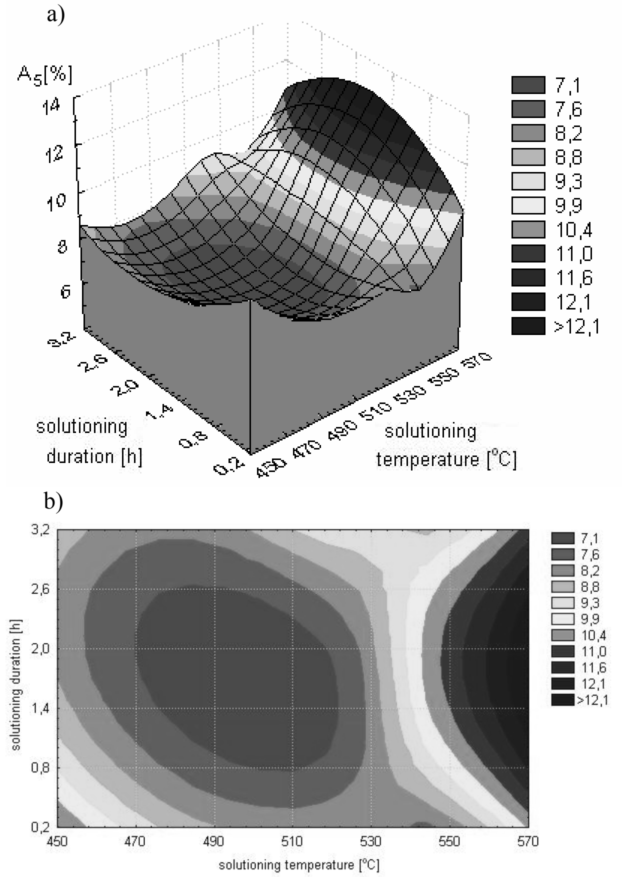


Fig. 9. Effect of temperature and time of solutioning treatment on tensile strength R_m of the EN AB-42000 alloy: a) spacial diagram, b) isohypse diagram

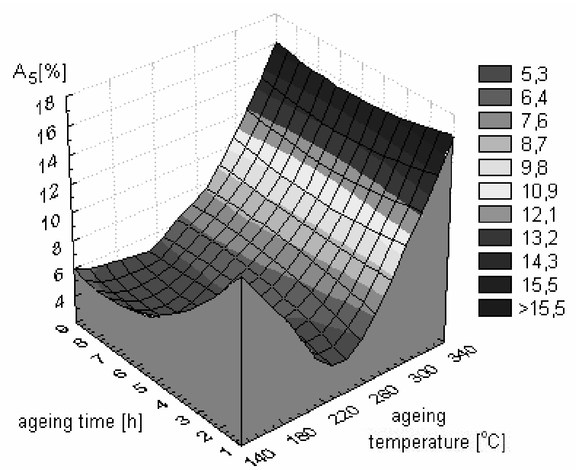


Fig. 10. Effect of temperature and duration of ageing on tensile strength R_m of EN AB-42000 alloy

4. Conclusions

On base of obtained test results it should be ascertained that heat treatment of the EN AB-42000 alloy effects in growth of its tensile strength R_m and elongation A_5.

Usage of ATD enabled initial determination of temperature ranges of solutioning and ageing treatments of the investigated alloy.

The highest values of tensile strength R_m were obtained for the following parameters of the heat treatment process:

a) solutioning temperature - 520 ÷ 550 °C,

b) solutioning time - 1,5 ÷ 3 h,

c) ageing temperature - 165 °C

d) ageing time - 5 ÷ 8 h.

The highest elongation A_5 were obtained for the following parameters of the heat treatment process:

a) solutioning temperature - 520 ÷ 550 °C,

b) solutioning time - 3 h,

c) ageing temperature - 325 °C

d) ageing time - 5 ÷ 8 h.

Improvement of mechanical properties of EN AB-42000 silumin through implementation of the heat treatment is possible only in case of selection of suitable parameters of solutioning and ageing treatments. Improperly selected parameters of the heat treatment process result in worsening of mechanical properties of the alloy, comparing with the alloy without heat treatment.

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