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Heat Treatment of AlZn10Si7MgCu Alloy and its Effect on Change of Mechanical Properties

J. Pezda*
Faculty of Chipless Forming Technology, University of Bielsko-Biała, Willowa 2, 43- 300 Bielsko - Biała, Poland
*Corresponding author. E-mail address: jpezda@ath.bielsko.pl

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Abstract

The most important parameters which predetermine mechanical properties of a material in aspects of suitability for castings to machinery components are: tensile strength (R_m), elongation (A_5, hardness (HB) and impact strength (KCV). Heat treatment of aluminum alloys is performed to increase mechanical properties of the alloys mainly. The paper comprises a testing work concerning effect of heat treatment process consisting of solution heat treatment and natural ageing on mechanical properties and structure of AlZn10Si7MgCu alloy moulded in metal moulds. Investigated alloy was melted in an electric resistance furnace. Run of crystallization was presented with use of thermal-derivative method (ATD). This method was also implemented to determination of heat treatment temperature ranges of the alloy. Performed investigations have enabled determination of heat treatment parameters' range, which conditions suitable mechanical properties of the investigated alloy. Further investigations will be connected with determination of optimal parameters of T6 heat treatment of the investigated alloy and their effect on change of structure and mechanical/technological properties of the investigated alloy.

Keywords: Heat Treatment, Aluminum Alloys, ATD, Natural Ageing, Mechanical Properties

1. Introduction

Mechanical properties and structure of aluminum casting alloys are dependent on conditions of performed melting process, rate of solidification, technology of casting process and implemented heat treatment. Alloys from Al-Zn-Si-Mg group, called as zinc silumins, are – in spite of their many advantages – unpopular and used in very limited applications [1]. Relatively high range of formation of solid solution Zn in Al is characteristic in case of Al-Zn alloys [1, 2]. The alloy features very good castability, good wear resistance, low thermal resistance and very good mechanical machining properties [3]. Zinc as addition in Al-Si alloys is of a special importance, does not interact with other constituents in small quantities, and does not have any practical effect of mechanical properties of the alloys [1].

Such interaction of zinc in ternary AI-Zn-Si alloys can be justified in AI-Zn system. It is a system with eutectics 95% Zn and eutectoid mixture 78% Zn, created in temperature 275°C, consisting of terminal solid solution of zinc in aluminum α with contents of 31.6% zinc and crystals of terminal solid solution of aluminum in zinc β with contents of 0.6% Al. As temperature decreases, solubility of zinc in aluminum decreases as well, and in ambient temperature reaches nearly zero value [1]. Composition of Al-Zn-Si alloys comprising up to 15% Zn does not differ significantly from composition of silumins [4].

All Al-Zn based alloys have excellent corrosion resistance in variety of environments. In general, presence of aluminum in these alloys enhances well-known corrosion resistance of zinc, which is the main constituent of the alloys.

To advantages of the zinc silumins belong: their reduced susceptibility to sparking in contact with steel, what can predispose these alloys to applications in mining industry. [1].

Mechanical properties of Al-Si and Al-Zn-Si depend, besides contents of Si, Zn, Mg and Fe, more on distribution and shape of silicon particles [1, 2, 5]. Presence of additional elements in Al-Si or Al-Zn alloys allows formation of many complex intermetallic phases, such as binary phases (e.g. Mg_2Si, Al_2Cu), ternary phases (e.g. Al_2CuMg, Al_5FeSi, AlFeMn, $A17Cu_4Ni$ i AlFeNi) and quaternary phases (e.g. cubic α-Al15 $(FeMn)_3Si_2$ and $Al_5Cu_2Mg_8Si_6$), all of which may have some solubility for additional elements [5].

Suitable selection of temperatures and durations of solutioning treatments of the alloy belong to important aspects in case of T4 treatment. Definition of these parameters can be performed with use of thermal-derivative analysis methods, such as ATD and ATND methods, providing opportunity of selection of solutioning temperature ranges, mainly taking into consideration their temperature of melting, having an effect on level of maximal temperature of the solutioning.

In case of temperature, to determine temperature ranges, one can make use of the ATD thermal method of crystallization process analysis [1, 2, 6-9]. The ATD method, based on analysis of temperature changes' course, enables registration of phenomena arisen in result of melting and solutioning treatment of alloys. Implementation of that method enables determination of melting temperature of the material, and the same, permits to determine maximal temperature of the solutioning treatment with elimination of possibility of partial melting of the material (casting).

2. Methodology of the research

Investigated alloy was melted in electric resistance furnace and refined with Rafal 1 preparation in quantity of 0.2% of mass of charge, in temperature 720°C. After completion of the refinement (30 minutes) one removed oxides and slag from the metal-level.

Specimens to strength tests were poured in metal mould heated to temperature 250°C, and were prepared according to PN-88/H-88002 standard.

Poured specimens undergo dispersion hardening with heating of the alloy near solidus line. The treatment consisted in heating of poured specimens to temperature of the solutioning, holding the specimens in such temperature, and next cooling down in cold water (20°C), and next, treatment of natural ageing**.**

Process of solidification and melting of the alloy (ATD method) was recorded with use of fully automatic Crystaldimat analyzer (Fig. 1.)

Fig. 1. Crystaldimat analyzer [s]

After completion of the heat treatment one performed static tensile test on ZD-20 tester. Static tensile test was performed according to PN-EN 10002-1: 2004 standard. In turn, hardness measurement was made according to PN-91/H-04350 standard. Impact strength test was made on base of PN-EN 10045-1:1994 standard.

Photos of structure of the investigated alloy were made with use of Neophot 32 microscope and MultiScan system to picture analysis.

In the Table 1 is presented percentage share of main alloy-forming elements being present in the investigated alloy.

Table. 1.
Main alloy-forming elements

Si	Cu	Zn	Fe	Mg	Mn	Ni	Al
[%]	[%]	[%]	[%]	[%]	[%]	[%]	[%]
4.8	0.93	9.8	1.0	0.8	0.2	0.5	rest

Analysis of chemical composition was performed with use of spectrometry method (emission spectrometer with glow-discharge excitation of GDS 850A type).

In the Figure 2 are presented curves of heating (melting) and crystallization of the alloy, recorded with use of ATD method.

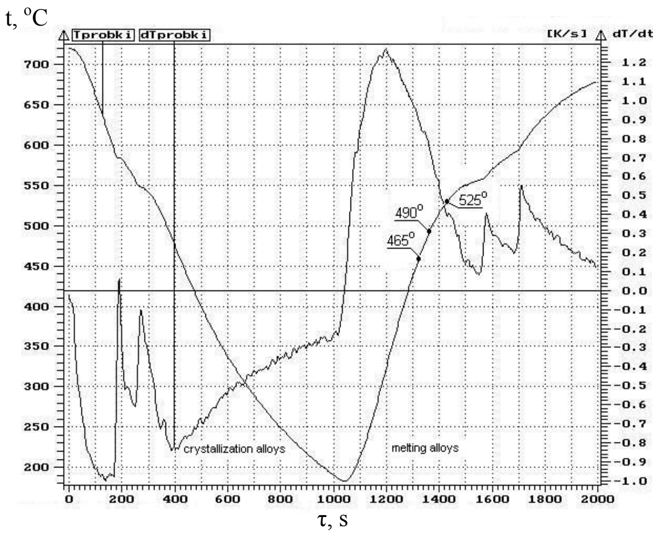

Fig. 2. Curves from ATD method for AlZn10Si7MgCu alloy

On thermal curve (Fig. 2) are marked temperature ranges of solution heat treatments of the investigated alloy (465÷525°C).

Durations of solution heat treatment were determined in range from 30 to 120 min. Duration of natural ageing amounted to 7 days.

3. Description of obtained results

For the raw alloy (without heat treatment) one obtained the following mechanical properties:

- tensile strength R_m from 240 to 250 MPa,
- elongation A_5 from 1.4 to 1.6%,
- hardness HB from 88 to 94,
- impact strength KCV from 1.15 to 1.85 J/cm^2.

After performed natural ageing there were obtained the following properties of the investigated alloy:

- tensile strength R_m from to 329 MPa,
- elongation A_5 from 0.4 to 2.3%,
- hardness HB from 97 to 117,
- impact strength KCV from 3.5 to 6 J/cm^2.

In the Figs. 3-6 are presented graphically obtained results from individual tests of mechanical properties of AlZn10Si7MgCu alloy after natural ageing.

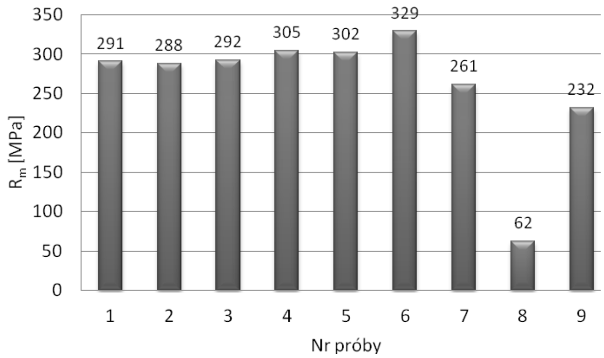

Fig. 3. Effect of temperature and duration of solutioning on tensile strength R_m

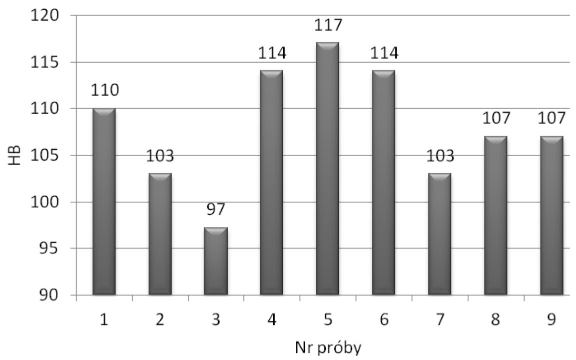

Fig. 4. Effect of temperature and duration of solutioning on hardness HB

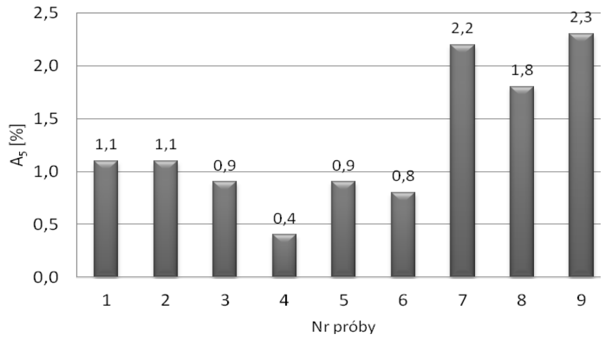

Fig. 5. Effect of temperature and duration of solutioning on elongation A_5

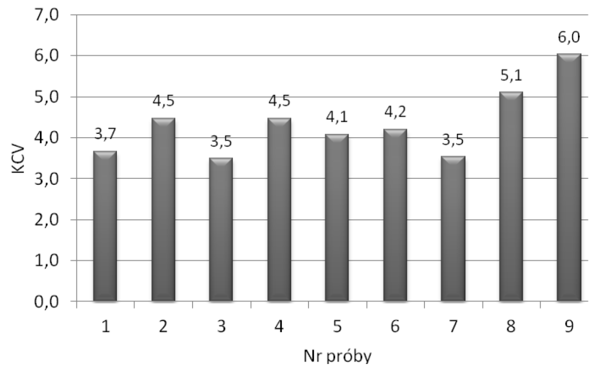

Fig. 6. Effect of temperature and duration of solutioning on impact strength KCV

Maximal values of mechanical properties were obtained for the following parameters of solution heat treatment:

a) tensile strength R_m = 329 MPa for solutioning temperature 490˚C and solutioning duration 120 minutes,
b) elongation A_5 = 2.3% for solutioning temperature 525˚C and solutioning duration 120 minutes,
c) hardness HB = 117 HB for solutioning temperature 490˚C and solutioning duration 60 minutes,
d) impact strength KCV = 6 J/cm^2 for solutioning temperature 525˚C and solutioning duration 120 minutes.

In the Table 2 are presented temperatures and solutioning durations for individual tests.

Table. 2.
Temperature and duration of solutioning for individual tests

No. of test	1	2	3	4	5	6	7	8	9
Solutioning temperature [^{o}C]	465	465	465	490	490	490	525	525	525
Solutioning duration [min.]	30	60	120	30	60	120	30	60	120

In the Fig. 7 is shown a structure of the raw alloy (without heat treatment), and the structure after natural ageing for specimens characteristic of the lowest and the highest tensile strength R_m.

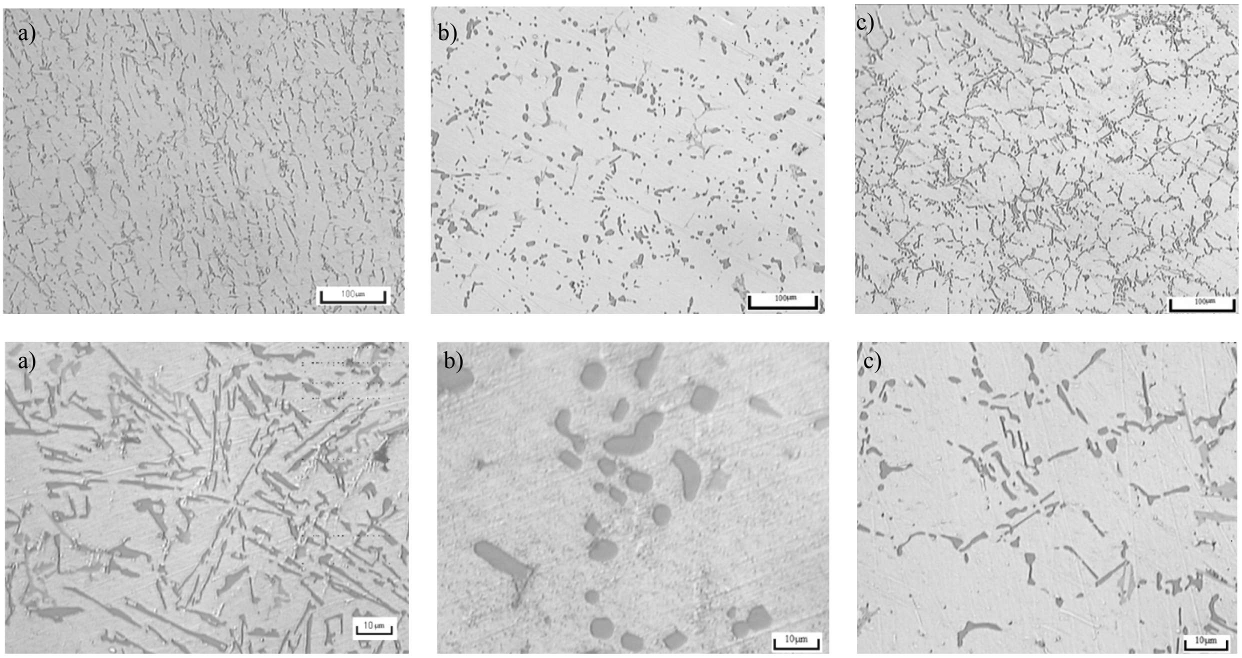

Fig. 7. Structure of AlZn10Si7MgCu alloy: a) raw alloy (without heat treatment), b) after natural ageing with the lowest tensile strength R_m, c) after natural ageing with the highest tensile strength R_m

Structure of the raw alloy is characteristic of, typical for not modified silumin, precipitations of eutectic silumin having lamellar form. Structure of the alloy after heat treatment is characteristic of visible change of silicon form. Alloy supersaturated in temperature 525^{o}C is characteristic of big precipitations of silicon, what results in reduction of mechanical properties with simultaneous growth of impact strength. In turn, the alloy supersaturated in temperature 490^{o}C features precipitations of silicon distributed on boundary of grains, what promotes strengthening of the material, and hence, growth of its mechanical properties.

4. Conclusions

On base on performed investigation one can state that heat treatment has an effect on change of mechanical properties of AlZn10Si7MgCu alloy. Selection of suitable temperatures and durations of solution heat treatment leads to improvement of tensile strength R_m and other mechanical properties (A_5, HB, KCV).

Too high temperature of solution heat treatment (525^{o}C) results in drop of mechanical properties of the investigated alloy, with simultaneous double growth of impact strength.

Optimal, from improvement of mechanical properties point of view, temperature of solution heat treatment, determined on base of performed investigations amounted to 490^{o}C.

A further work will concern investigations of an effect of T6 treatment on mechanical properties (R_m, A_5, HB, KCV) of the investigated alloy.

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