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Influence of the ageing on mechanical properties of the aluminium alloy AlSi9Mg

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ABSTRACT

Purpose: The goal of this paper was study the influence of temperature and time in the age-hardening on the selected mechanical properties and hardness of the AlSi9Mg alloy.

Design/methodology/approach: The efficiency of the age-hardening were tested on laboratory specimens through the statically tension test on ZWICK/Z100. Damages were critically assessed through SEM investigations. Evaluation the mechanical properties of prepared samples were realized by solutioning and then ageing in different periods of time.

Findings: Adequately selected time of the ageing improved the hardening and plasticity and reduce the tendency of aluminium to formation of coagulations.

Research limitations/implications: The described investigations were limited to changes the mechanical properties of the specimens in different periods of time of aging, in solid temprature. In future research works should show the influence of change of temperature process on studied AlSi9Mg alloy, as well as different lightweight alloy.

Originality/value: The paper contributes to better understanding and recognition the mechanisms of age-hardening.

Keywords: Mechanical properties; Age-hardening; Aluminium; Solutioning

PROPERTIES

1. Introduction

The Al-Si alloys, commonly named silumins, pertain to the most popular aluminium casting alloys. The silumins characteristic low density with equal about 3.0 g/cm^3 and low density advantageously increased weight strength, with determined by ratio between tensile strength and specific gravity (Rm/ρ). This relations enable to easy compare different group of the construction materials [1-6].

The aluminium created with many of the elements (silicon, copper, magnesium, nickel, iron) primary solid solution and their solubility is depends on the temperature. This phenomena made enable to realized the heat treatment of that alloys which is connected with changed solubility and separated from the solution intermetallic compounds, characterized by high hardness [3-10].

To the operations of the heat treatment, used to aluminium casting alloys belong: soft annealing, stress relief annealing, solutioning and quench ageing. For the majority of the alloys solutioning temperature contain between 490÷530°C; for alloys with magnesium and zinc the temperature is a little low; whereas Al-Cu alloys solutioning between 510÷540°C. Heating may by realized as quick. Heating to such high temperature guaranteed total solubilize alloying component in solid solution. While casting the alloys to the permanent-mould the cast will had small grains, soaking time equal between 2÷4 hours and while casting to the sand mould the cast will had random logic structure, so the soaking time will equalled between 6÷12 hours [8, 10-15].

Table 1.
Ladle chemical analysis aluminium alloy AlSi9Mg

Alloy	Average chemical composition (wt) [%]						
AlSi9Mg	Al	Si	Mg	Cu	Fe	Mn	rest
	rest	9,16	0,38	0,23	0,33	0,33	0,25

Structure received after solution heat treatment is unstable and the component dissolved into solid solution is susceptible to separate from the solution. Therefore is necessary to realize next operation of the heat treatment which is ageing. Ageing may proceed in the temperature range of 150÷230°C and operation time may be between 5÷20 hours [10-12].

2. Experimental procedure

Materials testing were realized on test pieces from the aluminium casting alloys AlSi9Mg which is embrace PN-EN 1706:2001 standard. Chemical constitution of the research alloy was shown in table 1. Test pieces to strength test were received by casting to permanent-mould form in temperature equal 693°C.

After casting the test pieces were shaped through machining to make later the strength test (fig.1). Overall dimensions of test pieces were determinate on the basis of PN-EN 10002-1:2004 standard.

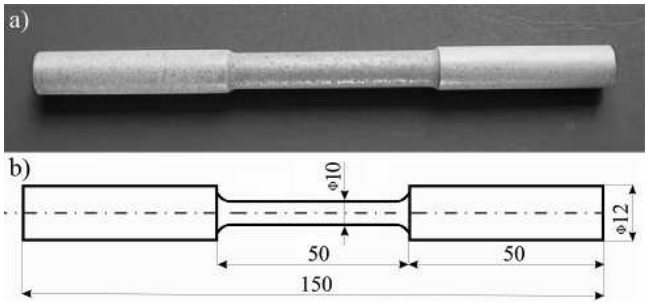

Fig. 1. a) photo of the test specimen, b) line drawing of the sample

Prepared test pieces were cleaned from impurity into acetone then were realized the heat treatment which first were solutioning and then ageing. Solutioning and ageing parameters were showed in table 2.

Table 2.
Solutioning and ageing parameters for AlSi9Mg

Heat treatment operation	Temperature [°C]	Time [h]	Cooling medium
Solutioning	520±5	6	Water – 20°C quenching
Ageing	150±10	3, 6, 9, 12, 15	Air cooling

In order to investigated influence of the heat treatment, especially the influence of the ageing on mechanical properties and on the structure aluminium casting alloy AlSi9Mg, were made the following researches:

- selected mechanical properties (hardness, tensile strength, yield strength, elongation);
- macroscopic observation of the fractures after statically tensile test.

Evaluation of the hardness was made on the basis of measurements by the Rockwell hardness method with steel ball indenter about diameter equal 1/16".

The measurements were made on hardness testing machine named ZWICK/ZHR, there were used B scale of the hardness testing machine. Evaluation of the mechanical properties was made on the basis of taken measurements from statically tensile test on the testing machine named ZWICK / Z100. The fractures observations were made on scanning electron microscope named DSM-940. The magnification range was between 10 and 2000 time and the accelerating voltage equaled 20kV.

3. Results and discussion

The results of hardness test the aluminium casting alloy AlSi9Mg after made the heat treatment depend only on solutioning and after the age hardening (solutioning + ageing) were shown in table 3.

Table 3.
Results from hardness testing after solutioning and ageing AlSi9Mg alloy

Heat treatment	Time [h]	Average hardness [HRB]
Solutioning: 520°C	6	26,7
Ageing: 150°C	3	37
	6	40,1
	9	41
	12	48,6
	15	54,7

As results of made statically tensile test for AlSi9Mg alloy were received: tensile strength – Rm, yield strength – Rp0,2, Young's modulus – E, elongation – A5. Obtained results depending on parameters used in the treatment, were shown in table 4.

Table 4.
Results from the statically tensile test AlSi9Mg alloys

Heat treatment	Time [h]	Average $R_{p0,2}$ [MPa]	Average R_m [MPa]	Average A_5 [%]
Solutioning: 520°C	6	176	283	8,1
Ageing: 150°C	3	265	288	1,2
	6	296	296	1,5
	9	258	287	3,8
	12	265	297	2,3
	15	300	330	2,3

During the observation of test pieces which were put to the solutioning process with using scanning electron microscope watched that the test pieces have got plastic fracture. The plastic

fracture arisen participation with plastics strains (fig. 2). Plastic fracture is characterized by fibrous appearance and by big development of surface.

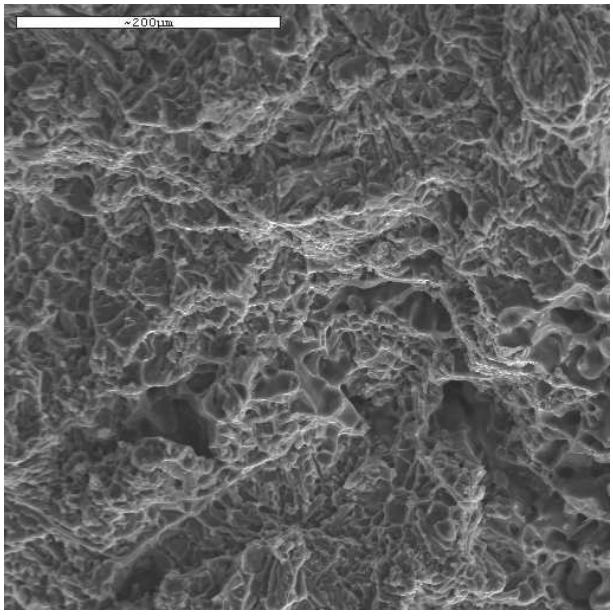

Fig. 2. Fracture of AlSi9Mg alloy after solutioning process where temperature was 530°C and time 6 hours

That fracture is characteristic for aluminium casting alloy and it's easy to identify because on the view from scanning electron microscope can saw „mountains and valleys".

Most characteristic plastic fracture form all observed test pieces was that viewed after age hardening by 15 hours in 150°C (Fig. 3).

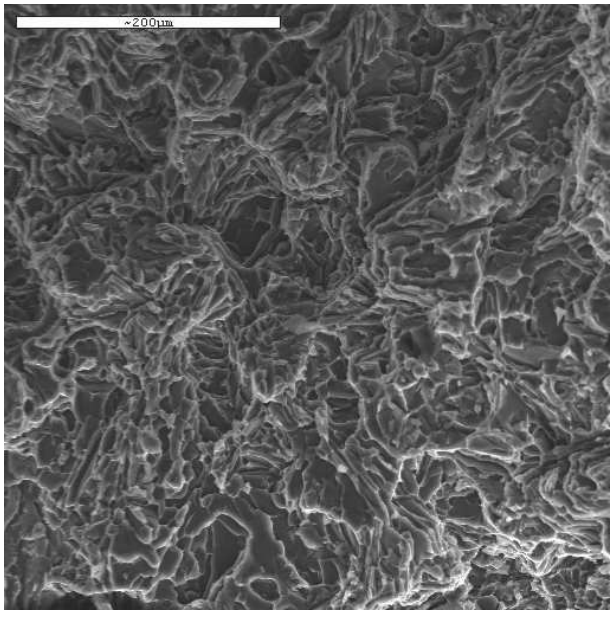

Fig. 3. Fracture of AlSi9Mg alloy after ageing in 150°C by 15 hours

Lengthen the ageing time until to 15 hours hardness gradually was increase (fig. 4) and reach value 54,7 HRB what is twice time higher value than hardness obtained after solutioning process.

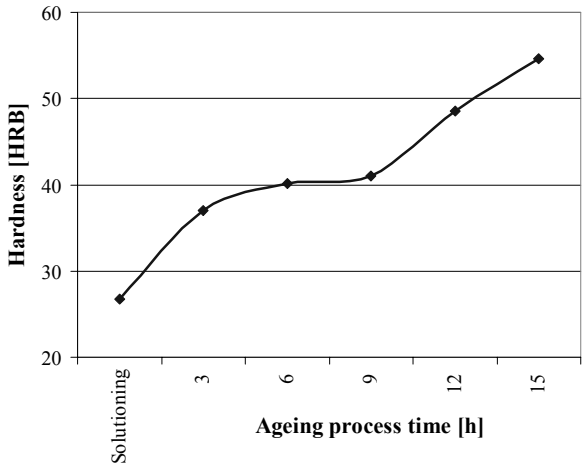

Fig. 4. Hardness changed depending on the heat treatment parameters

Realized statically tensile test for test pieces after solutioning provided to the following result: $R_{p0,2}$ = 176MPa. After ageing process in 150°C independently of the time made investigations (withtin the range 3÷15 hours), field strength value was increase about 45÷68% in relation to yield strength value after solutioning process (fig. 5), and made for 300MPa, when ageing gone on by 15 hours.

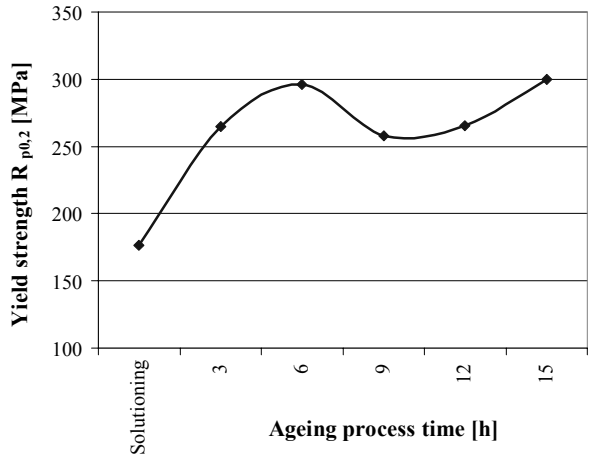

Fig. 5. Field strength changes depending on the heat treatment parameters

Likewise results, which were got in test the yield strength, were observed in case of tensile strength test – R_m. Realized the ageing process in 150°C, were observed that when the time enlarge, between 3 and 15 hours, in test pieces occur growth tensile strength (fig. 6). For the test pieces which were soaking through 3 hours, tensile strength made for about 288MPa and after ageing operation by 15 hours R_m reach about 330MPa.

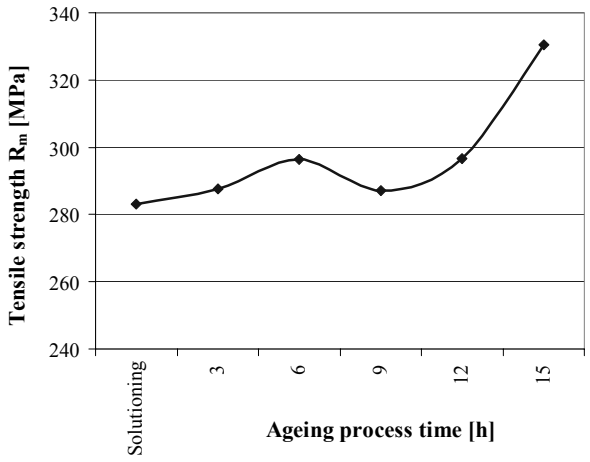

Fig. 6. Tensile strength changed depending on the heat treatment parameters

After solutioning elongation were equal about 8% and in consequence realized ageing operation, value of the elongation were decrease to 2÷4% level (fig. 7).

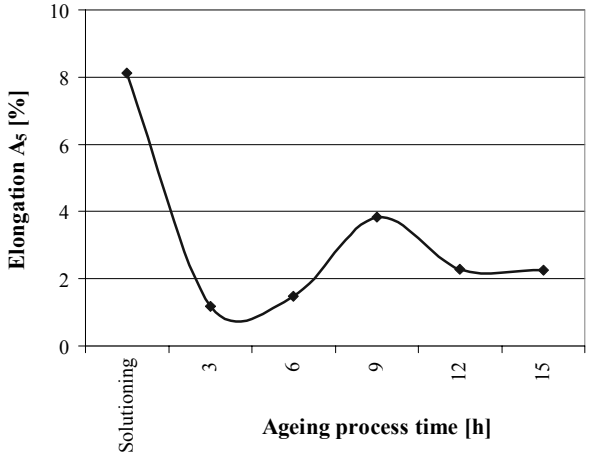

Fig. 7. Elongation changed depending on the heat treatment parameters

4. Conclusions

Ageing temperature for the AlSi9Mg alloy, should include between 150 and 180°C, what guaranteed increase mechanical properties after realized heat treatment. Even if the ageing time at least was 3 hours hardness increase with relation to hardness after solutioning to 37 HRB. Every next 3 hours soaking resulted in increase hardness of the testing pieces.

Temperature and time of the ageing process play the meaningful role and also have got the biggest influence on the plastically properties on material from which the test pieces were made. Apart from that how long the process duration, plastically properties, represented by elongation – A_5, were decrease.

References

[1] F. Binczyk, Construction casting alloys, Silesian University of Technology Publishing, Gliwice, 2003 (in Polish).
[2] A. Kosowski, Metallography of casting alloys, AGH University of Science and Technolory Publishing, Cracow, 1996 (in Polish).
[3] R. Cook., Grain Refinement Of Aluminium-Silicon Foundry Alloys, London & Scandinavian Metallurgical Co Limited, 2006.
[4] J. Dutkiewicz, Structure and mechanical properties of high strength aluminium alloys, Advanced light Alloys and Composites, Kluwer Academic Publisher, 1998.
[5] E. Kalinowska-Ozgowicz, R. Domagała, W. Kurkiewicz, The influence of precipitation hardening on the structure and mechanical properties of the AISi casting alloys, Ores and non-ferrous alloys 5, 2000 (in Polish).
[6] J. Król, A. Dytkowicz, The precipitation strengthening of directionally solidified AlSiCu alloys, Solidification of Metals and Alloys, PAN – Foundry Commission 28, 1996.
[7] G. Mrówka-Nowotnik, J. Sieniawski, Influence of the precipitation strengthening parameters on the microstructure and mechanical properties of AlSiMgMn alloy, Materials Engineering 27/3 (2006) 217-220 (in Polish).
[8] J.H. Sokolowski, M.B. Djurdjevic, C.A. Kierkus, D.O. Northwood, Improvement of 319 aluminium alloy casting durability by high temperature solution treatment, Proceedings of the 7th Scientific Conference „Achievements in Mechanical and Materials Engineering" AMME'1998, Gliwice-Zakopane, 1998, 475-478.
[9] S. Tkaczyk, M. Kciuk, The stress corrosion of aluminium Al–Mg–Si alloys, Proceedings of the 7th Scientific Conference „Achievements in Mechanical and Materials Engineering" AMME'1998, Gliwice-Zakopane, 1998, 527-530.
[10] M.M. Haque, A. F. Ismail, Effect of superheating temperatures on microstructure and properties of strontium modified aluminium-silicon eutectic alloy, Proceedings of the 13th International Scientific Conference „Achievements in Mechanical and Materials Engineering" AMME'2005, Gliwice-Wisła, 2005, 267-270.
[11] M. Kciuk, The structure, mechanical properties and corrosion resistance of aluminium AlMg1Si1 alloy, Journal of Achievements in Materials and Manufacturing Engineering 16 (2006) 51-56.
[12] L.A. Dobrzański, M. Kasprzak, W. Kasprzak, J.H. Sokolowski, A novel approach to the design and optimisation of aluminium cast compo-nent heat treatment processes using advanced UMSA physical simulations, Journal of Achievements in Materials and Manufacturing Engineering 24/2 (2007) 139-142.
[13] T. Haga, H. Sakaguchi, H. Inui, H. Watari, S. Kumai, Aluminium alloy semisolid strip casting using an unequal diameter twin roll caster, Journal of Achievements in Materials and Manufacturing Engineering 14 (2006) 157-162.
[14] J. Adamowski, C. Gambaro, E. Lertora, M. Ponte, M. Szkodo, Analysis of FSW welds made of aluminium alloy AW6082-T6, Archives of Materials Science and Engineering 28/8 (2007) 453-460.
[15] G. Mrowka-Nowotnik, Damage mechanism in AlSi1MgMn alloy, Archives of Materials Science and Engineering 29/2 (2008) 93-96.