EFFECT OF HEAT TREATMENT AND DIFFERENT AMOUNTS OF Mg ON THE MICROSTRUCTURE AND HARDNESS OF Al-Si-Mg CAST ALLOYS

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1. Introduction

Properties of Al-Si cast alloys are more influencing by morphology, shape and distribution of matrix, Si particles, second phases and defects. These structural features are influenced with the composition, melt treatment conditions, grain refining, modification, solidification rate, casting process, heat treatment, and so on [1-3]. Producers of aluminum casts increase the tensile strength and yield strengths especially with heat-treating.

Precipitation hardening heat treatment is the most commonly used process to obtain the optimal combination of strength and ductility of Al-Si-Mg casts' thanks the Mg addition. Magnesium increases the strength and hardness of the alloys, but especially in castings. The strengthening is ensured with forming the precipitates of Mg_2Si phases during T6 heat treatment. The formation of large Mg_2Si phase of about 4÷8 µm during the solidification of conventional cast alloys is detrimental to the alloys' ductility and impact resistance, too [4-5].

For this reason, the present paper is focused on the effect of precipitation hardening (age hardening) on microstructure and hardness of the production AlSi7Mg0.3 and AlSi7Mg0.6 cast alloy.

2. Experimental materials

The experimental material used in this study was hypoeutectic aluminum-silicon-manganese alloys prepared by gravity die casting to the sound molt in company Uneko. Ltd.

For comparison, the strengthening effect in such types of materials were used AlSi7Mg materials with 0.3 wt. % of Mg (alloy A) and 0.6 wt. % of Mg (alloy B) for studies (Table 1).

Table 1. The chemical composition of experimental materials, in wt. %.

Alloy	**Si**	**Mg**	**Fe**	**Mn**
A	7.028	0.354	0.123	0.009
B	6.742	0.519	0.128	0.046
Alloy	**Cu**	**Zn**	**Ti**	**Al**
A	0.013	0.036	0.123	balance
B	0.012	0.005	0.108	balance

3. Experimental methodology

Experimental materials were age-hardened. The age-hardening (T6) for experimental alloys consist of: solution heat treatment at 525 °C with holding time 6 h, rapid quenching at water for 60 °C, that artificial aging at 175 °C for 6 hours.

After hardening were samples subject for assessment on an optical microscope and a scanning electron microscope (SEM) VEGA LMU II (having both secondary electron (SE). Quantitative analysis (image analysis) were performed with NIS Elements software on optical microscope. Each measured data are average values of min. 60 measured microstructural features. The metallographic samples were prepared according to standard metallographic procedure (wet ground on SiC papers, DP polished with 3µm diamond pastes followed by Struers Op-S). The etcher 0.5 % HF was used for chemical etching. The 3D morphology of eutectic Si, was studied with using scanning electron microscope on samples etched with HCl.

Hardness measurements were performed according to STN EN ISO 6506-1: Brinell hardness tester with a load of 250 kp (1 kp = 9.81 N), 5 mm diameter ball and a dwell time of 15s (HBW 5/250/15) and Vickers hardness tester with a load of 49.02 N and a dwell time of 10s (HV 5/10). The evaluated HBW and HV reflect average values of at least six separately experimental specimens. The hardness of microstructural features was measured with using Vickers microhardness testing machine ZWICK/Roel ZHµ with the evaluation software ZWICK/Roel ZHµ/HD under a 10 g load for 10 s (HV 0.01) on metallographic samples. The evaluated HV 0.01 reflect average values of at least ten measurements on each structural parameters.

4. Results and discussions

The used heat treatment of experimental materials lead to changes in microstructure and hardness. The Si particles in form of small plate (in as-cast state - Fig. 1a) were fragmented and spheroidizated to smaller rod (Fig. 1b) by heat treatment.

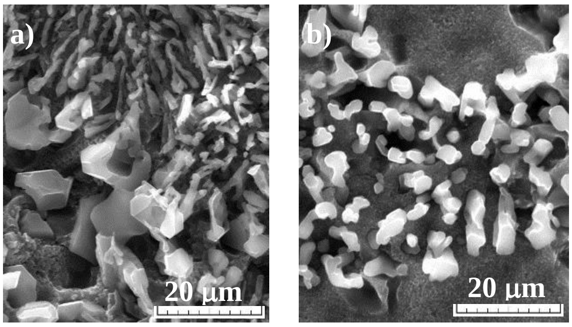

Fig. 1. Morphology of eutectic Si, etch. HCl
a) experimental alloys in as-cast state;
b) experimental alloys after T6.

The metallography observation (Fig. 2) shows changes not only in Si particles but also in other microstructural features: intermetallic phases.

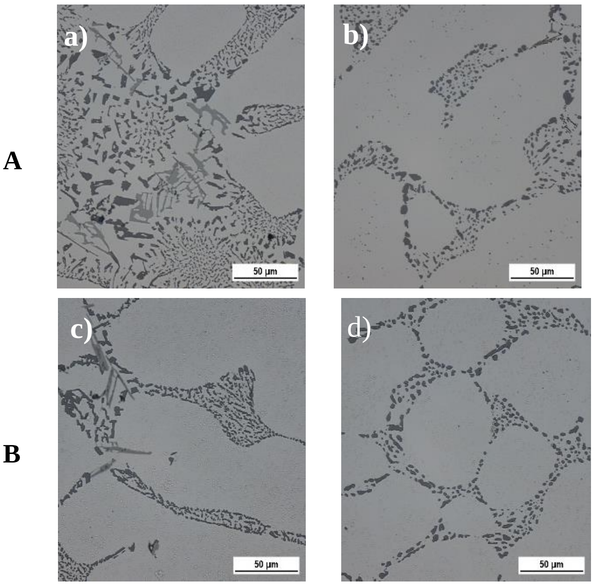

Fig. 2. Microstructure of experimental alloys, etch. 0.5 % HF
a) c) experimental alloys in as-cast state;
b) d) experimental alloys after T6.

The greatest changes were observed in material A in which after age-hardening the intermetallic phases especially Fe-rich phases were fragmented from long skeleton like (Fig. 2a) to small particles (Fig. 2b).

The greatest changes of results of quantitative analysis were also confirmed in material A (Tab. 1).

Hardness measurements (Tab. 2) shows that higher hardness have materials after age-hardening which related with formation of Mg_2Si precipitates in substructure of experimental materials. Microhardness of the matrix ($HV0.01^{Al}$) shows greater influence of strengthening with precipitates (Table 2).

Table 1. The results of quantitative analysis.

Alloy	SDAS [μm]	Area fraction of Si [%]	Shape factor of Si	Area fraction of porosity [%]
A	64	6.4	0.845	2.4
A^{T6}	75	8.1	0.921	2.2
B	69	7.9	0.825	2.2
B^{T6}	69	7.0	0.874	2.6

Table 2. The results of hardness measurements.

Alloy	A	A^{T6}	B	B^{T6}
HBW 5/250/15	54.8	93.2	50.8	103
HV 5/10	61	109	58	125.8
$HV0.01^{Al}$	54.3	94.6	49	94

5. Conclusions

The results of this study confirms that higher amount of Mg did not lead to increasing in hardness (materials in as-cast state). Greater influence have age - hardening, which shows with increasing amount of Mg increasing the hardness of materials.

Acknowledgements

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References

[1] Tillová, E.,Chalupová, M., Hurtalová, L. Evolution of Phases in a Recycled Al-Si Cast Alloy During Solution Treatment, Rijeka: InTech (2012), Dr. Viacheslav Kazmiruk (Ed.), Scanning electron microscopy, 2012.

[2] Kuchariková, L., Tillová, E., Bokůvka, O. Recycling and properties of recycled aluminium alloys used in the transportation industry *Transport problems.* 11 (2), 117-122 (2016).

[3] Campbell, J. R. A. Harding, Solidification Defects in Castings. TALAT Lecture 3207, EAA - European Aluminium Association, 1994.

[4] Salleh, M.S. Omar, M.Z., Syarif, J. The effect of Mg addition on the microstructure and mechanical properties of thixoformed Al5%Si-Cu alloys. *Journal of alloys and compounds.* 621, 2015, 121-130

[5] Sani A Salihu, Aliyu Isah, Polycarp Evarastics. Influence of Magnesium Addition on Mechanical Properties and Microstructure of Al-Cu-Mg Alloy. *Journal of Pharmacy and Biological Sciences.* 4, 2012, 15-20.