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Effect of the AlCr20 Addition on the Microstructure of Secondary AlSi7Mg0.3 Alloy

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Abstract

This paper deals with influence of chrome addition and heat treatment on segregation of iron based phases in the secondary alloy AlSi7Mg0.3 microstructure by chrome and heat treatment. Iron is the most common and harmful impurity in aluminum casting alloys and has long been associated with an increase of casting defects. In generally, iron is associated with the formation of Fe-rich intermetallic phases. It is impossible to remove iron from melt by standard operations, but it is possible to eliminate its negative influence by addition some other elements that affect the segregation of intermetallics in less harmful type or by heat treatment. Realization of experiments and results of analysis show new view on solubility of iron based phases during melt preparation with higher iron content and influence of chrome as iron corrector of iron based phases.

Keywords: Secondary AlSi7Mg0.3 based alloys, Iron phases, Thermal analysis, Iron correctors, AlCr20, Heat treatment

1. Introduction

Due to increase requirements on the quality of castings, final fatigue properties and due to the pressure on price of final castings, it is necessary to search compromises in the casting production from secondary alloys with the presence of various impurities. Basis for initiating of this work was lack of theoretical knowledge by using secondary Al-Si-Mg alloys with higher amount of iron and its appropriate and efficient elimination in production of demanding casting for automotive industry by serial conditions. Secondary aluminum alloys are made out of aluminum scrap and workable aluminum garbage by recycling.

Production of aluminum alloys belong to heavy source fouling of live environs. Care of environment in industry of aluminum connects with the decreasing consumptions resource as energy, materials, waters and soil, with increase recycling and extension life of products. More than half aluminum on the present produce in European Union comes from recycled raw material. By primary aluminum production we need a lot of energy and constraints decision mining of bauxite so European Union has big interest of share recycling aluminum, and therefore increase interest about secondary aluminum alloys and cast stock from them.

2. Experimental work

An experimental melts were realized at foundry laboratory located in Department of Technological engineering - University of Žilina. Melts was carried out in an electrical resistance furnace T15, controlled by PID regulator CAL 3200 in a graphite crucible treated by protective coating. Individual casts consisted from creating four samples poured at a temperature 760 ± 5 °C. Melt was poured into chill mold with minimal temperature of 100 °C. As an experimental material was used AlSi7Mg0.3 alloy. The chemical composition of used alloy is shown at Table 1.

Table 1.
Chemical composition of AlSi7Mg0.3 cast alloy

El.	Si	Fe	Cu	Mn	Mg	Ni
[wt.%]	6.93	0.1204	0.0036	0.0037	0.3896	0.0042
El.	**Cr**	**Pb**	**Ti**	**Zn**	**Sb**	
[wt.%]	0.0011	0.0033	0.1141	0.0083	0.0001	

Into experimental alloy was added certain amount of AlFe10 master alloy (deliberate "contamination"), to increase the iron content. The main aim was to increase the iron content in alloy, so that amount is close to maximal allowed content by customer specification for automotive components, made from secondary alloys AlSi7Mg0.3. Added amount of AlFe10 into the basic AlSi7Mg0.3 was 70000 ppm of the total batch. The chemical composition of alloy with higher amount of iron is shown in Table 2.

From experimental melts were taken samples (1-with Fe; 2- with 0.5 wt.% Cr, 3- with 1 wt.% Cr and 4- with 1.5 % Cr). For these samples were prepared samples for metallographic observation and mechanical tests (Brinell hardness and tensile strength). Half of samples was tested in as cast state and half after heat treatment (Fig.1).

Table 2.
Chemical composition of AlSi7Mg0.3 cast allloy with addition of iron

El.	Si	Fe	Cu	Mn	Mg	Ni
[wt.%]	6.49	1.280	0.053	0.092	0.349	0.034
El.	**Cr**	**Pb**	**Ti**	**Zn**	**Sb**	
[wt.%]	0.087	0.006	0.113	0.027	< 0.0004	

To influence the segregation of iron based phases a master alloy AlCr20 had been used. Into alloy with higher amount of iron, different amount of master alloy AlCr20 had been added: 0.5 % (melt no. 2), 1 % (melt no. 3) and 1.5 % (melt no. 4). The chemical compositions of these melts are in Table 3.

Table 3.
Chemical composition of melts after addition of master alloy AlCr20

a) 0.5 % Cr

El.	Si	Fe	Cu	Mn	Mg	Ni
[wt.%]	6.41	1.737	0.054	0.128	0.330	0.080
El.	**Cr**	**Pb**	**Ti**	**Zn**	**Sb**	
[wt.%]	0.289	0.006	0.111	0.027	< 0.0004	

b) 1 % Cr

El.	Si	Fe	Cu	Mn	Mg	Ni
[wt.%]	6.43	1.733	0.055	0.128	0.324	0.081
El.	**Cr**	**Pb**	**Ti**	**Zn**	**Sb**	
[wt.%]	0.411	0.006	0.110	0.027	< 0.0004	

c) 1.5 % Cr

El.	Si	Fe	Cu	Mn	Mg	Ni
[wt.%]	6.45	1.654	0.055	0.119	0.347	0.081
El.	**Cr**	**Pb**	**Ti**	**Zn**	**Sb**	
[wt.%]	~ 0.472	0.006	0.109	0.027	< 0.0004	

By closer look at chemical composition we can see an increasing amount of iron content with increasing amount of AlCr20 alloy. In all cases there was an increase of iron content over 1 % Fe, what is maximum allowable content for this type of alloy.

To influence the segregation of iron based phases a heat treatment T6 had been used (Fig.1).

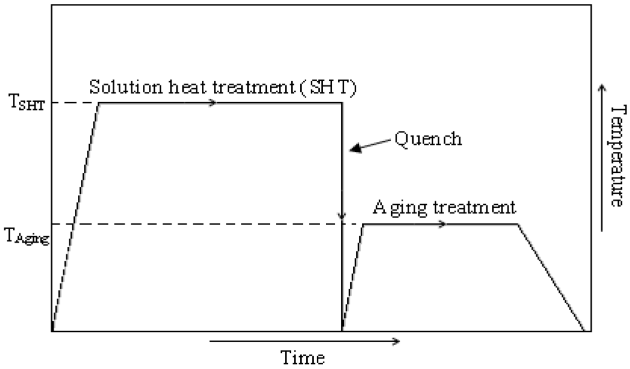


Fig. 1. Heat treatment of alloy

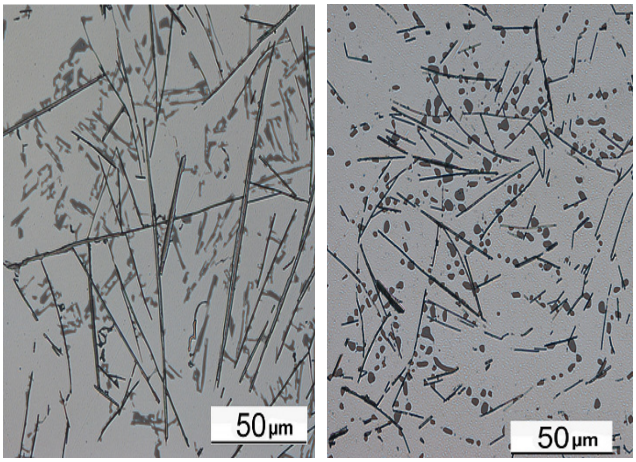
Heat treatment of this alloy constists of solutionising (keep in furnace at 535 °C for 6 Hrs); quenching (sudden quenching in water at 50 °C); natural ageing (up to 8 Hrs);
and precipitation (keep in furnace at 170 °C for 4 Hrs).

At Fig. 2, Fig. 3, Fig. 4 and Fig. 5 are shown microstructures of samples from melts with higher amount of iron and with addition of AlCr20 in as cast state and after heat treatment. Influence of the iron amount on the microstructure and shape of intermetallic phases was studied by classic black – white contrast method. Sample preparation and execution of metallographic image was executed in a standard way for evaluation of intermetallic phases in aluminum alloys. Evaluated samples were etched by 20 ml of H_2SO_4 + 100 ml of H_2O. Images of alloy microstructures were obtained by light microscope NEOPHOT 32. In Fig. 2 is shown microstructure of sample from melt with higher amount of iron. The structure consists of silicon eutectic, dendrites of α – phase excreted in the form of white unites and black areas as iron based particles. The dominant phase is phase knows as beta- or ß- needles phase Al_5FeSi. By analysis of the microstructure we can see impact of the iron on iron based particles themselves. Addition of chrome decreases the amount of phases (needle-like) and we can also see segregation of so called "sludge particles" (Fig. 3a).

For all samples were evaluated tensile strength and elongation. The tensile test was performed on a tensile machine WDW – 20 in the laboratory of mechanical tests, University of Žilina at 22 °C. Results of tensile strength measurements are presented at Fig 6.

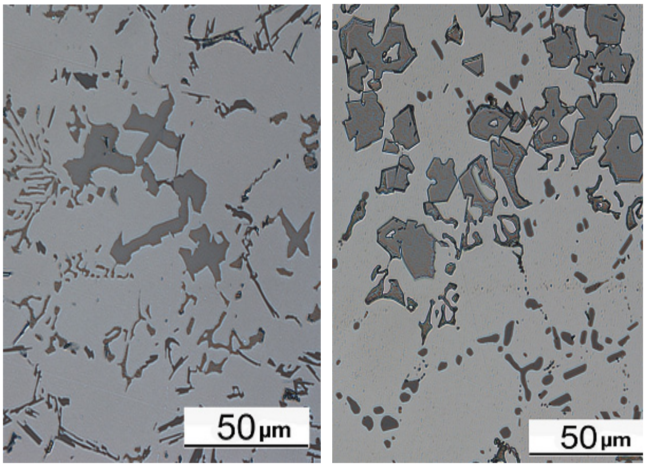
After heat treatment were observed the spheroidisation of eutectic Si and segregation and solution of long Fe-rich needles (Fig. 2b,4b)

After addition of iron into the basic alloy decreased tensile strenght on 167 MPa. But after addition of chrome increased tensile streght above 170 MPa, except for the 1.5 % Cr. Tensile strenght was also measured after heat treatment. Results of tensile strength measurements are presented at Fig. 7.



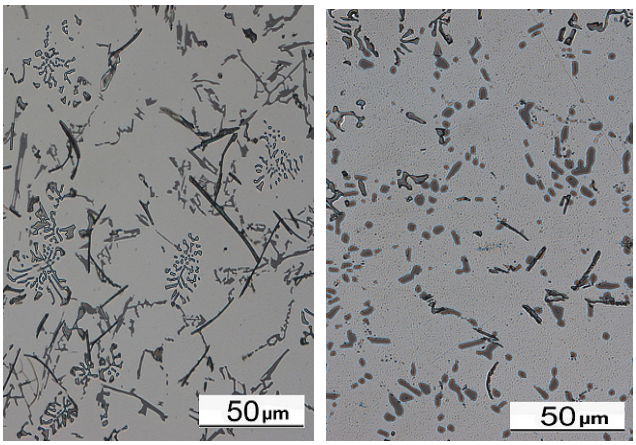
a) Cast state b) after heat treatment

Fig. 2. Microstructure of AlSi7Mg0.3 (1.280 wt.% Fe; 0 wt.% Cr), *etch.* H_2SO_4



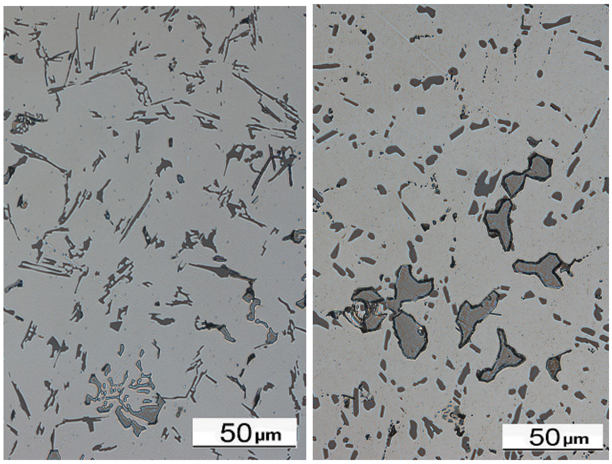
a) Cast state b) after heat treatment

Fig. 3. Microstructure of AlSi7Mg0.3 (1.737 wt.% Fe, 0.5 wt. % Cr), *etch.* H_2SO_4



a) Cast state b) after heat treatment

Fig. 4. Microstructure of AlSi7Mg0.3 (1.733 wt.% Fe, 1 wt. % Cr), *etch.* H_2SO_4



a) Cast state b) after heat treatment

Fig. 5. Microstructure of AlSi7Mg0.3 (1.654 wt.% Fe, 1.5 wt. % Cr), *etch.* H_2SO_4

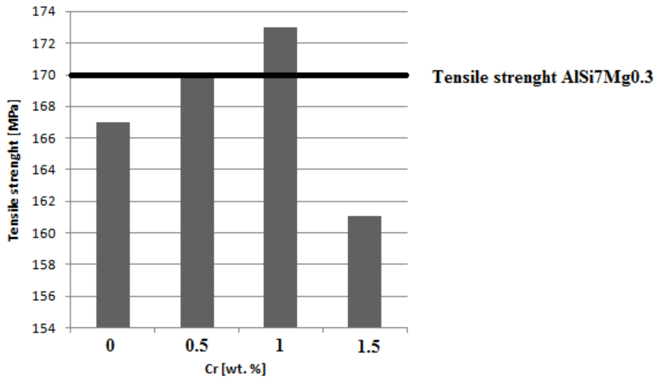


Fig. 6. Tensile strength of alloys after chrome addition

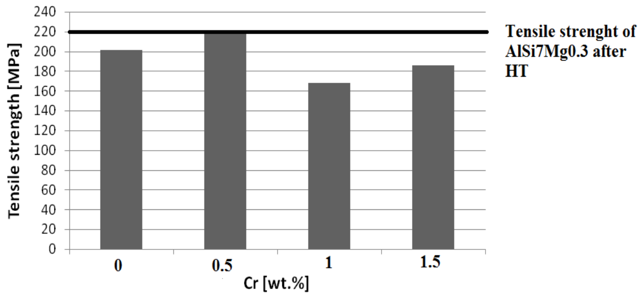


Fig. 7. Tensile strength of alloys after chrome addition and heat treatment

In all cases, tensile strenght did not reached the minimum required value for this type of alloy after heat treatment.

Elongation of basic alloy is according to European Standard in range of 1 – 2 %. Results of elongation measurements after addition of chrome are presented in Fig. 8.

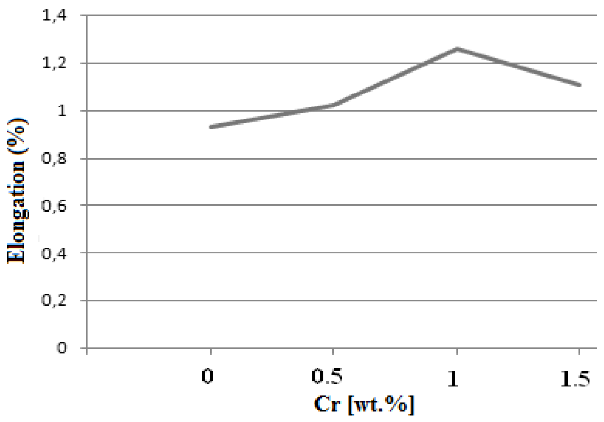


Fig. 8. Ductility of alloys after chrome addition

Brinell hardness tests have been performed at the Department of Technological engineering laboratory. Brinell hardness measurement has been performed at 22 ° C on the measuring device Innova Test, model Nexus 3002 XL with a digital output. The prints have been made by using the ball of 5 mm diameter. Compressive strength was equal to 2452 N (250 kp) and compressive strength endurance time was 15 s (HBS 5/250/15). Processed results of measurements are shown in the Fig. 9.

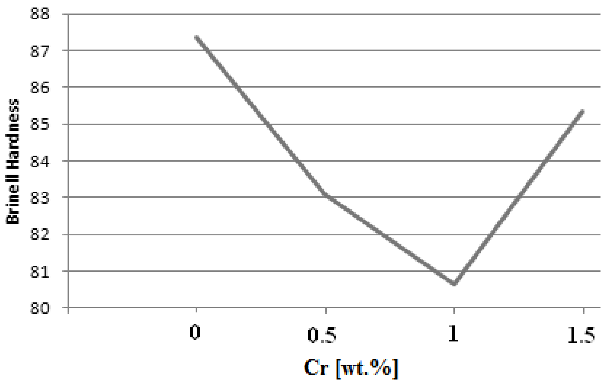


Fig. 9. Brinell Hardness of alloys after chrome addition

3. Conclusions

The goal of the article was to evaluate the effect of chrome and heat treatment in secondary alloy AlSi7Mg0.3. It is possible to conclude that high chrome content has detrimental influence on microstructure – occurrence of very thick and long iron based β (Al_5FeSi). Presence of AlCr20 has also impact on the other phases occurrence, whose chemical composition will be examined by EDX analysis in further work. Addition of chrome increases tensile strength and decreases elongation; however, even higher amount of chrome decreases tensile strength. Heat treatment of alloy after addition of chrome increased tensile strength, but its value is still not sufficient. The heat treatment also changes Fe-rich phases. Long needle particles were shortened and narrowed into small needles phases. Therefore we can say that chrome can be used as iron corrector in secondary aluminum alloys.

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