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Elimination of Iron Based Particles in Al-Si Alloy

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Abstract

This paper deals with influence on segregation of iron based phases on the secondary alloy AlSi7Mg0.3 microstructure by chrome. 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 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. 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. By experimental work were used three different amounts of AlCr20 master alloy a three different temperature of chill mold. Our experimental work confirmed that chrome can be used as an iron corrector in Al-Si alloy, due to the change of intermetallic phases and shortening their length.

Keywords: Secondary AlSi7Mg0.3 alloys, Iron phases, Iron correctors, AlCr20

1. Introduction

In recent years are aluminum alloys uses in applications in the industries of aerospace, automotive and even commercial products. In particular, the automotive industry demands both low weight and low cost materials in order to reduce fuel emissions and improve fuel economy at affordable prices [1]. The need for aluminium alloys having a good toughness, high strength, adequate damage tolerance capability, good fatigue resistance and good corrosion resistance for use in industries led to study of the properties and the structure these materials [2]. Today an increasing amount of the aluminium going into producing new aluminium alloy products is coming from recycled products. Nowadays, recycled metal become more available what is a positive trend by all means. Secondary metal produced from recycled metal requires only about 2.8 kWh/kg of metal produced while primary aluminium production requires about 45 kWh/kg of metal produced. It is to the aluminium industry`s advantage to maximize the amount of recycled metal, for both the energy-savings and the reduction of dependence upon overseas sources. Increasing the use of recycled metal is also quite important from ecological standpoint, since producing aluminium by recycling creates only about 4 % as much CO_2 as by primary production.

The quality of recycled Al-Si casting alloys is considered to be a key factor in selecting an alloy casting for a particular engineering application. The Al-Si-Mg cast alloy contains a certain amount of Fe that is present either accidentally. This element partly goes into solid solution in the matrix and partly forms intermetallic particles during solidification. The size, morphology and volume of intermetallic phases are functions of chemistry, solidification conditions and heat treatment. Iron is a common impurity in Al- alloys. Fe-containing intermetallics are formed between the aluminium dendrites (α-matrix). The type of Fe-phase formed depends mainly on the cooling rate and the Fe to Si ratio of the alloy. Fe-rich intermetallic phases can adversely affect mechanical properties, especially ductility, and also lead to the formation of excessive shrinkage porosity defects in casting. Morphology of Fe- rich phases influences harmfully the fatigue properties.

The dominant Fe- phase is plate/needle –like Al_5FeSi phase which is very hard and brittle and has relatively low bond strength with the matrix. Al_5FeSi needles are more unwanted, because adversely affect mechanical properties, especially ductility. The deleterious effect of Al_5FeSi can be reduced by increasing the cooling rate, superheating the molten metal, or by the addition of a suitable „neutralizer“ like Mn, Co, Cr, Ni, V, Mo and Be. [3]

2. Experimental work

An experimental meltings were realized at laboratory for foundry experiments at Department of Technological engineering at 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 metal mold with three different temperatures (100 °C, 150 °C and 200 °C. As an experimental material was used AlSi7Mg0.3 cast alloy. The chemical composition of used alloy is in 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.

Table 2.
Chemical composition of AlSi7Mg0.3 cast alloy 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

	El.	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Ni**
Melt 2 0.5% AlCr20	**[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	
	El.	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Ni**
Melt 3 1% AlCr20	**[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	
	El.	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Ni**
Melt 4 1.5% AlCr20	**[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 over to maximum allowable content for this type of alloy. This increase can be explained by 0,32 wt.% of Fe in AlCr20 master alloy.

In Fig. 1, Fig.2, Fig.3 and Fig. 4 are shown microstructures of samples from melts with higher amount of iron and with addition of AlCr20 and with three different temperatures of metal mold.

Influence of the chrome on the microstructure and shape of intermetallic phases was studied by classic black – white contrast method. Sample preparation and execution of metallographic image was done 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.

At Fig. 1 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. On the microstructure is visible impact of the iron on iron based particles themselves.

At Fig.2 to Fig.4 we can see the presence of new intermetallic particles mostly in script-like form or skeletal-like form, but this has yet to be confirmed by electron microscope. According to these images we can say, that different temperature of mold causes the formation of particles, which are referred in the literature as "sludge" particles. Therefore temperature of mold (200 °C) is not considered as optimum. Especially by higher amount of chrome that is also responsible for the formation of "sludge" particles.

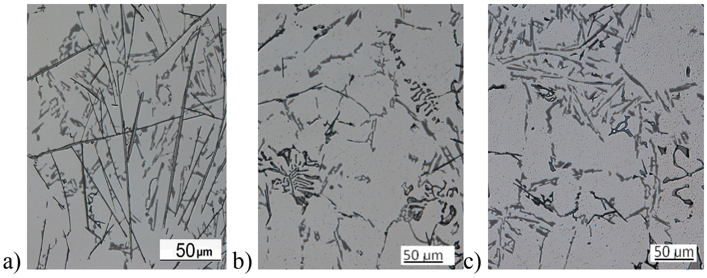

Fig. 1. Microstructure from alloy with higher amount of iron
a) 100 °C b) 150 °C c) 200 °C

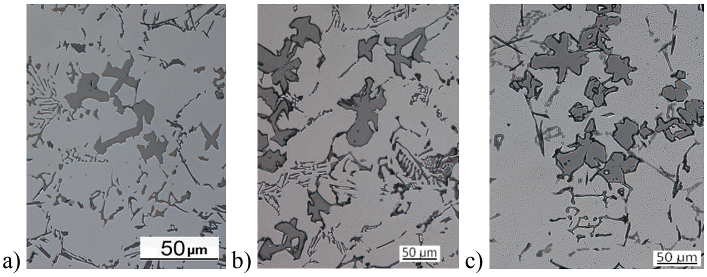

Fig. 2. Microstructure from alloy with 0.5 % Cr
a) 100 °C b) 150 °C c) 200 °C

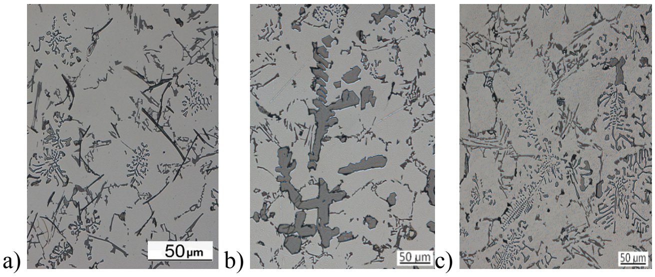

Fig. 3. Microstructure from alloy with 1 % Cr
a) 100 °C b) 150 °C c) 200 °C

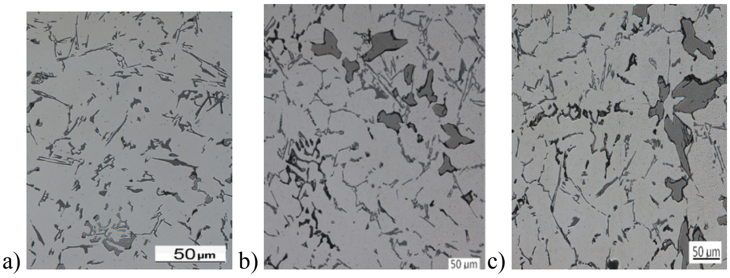

Fig. 4. Microstructure from alloy with 1.5 % Cr
a) 100 °C b) 150 °C c) 200 °C

For all samples was evaluated the tensile strength. 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 in Fig 5.

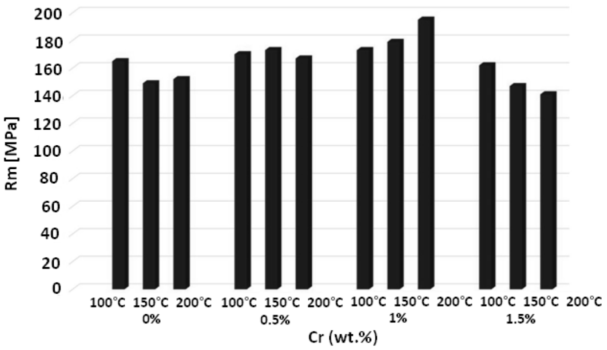

Fig. 5. Tensile strength of alloys after chrome addition

After addition of iron into the basic alloy decreased tensile strength on 167 MPa. But after addition of chrome increased tensile strength above 170 MPa, except for the 1.5 % Cr.

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. 6

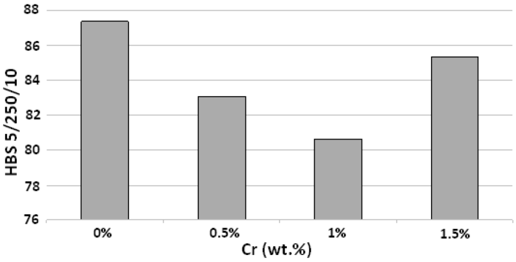

Fig. 6. Brinell Hardness of alloys after chrome addition

According to equations (1) and (2) were performed calculations of influence chrome on cooling rate of castings.

$$\log\frac{dT}{dt}=-\left(\frac{\log(DAS)-1{,}66}{0{,}4}\right) \tag{1}$$

$$DAS=\frac{l}{n-1} \tag{2}$$

where:

n- number of secondary arms in measured area

Results of cooling rate calculation are presented in Fig. 7. The greatest impact on cooling rate was determined by addition 1,5 % of chrome.

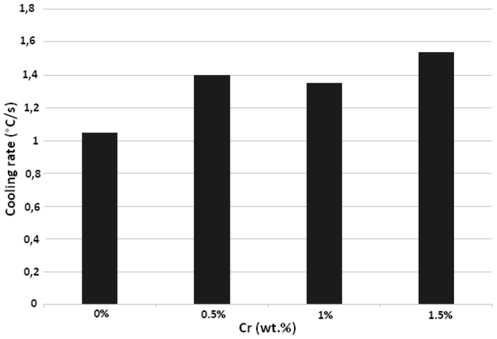

Fig. 7. Influence of chrome addition on cooling rate

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.

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