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Influence of Nickel Addition on Properties of Secondary AlSi7Mg0.3 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 nickel. 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. Some elements eliminates iron by changing iron intermetallic phase morphology, decreasing its extent and by improving alloy properties. 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 nickel as iron corrector of iron based phases.

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

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. Secondary aluminium alloy castings generally have inferior ductility compared to primary alloy castings as the higher level of impurities form brittle intermetallic phases. It is possible to reduce the detrimental effect of impurities by grain refinement thus reducing the size of these brittle phases.

Various elements like Mn, Cr, Be, Co, Mo, Cd, Ni, S, V, ell, Ca, and RE (La, Ce, Y, Nd) have been found to neutralize the ill effects of Fe in the cast alloys to different levels either individually or in combination with other elements. Each element has its own advantages and limitations. Ni is a strongly partitioning and slow-diffusing element, and therefore, the matrix is unlikely to contain levels above the equilibrium solubility. At low levels, Ni is mainly associated with iron to form AlFeSi intermetallics at the grain boundaries.

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. In **Fig. 1a)** can be seen microstructure with intermetallic phases in basic AlSi7Mg0.3 alloy without addition of iron and in **Fig.1b)** can see microstructure with intermetallic phases in alloy after the addition of iron and without iron corrector.

Table 2.
Chemical composition of AlSi7Mg0.3 cast alloy after 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 AlNi20 had been used. Into alloy with higher amount of iron, different amount of master alloy AlNi20 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 AlNi20

a) 0.5 % AlNi20

El.	Si	Fe	Cu	Mn	Mg	Ni
[wt.%]	6.66	1.716	0.053	0.135	0.328	0.182
El.	Cr	Pb	Ti	Zn	Sb	
[wt.%]	0.212	0.006	0.111	0.027	<0.0004	

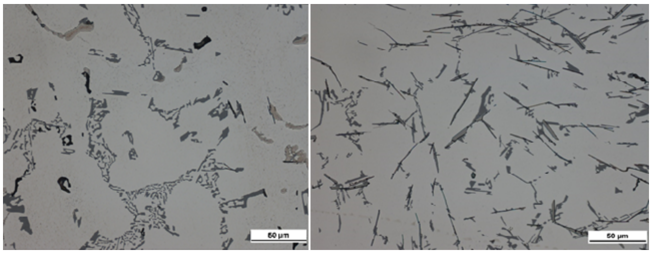
b) 1 % AlNi20

El.	Si	Fe	Cu	Mn	Mg	Ni
[wt.%]	6.31	1.541	0.049	0.117	0.317	0.252
El.	Cr	Pb	Ti	Zn	Sb	
[wt.%]	0.159	0.005	0.113	0.027	<0.0004	

c) 1.5 % AlNi20

El.	Si	Fe	Cu	Mn	Mg	Ni
[wt.%]	6.28	0.878	0.004	0.007	0.331	0.275
El.	Cr	Pb	Ti	Zn	Sb	
[wt.%]	0.001	0.002	0.116	0.010	<0.0004	

By closer look at chemical composition is interesting a decreasing amount of Fe after addition AlNi20 master alloy from 1.716 wt. % to 0.878 wt. %, because it is impossible to remove iron from melt. It is just possible to change a negative form of iron phases to less harmful type.



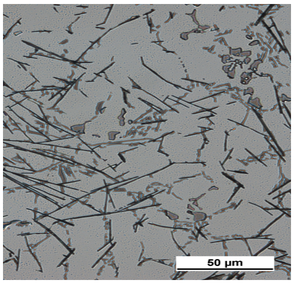
a) *b)*

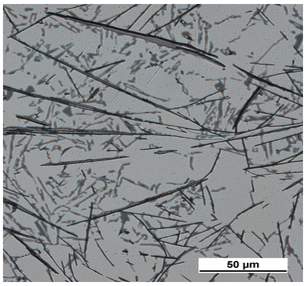
Fig. 1. Microstructures of alloys a) AlSi7Mg0.3 alloy b) with 70 000 ppm of AlFe10 and without addition of AlNi20

Influence of iron corrector 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.

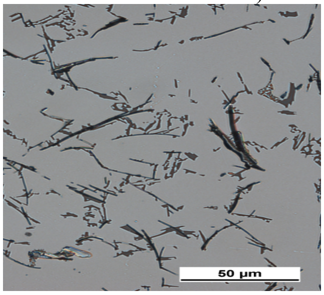
The structure consists of silicon eutectic, dendrites of α – phase excreted in the form of white unites and black areas as iron based particles. On the microstructure is visible impact of the iron on iron based particles themselves.

At Fig.2 we can see the presence of new intermetallic particles mostly in needle-like form, which chemical composition was confirmed by electron microscope. But also can be seen particles with undefined shape, which were also studied with electron microscope. The detail of one of these particles is at Fig. 3. On these microstructures was also measured the length of iron particles. Results of these measurements are presented in Table 4.





a) 0.5 wt. % AlNi20 b) 1 wt. % AlNi20



c) 1.5 wt.% AlNi20

Fig. 2. Microstructures with different amount of iron correctors

Table 4.
Results of measurements of length of iron based particles

Amount of iron corrector	Without iron corrector	Length of particles after addition of iron corrector (µm)
0.5	37.10	50.45
1		40.81
1.5		42.03

From results of measurements of length of iron based particles can see, that addition of AlNi20 does not have a significant effect on length of iron based particles.

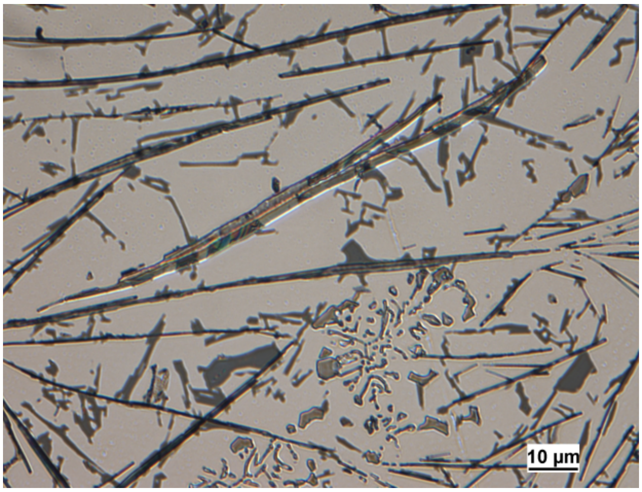
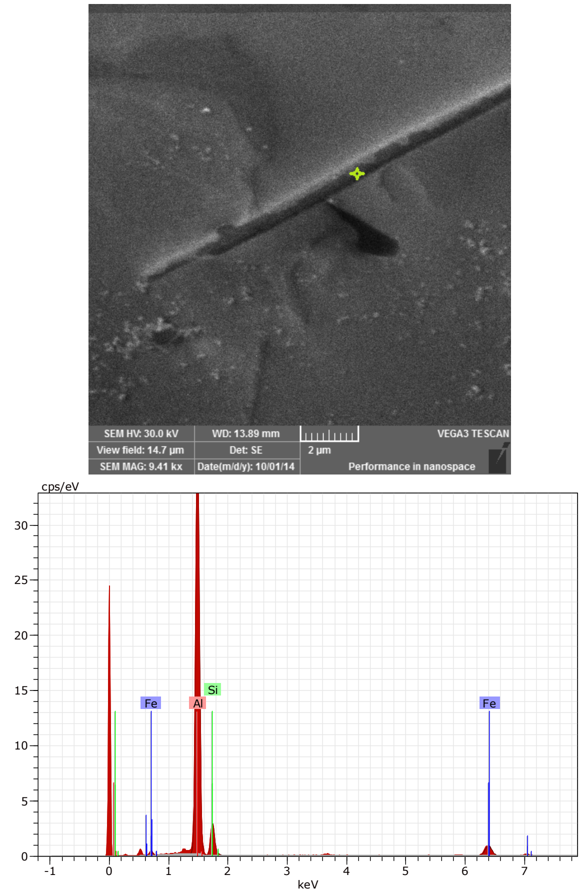


Fig. 3. Detail of large iron particle

Chemical analysis of these large particles was obtained from electron microscope. Sample of that analysis is on Fig. 4.



Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (3 Sigma) [wt.%]
Aluminium	K-series	72.88	74.97	78.51	11.08
Silicon	K-series	17.15	17.64	17.75	2.53
Iron	K-series	7.18	7.39	3.74	0.74
	Total:	97.22	100.00	100.00	

Fig. 4. EDX analysis of large iron particle

As we can see from results of chemical analysis, these particles consist of three elements: Al, Si and Fe. From literature sources we can say that this is a phase Al_5FeSi or β-phase.

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.

For all samples were evaluated tensile strength and elongation. The tensile test was performed on a tensile machine WDW – 20 in the laboratory for mechanical tests, University of Žilina at 22 °C. Results of measurements of tensile strength are presented from Fig. 5 to Fig. 8.

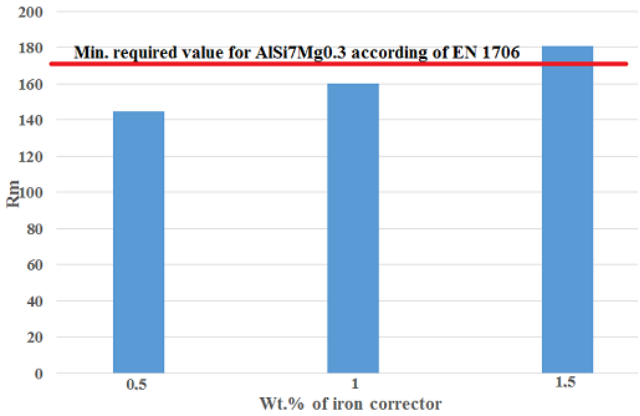


Fig. 5. Results of measurements of tensile strength

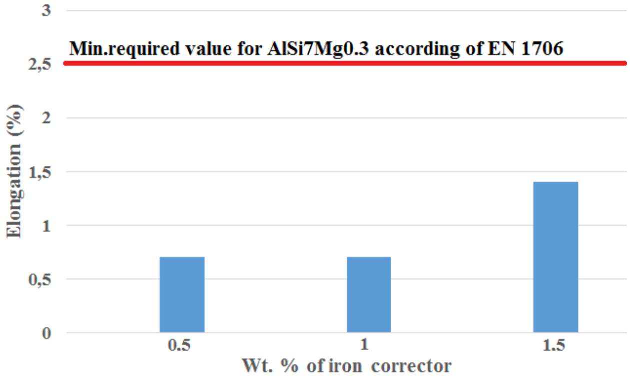


Fig. 6. Results of measurements of elongation

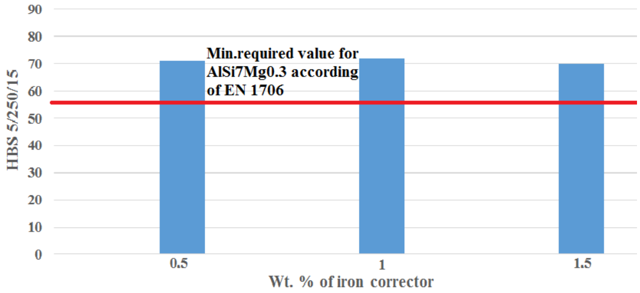


Fig. 7. Results of measurements of Brinell Hardness

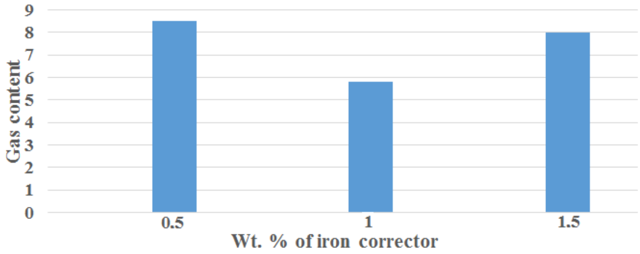


Fig. 8. Results of measurements of gas content

3. Conclusions

The goal of the article was to evaluate the effect of nickel addition to the secondary AlSi7Mg0.3alloy. It is possible to conclude that addition of nickel doesn`t have a detrimental effect on shape of β(Al_5FeSi) particles. These particles are present in all samples, including samples with addition of AlNi20 master alloy. Better results can be seen from measurements of tensile strength and elongation. In both cases the best results can seen after addition of 1.5 wt. % of AlNi20 to the secondary alloy. From measurement of Brinell Hardness can be seen, that addition of AlNi20 doesn`t have a detrimental effect on increasing of hardness in secondary alloy. It is clear that addition of AlNi20 master alloy has a less negative effect on gas content. Degreasing of gas content can be made by degasing of secondary before casting. According to these all results and after further research and verification their effect, AlNi20 can be used as an iron correctors in secondary aluminum alloys. Based on our results we can say that alloys with higher iron content after treatment with iron corrector could be used in the production of castings with higher demands for the automotive industry.

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