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Improvement of mechanical properties of AlSi7Mg alloy with fast cooling homogenous modifier

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Abstract

The results of modification of eutectic and hypoeutectic aluminum-silicon alloys by sodium, strontium, antimony and other additions in the metallurgic process have been already analyzed and described. Literature on the topic provides scant information on silumin modification with modifiers obtained from the treated alloy by fast cooling
Results of studies on the modification of AlSi7Mg alloy with a homogenous modifier obtained by fast cooling of AlSi7Mg alloy at rate 300°C/s are presented in the paper. The effects of cooling rate and w/w concentration of the modifier in the melt on tensile strength, percentage elongation, Brinell hardness and abrasive wear are illustrated graphically.

Keywords: Theory of crystallization, Al alloys, Silumin, Crystallization, Mechanical properties

1. Introduction

Aluminum-silicon alloys have the potential for excellent castability, good weldability, good thermal conductivity, high strength at elevated temperatures and excellent corrosion resistance [1,2].

However, in recent years it has been established that the technological properties of aluminum-silicon alloys can be enchanced by adding modifiers and by applying suitable thermal treatmens. The modification behavior of Al-Si alloy was ferst studied in 1920 by Pacz, who shows that the additions of sodium or its salts to the molten alloys leads to structural modification during solidification and hence, to a considerable improvement in its mechanical properties [3]. In 1966 Thiele and Dunkel showed that the effects of strontium on such alloys are similar and longer-lasting than those of sodium [4].

Strength and malleability are important reasons for increasing applications of this alloy system. Mechanical properties of Al-Si cast alloys depend not only on chemical composition but, more importantly, on microstructural features such as morphologies of dendritic α-Al, eutectic Si particles and other intermetallics that present in the microstructure. Addition of sodium or strontium modifiers in Al-Si cast alloys have been found to improve mechanical properties considerably, especially the ductility [5,6,7]. The improvement in mechanical properties generally has been attributed to the variations of the morphology and size of the eutectic silicon phase particles. It is worth noting, however, that at the same time when eutectic silicon particles change from acicular to fiber, the amount, morphology and size of dendritic α-Al phase are varying too. The contribution of these to the improvement of the mechanical properties has not been paid more attention. It is well known that grain refining is beneficial to mechanical properties. However, no final conclusion has yet been reached on whether the transition of dendrite α from a long columnar morphology to a fine equiaxed one results in improved mechanical properties in near-eutectic Al-Si alloy. From the point of view of microstructure control, it is necessary to investigate the correlation between mechanical properties and dendritic or eutectic morphologies a in near-eutectic Al-Si alloys. The mechanical properties in Al-Si cast alloys depend not only on the amount, the morphology and the size of dendritic α-Al. The morphology and size of the silicon phase particles, spheroidizing of eutectic silicon, and precipitation of the Mg_2Si phase during heat treatment also exert important influences on the mechanical properties. The combined effects of these structures are rather complicated. The results of modification of eutectic and hypoeutectic aluminum-silicon alloys by sodium, strontium, antimony and other additions in the metallurgic process have been already analyzed and described by numerous authors [4,8,9-15].

However, literature on the topic provides scant information on silumin modification with modifiers obtained from the treated alloy by fast cooling homogenius modifier.

The main aim of the present investigation was to evaluate influence of homogenous modifier cooling at rate 300°C/s on properties of AlSi7Mg alloy.

2. Aim of the study, methods and results

The objective of the present study was to determine whether hypo-eutectic alloy AlSi7Mg can be modified by means of AlSi7Mg alloy cooled at rates 300°C/s, used as a modifier.

Homogenous modifiers are additions designed for modification of the same alloys from which they were obtained. To obtain a homogenous modifier, AlSi7Mg alloy was melted and then cooled on a metal plate at rate, 300°C/s. The components, which were refined immediately before adding to the alloy, were put into a crucible containing liquid AlSi7Mg alloy, and kept there for one minute. The alloy temperature was 850°C. The modifier content of the alloy is given as weight in weight concentration (mass fraction) 0.2, 0.4, 0.6, 0.8 and 1.0%. For comparative purposes, two castings were produced (without additions), at the beginning and at the end of the study.

The casting mold used in the study is shown at paper [16]. Two samples, 16x140 mm, were obtained in each experiment. 10 mm strip was cut off at the bottom of each sample. The face of cut served as metallographic specimen for microstructure analysis. Samples for mechanical tests were obtained from the upper part of the casting. A tensile strength test was performed according to the Polish Standard PN-EN 10002-1+AC1: 1998 Metals-Tensile test-Test method, at ambient temperature, using a universal strength testing machine (W.P.M. Germany), determining tensile strength R_m and percentage elongation A. Brinell hardness was performed according EN 10003-1, by Brinell/Vickers HPO-250, ball at diameter 2.5 mm, stress 612.9 N. Abrasive wear tested using Schopper machine by corundum abrasive disk at grainy 400 for parameters:

- abrasive disk diameter	ϕ=0.158	m
- abrasive disk revolutions	n = 14.1	obr/min.
- sample revolutions	n = 0	obr/min.
- holding down	F = 200	N
- unit pressure for area of samples	N=3.9	MPa
- working distance	l = 400	m
- running speed	v=0.12	m/s

The analysis of tensile strength, shows that the greatest benefits were achieved after AlSi7Mg alloy treatment with a homogenous modifier cooled at 300°C/s, which substantially improved alloy properties (Fig. 1).

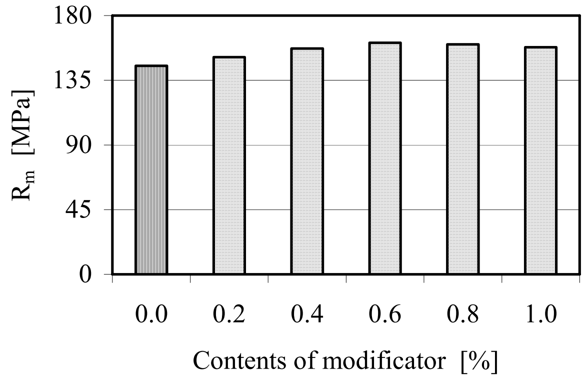

Fig. 1. Tensile strength (R_m) AlSi7Mg alloy after treatment homogenical modifier cooled with 300°C/s

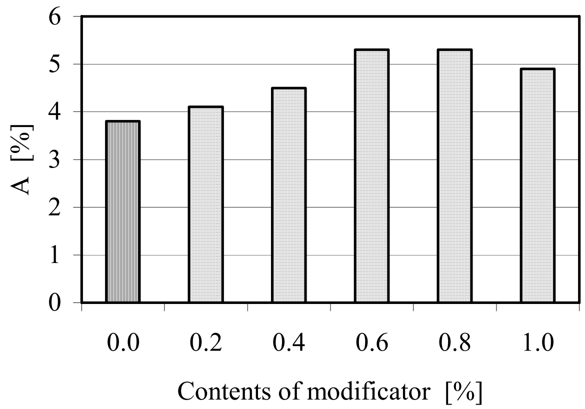

Fig. 2. Unit elongation (A) AlSi7Mg alloy after treatment homogenical modifier cooled with 300°C/s

The optimum concentration of homogenous modifiers was 0.6% w/w. The fact that larger amounts of a homogenous modifier were required to effectively improve the properties analyzed can be explained by the presence of big eutectic silicon precipitates in AlSi7Mg alloy. When the value of 0.8% was exceeded, tensile strength decreased. The value of elongation A (fig. 2) increased significantly following the addition of 0.2% of the modifier analyzed. The maximum effect, i.e. an increase in tensile strength by 40%, to 5.3%, was achieved at a relatively low content of the modifying agent (0.6% w/w). A further increase in the amount of a homogeneous modifier, to over 0.8%, resulted in a slight decrease in elongation (at w/w concentration of the modifier of 1%, it a little reduced of the maximum value obtained for this modifier).

The maximum effect an increase in Brinell hardness number after AlSi7Mg alloy treatment with a homogenous modifier cooled at 300^{o}C/s, (fig. 3) by 17%, from 53 to 62 HB, was achieved at a relatively low content of the modifying agent (1.0% w/w).

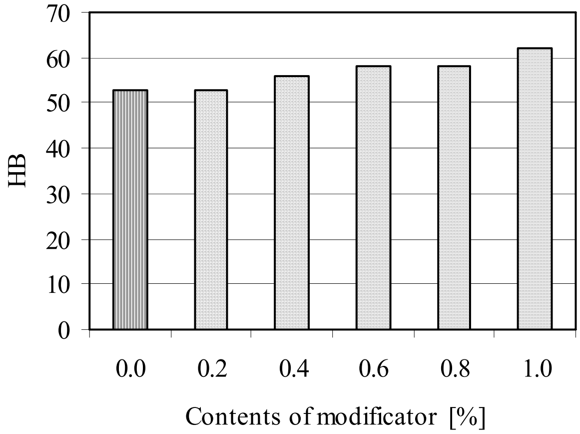

Fig. 3. Brinell hardness (HB) AlSi7Mg alloy after treatment homogenical modifier cooled with 300^{o}C/s

The maximum abrasive wear 0.384 g after modification was achieved at 0.2%, and minimum 0.342 g at 1.0% w/w (fig. 4).

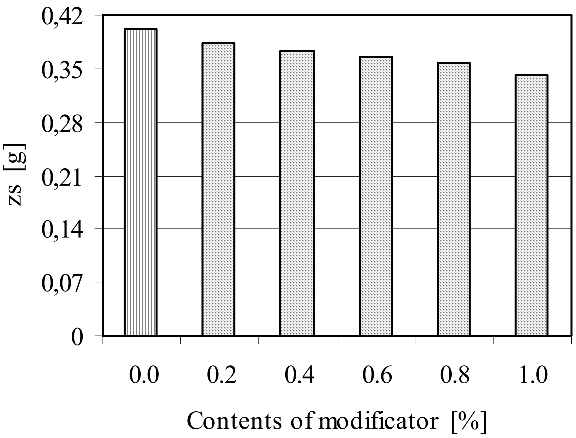

Fig. 4. Abrasive wear (zs) AlSi7Mg alloy after treatment homogenical modifier cooled with 300^{o}C/s

Different in unmodified and modified alloy AlSi7Mg with homogenous modifier cooling with rate 300^{o}C/s showed at Fig 5 and 6.

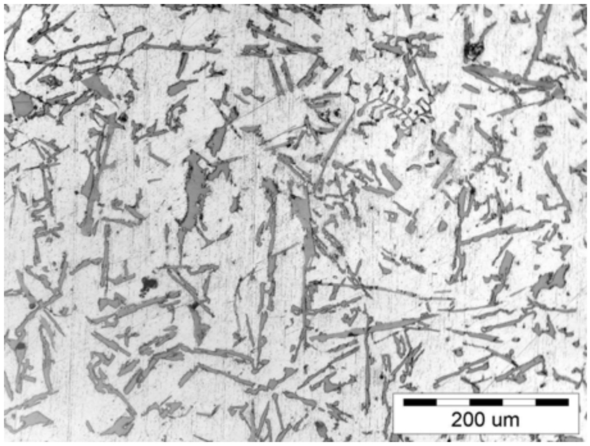

Fig. 5. Microstructures of the unmodified AlSi7Mg alloy

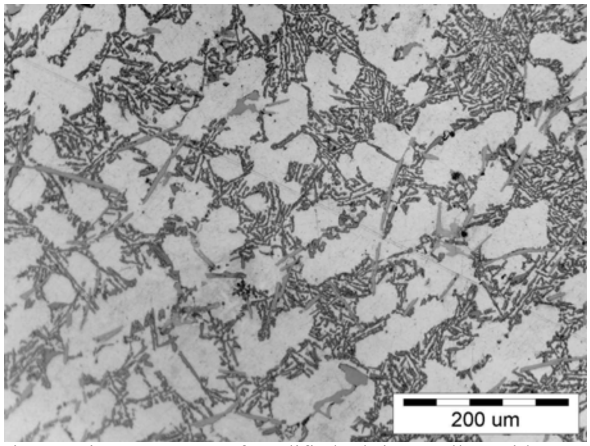

Fig. 6. Microstructures of modified AlSi7Mg alloy with 0.6% w/w homogenous modifier cooled at rate 300^{o}C/s

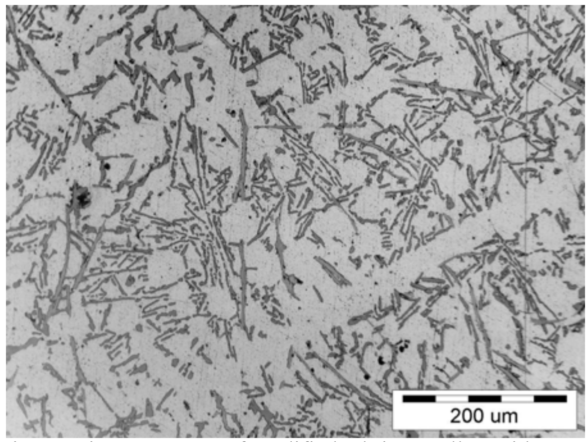

Fig. 7. Microstructures of modified AlSi7Mg alloy with 1.0% w/w homogenous modifier cooled at rate 300^{o}C/s

The microstructure of the sand cast specimen consist od α-aluminum dendrites, acicular silicon and eutectic silicon plates, typical of the unmodified structure. In similar fashion, Fig 6 shows microstructure alloy modified with 0.6% w/w homogenous modifier, this microstructure is typical of a modified alloy.

Figure 7 shows the same cast microstructures the same cast after treatment 1.0% w/w modifier. In both structures the eutectic silicon had a branched morphology. Then, increase of homogenous modifier, over optimal contents, create decrease factor of modification alloy.

3. Conclusions

The analysis of the process of hypo-eutectic Al-Si alloy modification with a homogenous modifier obtained from treated alloy by fast cooling at a rate of $300^{o}C/s$ shows that this modifying addition affected mechanical properties of AlSi7Mg alloy. An increase in the content of a homogenous modifier cooled was accompanied by an increase in the values of the parameters analyzed in the study. An increase in their values was also noted when the concentration of a modifier obtained by cooling at a rate of $300^{o}C/s$ was increased to about 0.8% w/w. A further increase in modifier content (mass fraction) caused a gradual decrease in the mechanical properties examined. The best results were recorded for a modifying addition, which enabled to achieve the highest values of all analising parameters (in this experimental design) at 0.6% w/w. Another advantage of this modifying agent is the fact that the values analyzed decreased slightly only when the critical value of its w/w concentration was exceeded.

Changes of mechanical properties Al-Si7Mg alloy modification homogenical modifier produced by fast cooling rate are effect refinement of structure, what is visible at fig. 5-7. In particular λ parameter (β-phase distance).Eutectic after treatment is size reduction and has oval vertex. It`s elimination noth effect and increase mechanical properties.

There are a fully relationship between mechanical properties and microstructure.

The method for Al-Si alloy modification with a homogenous modifier obtained from treated alloy by fast cooling, proposed in this paper, meets relevant ecological and environmental standards. No chemical elements that could hinder recycling are introduced into the alloy.

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