

Structure and mechanical properties of Al-12%Si alloy with fast cooling Al-12%Si

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Abstract

A homogenous modifier obtained by the rapid solidification at a cooling rate equal to $v=300$ K/s was applied to the modification of the Al-12%Si alloy. The different modifiers were obtained by means of the Al-Si alloys. The components Al-12%Si were put into crucible containing the liquid Al-12%Si alloy and kept for one minute to obtain a new homogenous alloy which after break-up was homogenous modifier. Both, effect of cooling rate applied to obtain modifier and weight in weight modifier concentration in the melt on structure, tensile strength, elongations and hardness of Al-12%Si alloy are determined. A structural, physical and mechanical properties resulting from the Al-12%Si alloy treatment by modifiers are studied in details.

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

1. Introduction

Aluminium-silicon casting alloys are used extensively in many industrial applications of their excellent mechanical, chemical and casting characteristics. However, the coarse acicular silicon phase morphology adversely affects the used properties of these alloys [1].

However, a serious disadvantage of those alloys is coarse-grained structure responsible for a decrease in mechanical properties (mainly tensile strength and unit elongation).

Modification is important because it improves the mechanical properties of Al-Si alloys. Unmodified alloys contain large, brittle flakes of silicon that cause brittle fracture and poor ductility in castings. Several modifiers are known (e.g., strontium, antimony, sodium, barium, calcium), of which strontium is the most frequently used in the Al-Si alloy industry because it is easy to handle, has a good modification rate, a long incubation time a low fading effect [2, 3, 4, 5]. The techniques to method of changes

structures and properties we can shown of method: thermal, mechanical and chemical [6, 7, 8, 9, 10, 11].

There are other modifications method, for example directional solidification [12, 13], exothermal mixtures [14], too.

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 [15]. 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.

However, literature on the topic provides scant information on silumin modification with modifiers obtained from the treated alloy by fast cooling homogenous modifier [16, 17].

The main aim of the present investigation was to evaluate influence of homogenous modifier cooling at rate 300 K/s on properties of Al-12%Si cast alloy.

2. Aim of the study, methods and results

The objective of the present study was to determine whether eutectic alloy Al-12%Si can be modified by means of Al-12%Si 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, Al-12%Si 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 Al-12%Si alloy, and kept there for one minute. The alloy temperature was 1023 K.

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 fig. 1.

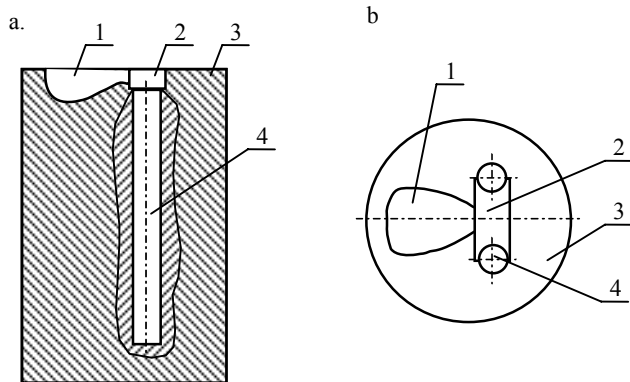


Fig. 1. Sections of the casting mold: a. section, b. top view of the casting mold: 1 – reservoir, 2 - cross-gate, 3 – mold, 4 - sample for strength tensile test

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 612.9N.

Microstructural changes that occur increasing modifier Al-12%Si alloy cooled at the rate: 300 K/s show at Fig 2-7. Raw Al-12%Si alloy (Fig.2) showed that the eutectic Si particles are in the form of acicular plates (i.e. of large average area and length). With increase Al-12%Si addition to 1.0 wt.% partial size of Si-phase is slightly changed. The best results are obtained with the addition of 0.6 wt% Al-12%Si alloy, were both particle size and

morphology are observed to be significantly reduced. Next increasing of modifier was cause decreased eutectic Si-phase at alloy (Fig. 6,7). The increased or decreased measured eutectic Si-phase are corresponding with wt.% of additions Al-12%Si alloy.

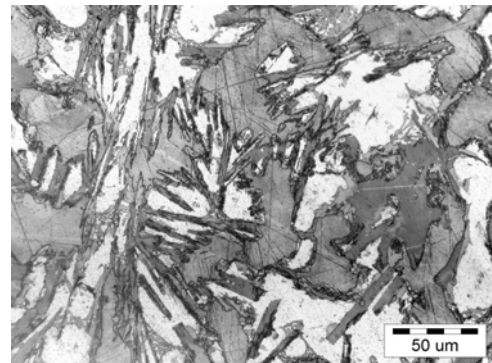


Fig. 2. Microstructure of the raw Al-12%Si alloy

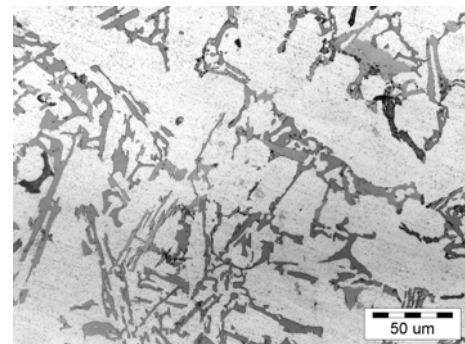


Fig. 3. Microstructure of the Al-12%Si alloy with 0.2 wt.% addition of the Al-12%Si modifier cooled at the rate: 300 K/s

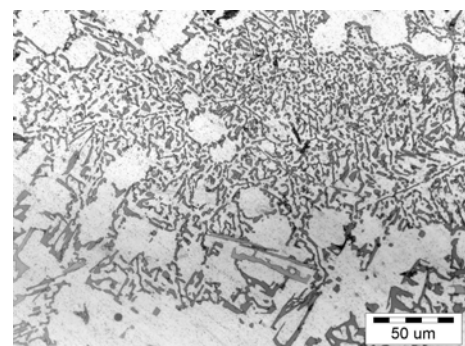


Fig. 4. Microstructure of the Al-12%Si alloy with 0.4 wt.% addition of the Al-12%Si modifier cooled at the rate: 300 K/s. Addition of the Al-12%Si

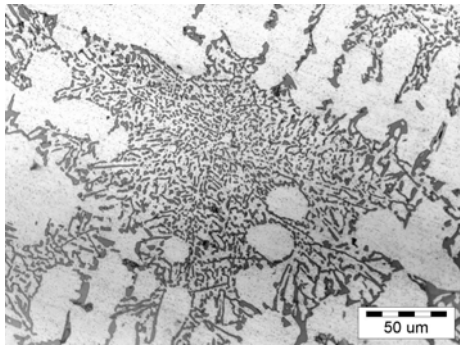


Fig. 5. Microstructure of the Al-12%Si alloy with 0.6 wt.% addition of the Al-12%Si modifier cooled at the rate: 300 K/s

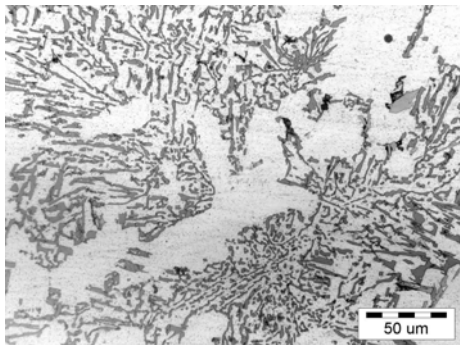


Fig. 6. Microstructure of the Al-12%Si alloy with 0.8 wt.% addition of the Al-12%Si modifier cooled at the rate: 300 K/s

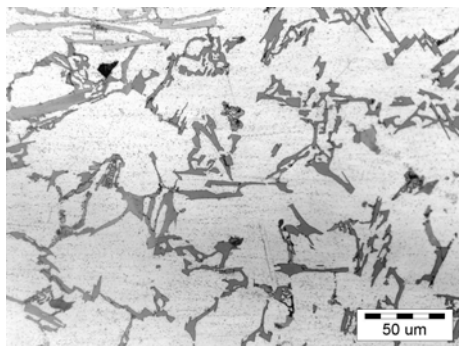


Fig. 7. Microstructure of the Al-12%Si alloy with 1.0 wt.% addition of the Al-12%Si modifier cooled at the rate: 300 K/s

The analysis of tensile strength, shows that the greatest benefits were achieved after Al-12%Si alloy treatment with a homogenous modifier cooled at 300 K/s, which substantially improved alloy properties (Fig. 8). Optimal effect was obtained for treatment alloy with 0.4 wt% of modifier. Similar values tensile strength obtained for 0.6 and 0.8 wt %, too. When the value of 0.8% was exceeded, tensile strength decreased. Increased wt. % of modifier to 1.0% obtained decreased tensile strength about 18% to 148 MPa.

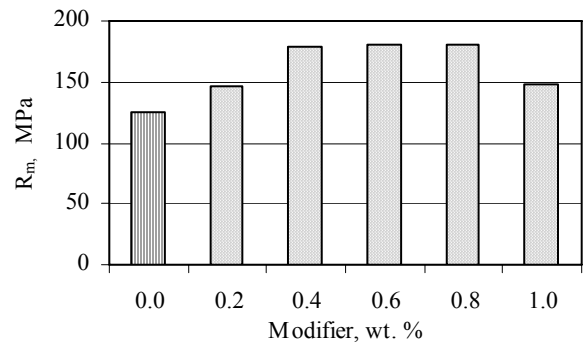


Fig. 8. Tensile strength R_m , after a treatment of the Al-12%Si alloy by means of the homogenous modifiers

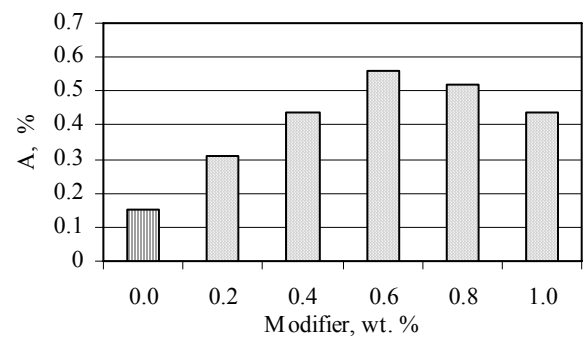


Fig. 9. Elongation A , after a treatment of the Al-12%Si alloy by means of the homogenous modifiers

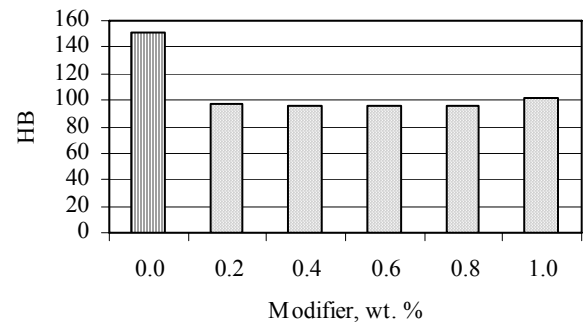


Fig. 10. Hardness HB, after a treatment of the Al-12%Si alloy by means of the homogenous modifiers

The value of elongation A (Fig. 9) increased significantly following the addition of 0.2% of the modifier analyzed. The maximum effect, i.e. an increase in tensile strength by 250%, to 0.6%, was achieved at a relatively low content of the modifying agent (0.6 wt.%). 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 distinct reduced of the maximum value obtained for this modifier).

Brinell hardness number after Al-12%Si alloy treatment with a homogenous modifier cooled at 300 K/s, (Fig. 10) decreased to the value 96 HB and was compared for all apply wt% contents of Al-12%Si alloy.

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 K/s shows that this modifying addition affected mechanical properties of Al-12%Si alloy.

Mechanical properties of the Al-12%Si cast alloy with fast cooled Al-12%Si alloy mainly depends on the shape, size and size distribution of the α -phase (rich on Al), eutectic silicon morphology and other particles elements (in general rich on Fe, Cu and other).

Different in unmodified and modified alloy Al-12%Si with homogenous modifier cooling with rate 300 K/s showed at Fig 2 and 4 or 6.

The optimum concentration of homogenous modifiers was 0.4% 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 Al-12%Si alloy.

There are a fully relationship between mechanical properties and microstructure.

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