MODIFICATION OF ALSI7MG ALLOY WITH SR AND SB

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Abstract. Hypoeutectic aluminum-silicon alloys called hypoeutectic silumins have been used for foundry structural elements. Their properties depend directly on the microstructure. They are one of the few metal alloys that are characterized by a simultaneous increase in strength and elongation. This is possible by changing the shape of the eutectic silicon precipitates from the lamellar form to the dendritic or, less frequently, spheroidal form. Hard and at the same time brittle silicon plates are natural notches occurring in silumins. They are also places of nucleation and development of microcracks leading to the destruction of the material. Modification of the shape of this unfavourable phase to an oval shape leads to an increase in the properties of the alloy. A number of silumin modification processes are known in the literature. These processes can be divided into technological ones, in which the geometric form of eutectic silicon is changed, e.g. by controlling the crystallization of the alloy by means of a temperature gradient. The second group of processes are chemical modification processes. During these processes, chemical additives introduced into the liquid alloy by affecting the crystallization process cause changes in the microstructure. The influence of a very large number of chemical elements on the alloy crystallization process is known. Unfortunately, among so many reports, there is contradictory information about the impact of individual additives. In this work, it was decided to check the repeatability of the test results found in the literature in other technological conditions. Typical hypoeutectic silumin containing 7% silicon with the addition of magnesium was tested. The alloy was modified only with antimony and a double modification consisting in modification with strontium and then with antimony was carried out. The contents of antimony and strontium were taken from the literature. As a result of the tests, it was noticed that the addition of antimony leads to the modification of the microstructure, and thus to the increase of the mechanical properties of the alloy. After double modification with strontium and then with antimony, changes in mechanical properties oscillating around the measurement error were obtained. It can therefore be assumed that modification of the alloy with antimony after prior permanent modification with strontium is not very effective.

Keywords: Al-Si alloy, modification, strontium, antimony.

Introduction

Aluminum-silicon casting alloys are still very popular. In raw silumin there is an unfavourable microstructure, which results in low mechanical parameters of the casting [1-10]. For many years, research has been carried out to refine the microstructure and, as a result, to increase the mechanical properties of the alloy. Two main modifiers of hypoeutectic silumins are known. They are sodium and strontium [11-18]. A small addition of these elements to the liquid alloy will change the process of its crystallization, which results in fragmentation of large needles of eutectic silicon. In industrial conditions, modification is carried out with mixtures of one of these two elements (mainly strontium) and salts of various metals. The composition of the mixtures used in industrial conditions to modify silumins remains known only to the alloy manufacturer [19-28].

Many papers describe the results of research in the modification of hypoeutectic silumins carried out in laboratory conditions on high purity alloys. The effects of these works are valuable in terms of knowledge, but they are not always used in industry. The reason for the large discrepancies between the ideal laboratory conditions and the real conditions prevailing in the industry are differences in the actual chemical composition of the alloys. These differences are mainly influenced by impurities originating not only from the course of metallurgical processes, but mainly due to the use of input material in the form of reprocessing of material after the exploitation process or waste material from other production processes [29-36].

The literature describes a lot of research on the process of increasing the quality of hypoeutectic silumins with the use of various elements and chemical compounds. The authors use different amounts of modifiers in their studies, introduce them in different ways, obtaining different test results. Analyzing the described impact of antimony on the properties of the alloy, it was noticed that the authors introduced it in various amounts, ranging from hundredths to tenths of a percent. The influence of antimony has also been interpreted in various ways [37-45].

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In the work it was decided to check the effect of antimony on the mechanical properties of hypoeutectic silumin. It was decided to introduce antimony alone as well as with strontium.

Materials and methods

The tests were carried out on industrial silumin AlSi7Mg. The alloy was melted in a ceramic crucible in an electric furnace without the use of a protective atmosphere. The chemical composition of the tested siluminium is shown in Table 1.

Table 1

Chemical composition of AlSi7Mg, wt.%

Si	Mg	Mn	Fe	Cu	Ti	Ni	Al
7.11	0.34	0.32	0.42	0.10	0.1	0.006	balance

The modification process was carried out in a casting crucible with a capacity of 1 dcm3. This process was carried out in two variants. In the first variant, the alloy was modified with antimony, adjusting the amount of antimony to the weight of the processed silumin. The amount of antimony was determined according to [46] as: 0%, 0.005%, 0.01%, 0.02 and 0.04% Sb (in the form of Sb lumps). In the second variant, 0.02% strontium (in the form of mortar AlSr) was added to the silumin, the alloy was cooled to ambient temperature, then melted again and added, respectively: 0%, 0.005%, 0.01%, 0.02 and 0.04% Sb. The alloy modification temperature was set at 850°C and the modification time at 60 minutes. After modification, the alloy was cast into a mold made of the casting mass. Two cylindrical samples with a diameter of 10 mm and a length of 140 mm were cast. The pouring of the casting mold was carried out using the siphon method after removing impurities from the surface of the liquid alloy. After cooling the alloy, the casting was punched out by hand. For each point of the research plan, 3 melts were carried out. The results of the arithmetic mean for each of the points from three tests were analyzed. Samples for mechanical tests were made from the cast samples. The static tensile test was carried out on the ZD10 machine on five-fold cylindrical samples with a measuring diameter of 8 mm according to EN ISO 6892-1:2016 [48]. Two samples for each heat were tested.

Results and analysis

The AlSi7Mg alloy microstructure after modification according to the methodology presented in the work is shown in Fig. 1.

The microstructure of the alloy without the modifying additive is shown in Fig. 1a. The microstructure of the alloy with 0.005% Sb is shown in Fig. 1b. The microstructure of the alloy with 0.02% Sb is shown in Fig. 1c. The microstructure of the alloy after double modification with 0.02% Sr and then 0.02% Sb is shown in Fig. 1d.

The microstructure of the alloy cast without modification consists of a coarse-grained β phase in the form of plates and grains and large dendrites of the α phase, Fig. 1a. After the introduction of 0.005% Sb, a slight fragmentation of the eutectic β phase was observed. The grains of the β phase are still visible in the microstructure. After modification of the alloy with 0.02% Sb, further fragmentation and disappearance of granular precipitates of the β phase were observed.

The microstructure after a two-stage modification of 0.02% Sr and then 0.02% Sb showed a fine lamellar eutectic composed of β and α phases. No fragmentation of the dendritic α phase was noted in any of the treatment variants.

The mechanical properties of AlSi7Mg silumin after modification with appropriate modifiers are shown in Fig. 2 to Fig. 5.

Tensile strength for appropriate modifications of silumin AlSi7Mg with antimony is shown in Fig. 2. A systematic increase in the tensile strength was found with the increase in the amount of modifier introduced into the alloy to 0.02% Sb. For 0.04%Sb, the upward trend was halted, and even a slight decrease in strength was noted. Comparing the obtained strengths to work [46], in which the highest strength was obtained for 0.005% Sb, it was found that the highest strength shifted towards higher antimony contents. However, the general tendency to modify silumin was confirmed.

Two-stage modification of silumin AlSi7Mg 0.02% Sr, and then antimony (Fig. 3) did not confirm the results of publication [47], in which 9% higher tensile strength of AlSi7Mg alloy was obtained after two-stage modification. The strength values obtained oscillate within the limits of the measurement error and do not confirm the higher strength properties after the introduction of Sb.

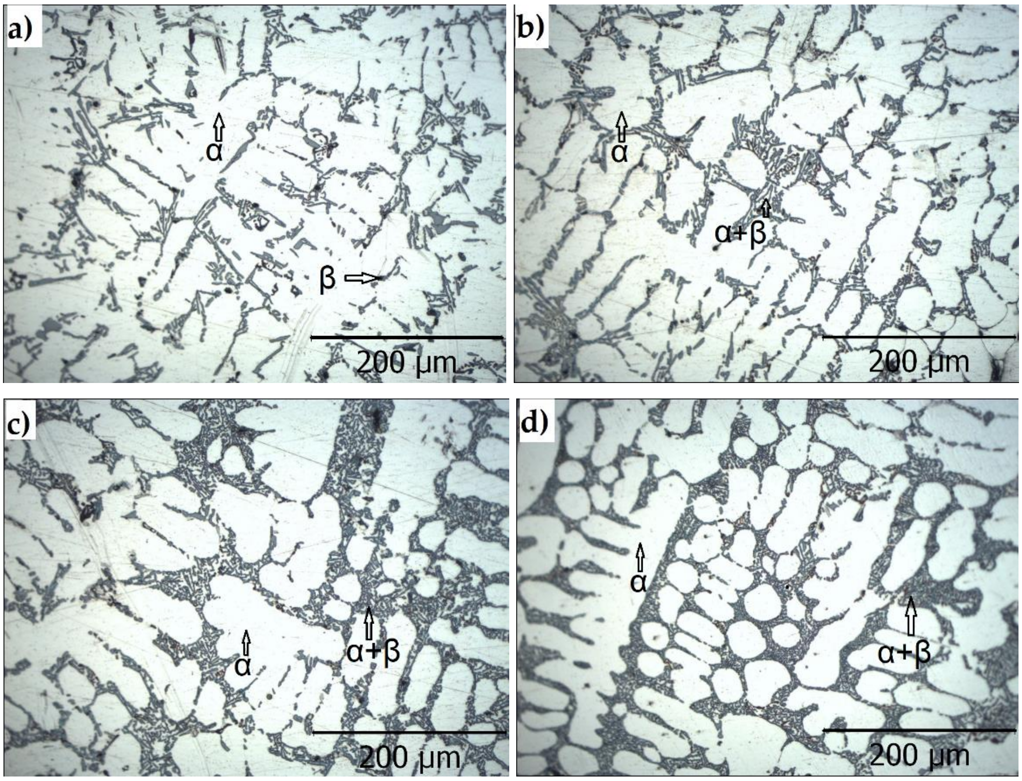

Fig. 1. **Microstructure of AlSi7Mg with:** a – 0.0% Sb; b – 0.005% Sb; c – 0.02% Sb; d – 0.02% Sr + 0.02% Sb

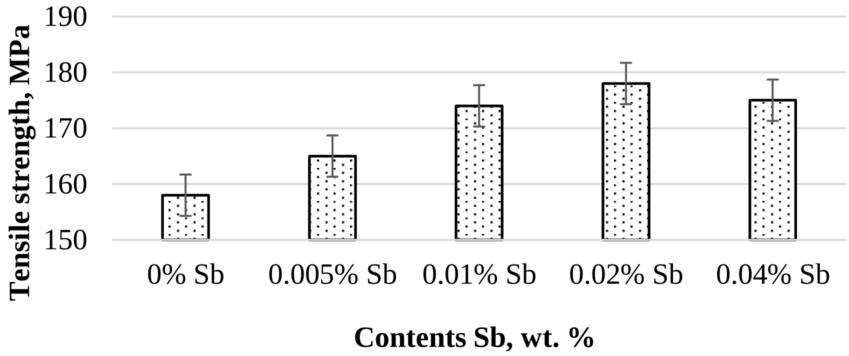

Fig. 2. **Tensile strength of AlSi7Mg alloy with Sb**

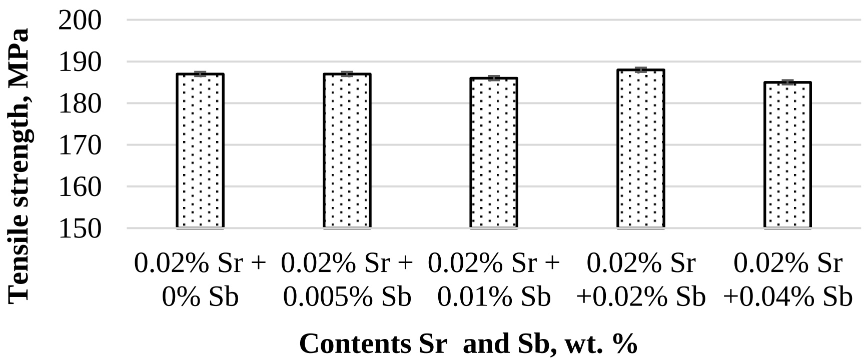

Fig. 3. **Tensile strength of AlSi7Mg alloy with Sr and Sb**

Similar relationships as for the tensile strength were found for elongation, Fig. 4 and Fig. 5, respectively. There was an increase in elongation after Sb modification (Fig. 4) and no evidence of a significant effect of double modification on elongation for Sr + Sb (Fig. 5).

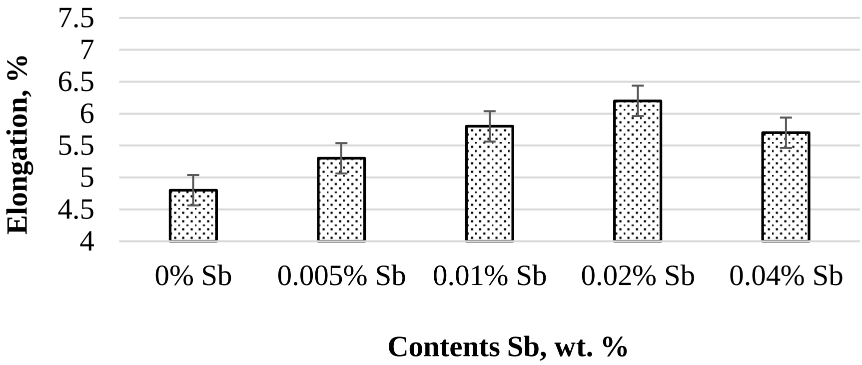

Fig. 4. **Elongation of AlSi7Mg alloy with Sb**

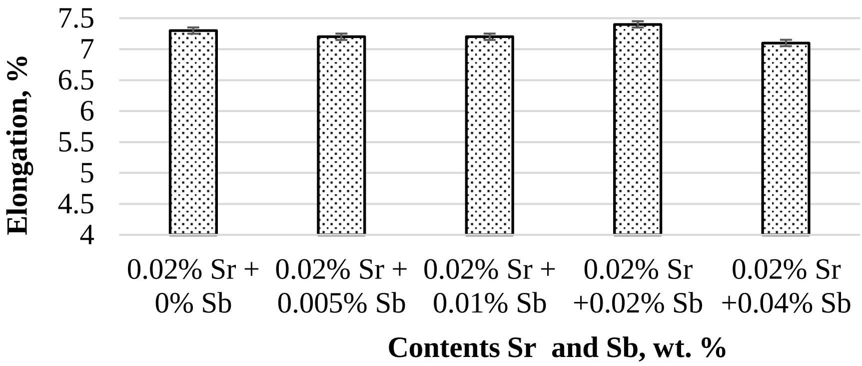

Fig. 5. **Elongation of AlSi7Mg alloy with Sr and Sb**

Inconsistencies obtained as a result of the conducted research with literature items [46] and [47] most likely result from different conditions of the research. The authors of paper [47] conducted research on a different alloy and used longer modification times (up to 120 minutes). The comparison of the results of our own research and those published in the literature shows a very large dependence of the results of research on silumin modification processes depending on the research conditions and the used research methodology.

Conclusions

Analyzing the results of the research, it was found that antimony affects the fineness of the microstructure and the related mechanical properties of the alloy. Compared to the tests presented in paper [46], a shift of the maximum mechanical parameters (tensile strength and elongation) to higher antimony contents (from 0.005% to 0.02% Sb) was obtained.

The results of the double modification did not confirm the influence of the second modifier on the microstructure and the analyzed mechanical properties of silumin.

Author contributions

Indicate the contribution of each author. Example: Conceptualization, T.L.; methodology, T.L.; validation, J.P.; formal analysis, T.L and J.P.; investigation, T.L.; writing and editing, T.L. and J.P. All authors have read and agreed to the published version of the manuscript.

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