INFLUENCE OF TI AND MELT NUMBER ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF AL-SI ALLOY ON AGRICULTURE MACHINE PARTS

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Abstract. Reducing the weight of the structure promotes improved machine performance and reduced fuel consumption. This can be achieved by optimizing the construction and use of light materials. It is the reason why aluminum is growing in popularity, mainly in the automotive industry and working machines, including agriculture. Al-Si alloys are still very popular mainly due to low density and high corrosion resistance. In order to reduce production costs, more and more machine parts are produced using the casting method. This favors the increase in the popularity of hypo-eutectic silumins. Among hypo-eutectic Al-Si alloys Al-9 %SiMg alloy is often used. Its raw microstructure consists of the plastic α phase and the large grains and needles of the undeformable *β* phase, which is the natural notch in the microstructure. This microstructure promotes the tendency to cracking the alloy. Through the modification process it is possible to fragmentation the beta phase and thus the plasticization of the alloy. By this method, the problem can be solved at the first melting. The market economy enforces the recovery of alloys and the use of waste from foundry production, such as risers, the gating system, castings with big defects, etc. It is then necessary to re-melt the alloy. It is uncertain whether the originally obtained microstructure, and therefore also the properties of the melts after a few melts, will not be adversely affected. Many salts and chemical compounds are used in the industry for modification. There is known modifying activity of such elements as: Na, Ca, K, Li, Ce, Te, Sr, Sb, Ti, B. Some of them have a permanent effect, but for most of them the effect of modification decreases with the time of holding the alloy in the liquid state and as expected, with the number of melts. With the number of melts also increases the holding time of the alloy in the liquid state. This paper presents the results of different ranges of Ti as a modification addition and melt number of the Al-9 %SiMg alloy. The effect of the Ti modifier on the microstructure, mechanical properties on the alloy was presented in graphs. As the research results showed the modification of a hypo-eutectic Al-9 %SiMg alloy firstly improved the alloy's properties, but with an increased number of melt the microstructure and mechanical properties were decreased.

Keywords: Al-Si alloy, silumin, modification, titanium, melt number.

Introduction

Ecology and requirements set by the market motivate to conduct research on improving the properties of constructional materials. Reducing the weight of the working machines it is able in the position to improve performance and reduce the fuel consumption and exhaust emissions. This can be achieved by optimizing the construction and use of light materials. It is the reason why aluminum is growing in popularity, mainly in the automotive industry and working machines, including agriculture. Suppliers for the automotive industry are constantly forced to design such materials, which not only ensure higher and higher properties, but also reduce the negative impact on the environment [1-8]. The material has also to reduce energy consumption in the production process. The modern construction material for components of work machines and vehicles must meet rigorous parameters regarding weight reduction, stability of material parameters, strength, corrosion resistance and surface quality. There are many alloys meeting the above criteria [9-11]. However, the Al-Si cast alloys are very attractive mainly because of their low density, good castability, high corrosion resistance, good thermal conductivity and durability [1; 11-19]. Aluminum alloys can be cast into complex shapes, and thus have potential to replace heavier cast iron and steel components.

Among hypo-eutectic Al-Si alloys Al-9 %SiMg alloy is often used. The alloy can be used on high-strength parts of machines [1; 2]. Its raw microstructure consists of the plastic solid solution of silicon in aluminum – α phase and the large grains and needles of the undeformable solid solution of aluminium in silicon – β phase, which is the natural notch in the microstructure [20-26]. This microstructure promotes the tendency to cracking the alloy. Through the modification process it is possible to fragmentation of the β phase or its eutectic (α+β) and thus the plasticization of the alloy [27-30]. By the modification method, the problem can be solved at the first melting [31-35]. The market economy enforces the recovery of alloys and the use of waste from foundry production, such as risers, the gating system, castings with big defects, etc. It is then necessary to re-melt the alloy. It is

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uncertain whether the originally obtained microstructure, and therefore also the properties of the melts after a few melts, will not be adversely affected. There are many salts and chemical compounds used in the industry for modification. There is known modifying activity of such elements as: Na, Ca, K, Li, Ce, Te, Sr, Sb, Ti, B [36-44]. There are well known other technological processes, too [45-51]. Some of them have a permanent effect, but for most of them the effect of modification decreases with the time of holding the alloy in the liquid state and as expected, with the number of melts. With the number of melts also the holding time of the alloy increases in the liquid state [25; 46].

The aim of this study was to simultaneous determine the influence of the Ti and melt number on the microstructure and mechanical properties of Al-9 %SiMg alloy.

Materials and methods

The Al-9 %SiMg alloy, obtained from industrial piglets, was tested in laboratory conditions. The alloy was melted in a ceramic crucible in an electric furnace. The modification process was carried out with Al-20 %Ti alloy. This proportion of the components ensured a single-phase microstructure of the Ti solid solution in Al (Fig. 1). The master alloy was modified at the crucible at temperature of 850°C for 5 minutes. The amount of Al-20 % Ti modifier was chosen in a way that ensured the introduction by weight of 0.05, 0.1 and 0.15 % Ti into the alloy. Cylindrical samples, 8 mm in diameter and 75 mm in length, for metallographic and mechanical tests were taken after completion of each modification stage. The remaining metal in the crucible was cooled to room temperature and then re-melted. Brinell hardness was tested by a ball with a diameter of 2.5 mm and by load 612.9 N in the HPO 250 hardness tester according to the standard ISO 6506-1:2014. Metallic materials - Brinell hardness test – Part 1: Test method. Six measurements were taken at every research point. The tensile stress was tested by the ZD30 universal tensile tester on two samples, ϕ6 mm, for each melting point, according to the standard ISO 6892-1: 2016. Metallic materials. Tensile testing Part 1: Method of test at room temperature.

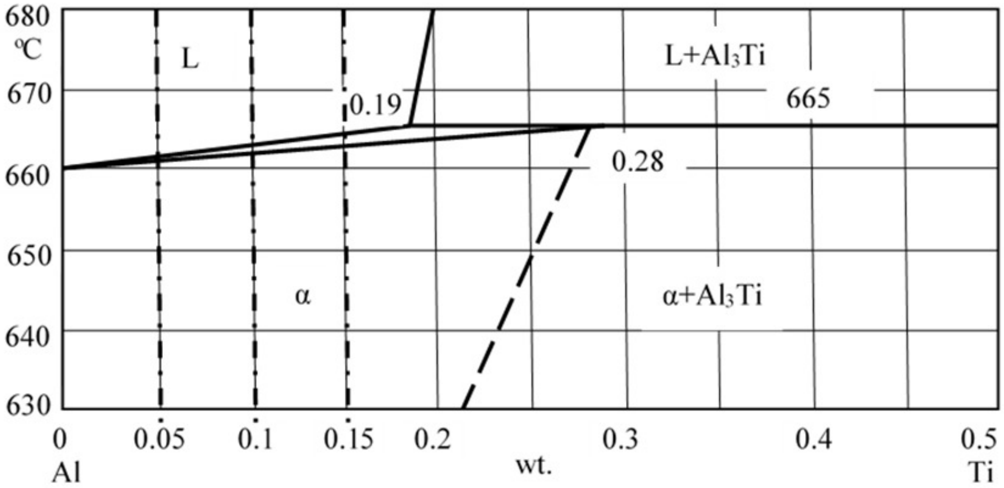

Fig. 1. **Fragment of Al-Ti phase diagram**

Results and discussion

The real average chemical composition of basic Al-9 %SiMg alloy is presented in Table 1.

Table 1

Real chemical composition of the tested Al-9 %SiMg, wt. %

Si	Mg	Mn	Ni	Cr	Fe	Cu	Zn	Ti	Al
9.24	0.34	<0.005	0.003	0.05	0,15	0.03	0.007	0.001	balance

Microstructures Al-9 %SiMg with 0.1wt %Ti: for the first melting is presented in Fig. 2, for the second melting it is similar as for the first melting (Fig. 3), for the third melting in Fig. 4, for the fourth melting in Fig. 5, for the fifth it is similar as for the third (Fig. 5).

Tensile strength of Al-9 %SiMg alloy with different Ti additions for 1 to 5 melt numbers is presented in Fig. 6, elongation in Fig. 7 and Brinell hardness in Fig. 8.

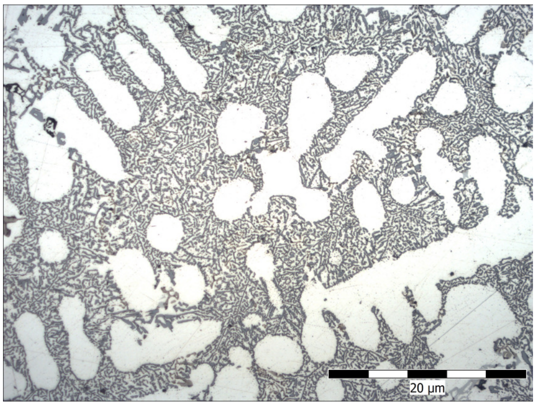

Fig. 2. **Microstructures Al-9 %SiMg with 0.1wt %Ti addition for first melting**

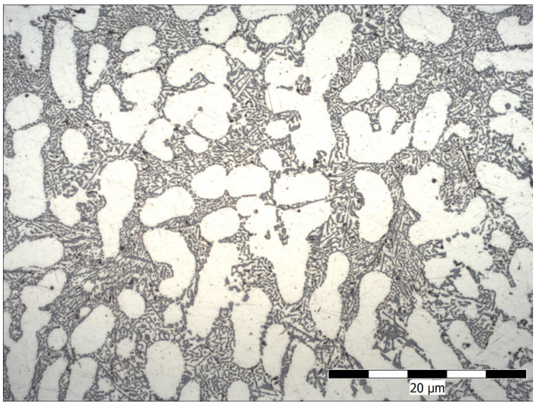

Fig. 3. **Microstructures Al-9 %SiMg with 0.1wt %Ti addition for second melting**

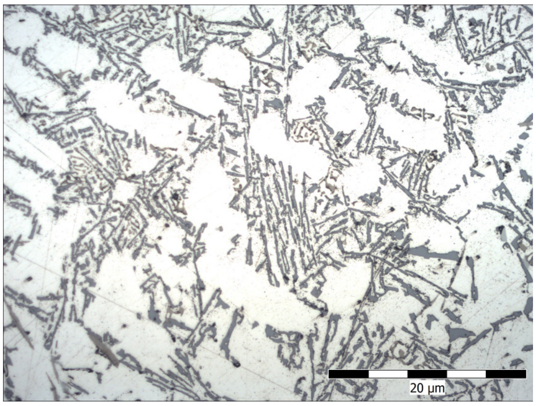

Fig. 4. **Microstructures Al-9 %SiMg with 0.1wt %Ti addition for first melting**

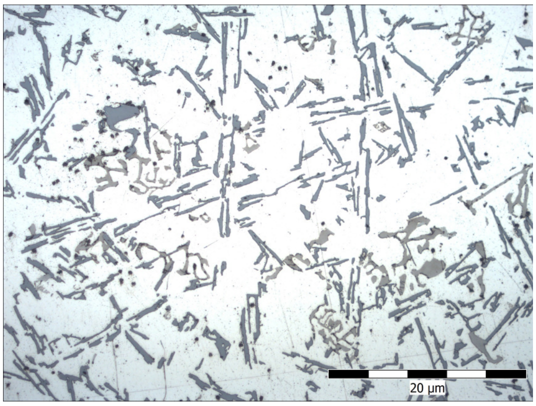

Fig. 5. **Microstructures Al-9 %SiMg with 0.1wt %Ti addition for fourth melting**

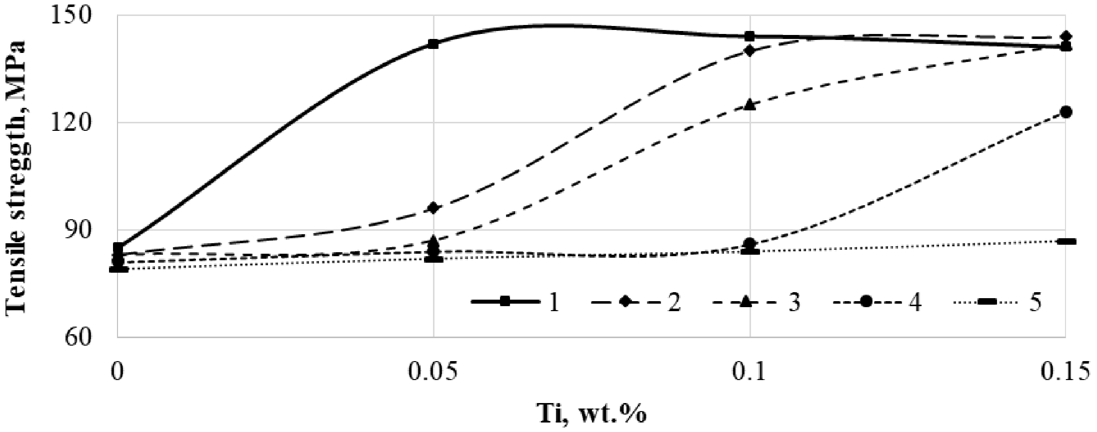

Fig. 6. **Tensile strength of Al-9 %SiMg alloy with Ti for 1 to 5 melt numbers**

On the basis of the microstructure and the results of the mechanical properties tests it was found that with the increase of the number of remelts for the optimum value of 0.1 % Ti in the microstructure larger and thicker eutectic silicon plaques are visible. This is confirmed by the tests of mechanical properties. After the second and subsequent remelting of the alloy, there was a decrease in the strength and plasticity in relation to the size of the previous remelting. It should be assumed that these changes are caused by the burning out of Ti. The distribution of the analyzed mechanical parameters indicates that the percentage loss of Ti is almost the same for similar initial contents of Ti in the alloy. One can see the trend towards higher loss at higher Ti content in the alloy.

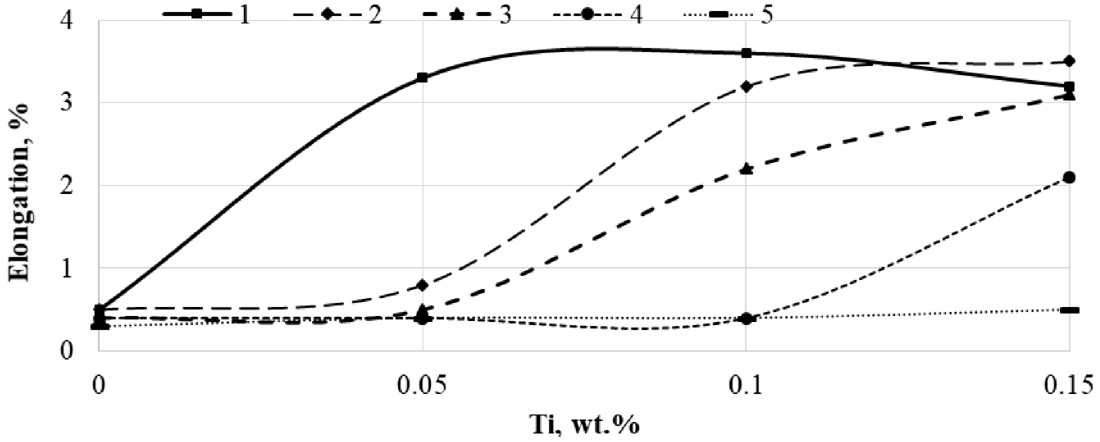

Fig. 7. **Elongation of Al-9 %SiMg alloy with Ti for 1 to 5 melt numbers**

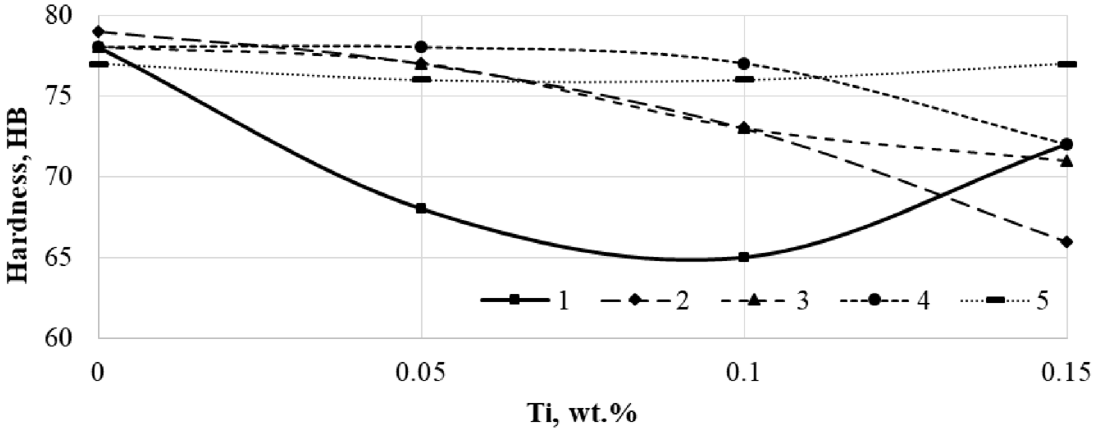

Fig. 8. **Brinell Hardness of Al-9 %SiMg alloy with Ti for 1 to 5 melt number**

Along with the increase in the amount of Ti introduced to value 0.05 % at the first melting, an increase in strength by 67 % and an elongation by 560 % was noted. After increasing the share of Ti to 0.1 %, there was a further slight increase in these parameters. After increasing the share to 0.15 %, there was a few percent drop in the strength and plasticity as well as an increase in the hardness of the alloy. Hardness in the range up to 0.8 % Ti decreased proportionally by 5 % and then increased to the initial value.

Conclusions

1. The results of the research confirmed the possibility of increasing the mechanical properties of hypoeutectic silumin with the addition of Al-Ti.
2. There was a change in the mechanical properties of the alloy with the number of remelts. The size and direction of this change depend on the amount of Ti introduced into the alloy. Most likely, the reason for this change is to reduce the amount of Ti in alloy, e.g. by burning.
3. The optimum Ti content, introduced in Al-Ti form, was determined to be 0.1 %. Considering the possibility of further melts of the alloy, the excess of Ti is clearly better than the deficiency.

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