Investigation of The Effect of Modifying the AlSi7Mg0.3 Alloy with A Fast-Cooled Master Alloy Using Heat Treatment

Kukartsev Viktor Alekseevich[1], Cherepanov Aleksandr Ivanovich[1], Tynchenko Vadim Sergeevich[1,2], Dokshanin Sergei Georgievich[1] and Dalisova Natalia Anatolievna[1,3]

[1]Siberian Federal University, Krasnoyarsk, Russia

[2]Reshetnev Siberian State University of Science and Technology, Krasnoyarsk, Russia

[3]Krasnoyarsk State Agrarian University, Krasnoyarsk, Russia

Introduction

Aluminum-silicon alloy AK7 or (ASi7Mg0.3) is a typical silumin, which is in demand in the automotive industry, construction, aircraft construction, machine, automobile and tractor production. It is appreciated for its good casting properties, weldability, machinability and corrosion resistance [3]. To ensure the required properties, in alloy smelting, modification is used, which can be carried out in one of the following ways: modification with salts, modification with ligatures, modification with strontium, boron, etc. [4].

Modification leads to the refinement of crystal grains or their constituents during crystallization. For its implementation, substances are introduced into the melt that slightly change the composition of the alloy. This substance is introduced in such a small amount that it does not affect the parameters of the crystal lattice, and therefore is not a dopant. As a result of refinement of the structure and change (improvement) of the configuration of individual phases, an increase in the mechanical properties of alloys and other operational properties occurs. In addition, its technological properties improve, the tendency to form cracks decreases, porosity decreases, as a result of which the tightness increases [5].

A new direction in the development of modification technology is the study of the principle of self-modification from a technological and economic point of view, which can give an economic effect and improve the environmental friendliness of the alloy smelting process. Studies carried out using highly sensitive gamma densitometry have shown that a liquid metal alloy, as a rule, is not a completely homogeneous liquid in a stable equilibrium state. Near the liquidus temperature, the alloy is in a micro-nonequilibrium state; therefore, its structure and properties are characterized by heterogeneity, the formation of groups of dissimilar atoms, and a different short-range order structure depending on the degree of overheating of the melt. Destruction of microinhomogeneities can occur only at high temperatures or with long isothermal holdings. This can lead to changes in the structure and properties of the solid metal [9, 10].

Regarding the hypoeutectic alloy Al93Si7, in order to obtain high operational properties, it is necessary to know the temperature of the metastable state of the melt, at which the formation of microheterogeneous particles, about 15 nm in size, occurs. This temperature can be determined experimentally for a specific alloy, by methods of measuring structure-sensitive characteristics during heating and cooling: kinematic viscosity, density, electrical resistivity, magnetic susceptibility. By quenching from the liquid state, it is possible to obtain a master alloy, the chemical composition of which corresponds to the composition of the alloy and use it for modification instead of the Al-Sr and Al-Ti-B master alloys. This can positively affect the cost of the product and make it more competitive [11].

The purpose of this work is to study the use of ligatures corresponding to the chemical composition of the AlSi7 alloy, obtained by rapid crystallization from the liquid state, for modifying the same alloy.

Experimental Study

To prepare the AlSi7Mg0.3 alloy, an SSHOL 10/10 resistance furnace was used (Fig. 1). The starting materials were aluminum grade A8, silicon Kr00 and magnesium Mg90. The crucible was heated to a temperature of 600 ° C. Then loaded with aluminum. The molten aluminum was heated to a temperature of 850 - 900 ° C. Then silicon (Si) was introduced 7% of the total weight of the melt at a temperature of 850 ° C. Magnesium was introduced at a temperature of 710 - 720 ° C.

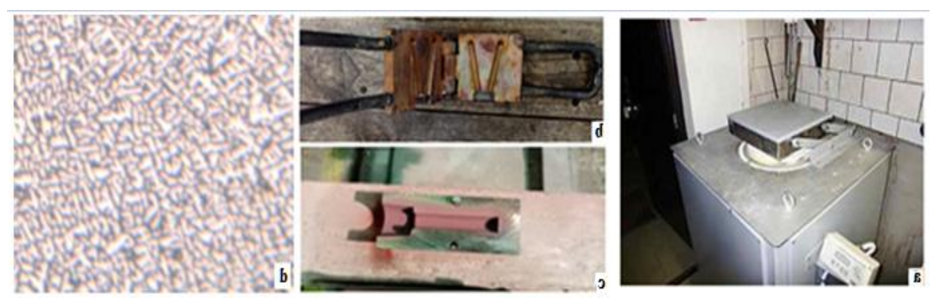

Fig. 1. Melting furnace and chill mold: a - melting furnace SSHOL 10/10; b - copper chill mold "Rensley", c - steel chill mold; d - microstructure of rapidly crystallized master alloy.

As a result, a base alloy of the following chemical composition was obtained: Si = 7.25; Mg = 0.290; Ti = 0.119; Mn = 0.001; Cu = 0.003; Zn = 0.994; Fe = 0.082 and B = 0/0008%, which corresponds to the AlSi7Mg0.3 grade.

After that, refining was carried out with hexachloroethane (C2Cl6) 0.1% of the total weight of the melt as follows: hexachloroethane was placed in food foil and then in a "bell", which was immersed on the bottom of the crucible, and up and down, the metal was cleaned. After the refining procedure, the oxide film and slag were removed. To establish the duration of the modification effect, the alloys were held for 15 minutes and 3 hours. The rapidly cooled modifying master alloy was obtained by pouring a part of the base alloy into a Rensley chill mold (Fig. 1) at a temperature of 740 ° C. The chill temperature is 25 ° C (Fig. 2). For modification, samples were taken in the form of cast rods, 6 mm in diameter, which solidified at a rate of 0.5 * 103 - 104 K / s. The microstructure of the obtained rapidly crystallized master alloy is shown in Figure 1d.

The resulting modifier in an amount of 0.5% of the melt weight was introduced into the finished alloy at a temperature of 700 ° C. The prepared alloy for research was poured into a steel chill mold (Fig. 1c). Heat treatment was carried out in a resistance furnace according to the following regime: heating for hardening 535 ± 5 ° C for 5 hours; quenching in water at a temperature of 80 - 100 ° C; aging - heating to a temperature of 150 ± 5 ° C, holding for 5 hours.

Discussion

The macrostructure of the samples is shown in Figure 2.

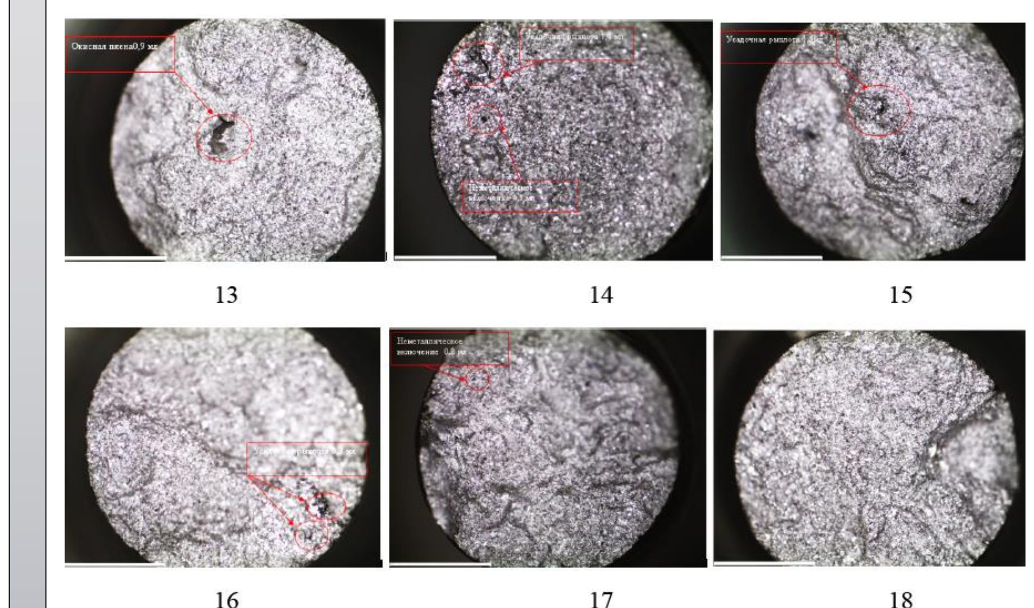

Fig. 2. Macrostructure of specimen fracture.

All samples have defects in the form of pores and gas-shrink cavities, the appearance of which is characteristic of hypoeutectic silumins. Despite the existing defects, the mechanical properties meet the technical requirements and ensure the structural strength of the castings. The following defects were found in the macrostructure: 1. Sample No. 13 - one oxide film. 2. Sample No. 14 - one shrinkage looseness of 1.4 mm and one non-metallic inclusion of 0.1 mm. 3. Sample No. 15 - one shrinkage looseness 1.5 mm in size. 4. Sample No. 16 - one shrinkage looseness of 0.3 mm. 5. Sample No. 17 - one non-metallic inclusion 0.2 mm in size.
No defects were found in sample # 18. The detected defects did not significantly affect the results of mechanical tests.

When making samples from the AlSi7Mg0.3 alloy, using the technology of inoculation of a rapidly cooled alloy with a master alloy, to assess the preservation of the effect of modification, casting into a chill mold was made after 15 and 180 minutes. The microstructure of the samples (Fig. 3) consists of a solid solution and eutectic and corresponds to the modified state of the alloy. The microstructure of AlSi7Mg0.3 alloy samples consists of a - solid solution and eutectic, corresponds to the modified state of the alloy, provides the level of mechanical properties of castings and allows casting without loss of mechanical properties within 3 hours.

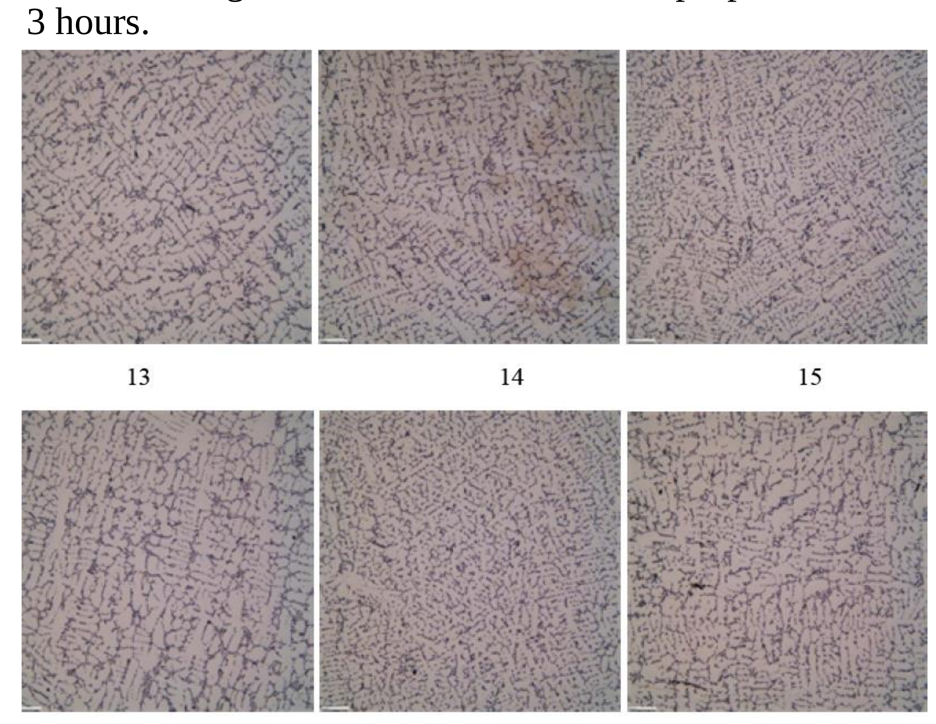

Fig. 3. Microstructure of samples

Conclusions

The dimensions of the axes of the secondary dendrites of the samples made of AlSi7Mg0.3 by the technology with the use of modification with a rapidly crystallized master alloy are shown in (Fig. 4).

The size of the dendritic cell of the alloy samples is in the range of 18-26 microns. The ligature used for modification has the size of the dendritic cell determined when examining the microstructure of the sample using a Leica DMi8 microscope, 5-6 times smaller and is 4.08 microns.

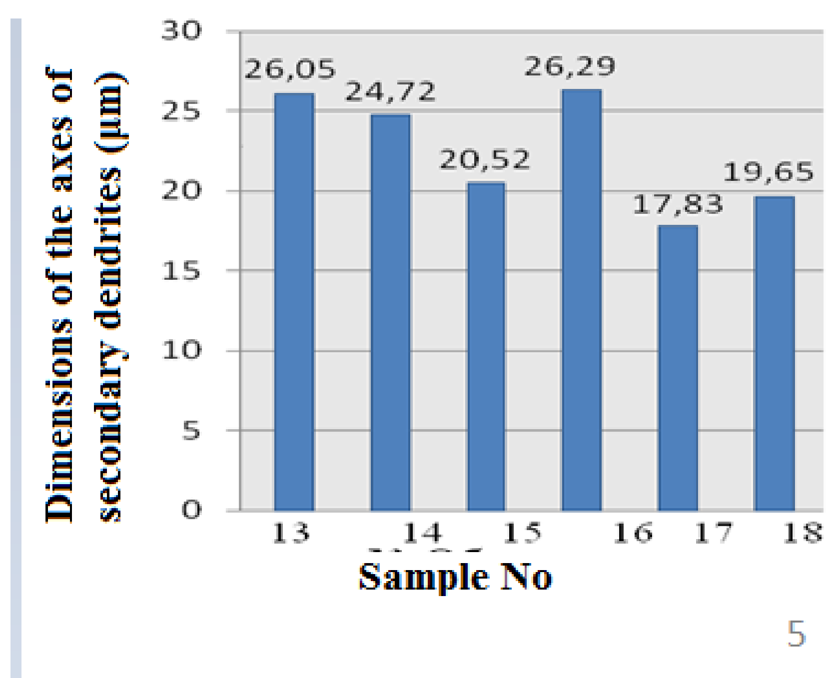

Fig. 4. The size of the axes of secondary dendrites (μm): 13,14,15, 16,17,18 - heat-treated samples.

The principle of “self-modification of the AlSi7MgO.3 alloy with subsequent heat treatment has been investigated. Modification with the rapidly cooled AlSi7Mg0.3 alloy retains this effect for 3 hours, which allows maintaining the level of mechanical properties in accordance with GOST 1583-93.

The principle of structural and dimensional correspondence has been confirmed, which facilitates the crystallization process with the formation of crystallization centers, the number and size of which will depend on the thermal-time parameters of obtaining the master alloy, working alloy, as well as the holding time of the working alloy before casting into molds.

It has been established that the size of the dendritic cell of the master alloy obtained by casting in the "Rensley" chill mold, with the provision of the cooling rate of the master alloy in the range of 5 * 102 - 1.5 * 103 K / sec, is 5-6 times less than when casting the alloy into a steel chill mold.

The introduction of the technology for the manufacture of rapidly crystallized master alloy will create conditions for carrying out the modification without the use of Al-Sr and Al-Ti-B master alloys.