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COMPREHENSIVE INFLUENCE OF HEAT TREATMENT AND IRON IMPURITIES ON THE STRUCTURE OF SECONDARY SILUMINS

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Statement of the problem. It is well known that the composition of aluminum alloys can be identified as consisting of the main alloying elements, injected to strengthen the material, additional alloying additives (plasticizers, additional reinforcers , modifiers), neutral and harmful impurities. The quantity of the last mentioned elements increases noticeably when scrap and waste products are used. Among the harmful elements that significantly degrade the strength, ductility, cracking resistance and endurance of secondary silumins iron holds the main position [1-4]. Opportunities to improve mechanical and service properties of secondary silumins up to the level of their primary analogs are not completely exhausted yet. In this connection, the question arises: is it the result of influence of harmful impurities or incongruity of heat treatment mode to the characteristical features of the chemical composition and structure of silumins made from recycled materials.

Analysis of recent research and publications. Analysis of the literature shows that researchers have paid almost no attention to the possible interconnection between iron content and heat treatment mode of secondary Al-Si alloys. There are only few and conflicting data on the influence of heat treatment parameters on the quantity, size and morphology of intermetallic phases based on iron. The main results in this direction are presented in works [5-8].

Purpose of work. Whereas the problem of combating the negative influence of iron on the quality of secondary aluminum alloys is still not fully resolved, and quenching and aging operations are in most cases required in the manufacture of products from silumins, the purpose is to study the effect of heat treatment on Al-Si alloys with different iron content.

Discussion of research results. The study was conducted by rotational plan of multifactor experiment of the second order 2^3, varying the timing parameters of heat treatment and iron content. Concentration range of iron impurities in the alloy was chosen basing on the following considerations. It is known that iron in a relatively small quantity (~ 0.5 wt. %) positively affects the strength of silumins due to the formation of intermetallic phases. With increase of iron content the morphology of iron-based phases changes to the unfavorable, the size of phases increases, which causes the significant deterioration of mechanical properties of alloys. International standart ГОСТ 1583-93 regulates permissible content of iron impurities for most hypoeutectic silumins at 1.1...1.2 wt. %, which was chosen as the upper limit of the concentration range of investigated iron content.

It should be noted that according to ГОСТ 1583-93 the use of a large range of holding time by quenching and aging is allowed. On the one hand the use of long holdings is not economically expedient, as it significantly increases the cost of production. On the other hand, too short holding times are insufficient for the passage of diffusion processes, phase and morphological changes and negatively affect the properties of the resulting material. Based on these considerations, the correlation between holding time during quenching (τ_q) and aging (τ_{ag}) and the concentration of iron (Fe) in the secondary silumins was investigated.

Melting of the alloy AK8M3 (8,49...8,51% Si, 3,09...3,11% Cu; 0,99...1,0% Zn; 0,53...1,23% Fe; 0,4% Ni; 0,32% Mn; 0,08% Mg; 0,09% Ti; remainder Al) was performed on the secondary charge. Metal was refined and modified by complexes, which have shown high efficiency in the manufacture of castings from secondary hypoeutectic silumins [9-11]. Quenching and aging of the silumin AK8M3 was carried out at temperatures of 500 ± 10 °C and 180 ± 10 °C respectively.

Metal microstructures for different variants of heat treatment and with different concentration of iron is given in Figure 1. According to the received images the phase $Al_{15}(FeMn)_3Si_2$ the form of Chinese characters and branched eutectic crystals at low iron content (Fe=0,51...0,65 wt. %) was obtained. At concentrations of 1.05...1.19 wt. % the iron-based intremetallic phase $Al_{15}(FeMn)_3Si_2$ acquired the form of primary polyhedral crystals. Moreover, with the increase of iron content the quantity of iron-based intermetallic phases increased. Eutectic of the alloys with a higher concentration of iron was rougher, because it containing a greater quantity of phases based on iron in its composition. In alloys with low iron content processes of structural changes specific for quenching and aging occurred much faster, which may be due to easier passage of diffusion in the material.

To clarify the influence of parameters of heat treatment on the structure and thus the properties of secondary silumins the processes that occur in alloys at zero level (by varying the holding time during quenching and aging at constant iron content) were studied. The structure of the alloy number 11 was characterized by heterogeneity, rough cristallinity and large size of the components. Eutectic silicon particles looked like long stretched plates, and the particles of the phase $Al_{15}(FeMn)_3Si_2$ shaped aggregations in certain areas of microsection. The phase Al_2Cu was mainly located within the eutectic colonies. After heat treatment the eutectic of the alloy number 12 obtained a strong granulation and fragmentation. Iron-based intermetallides looked like flakes, were present in small amounts, but were situated irregularly on the surface of microsection.

Crystals of eutectic silicon in the structure of the alloy number 13 were rough, but the length of particles was relatively low. Iron-based phase $Al_{15}(FeMn)_3Si_2$ was found as branched crystals of small size and globular aggregations of particles. The size of the structural components and their distribution was uneven at the crossection of microsection.

Particles of eutectic silicon of the alloy number 14 had large sizes and dimensions and unclear cut. Allocations of phase $Al_{15}(FeMn)_3Si_2$ were concentrated in certain areas of the microsection and had hexagonal shape. After quenching and prolonged aging little and evenly distributed compact crystals of strengthening intermetallic phase Al_7Cu_4Ni were observed in the structure, i. e. eutectic particles of the phase Al_2Cu easily diffuse during quenching, and copper, which transitioned into solid solution, segregated during further aging in the composition of the compound Al_7Cu_4Ni.

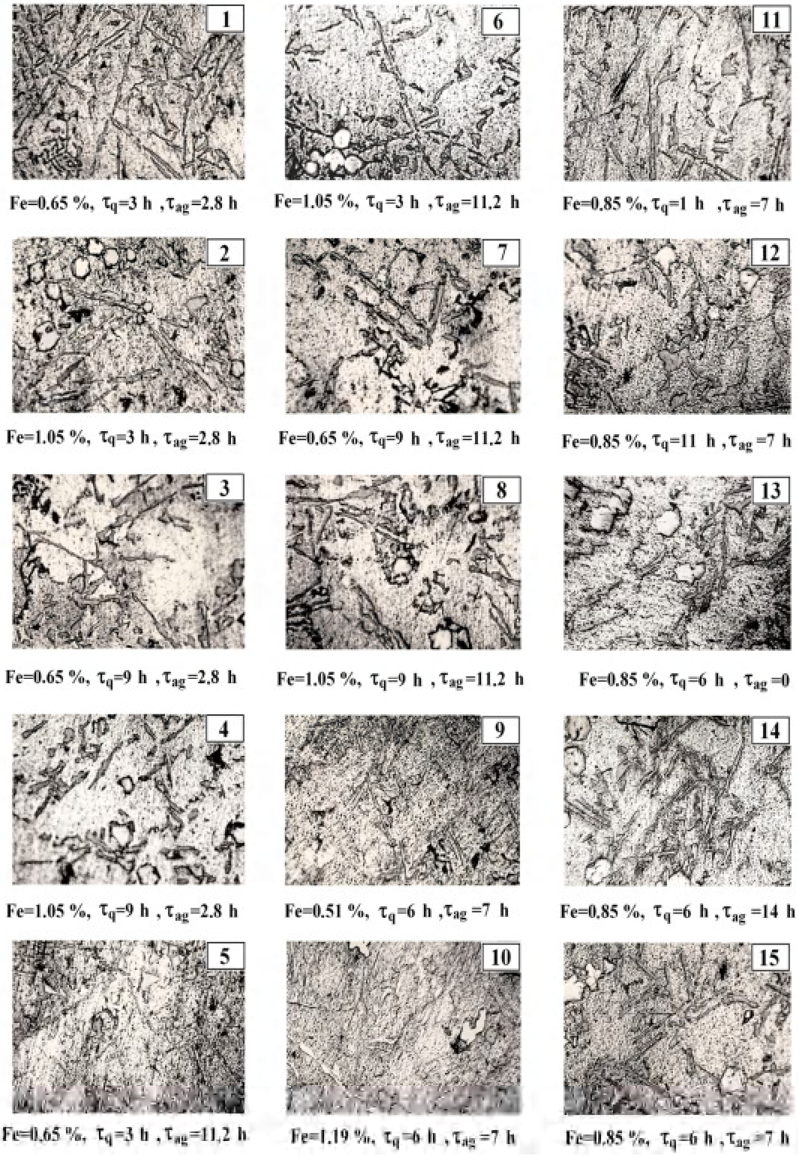

Fig. 1. The microstructure of the alloy AK8M3 according to the matrix design of experiments (x200): 1...8 – plan of the matrix 2^3; 9, 10 – star points, 11...15 – points of the center of the plan (zero level of varying)

The results of measurement of lattice parameter of a solid solution of aluminum in the alloy AK8M3 depending on heat treatment mode are shown in Figure 2.

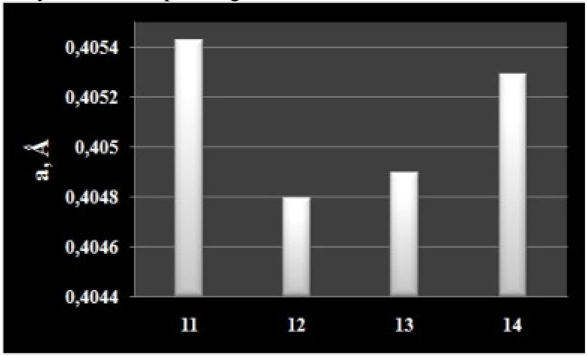

Fig. 2. The lattice parameter of a solid solution of aluminum in the alloy AK8M3.

The decrease of the lattice parameter of HCL (Al)- matrix during quenching associated with the transition of atoms of alloying elements to the solid solution, especially silicon and copper, and iron too, atomic radiuses of which are smaller than the radius of atom of aluminum (0,117 nm, 0,128 nm and 0,127 nm for silicon, copper and iron as compared to 0,143 nm for aluminum, respectively) and formation of substitutional solid solutions. Allocation of excessive phases during aging was accompanied by an increase of the lattice parameter of (Al)-solid solution.

Thus, depending on heat treatment mode iron-based intermetallic phases either uniformly distributed at the crossection of microsection or concentrated in certain microvolumes and acquired somewhat different forms, i. e. some variants of heat treatment are more favorable than others depending on the concentration of iron in alloy. According to the results, it is necessary to adjust the time of heat treatment of secondary silumins, depending on the content of the most harmful impurity – iron, which is associated with a significant amount of iron-containing intermetallic compounds in the structure and their unfavorable morphology and large sizes, and, therefore, longer time for passage of diffusion processes during quenching and aging.

Conclusions. A wide range of variation of the chemical composition of secondary silumins and increased quantity of harmful impurities cause different ratio of excessive phases in the structure of the alloys, which necessitates the selection of different parameters of heat treatment. It is likely that by dint of the heat treatment solely the achievement of the leveling of influence of iron on the quality of secondary silumins cannot be reached, but as additional to the known methods of physical and chemical effects on the melt it can show good results not in the common sense of effect on the main alloying elements only, but in the context of action on harmful impurity of iron.

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