Influence of samarium and europium on Al+1.9%Mn alloy phase composition and microstructure

T M Umarova and O Normahmedov

Lomonosov Moscow State University in Dushanbe, 35/1 Bokhtar Street, Dushanbe, Tajikistan

E-mail: umarova04@mail.ru

Abstract. The experimental results were proposed on the base of the research of the X-ray phase and microstructural analysis of eutectic structured aluminum-manganese alloy, modified by samarium and europium (up to 0.10 wt. %). The optimal concentration of europium was determined by the metallographic microscopy in order to obtain a fine dispersed structure. The results of microstructural analysis indicate the effectiveness of modifying the aluminum-manganese alloy of the eutectic composition with samarium and europium, especially Eu, in the existence of which the primary precipitates become compact, leading to a spherical shape, which allows us to consider the synthesized Al-1.9% Mn- 0.05% Eu alloy in the future as a more promising (compared with the Al + 1.9% Mn alloy doped by samarium) structural material with improved physicochemical properties.

1. Introduction

Alloys of the Al-Mn system are the most important for welded structures and cold stamping. The high ductility, good weldability (by all types of welding), high corrosion resistance, and plastic deformation hardens are characterized by the most famous AMn and AMn1 brands industrial alloys of the alloys almost twice [1].

For a long time this system had been used in industry, however, nowadays this alloys continue to attract the attention of the scientists to interesting patterns of changes in structure and properties: because of supersaturated solid solutions deformation at a process of fast crystallization rates and the solid solution the decomposition upon subsequent heating, etc.

Accelerated cooling of aluminium-manganese alloys, creates the crystallization conditions of sharp supercooling, which causes the eutectic point to shift to the region of high manganese concentrations. By change the period of crystalline and metallographic analysis was found that the most of the manganese in continuous casting remained in the supersaturated solid solution. It was found that the supersaturated solid solution formed during crystallization along manganese with subsequent heating to 450 - 500°C disintegrates, as this temperature corresponds to the tempering temperature of alloys of this system [2].

It is known that the alloys of high electrical conductivity could be used in electrical products as well as aluminum alloys having low electrical conductivity (high resistivity). These alloys are used for motor rotors because the requiring lower conductivity than aluminum and its conductor alloys. They are casting alloys containing 1-2% Mn and/or 0.8 to 13% Si [2].

The aluminum alloy with 0.8- 2.0% Mn containing cerium and nickel for finefilm conductors and microcontact pads could be f practical used [3].
Not only Cerium, but other rare-earth metals (REM) are increasingly used in aviation make a certain contribution to changing the structure and properties of Aluminum alloys. Since the solubility of REMs metals in aluminum is extremely small, but even that alloys no more than 0.5% (by weight), significantly affect the properties of aluminum alloys. In this case, it is necessary to note the dual role of REM alloying additions: on one hand, lanthanides are effective refiners, because, due to their high chemical activity, they neutralize the harmful effects of impurities, forming refractory chemical compounds, and on the other hand, as surface-active elements, they located on the phase interfaces (grain boundaries, block boundaries, interphase boundaries), strengthening these surfaces and inhibiting the development of diffusion processes.

Therefore, REMs have a positive effect on the structural stability of alloys, reduce their segregation heterogeneity, and prevent the formation of harmful structural components.

In the melting process, microadditives grind grain neutralize impurities, linking them into finely dispersed compounds, while improving the manufacturability of the alloy during subsequent processing by pressure [4]. The versatile positive effect of lanthanide microadditives makes it possible to improve existing and create new alloys for producing working blades of modern aircraft engines with a unique combination of various properties.

Thus, a promising way to improve the properties of structural materials is microalloying them with a metal of the lanthanide group, which, by modifying the structure, significantly increases the mechanical and technological properties of the alloys. Therefore, the use of REMs will be economically justified.

The aim it is to study the effect of REMs (samarium and europium) on the physicochemical properties of eutectic aluminum-manganese system alloys. The subject is a part of general research concerning the effect of REMs on aluminum alloys [5-7].

2. Research methods
In that research work, the alloys of the eutectic Al-Mn system are synthesized, modified with samarium and europium (alternately) in the content of: 0.01; 0.02; 0.05 and 0.10 wt.% Under vacuum at a temperature of T = 1000°C.

For that research alloys were obtained from aluminum grades: A995 (GOST 11069-74), since the influence of impurities (Fe and Si) are quite substantial and the solubility of manganese in aluminum sharply decreases existing iron, electrolytic manganese MP00 (GOST 6008-82) with an impurity of 99.95%, samarium - 99.9%, the latter were introduced ligatures Al-Mn (10%) and Al-Sm (3%), metal europium with a purity of 99.9%.

The metal charge was sealed in a quartz ampoule.

The following equipment and instruments were used for the synthesis and study of alloys: KS 400/10 furnace (Germany); vacuum post; NIKON SMZ 670 microscope, D2 Phaser diffractometer (Bruker, Germany) with CuKα (λ = 1.5418 Å). Processing of the obtained data was carried out using the Diffrac.eva software products.

Figure 1 shows the diffraction patterns of powders of an alloy of the Al-Mn system (1.9%) modified with europium (up to 0.10 wt.%). A similar X-ray phase analysis was carried out of Al + 1.9% Mn powders, modified with samarium (up to 0.10 wt.%).

According to the results, by the increase of the doping component (Sm and Eu) the diffraction peaks increase could be. The diffraction patterns of all samples are similar to all diffraction peaks from the PDF database.

For preparation the alloys samples: the Al-Mn-Eu and Al-Mn-Sm systems for microstructural analysis we have used the recommendations of the author [5]. Before analysis should be done the mechanical processing of samples (grinding and polishing to a mirror surface).
Figure 1. Diffractograms of Al + 1.9% Mn powders modified with europium in the contents of: 0.01 (1), 0.05 (2) and 0.10 wt.% (3).
To reveal the microstructure of the studied alloys, the samples were etched with various reagents, depending on the composition of the alloy and the presence of the phase present.

For example, reagent No. 53 (0.5% HF) was used for the studied alloys for 30–40 seconds (at a temperature of 500 °C). Microstructural analysis was carried out by Nikon optical microscope at a metallographic increase of 200 times, which made it possible to observe a change in the microstructure of the samples, depending on the composition. Figures 2 and 3 show the microstructures of the synthesized alloys of the Al-Mn-Sm and Al-Mn-Eu systems (respectively).

The aluminum-manganese microstructure alloy study by the eutectic composition modified with samarium to 0.05% (figure 2) indicated that it is a branched dendrite. The effect of europium on aluminum-manganese eutectic was more affective. Comparing the photographs of the microstructures of the Al-Mn-Sm and Al-Mn-Eu alloys, could be noted that, unlike samarium, the addition of 0.05% europium leads to the fine grained structure. The twofold increase in the concentration of europium (from 0.05 to 0.10%) the structure of the ternary alloy, where the fine-grained structure changes its shape, that in that sphere of the plate looks like needles.

Thus, by analyzing the obtained results, we noted that the interpretation of the diffraction patterns of the Al-Mn-Sm and Al-Mn-Eu alloys showed in both cases the presence of intermetallic compounds: Al 0.97 Mn 0.03 and Al 6.43 Eu 0.77 Mn 2.8, respectively.

A ternary compound was not found in the Al-Mn-Sm system in the selected concentration range (1.9% Mn and up to 0.10% Sm).

Figure 2. Microstructure (x 200) of Al + 1.9Mn modified alloy: a – 0%; b – 0.01%; c – 0.02%; d – 0.05% wt. Sm.
3. Conclusion
The results of microstructural analysis indicate the effectiveness of modifying the aluminum-manganese alloy of the eutectic composition with samarium and europium, especially Eu, in the existence of which the primary precipitates become compact, leading to a spherical shape (figure 3b), which allows us to consider the synthesized Al-1.9% Mn-0.05% Eu alloy in the future as a more promising (compared with the Al + 1.9% Mn alloy doped by samarium) structural material with improved physicochemical properties.

References
[1] Fomin B, Moskvitin V and Makhov S 2004 Metallurgy of Secondary Aluminum (Moscow: Metallurgiya) p 240
[2] Industrial Aluminum Alloys 1984 ed by S G Aliev, M B Altman and S B Hambartsumyan (Moscow: Metallurgiya) p 528
[3] Bessonov V A, Bogatov P N and Bochvar N R 1977 Aluminum based alloy. Copyright Certificate No. 544703. Description of the invention to copyright Certificate 980454 A
[4] Ospennikova O G 2012 Aviation Materials and Technologies (Moscow: VIAM) pp 19–36
[5] Umarova T M 2016 Materials Science and Engineering Technology vol 890 331–338
[6] Umarova T M and Ganiev I N 2008 Anode Alloys of Aluminium with Manganese, Iron and Rare Earth Metals. Monograph (Dushanbe) p 273
[7] Umarova T M, Jalolov F N and Ganiev I N 2019 Reports of the Academy of Sciences of the RT vol 62, No 3-4 203–207
[8] Kovalenko V S 1981 Metallographic Reagents. Handbook 3rd ed. p 120