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The Study Of Composite Material Of Al-C System

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Abstract: In this work was done an investigation of the phase composition of the composite AL-C system using a computer simulation in software ThermoCalc. Evaluated the stability of the system by the method of analysis of Gibbs energy for the entire range of carbon content. The technology of obtaining samples of the AL-C system using the fine carbonaceous materials. Studied the microstructure of the samples and mechanical characteristics. It was found that carbon has positive influence on the properties of the obtained materials.

Introduction

Currently in the world is planned to increase research in the field of development and wide application metal-matrix composite materials. These materials possess high anti-friction and mechanical properties, heat resistance, stiffness, low density. The properties of these materials provide a significant reduction in the mass of products and designs that reduce the flow of material into the product while enhancing the reliability and increase the resource of their work. An actual problem of modern materials science is the search for compositions using nanomaterials for the development of new materials with physical properties that caters to the needs of modern technology. The literature analysis shows that materials based on aluminum effectively strengthened when bringing them to sub-ultrafine-grained or nanostructural level [1-6], but the properties of aluminum alloys obtained using nanomaterials are insufficiently studied.

The purpose of this work is study of composite material of Al-C system.

Research methods

To determine the phase components of the composite material in the first place it is necessary to study the phase state diagram (fig. 1). Chart phase state was built in the software ThermoCalc. Analysis of the phase diagram shows that when the content of 25% or more, the composition of the material is presented at a temperature below 2150˚Cby carbide aluminium and graphite, with the increase in the content of carbon, increases the content of graphite in the composite material. Above this temperature there is a fluid and graphite. When the carbon content is less than 25% of the liquid is maintained until the temperature 658°C, below this temperature the phase composition of the composite material presents a mechanical mixture of carbide and aluminium solid solution of carbon in aluminum FCC lattice. Also the figure shows the liquidus line of the composite material.

To assess the stability of the system in terms of phase transitions the analysis of the Gibbs energy of the system in the relevant temperature conditions. For a composite material with carbon content greater than 25% at a temperature of 2150°C, the system is in equilibrium for pure materials. The chemical composition of the material does not affect the thermodynamic stability of the carbide of aluminum and graphite. When reducing the carbon number of the liquid phase will increase, and aluminum to decrease. Further decrease of the temperature to 658˚Ccauses a decrease in the Gibbs energy, and, as a consequence, the system is more stable.

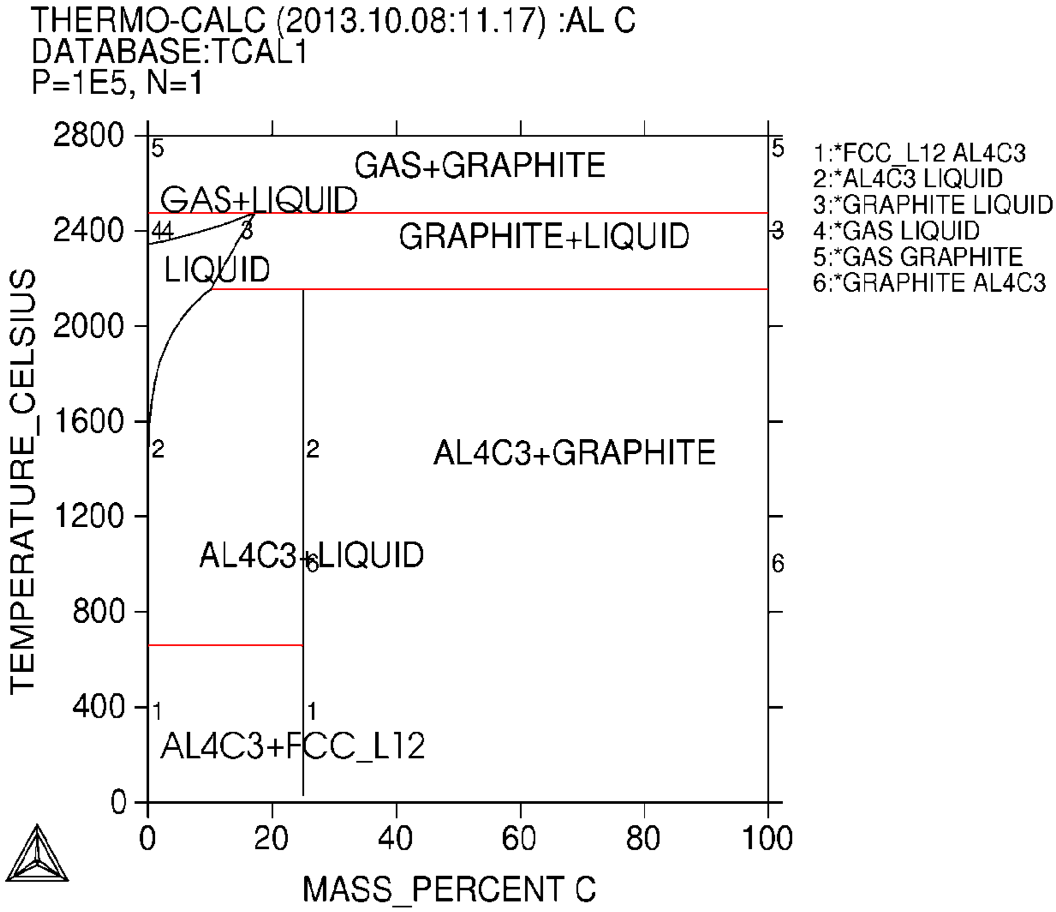

Fig. 1 – Chart phase state of the composite Al-C system

At temperatures below 2150˚Cwith any content of carbon in the structure of the material will be a carbide of aluminum. When the carbon content is less than 25% from the liquid in the first place will be allocated a carbide of aluminum, while the maximum content of solid carbide aluminum in the composite material will not exceed 40%.

Composite material at room temperature will consist of a phase of a carbide of aluminum and, depending on the carbon content, the solid solution of carbon in aluminum or graphite. At all temperatures the carbide of aluminum consists of 25% of carbon and 75% aluminum. Liquid at lower temperature is depleted of carbon, at a temperature below 1600˚Cconsists entirely of aluminum, and the temperature 658˚Ccrystallized with the formation of FCC solid solution of carbon in the aluminum. The carbon content in the solid solution of aluminum at room temperature is $5x10^{-13}$%.

The next stage of research was the formulation of the physical experiment. For the experiment in the first place, there were prepared samples used as ligature. The samples were prepared from aluminum powders with a particle size of the main fraction is 5-100 µm or crushed chips alloy AK9 and number of nanocarbon materials in the ratio of Al - 10 mass. % C in the original mixture.

As the carbon materials used:

- fullerene-containing soot, production Institute Ioffe, St. Petersburg;
- fullerenes C_{60}, manufacturing Institute Ioffe, St. Petersburg;
- fullerene mobile, Institute Ioffe, St. Petersburg;
- carbon microparticles of size 3, 4, 9 µm, the production of ASBURY GRAPHITE MILLS, INC., USA.

To obtain the developed composite material as the base used alloy AK9.

The technology of obtaining ligatures included: mechanical activation processing of source materials in the planetary mill, the compacting in rigid molds and hot extrusion. Mechanically activated powders were compactional in tablets at P=450 MPa. Next, the tablets were extrudible at a temperature of 450-500˚CWith a drawing ratio ≥ 10 and received a ligature in the form of rods.

Mechanical activation treatment was carried out for 30-40 minutes at frequency of rotation of the Central shaft 400-600 rpm and the ratio of the mass of grinding bodies to the mass download of 20:1.

The melt was prepared in an induction furnace ISV 0,004. Ligatures containing 10 wt.% carbon was introduced into the melt AC at a temperature of 750-780°C, while the melting alloys amounted to 3-5 min. Number of input ligatures in aluminum melt was calculated from the condition 1 wt.% carbon composite. The temperature was controlled by a multichannel detector RMT 39D, connected to the PC.

Results and discussion

After obtaining a composite material moved on to study mechanical properties and microstructure.

During compression tests it was used 5 samples, with a side of a square of 5 mm, height 10 mm. The test results are shown in table 1.

Table 1 - Mechanical properties of the alloy

	Description			
	Yield strenth, MPa	Contraction, %	Hardness Vickers	Brinell dynamic hardness
AK 9	320	38	460	50
Composite material of Al-C system	360,4	35	471	56

As can be seen from the data, in the result of adding carbon to the forging aluminum observed increase of the yield stress in compression is 11%, while there has been some reduction in plasticity: 7-8%. In addition, there is an increase in hardness, both dynamic and static, compared to conventional forging aluminum.

The results of the study of the microstructure by scanning electron microscope is presented in figure 2. The analysis of the microstructure shows that the texture of crystallization is missing. On the microsections, studied in all three directions noticeable presence of inclusions. For all of microsections characterized by the inclusion of bright colors skeletal form. Moreover, the formation of particles skeletal form occurs only in the longitudinal direction, evidenced by the fact that the particles skeletal forms found only in one direction. On the microsections prepared in the other two directions, there are sections of inclusions skeletal form. The sizes of the inclusions range from 50 to 80 μm. The thickness of the particles skeletal form varies from 1 to 5 μm. Also on the microsections detected traces of carbon.

Analysis of the microstructure with increasing 2500 times showed addition to the presence of large inclusions more dispersed inclusions with sizes up to 1 μm. Fine inclusions are uniformly distributed over the cross section of the sample that will provide effective dispersion strengthening, as well as inhibition of the boundaries of structural components.

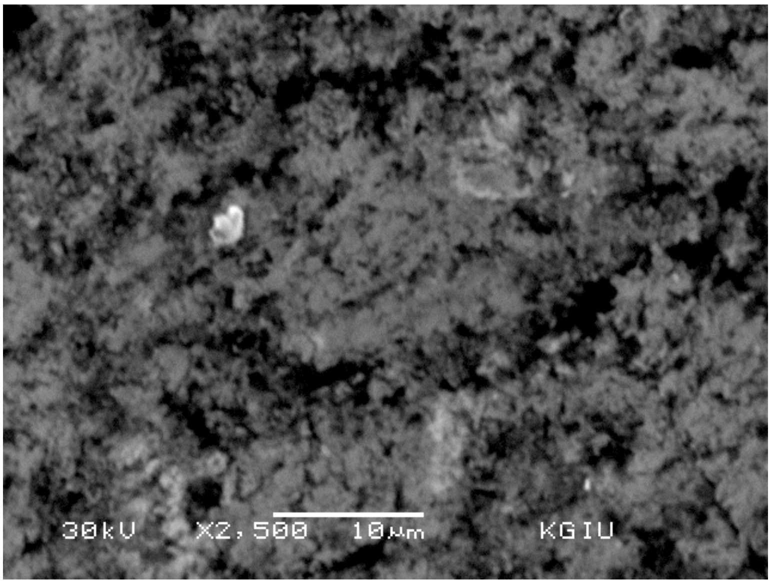

Fig. 2 –Microstructure of the sample obtained by scanning electron microscope, X2500

Conclusions

With the help of computer modelling of composite material systems Al-C using ThermoCalc software system was determined phase composition of the material for the entire range of chemical composition, built a state diagram and identified lines of liquidus-solidus. The content of chemical elements in phase components and assessed the nature of its changes depending on temperature.

Thus, it is possible to draw a conclusion about the feasibility of using carbon as an alloying element in aluminum alloys. Adding 1% of carbon causes a noticeable increase in strength characteristics. In addition, modification of carbon allows to obtain more dispersed structure of the alloy.

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