THE USE OF ALUMINA AND ZIRCONIA NANOPOWDERS FOR OPTIMIZATION OF THE Al-BASED LIGHT ALLOYS

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Abstract

The paper presents data on the structure, phase composition and other properties of zirconia and alumina powders obtained by electric explosion of wire and plasma-chemical deposition methods. Scanning and transmission electron microscopy reveal that the nanoscale powders are composed of spherical particles and aggregates formed by these particles. X-ray diffraction is used to identify the parameters of the crystal structure of these powders. Specific surface area is determined for all powders by BET method. Powders are used to improve the mechanical properties of aluminum alloys. For the optimization of introduction reinforcement nanoparticles used ultrasonic treatment of the melt.

Introduction

One way to improve the mechanical properties (tensile strength, Young's modulus, hardness) of aluminum-based alloys is by adding nanoparticles of various oxide powders (nitrides, carbides) into the melt [1]. Micro- and nanoparticles of Al₂O₃, ZrO₂, SiC etc. are used as reinforcing ones providing reduction of development of dislocations in accordance with Orowan’s mechanism [2, 3] in the process of alloy deformation which improves strength characteristics. Nowadays, the most promising methods of production of oxide nanopowders with high capacity are plasma chemical method and electrical explosion of wires (EEW) [4]. EEW takes place when a current pulse passes through a metal wire. Depending on the type of gas surrounding the wire and the metal of which this wire is made this method makes it possible to produce nanopowders of metals, alloys, chemical compositions as well as composite nanopowders. Plasma-chemical systems are characterized with high energy intensity of the heat flux: the temperature of plasma heat transfer media comprises ~ 10⁴ K while their enthalpy comprises (1-2)×10^2 kCal/mol [5], which provides high specific production capacity of equipment. Therefore the use of plasma chemical method is the most efficient for endothermic processes, e.g. metal nanooxide production from salt solutions.

It is known that morphology, particle size, phase composition and structural parameters of nanopowders are determined by the method of production. Thus, the properties of powders used for reinforcement of Al alloys are to be carefully studied in order to ensure required properties of materials produced using these powders. Direct introduction of nonmetallic particles into the liquid metal is not suitable due to their tendency to agglomerate as they have low wettability by the melt. This problem can be solved using ultrasonic processing of liquid metal containing nanoparticles which leads to de-agglomeration of the particles and their homogeneous distribution throughout the melt volume and as a result throughout the ingot structure [6].
The main objective of this work is to study the use of plasma-chemical and EEW technology of synthesis of alumina and zirconia nanopowders for optimization of structure of alloys.

**Experimental**

Two methods were used for production of micro- and nanoparticles of oxides, i.e. plasma-chemical and electrical explosion of wire (EEW).

In plasma-chemical method fine powders were synthesized by means of thermochemical decomposition of liquid sprayed agents in a high-temperature heat transfer medium. Alumina and zirconia powders were produced from sprayed water solutions of salts in air flow heated to low-temperature plasma state using a 70 kW high-frequency unit. The diagram of the unit is given in Fig.1. Sprayed solution is supplied to plasma jet of the heat transfer medium generated by plasmatron 3 in the plasma chemical reactor 2 via nozzles 1. The powders produced are separated by filter 5 and supplied to collector 9. Vapor-gas flow after cooling down in apparatus 6 is separated from the liquid (condensate is collected in tank 10) and prior to emission to atmosphere is cleaned in scrubber 7. In order to obtain metal oxides initial nitrate solutions of corresponding metals of these compounds were prepared with stoichiometric ratios of components and optimal temperature mode of the reactor of plasma-chemical unit was selected. The plasmatron was remotely activated 3-5 seconds after application of voltage to ignition electrode from the inductor at the pressure level in discharge chamber close to atmospheric pressure or higher. The principle of operation of plasma chemical unit consists in the following: the prepared initial solution with specified composition is sprayed by a spraying device – a pneumatic atomizer – forming a gas-droplet mix spray cone which is supplied to cylindrical reactor with gas (heat transfer medium) flow, in our case it is air heated up to 5000-6000K in a low-temperature plasma generator (plasmatron). Droplet size comprises 50-100 μm. Gas droplet mixture is heated by a plasma jet generated in induction plasmatron powered by a high-frequency generator. Heating process takes place in the plasma chemical reactor having a direct-flow cylindrical scheme, which provides reliable, steady and safe operation in various modes. Solvent is evaporated here from solution droplets with subsequent decomposition of nitrates of Zr, Al etc. to oxides. Powders produced are separated in containers.

![Figure 1. The diagram of plasma chemical powder synthesis unit](image-url)