Aluminum Composites With Small Nanoparticles Additions: Corrosion Resistance

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Abstract. Research of corrosion resistance of the aluminum powder composites containing microadditives (0.01 – 0.15% is executed about.) zirconium oxide nanoparticles. Extreme dependence of speed of corrosion of aluminum composites in 10-% solutions of sulfuric and nitric acid from the maintenance of nanoadditives is shown. It has been shown the dynamics of mass loss of aluminum composites with nanoparticles of ZrO_2 during corrosion tests in acids solutions. The lowest corrosion rate of 3.36 mm/a of nitric acid was observed in the sample containing ZrO_2 0.01 vol.% nanoparticles. For the case of sulfuric acid with the best result of 2.21 mm/a showed the material with 0.05 vol.% nano-additive.

Introduction. Nanotechnologies allow to create the strong and lightweight materials steady against various aggressive influences. Influence of nanoparticles on structure of material is caused by high superficial energy. There is a huge number of the works devoted to creation of composite materials, both with metal, and with a ceramic matrix, the nanoparticles strengthened by various concentration [1-7]. The light and strong materials, like aluminum alloys, for creation of various bearing designs of spacecraft have high value For astronautics [8-11]. In many works, the researchers conducted the development of aluminum composites containing nanoparticles of different nature in concentrations of more than 5 vol.%. It is rarely possible to find work devoted to low concentrations of nano-additives in aluminum [12-18]. This work is dedicated to the creation of aluminum composites with small amounts (0.01-0.15 %vol.) of nano-oxide ZrO_2 by powder metallurgy techniques.

Attention to small concentrations of the nanoparticles was based on the following provisions:

- high surface energy of nanoparticles;

- ease of uniform distribution of small amounts of nanoparticles and their disaggregation within the matrix;

- high impact of nanoparticles on the structure and properties of interfacial layers (matrix-MFS-nanoparticle).

The theory of irreversible processes and catastrophe theory say that small changes of operating parameters can jump the most important characteristics of the system [19,20]. Nanoparticles possessing high superficial energy, brings it in material and to interphase layer, influencing functional characteristics of composite in one direction or another. In this regard, a researcher separate issue is the determination of threshold effects of nanoparticles on the material and the search for the optimal technology of its receipt, depending on performance requirements.

The objective of the work was creation of aluminum composites, hardened with small additions of metal oxide nanoparticles like ZrO_2, and determination of its corrosion resistance in acids solutions. According to ideas of a number of famous scientists on the structure and properties of an interphase layer in solids nanoparticles having a high surface energy and making changes to structure of a matrix, even at very small concentration at the level of 0.001-0,. about. % can cardinally change characteristics of material [21-24]. In tab. 1 influence of nanoparticles on properties of materials is briefly explained.

1. Experimental procedure. The charge used: as a matrix - aluminum powder with mean diameter of 4 μm (ASD-4, "SUAL", Russia), as reinforcer - nanopowder of zirconia (d_{av} = 50 nm, S_{sp} = 32 m^2/g), Keldysh Research Center, Russia). The technology of preparation of composites consisted in the following. At the beginning aluminum powder was sieved through a sieve with a cell of 14 microns, then mixed with alcohol in a ratio of 1:4. Then, placed in an ultrasonic bath while stirring the mixture by rotary stirrer. Nanoparticles dispersed in ultrasound, after which the dispersion was added to the stirred alumina powder in alcohol. Quantity of nanoadditives varied from 0.01 to 1.5 vol.% Mixing lasted for 20-40 min. Drying of suspensions took place on air at a temperature of 60 ° C within 24 hours. The resulting blend compressed into a cylindrical mold with a pressure of 400 MPa. Next, sintering was performed in forevacuum at 640 ° C during 120-180 minutes.

The corrosion resistance was measured as follows. The total exposure time of samples was 15 hours. Samples were weighed prior to the experiment and during the measurements on scales up to 4-th sign. Samples were immersed in 10% solution acid (nitric acid or sulfuric acid). The difference in mass (primary - to experiment and obtained by checkweighing) was determined by mass loss of samples and plotted on it. At each check weighing and date recorded.

By results of tests of samples of aluminum composites for corrosion resistance values of speed of corrosion (γ) on a formula were calculated [25]:

$$\gamma = \frac{x \cdot 365 \cdot 24}{\rho \cdot 1000}, \text{ mm/a},$$

where x_1 – mass loss rate, $g/(m^2 \cdot h)$;

ρ – density of material, g/cm^3.

2. Results and discussions. The results are shown in Fig. 1-4. Particularly interesting is the results on corrosion resistance in a solution of nitric acid. The lowest rate of mass loss of 3.36 mm/a was observed in the sample containing nanoparticles of ZrO_2 0.01 vol.% . For the case of sulfuric acid with the best result of 2.21 mm/a showed the material with 0.05 vol.% of the nano-additive.

The worst level of resistance in H_2SO_4 showed a sample with 0.15 vol.% of nanoparticles. Perhaps this is due to the number and size of the brought defects (cavities) by mixing aluminum powder with nano-additives . Nevertheless, it should be noted that all of the samples in comparison with pure aluminum sintered showed considerably greater resistance to corrosion in both acid solutions. While first (pure aluminum) at all dissolved in nitric acid after 15 hours and in sulfuric through 10.

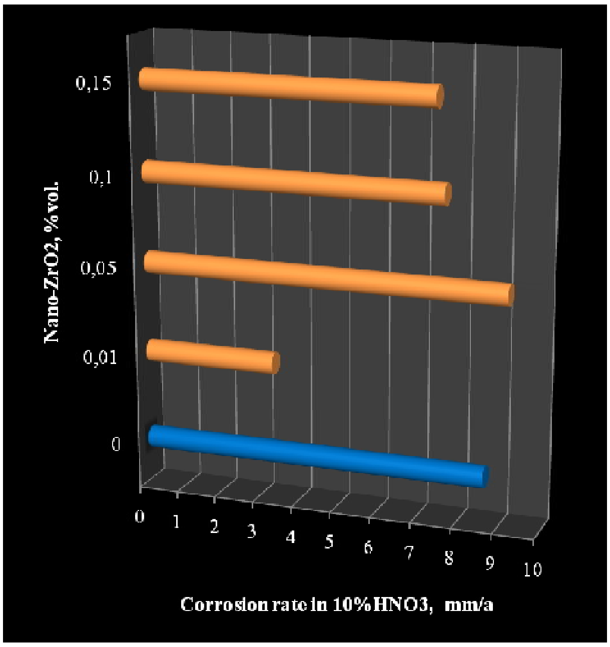

Fig. 1. The dependence of the aluminum composites corrosion rate of the content nanoparticles ZrO_2 (test in a 10-% nitric acid solution).

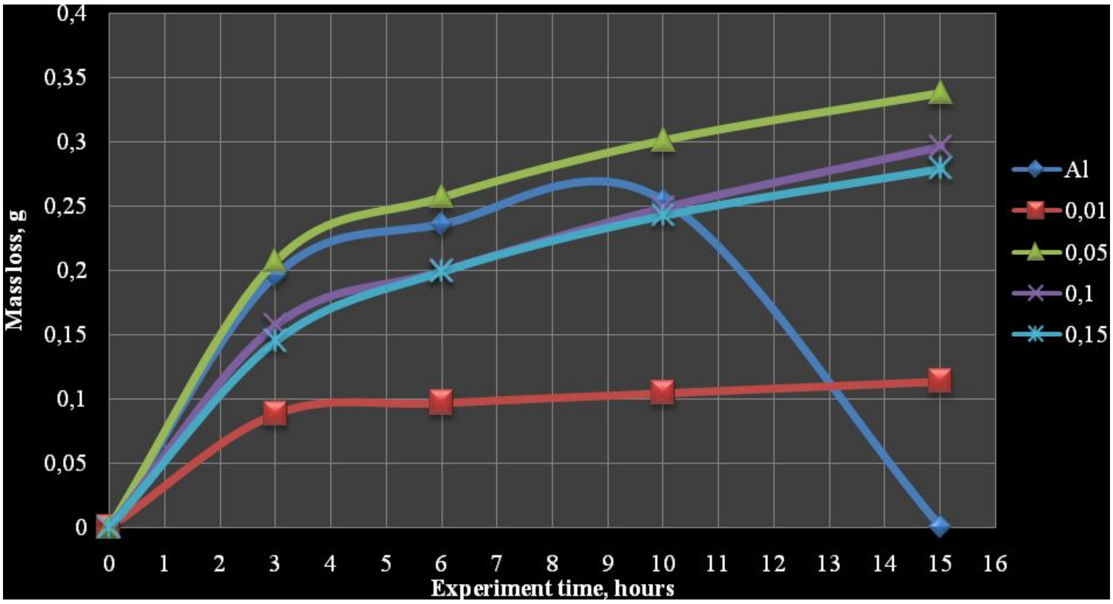

Fig. 2. Composites mass loss over time in a solution of nitric acid.

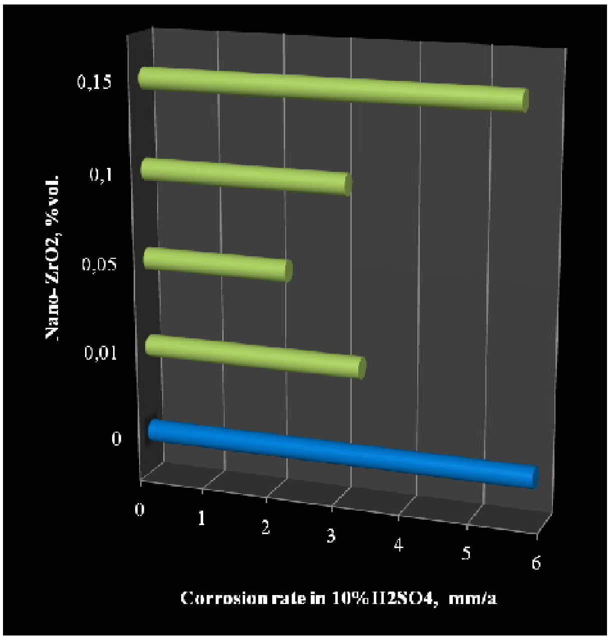

Fig. 3. The dependence of the aluminum composites corrosion rate of the content nanoparticles ZrO_2 (test in a 10-% sulfuric acid solution)

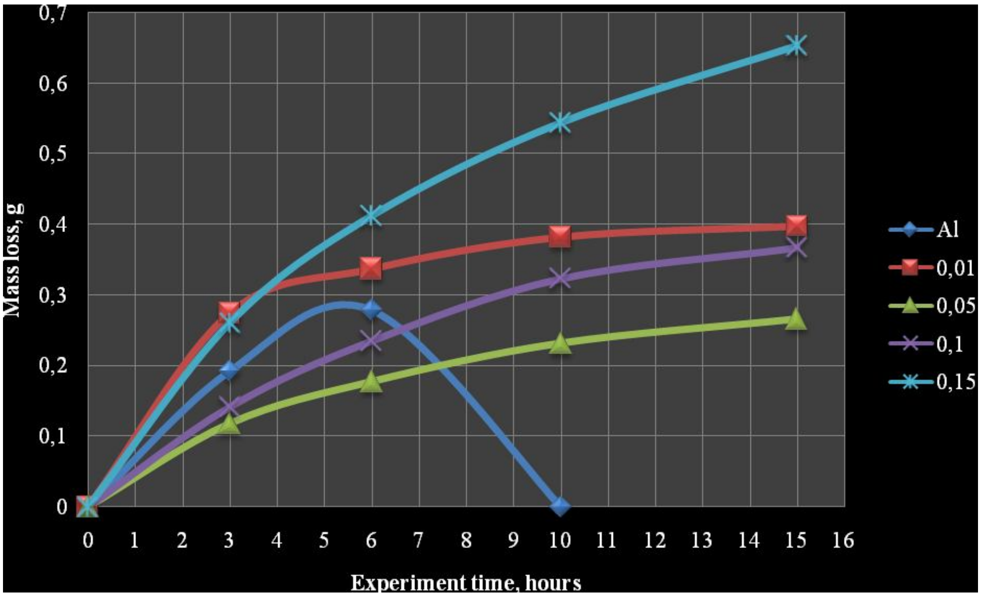

Fig. 4. Composites mass loss over time in a solution of sulfuric acid.

Summary. Samples of aluminum composites with ZrO_2 nanoparticles were examined for corrosion resistance in 10-% solutions of nitric acid and sulfuric acid. The lowest corrosion rate of 3.36 mm/a of nitric acid was observed in the sample containing ZrO_2 0.01 vol.% nanoparticles. For the case of sulfuric acid with the best result of 2.21 mm/a showed the material with 0.05 vol.% nano-additive.

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