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Comparative Analysis of the Resistance to Cavitation Erosion of Materials Samples of Ultrasonic Instruments

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Abstract

The article presents the results of a study of cavitation resistance of two methods of surface hardening materials, which lays in applying ceramic coatings on aluminum alloy 6060. The first sample obtained using the technology of microarc oxidation (MAO), the second with the help of technology detonation spraying (DS). The ultrasonic device (UD) was used to study cavitation erosion resistance. Analyses of mass loss, morphology of the surface after the cavitation test was examined by using analytical scales and scanning electron microscopy. The results show that the microstructure of MAO coating, compared to DS is more homogeneous, that allows increasing the cavitation erosion resistance of aluminum alloy.

Keywords: cavitation erosion, ultrasound, cavitation, microarc oxidation, detonation spraying

INTRODUCTION

Investigation of different materials properties and methods of improving operational characteristics of the superficial layer in cavitation resistance is relevant for various fields of technology.

In particular, after continuous work of ultrasonic (US) devices the destruction of the surface layer of the tool is observed. When choosing materials for ultrasonic tools operating in liquid fluid, one usually pays attention to their corrosion resistance and acoustic properties, and pays less attention to the issue of cavitation resistance. It is known that the cavitation resistance of a material does not depend on its mechanical properties because these properties are the average material properties, and depends on the mechanical properties of the structural components.

The research on the cavitation resistance of the materials with different chemical composition has been conducted with the following result: in the aluminum bronzes the alloys containing 13% of aluminum have the greatest cavitation resistance [1].

However, such alloys are still not comparable with a ceramic coating. Such methods of surface hardening as MAO [2,3] and DS are widely used for protection from wearing out of various machinery parts.

In the article [4] the influence of cavitation erosion on the surface layer of aluminum workpiece after microarc oxidation is considered and the mechanism of destruction, the dependence of the coating thickness and resistance to fracture are described. The authors concluded that the coating thickness of 70 microns is optimal.

In the scientific work [5]the authors made conclusions about the influence of the quality of the sample surface on the kinetics of cavitation destruction and found that with values of the parameter $Ra \leq 1.2$ microns, surface roughness does not affect the intensity of erosion.

EQUIPMENT

The paper [6] describes the various methods of testing materials for resistance to cavitation erosion, based on that the authors propose a method of vibration cavitation, where the cavitation is created by high frequency oscillations of the tool in the liquid. Fig. 1 (a) shows a general diagram of the installation consisting of a generator 1, the ultrasonic tool 2, test sample 3, the clamping device 4 and the container 5, the size “h” between the sample and the top of the tool is selected by an empirical method. We have used the USI “Hielscher UIP1000hd”.

EXPERIMENTAL PART

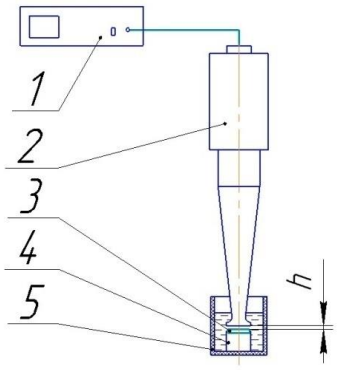
Samples of aluminum alloy 6060 in the form of disks with a diameter of 35 mm, a thickness of 5 mm, a surface roughness

Ra = 1.2 μm with a coating of MAO (for 15 min) and detonation deposition were made as objects of investigation.

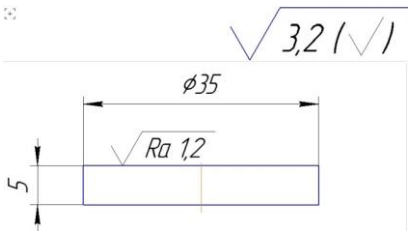
The frequency of ultrasonic vibration was 21 ± 0.5 kHz, the maximum amplitude of oscillations according to the passport of the device at the end face was 150 μm, the acoustic power was measured by calorimetric method and amounted to 1 ± 0.2 kW.

SAMPLES

Fig. 1 b shows the dimensions and tolerances of the processed workpiece. Aluminum alloy 6060 is taken as the basis. The surface of one workpiece was subjected to aluminum oxides DS. The second workpiece was gone through MAO, and corundum with a depth of approximately 70 μm was formed on the surface.



a)



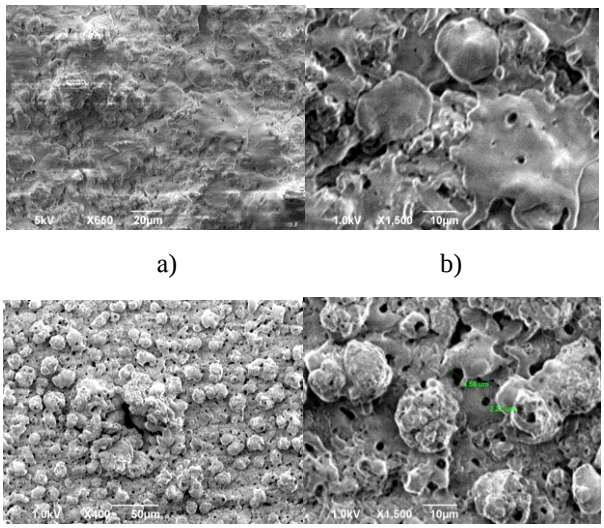
b)

Figure 1: Scheme of Ultrasonic Installation

Detonation coatings Al_2O_3 were obtained in a detonation sputtering installation with a barrel diameter of 20 mm, a length of 700 mm with the use of a gas detonating acetylene-oxygen mixture with a filling factor of 35%. The resulting coatings have high hardness, adhesion (above 150 MPa) and low porosity (less than 1%). [7]

Surface topography studies were carried out on a scanning electron microscope JSM-6390A of "Jeol" company with a "Jeol JED-2200" add-on device (the laboratory "X-ray Diffractometry of the Electron and Probe Microscopy" of the SSTU collective use center).

Fig. 2 shows snapshots of the microstructure of detonation sputtering samples and MAO. In the photographs of detonation deposition (Fig. 2a, b), one can see the average size of the obtained grain, it is 15 μm. The upper mullite layer is visible in the images of MAO (Fig. 2 c, d) obtained by scanning electron microscopy (SEM). A number of holes with an average diameter of 3.5 μm are due to the effect of micro discharges on the sample material. When grinding or processing this mullite layer is removed and a layer of corundum remains. Fig. 3 shows the prepared samples for the test.



a) b)

c) d)

Figure 2: Electronic Photographs of the Microstructure of the Samples Before Cavitation Processing.

(a, b) DS; (c, d) MAO

a) b) c)

Figure 3: The Samples Snapshot. (a) Al6060, (b) detonation sputtering, (c) MAO

Sequence of the tests. The tests were carried out in distilled water, placing the sample in a zone of developed cavitation. The period of continuous operation of the ultrasonic tool was limited to 2 hours, in order to avoid overheating of the transducer. The container with distilled water was cooled by circulating the liquid.

The sample was removed from the unit every 2 hours, washed with dionized water, dried in the air and weighed on analytical scales to within 0.1 mg. All presented results are average values of three averages from five weighings.

The general cycle of work with the sample lasted 20 hours.

The results of the tests are the obtained dependences of mass loss of samples on time. Similarly, the development of cavitation erosion can be judged from the photographs taken. Table 1 shows the average rates of mass loss by the samples.

The photographs analyzed such important parameters as the distribution density of cavitation wells, their average diameter, larger diameter, and the depth of the resulting cavities.

Fig. 4 shows a graph of the dependence of the mass loss rate on the test time, which clearly shows the dependence of the volume of the loss mass on the time of sample processing. So the aluminum sample in the first 2 hours of the test showed the same result as the sample of MAO but it is further seen that the dependence of mass loss assumes a virtually linear character. Dependences of mass loss of MAO and DS samples are similar, but due to the rapid destruction of DS at the beginning of the test, the mass loss volume of this sample is longer throughout the entire processing cycle.

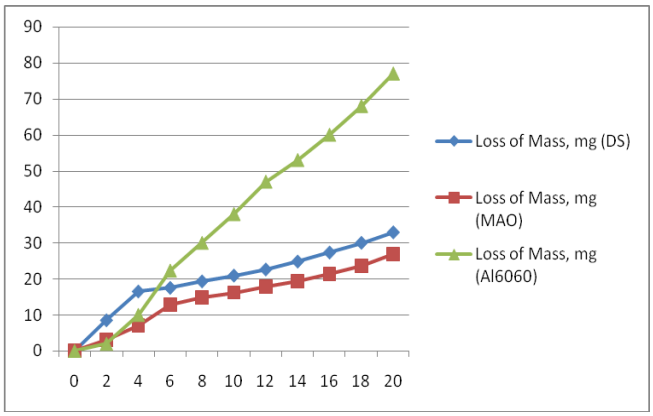


Figure 4: Mass Loss Graph

Table 1: The Samples Rate of Mass Loss Values

№	Alloy	Average Weight Loss Rate, mg/h
1	Al 6060	3,717
2	MAO	1,473
3	DS	1,883

PIT MORPHOLOGY

Fig. 5 shows the electronic images of the resulting cavitation pits in samples. Fig. 5.(a, b) shows a snap of an uncoated aluminum sample on which the diameter of the formed shells is on the average 500 μm and the places of their formation coincide with the channels obtained during the burnishing of the sample, it happens in the places of surface defects. On Fig. 5 (c, d, e, f) snaps of samples with detonation sputtering and microarc oxidation are shown respectively. In a sample with DS, it can be noted that the number of formed shells is larger than in a sample with MAO, which is probably due to the heterogeneity of the resulting coating, as seen in the structure sample snaps above. But in the sample with MAO the average size of the formed shells is larger and about 250 μm which can mean less amount of defects on the sample surface, less porosity and as a consequence fewer potential sites for the development of the shells, while the already formed shell provokes its further fracture on sharp edges.

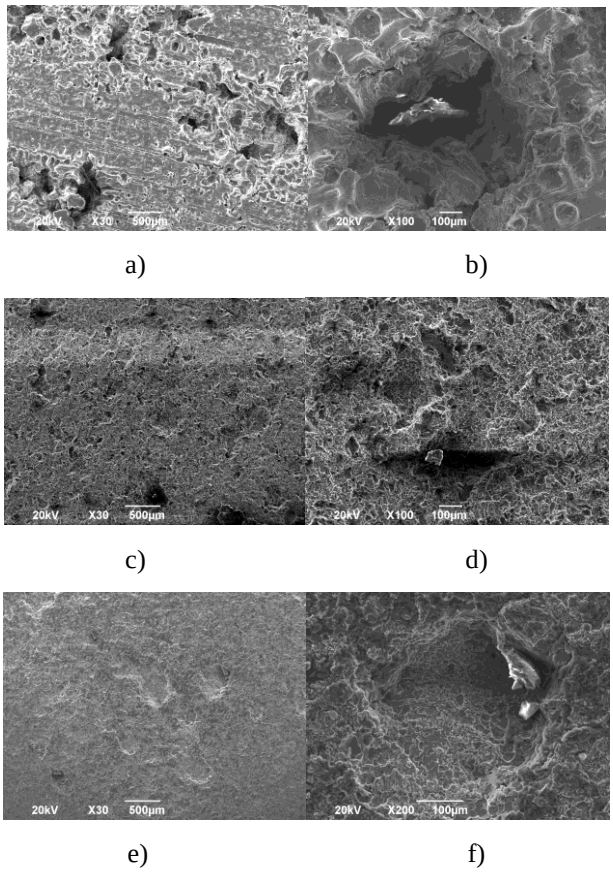


Figure 5: Electronic Images of Samples after 20 Hours of Processing. (a, b) Al 6060, (c, d) DS, (e, f) MAO

SUMMARY

1. Comparative data on the mass loss rate of three samples, which showed a significant improvement of this index when using microarc oxidation and detonation sputtering on samples are given.

2. It was found that under these conditions MAO shows the average mass loss rate lower than using detonation sputtering, which may be due to the following factors:
   a) a lower porosity of MAO which causes a greater distribution of seat and, consequently, a distribution of cavitation energy and a greater porosity contributes to a greater concentration in local seats;
   b) lower bond strength of the layers in detonation sputtering than in MAO;
3. The results obtained can be used to optimize the choice of the radiator material operating in corrosive liquid fluid in cavitation mode.
4. The destruction may be associated with a cumulative effect or collapse of a cavitation bubble in close proximity to the sample.

CONCLUSION

This work is one of the stages in the study of the cavitation effect on the metals and coatings surfaces. The next step is the research of cavitation causes and the subsequent behavior of bubbles, using a high-speed camera, studies of MAO and detonation coating samples on porosity and cohesion. The obtained data will allow to fully explain the influence of the coating microstructure on the resistance to cavitation erosion.

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