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Experimental study of cavitation resistance of restoring coatings

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Annotation. The article presents the results of an experimental study of the resistance of various metallic and nonmetallic coatings to cavitation failure. The method of accelerated cavitation resistance tests using an ultrasonic emitter is described. Comparative characteristics of the resistance of materials are given.

Introduction

The cavitation phenomenon has been known for a long time and is quite common. As a rule, its formation is negative, since the pair forms various structural elements on the surface (impellers of pumps, hydraulic turbines, narrow sections in cooling systems), which leads to their gradual and sometimes very intense wear [1].

Despite the popularity and prevalence, this phenomenon is difficult to mathematically describe. There are semi-empirical models in packages of numerical hydrodynamic modeling [2, 3]. It should be noted that such models require the determination of a number of empirical coefficients, for example, by comparing the results of modeling and experiment [4]. Sometimes cavitation models are supplemented by erosion models that allow one to assess the degree of surface wear [5].

Due to the imperfection of the mathematical apparatus for calculating cavitation, one of the main methods for assessing its intensity and influence is experiment [6, 7, 8]. Two main approaches can be distinguished in the experimental study of cavitation at the moment. The first is to directly test the device (some hydraulic system) in which cavitation wear occurs. This method will allow to determine the localization of cavitation spots, but not its intensity, since it takes a lot of hours to obtain significant cavitation erosion.

The second approach involves the application of accelerated cavitation wear methods, for example, cavitating jet and ultrasonic [9], which is described in [10].

This approach allows you to determine the resistance of a particular material to the effects of cavitation, if it is already known where exactly it takes place.

In this article, we considered the question of determining the relative cavitation resistance of various coatings applied using different technologies. Usually it is a question of determining the relative cavitation resistance [11, 12, 13], since it is difficult to draw a correspondence between the results of accelerated tests and wear in a real design.

This question is relevant at present, since many real structures where cavitation occurs can no longer be fundamentally changed to completely eliminate it. However, the use of cavitation-resistant coatings can significantly extend the service life of the units, bringing significant benefits.

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Description of the laboratory setup and selected materials

For testing, metallic and non-metallic coatings were selected. For electric arc surfacing, four different coating materials were selected. Their properties are showning the table below:

Table 1. Mechanical properties of welding wires

№ s/p	Name	σ_f , MPa	σ_t ,MPa	KCV for 10°C, J/sm2	KCV for -20°C, J/sm2	KCV for -45°C, J/sm2	T
1	4	640	840	-	69	56	-
2	3	600	840	100	-	-	-
3	1	-	-	-	-	-	380 HB
4	2	-	-	-	-	-	540 HB

These welding wires are characterized by high strength properties or high surface hardness. Wire 3 is used for the manufacture of hydropower equipment operating in conditions of cavitation wear. However, the achievement of the parameters indicated for it is ensured only after a long heat treatment, which is impossible in most cases of repair of hydraulic turbines, therefore, during laboratory tests, the sample coated with this material was also not subjected to heat treatment.

Wire 4 is a flux-cored wire, the deposited metal of which is characterized by high strength and plastic properties in combination with good corrosion resistance. The main field of application is the production of technological equipment for the pulp and paper industry and offshore platforms for the processing and transportation of oil and gas.

Wires 1 and 2 are solid wires and are recommended for surfacing products subject to intense mechanical wear. The deposited metal is characterized by high hardness due to the presence in the composition of a large amount of carbon (C) and chromium (Cr). For electrospark surfacing the following materials were selected: 6 — rhenium, 7 — molybdenum, 8 — VK8, 9 — nickel. For high strength properties, alloy 8 was selected for laboratory tests. The main mechanical properties are shown in table 2.

Table 2. Mechanical properties of the alloy

№ s/p	Name	$\sigma_т$, MPa	$\sigma_в$, MPa	a_HJ/sm^2	Hardness
1	8	-	1666	35	87,5 HRC

Belzona coatings were chosen as a non-metallic coating.

10 — Two-component polyurethane resin for coating metal and rubber parts of equipment that protects against cavitation and abrasive wear.

11 — Two-component high-temperature epoxy coating to protect equipment operating in continuous immersion at temperatures up to 95 ° C from erosion and corrosion.

12 — A two-component epoxy coating specially designed to increase the efficiency of pumps, pipelines, valves and other hydraulic pump equipment, which at the same time provides long-term protection against erosion and corrosion.

Since there are no domestic standards containing the installation diagram and methods for testing cavitation samples using the ultrasonic method, the American standard ASTM G32-10 “Standard test method for cavitation erosion using vibratory apparatus” was taken as a basis

The installation scheme for testing samples taken from the mentioned standard is shown in Figure 1. The installation includes a high-frequency generator, a magnetostrictive ultrasonic emitter, a metal extension cord — a waveguide, a container with distilled water for immersing the sample, and a thermal stabilization system.

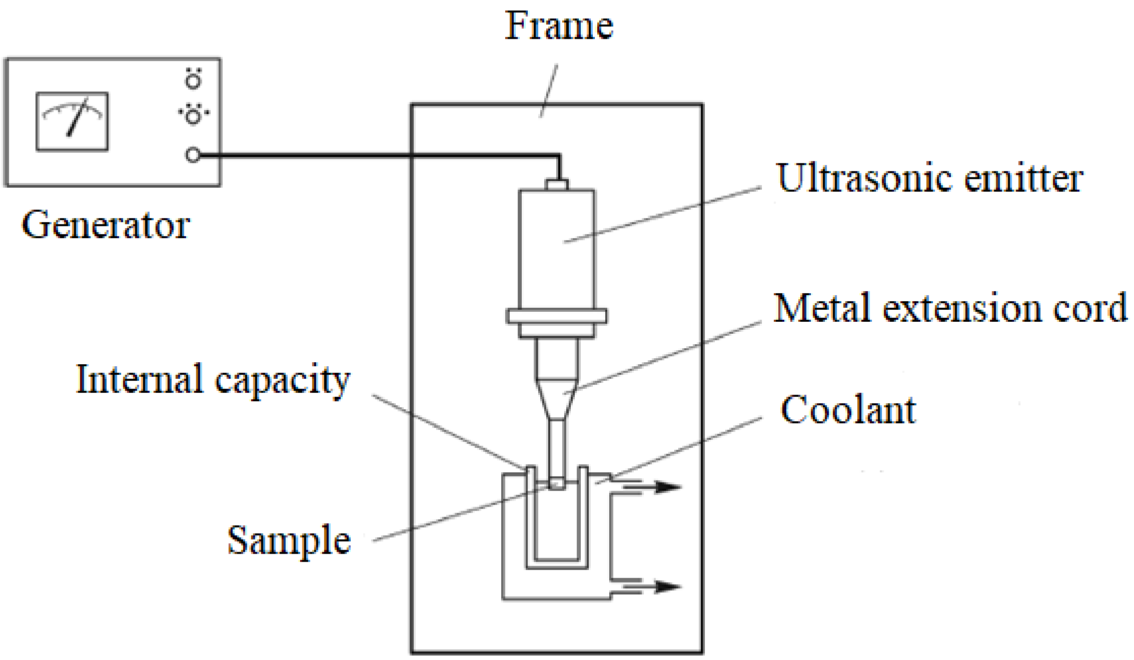

Figure 1. Installation diagram for testing samples for cavitation erosion by the ultrasonic method

Figure 2 shows an ultrasonic emitter and a high-frequency generator vertically mounted on a frame. A metal extension cord (horn) is rigidly attached to the end face of the output core of the emitter (on which ultrasonic vibrations are generated), to the end of which, in turn, a test specimen made of various materials is rigidly attached to the thread (test specimen). In this case, ultrasonic vibrations are transmitted from the core to the extension cord and from it to the sample due to the fact that their end metal surfaces are tightly adjacent to each other.

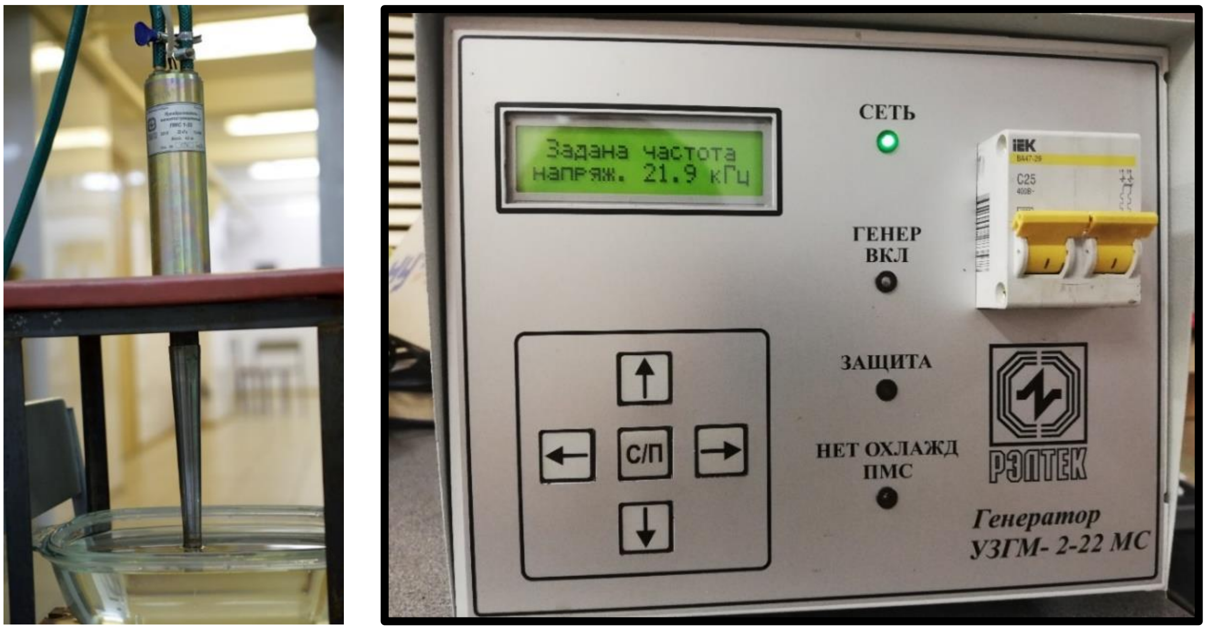

Figure 2. Photos of the test bench for samples created at the Department of E-10 MSTU. N.E. Bauman (the emitter on the stand on the left, the ultrasonic oscillation generator on the right)

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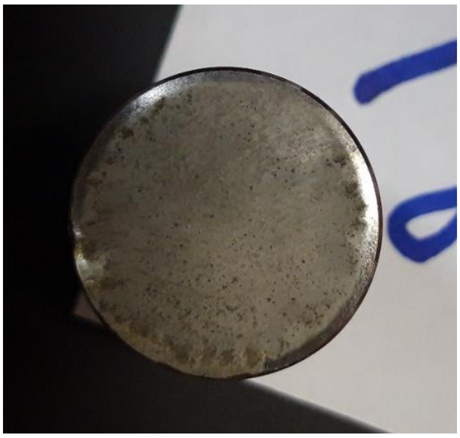
In order to maintain a constant water temperature during the tests, a thermal stabilization system was mounted on the test bench based on the digital thermostat STH0024UG-v3 with a remote sensor DS18B20. This module has all the necessary functionality and technical characteristics for the task. It also compares favorably with its analogues with a small measurement error (± 0.5 ℃) and a customizable hysteresis from 0.1 ℃.

The degree of cavitation wear was controlled by the gramometric method using an analytical balance (accuracy — +/– 0.1 mg). The tests were carried out in pure water with a temperature of plus 25 ± 0.5 ° C using the high-frequency vibration of the sample with a frequency of 20 ± 0.5 kHz. The oscillation amplitude of the sample was (according to the documentation for the emitter) 50 nm, the radiated acoustic power (measured on an ultrasonic oscillator) ranged from 0.9 to 1 kW.

Test results.

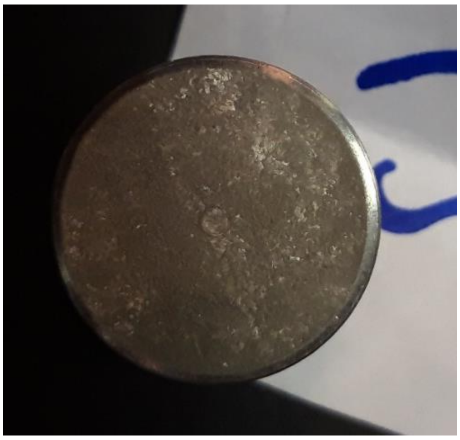
The test results are the obtained comparative dependences of the weight loss of the samples on time, as well as the rate of weight loss, presented in the form of the graphs below. In addition to weighing, visual inspection of the end surfaces of the samples was also carried out.

Sample 1

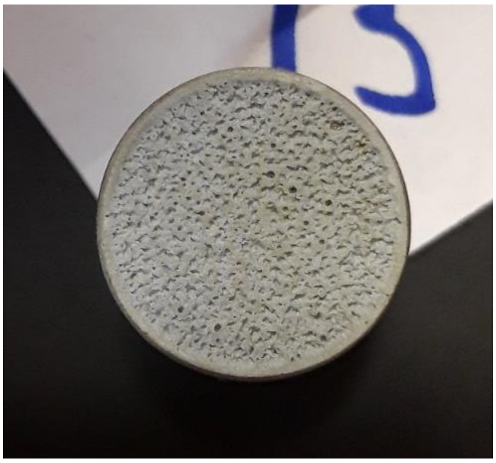


Sample 2

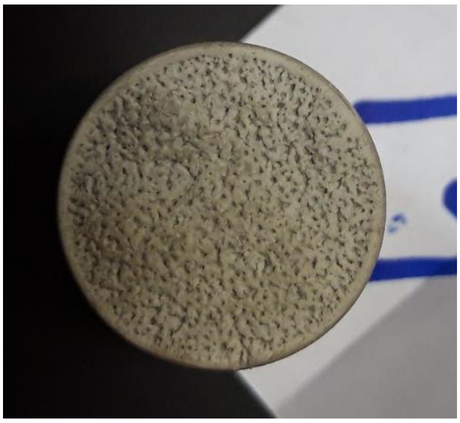
Sample 3



Sample 4

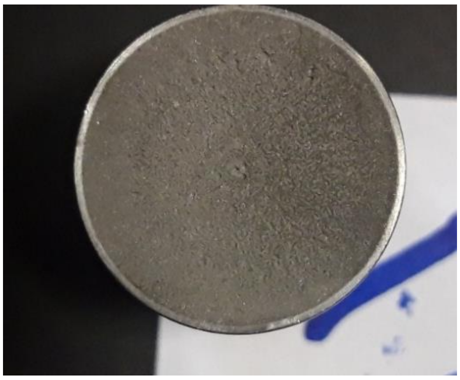


Sample10

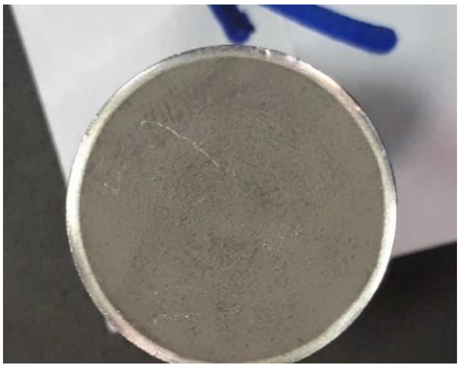


Sample11

Sample12

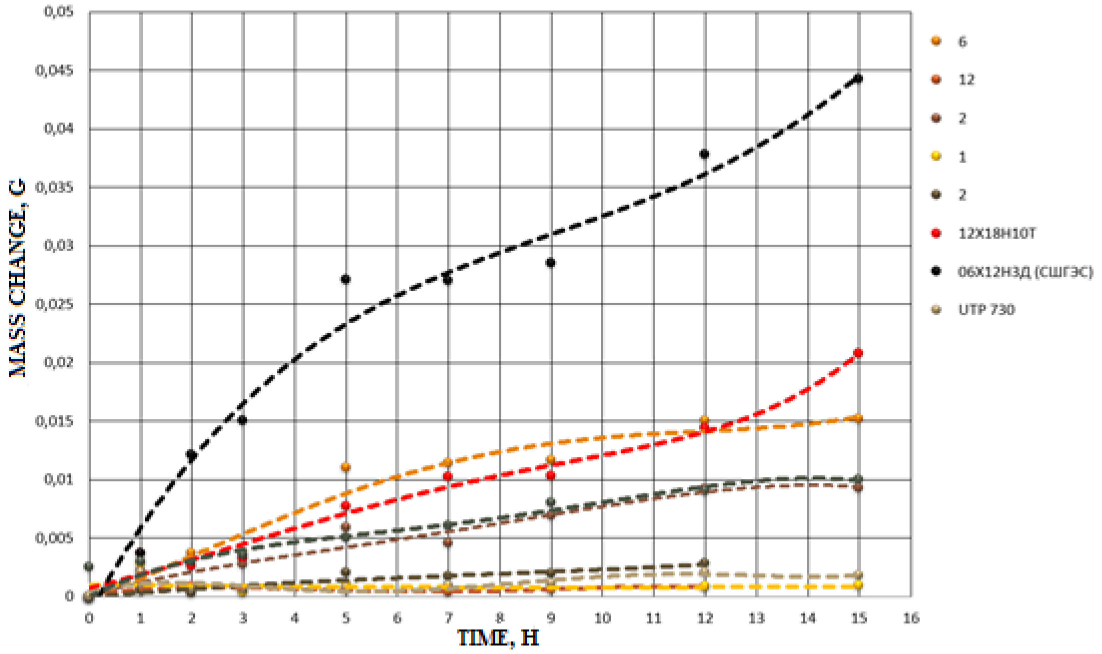


12X18H10T

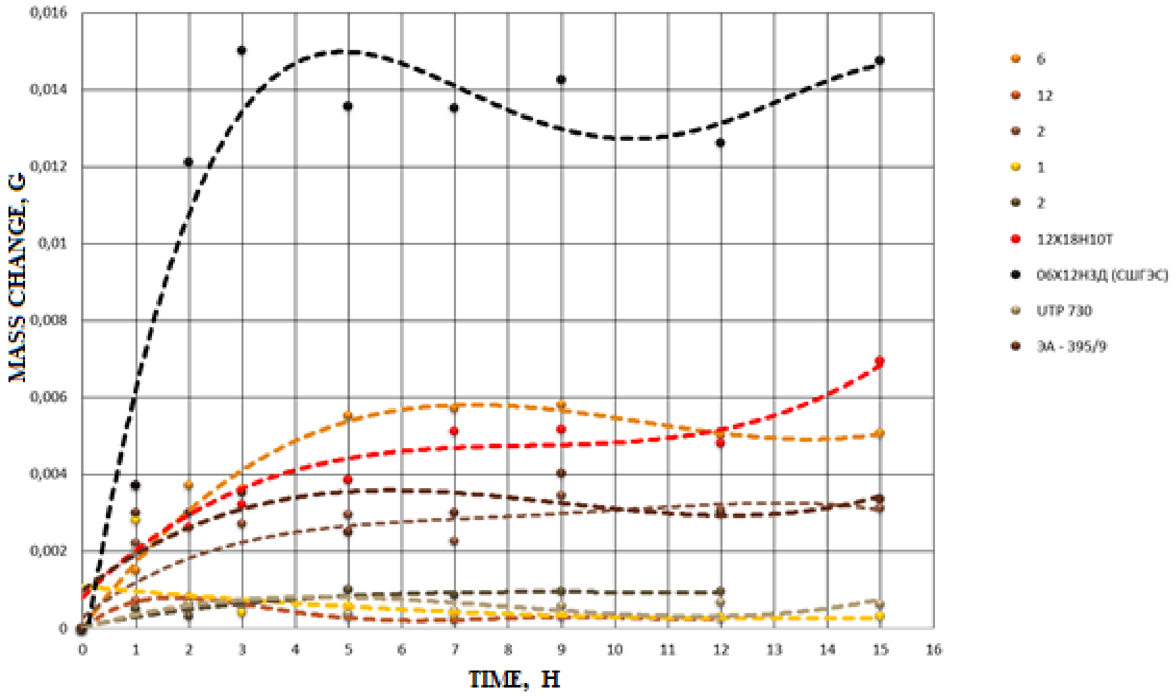


06X12H3Д

The test results are presented in the plots below.



Plot 1. Comparative dependence of weight loss on time of metal samples



Plot 2. Comparative dependences of weight loss on time of non-metallic samples

Conclusion

Based on the results of the tests, graphs were constructed for a relative comparison of the cavitation resistance of coating materials.

As a result of comparative tests, polymer coatings showed a result no worse than the best metal coatings

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