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METHOD OF ASSESSMENT OF CAVITATION-EROSION WEAR RESISTANCE OF METALS IN ELECTROLYTE MEDIA

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Summary. *The paper considers a method of assessing the cavitation-erosion wear resistance of metals, which can be used to obtain data on the cavitation-erosion wear resistance of materials and coatings in laboratory conditions, which correspond to the data of operational tests. The essence of the method is the intensification of corrosion processes during cavitation-erosive wear of samples on a magneto-strictive vibrator (MSV) with the help of their anodic polarization. The value of the polarization current is found by the values of the coefficient of amplification of the mechanical factor of the destruction of the surface during tests on a magneto-strictive vibrator (MSV) and the data of field tests. Corrosion current in a given environment is found during full-scale tests. To reduce the labor intensity and time of research, operational data is obtained on a specially designed and manufactured installation, which is a simplified version of a hydrodynamic tube (HT). The developed assessment method applies only to corrosive electrolyte environments.*

Key words*: cavitation-erosive wear, laboratory and operational tests, corrosion and mechanical factors of destruction.*

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Formulation of the problem. Today, corrosion-mechanical wear (KMZ), one of the types of wear, which is fixed by DSTU 28.23-94, where it is considered not only as a friction process between two metals, into the contact zone of which corrosive-active media penetrates, i.e. in systems metal + environment + metal (M1+S+M2), but also in systems metal + environment (M+S).

The existing theories of KMZ of metals in corrosive-active environments were analyzed, and a critical assessment of their reliability and compliance with experimental data and results of operation in the production conditions of food industries allowed us to settle on the theoretical model of KMZ developed by the scientific school of Prof. G. O. Preis, which is based on the fatigue-electrochemical nature of wear of metals in electrolyte media [1].

Currently, the most generally accepted point of view is that cavitation destruction of metal surfaces is a corrosion-mechanical process in which mechanical and corrosion factors of destruction interact [2].

Analysis of known research results. Hydrodynamic tubes (HT) or venturi nozzles, rotating disk installations (VDI), impact-erosion stands (IES) and magnetostrictive vibrator (MSV) installations are used to simulate the cavitation process [2]. At present, IES and MSV installations have become the most widespread.

The test method for the MSV is the basis of the standards for determining cavitation resistance in Czechoslovakia and the USA [3].

Installations with MSV are distinguished by their compactness, low power consumption, the possibility of conducting research, due to the small flow of liquid, in various environments, and high reproducibility of results.

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Tests of three identical materials (stainless steel, technically pure nickel, and aluminum alloy) in eleven USA laboratories equipped with different designs of MSV installations showed [3] that the same order of resistance of metals to cavitation destruction was obtained in all laboratories.

Most of the research on cavitation-erosive wear is devoted to the study of the laws of the mechanical factor of destruction. At the same time, it is known that during cavitation-erosive wear in corrosive-active environments, corrosive mass losses can reach 60% of total losses. Depending on the conditions of operation and testing, the ratio between corrosion and mechanical factors may be different. According to this ratio, the relative wear resistance of metals during cavitation-erosive wear changes. Thus, the order of placement of materials according to their cavitation resistance when tested on installations with a magnetostrictive vibrator (MSV) is slightly different from the order of wear resistance found during tests on an impact-erosion stand (IES). The difference is especially pronounced when comparing the data of laboratory tests with the indicators obtained directly under the conditions of operation of the equipment. During tests on the MVS, the 12Kh18N9 steel shows cavitation resistance comparable to the resistance of low-alloyed medium-carbon steels, and at the same time, turbine impeller blades lined with this steel have been successfully operated at a number of hydroelectric power stations in the country for several years.

The specified difference in wear resistance indicators is explained by the fact that during tests on the MSV and IES, the effect of the corrosion factor is practically not manifested due to the high intensity of the mechanical action of cavitation or the jet on the samples and the short duration of the tests (2...3 hours on the MSV and 6...12 hours on IES).

In order to obtain a more reliable dependence between laboratory and operational indicators of wear resistance of materials, it was proposed to conduct tests on the MSV with alternating cavitation (5 min) and corrosion (24 hours) exposure with a simultaneous decrease in the amplitude of oscillations of the magnetostrictive vibrator. The pulse method of cavitation tests is also used [2]. Such a combination of mechanical loads with corrosive effects allows obtaining data on the relative wear resistance of metals that are close to operating conditions. However, a significant drawback of all proposed methods is their duration (36 days or more).

The most reliable results about the intensity of cavitation-erosive wear can be obtained during tests in hydrodynamic tubes (HT). However, HT are very cumbersome, energy-intensive, expensive and quite complex in terms of the design of the installation, and very long tests are required to obtain noticeable destruction of strong and corrosion-resistant materials. Installations with rotating discs (VDI) are characterized by the same disadvantages.

Thus, currently known laboratory methods and installations for their implementation in order to obtain data on the cavitation wear resistance of materials close to field tests are aimed at increasing the time of the corrosive interaction of the medium with the metal while simultaneously reducing the intensity of the influence of the mechanical factor of destruction.

In order to use the advantages of tests on MSV (insignificant duration of research, small consumption of working environments, high reproducibility of results), it is necessary to ensure during the research that the intensity of the corrosion factor of cavitation destruction is increased in order to obtain results close to the results of field tests.

The goal of the work. Development of an accelerated method of assessing the cavitation-erosion resistance of metals and coatings in laboratory conditions, which would correspond to the conditions of their operation.

Research methodology. To conduct research, a simplified HT was designed, the main unit of which is a test chamber (Fig. 1), which allows studying the kinetics of the flow of electrochemical reactions during cavitation and erosion processes and to obtain results of wear resistance close to operational ones [4].

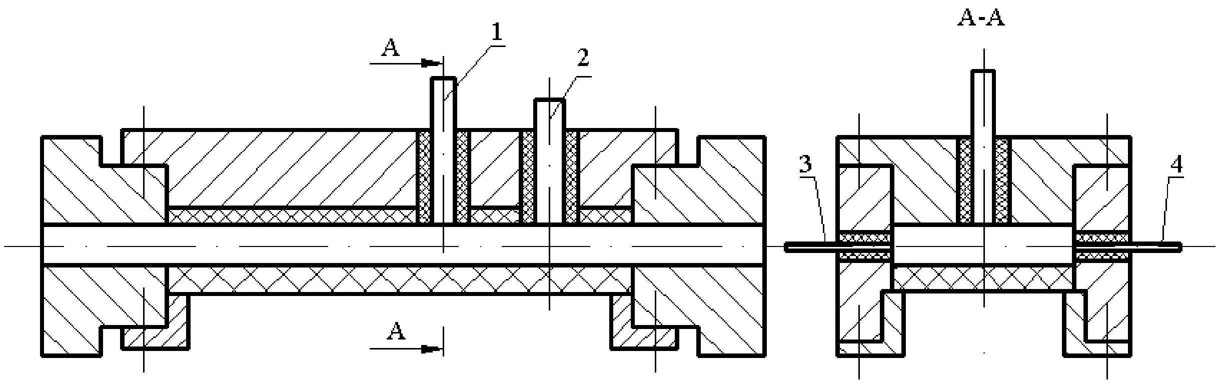

Figure 1. Construction of the GT chamber: 1 – sample; 2 – screw-obstacle; 3 – reference electrode; 4 – auxiliary electrode

The camera is made of stainless steel 08Rh18N10T. The working space of the chamber with a section of 35×15 mm is formed by four removable covers made of organic glass, which allows you to follow the processes of wear and vortex formation depending on the speed of supply of the working medium.

The test sample 1 and screw 2 with a head in the form of a semi-cylinder are installed in the upper cover, which acts as an obstacle that causes the appearance of a moving flow depending on its speed, vorticity or cavitation flows. The comparison electrode 3 is mounted in one of the side walls. The auxiliary electrode 4 is mounted in the other side wall. The area of its contact with the environment should not be less than the cross-sectional area of sample 1.

The HT is connected directly to the main line of the enterprise or complete with a pump, regulating equipment and measuring devices can work autonomously, in this case, with the help of measuring equipment, the characteristic of the medium flow is determined in advance and reproduced on the installation. If necessary, especially during tests of corrosion-resistant materials in the studied environment, anodic polarization of samples is carried out.

As a result of the continuity of technological processes at the enterprises of the chemical and food industries, field tests are not always possible. However, it is possible to experimentally select modes of conducting tests in HT that correspond to the data of full-scale tests (Fig. 2). The results of full-scale tests are given taking into account the large-scale wear factor according to the method described in [3]: ΔV ~ d_0^3, where ΔV is volumetric loss, d_0 – the diameter of the focus of destruction.

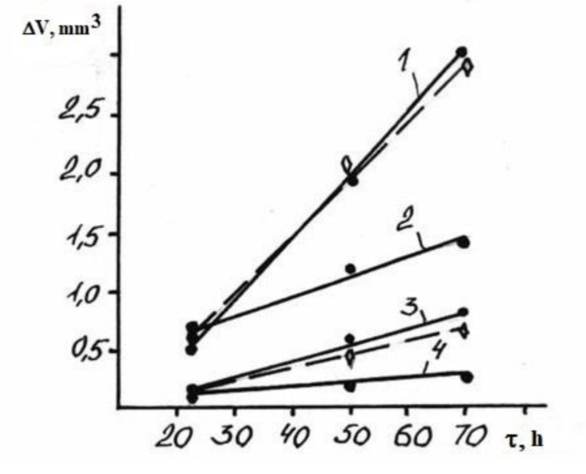

Figure 2. Losses of metal volume ΔV from time τ during tests in HT (–) and field tests (--) in the diffusion juice of sugar production:
1 – Grey Cast Iron Grade SCH20 during cavitation (media flow velocity V_{fl}=17,5 m/s);
2 – SCH20 during hydroerosion (V_{fl}=12 m/s);
3 – aluminum alloys AD-1 during cavitation (V_{fl}=17,5 m/s) and; 4 – aluminum alloys AD-1 during hydroerosion (V_{fl}=12 m/s)

The analysis of the obtained dependencies shows that the results of the experimental erosion and cavitation tests obtained on the proposed design of the HT practically coincide with the data of the operational tests.

Research results. The closest to the claimed method is Author's certificate of the USSR No. 1569668.-1990 «Method of research on hydroerosion resistance of metals» [5], where anodic polarization of samples is carried out during tests on MSV in the process of cavitation. The value of the polarization i_p current is determined by the value of the corrosion i_{cor} current and the coefficient of acceleration of the wear of the samples during tests on the MSV K_a compared to the wear under operating conditions. The disadvantage of this method is conducting preliminary long-term field tests to find the coefficient K_a and magnitude of the corrosion current i_{cor}.

The task is achieved by the intensification of corrosion processes during cavitation-erosive wear of samples on the MSV with the help of their anodic polarization, and the data of field tests to reduce the labor intensity and time of conducting research are obtained on a specially designed and manufactured installation, which is a simplified version of a hydrodynamic tube (HT) [2]. HT is included in the enterprise's working highway without disrupting its technological cycle. As a result of conducting such tests, the intensity of cavitation-erosive wear of materials is found in the appropriate environment, which corresponds to the operating conditions of the equipment.

The assessment of the relative cavitation-erosion wear resistance of the Deformed Aluminum Alloy D16T aluminum alloy and the Grey Cast Iron Grade SCH20 cast iron showed that the ratio of the intensities of destruction in the diffusion juice ν_{SCH20} / ν_{D16T} of sugar factories under operating conditions is 0,09/0,02 = 4,5 [6].

According to the mass loss of the samples during the tests in the HT, the intensity of the loss of materials in the conditions of their operation is found $\nu^{op} = \Delta G / \rho S \tau$, where G is the mass loss during the test τ; ρ – density of the material of the studied sample; S is its surface area.

For deformed Aluminum Alloy D16T in the diffusion juice of sugar production $\nu^{op}_{D16T} = 0{,}021 \mu m / h$, for cast iron Grey Cast Iron Grade SCH20 $\nu^{op}_{SCH20} = 0{,}09 \mu m / h$.

During tests on MSV in diffusion juice (amplitude of oscillations of the magnetostrictive vibrator 36 μm, frequency 22 kHz) for D16T $\nu^{MCV}_{D16T} = 2{,}64 \mu m / h$ and $K_a^{D16T} = \nu^{MCV}_{D16T} / \nu^{op}_{D16T} = 2{,}64 / 0{,}021 = 125{,}7$ for SCH20 $\nu^{MCV}_{SCH20} = 12{,}3 \mu m / h$ and $K_a^{SCH20} = 12{,}3 / 0{,}09 = 136{,}7$.

According to the obtained polarization curves and according to the known method [7], the corrosion currents of the investigated materials were found during tests on MSV in a given environment: $i^{D16T}_{cor} = 0{,}01 mA / cm^2$, and $i^{SCH20}_{cor} = 0{,}0256 mA / cm^2$.

Based on the found value of the corrosion currents, the polarization currents were found, which determine the modes of conducting tests on the MSW installation that correspond to the conditions of the material in operational conditions $\left(i_{pol} = K_a i_{cor} \right)$. $i^{D16T}_{pol} = 125{,}7 \cdot 0{,}01 = 1{,}26 mA / cm^2$; $i^{SCH20}_{pol} = 136{,}7 \cdot 0{,}0256 = 3{,}5 mA / cm^2$.

Next, tests were carried out on MSV during anodic polarization of the samples according to the found polarization current densities and the wear intensity of materials was determined in laboratory conditions that correspond to operating conditions: $\nu^{MCV}_{D16T} = 3{,}14 \mu m / h$; $\nu^{MCV}_{SCH20} = 14{,}4 \mu m / h$.

The assessment of the relative cavitation-erosion wear resistance of the D16T aluminum alloy and the SCH20 cast iron showed that the ratio of the fracture intensities ν_{SCH20} / ν_{D16T} in the diffusion juice of sugar mills under operational conditions (0,09/0,02), according to the known method of tests on MSV (12,3/2,64) and according to the proposed method with anodic polarization of the samples (14,4/3,14) is 4,5; 4,66 and 4,58, respectively. The relative error when using the proposed method is 1,7%, which is less than the 7% error obtained in the compared method.

According to operational data, the relative cavitation-erosion wear resistance of impellers made of steel 45 and steel 12Kh18N10T steels of COT-30 pumps when pumping tap water is 5,75.

The results of the calculations performed in the sequence of actions given above are summarized in Table 1. The analysis of the results of the table shows that the relative cavitation wear resistance of steel 45 and steel 12Kh18N10T found by the proposed evaluation method is 5,9, and according to the prototype – 5,4. The deviation from operational data is 2,6% and 6,1%, respectively.

Table 1

Comparative characteristic of finding the relative cavitation-erosion wear resistance of steel 45 and steel 12Kh18N10T in tap water by the proposed method and according to the prototype

Indicator	Designation and dimension	Material	
		steel 45	steel 12Kh18N10T
Mass losses on MSW without polarization	ΔG^{MSV}, mg/cm^2 h	7,6	3,05
Corrosion current during cavitation on the MVS	i_{cor}, mA/cm^2	0,1410	0,0083
Mass losses in operating conditions	ΔG^{op}, mg/cm^2 h	0,30	0,13
Gain factor	$K_a = \Delta G^{MCV} / \Delta G^{op}$	25,3	23,5
Polarization current	i_{pol}, mA/cm^2	3,57/3,31*	0,195/0,195*
Intensity of wear with anodic polarization	ν, μm/h	12,80/11,72*	2,17/2,17*
Relative wear resistanc	$\nu^{45} / \nu^{12Kh18N10T}$	5,9/5,4*	

*Note: The numerator is the results obtained by the proposed method; the denominator is according to the prototype.

Thus, the proposed method allows, on the basis of accelerated laboratory tests, to obtain data on the cavitation-erosion wear resistance of metals in corrosive environments, taking into account the corrosion factor of surface destruction. By changing the ratio of corrosive and mechanical wear factors, it is possible to obtain data on the wear resistance of metals in laboratory conditions that correspond to operational wear data in this environment.

Conclusions. A method of assessing the cavitation-erosion wear resistance of metals and coatings in laboratory conditions has been developed, which includes:

помітного руйнування міцних і корозійностійких матеріалів необхідні дуже тривалі випробування. Такими ж недоліками характеризуються установки з дисками, що обертаються (УВД).Таким чином, відомі на даний час лабораторні способи та установки для їх реалізації з метою отримання даних кавітаційної зносостійкості матеріалів, близьких до натурних випробувань, направлені на збільшення часу корозійної взаємодії середовища з металом з одночасним зменшенням інтенсивності впливу механічного фактора руйнування. Для використання переваг випробувань на МСВ (незначна тривалість досліджень, незначні витрати робочих середовищ, висока відтворюваність результатів) необхідно в ході проведення досліджень забезпечити підвищення інтенсивності корозійного фактора кавітаційного руйнування для отримання результатів, наближених до результатів натурних випробувань.

У роботі розглянуто спосіб оцінювання кавітаційно-ерозійної зносостійкості металів, який може бути використаний для отримання даних кавітаційно-ерозійної зносостійкості матеріалів та покриттів у лабораторних умовах, що відповідають даним експлуатаційних випробувань. Суть способу полягає в інтенсифікації корозійних процесів при кавітаційно-ерозійному зношуванні зразків на магніто-стрикційному вібраторі (МСВ) за допомогою їх анодної поляризації. Значення струму поляризації знаходять за величинами коефіцієнта підсилення механічного чинника руйнування поверхні при випробуваннях на магніто-стрикційному вібраторі (МСВ) і даними натурних випробувань. Струм корозії в заданому середовищі знаходиться при натурних випробуваннях. Для зменшення трудоємності й часу проведення досліджень експлуатаційні дані отримують на спеціально сконструйованій і виготовленій установці, яка являє собою спрощений варіант гідродинамічної труби (ГТ). Розроблений спосіб оцінювання стосується лише корозійних середовищ-електролітів.

Ключові слова: *кавітаційно-ерозійне зношування, лабораторні й експлуатаційні випробування, корозійний і механічний чинники руйнування.*

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