

SELECTION OF FILTER PARTITION MATERIAL FOR ULTRASONIC CAVITATION FILTRATION

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Abstract

When using the phenomenon of ultrasonic cavitation in the process of cleaning liquids, there is a risk of destruction of the filter baffles. To implement such filters, it is necessary to determine the structural material that will be most resistant to ultrasonic cavitation erosion and the factors that affect the rate and strength of cavitation erosion. The study of various structural materials that were exposed to the cavitation medium created by the introduction of an ultrasonic wave into a liquid.

Keywords: ultrasonic vibrations, ultrasonic cavitation, cavitation filtration, liquid purification, cavitation chambers, filtration materials.

INTRODUCTION

Water is one of the most valuable natural resources in the world. The constant increase of the population and intensive development of technologies require constant improvement of the quality of technologies for liquid filtration.

The development of chemical industries has led to the saturation of water resources with various harmful substances, and increasing the requirements for the quality of treatment of technological and wastewater requires the widespread use of various methods of treatment of liquid media. Currently, significant work is being done to create chemical plants that would not lead to pollution of water resources by wastewater, the use of wastewater in technological processes and in recirculating water supply systems is envisaged [1].

Methods of purification of liquid media can be divided into destructive and regenerative [2], [3]. Destructive methods of purification consist in the destruction of water-polluting substances by their oxidation or reduction. The resulting decomposition products are removed from the water in the form of sediment or gases, or remain in it in the form of soluble mineral salts. Regenerative methods allow to separate and utilize some substances contained in water.

These methods do not always purify water to a state where it can be discharged into reservoirs. In these cases, the water is purified by destructive methods.

Filter partitions are the basis of the filtration process. They have the greatest impact on the performance, degree of filtration and technological features of filters.

The requirements for filter baffles depend on the method of filtration for which they are applied. In the case of filtration with the formation of sediment, the partitions must have minimal adhesion to the sediment. Partitions used in bulk filter elements must have a high porosity and their thickness must be sufficient to retain as many solid phase particles and increase the duration of the filtration cycle.

Solid phase particles are retained not only mechanically. Fine particles are also adsorbed on the surface of the fibers of the filter partition. Therefore, the ability to retain solid particles depends on the physicochemical properties of the partition and the solid phase of the suspension [4]. Partitions for the separation of suspensions with specific physicochemical properties are selected experimentally. Over time, the filter baffle accumulates a significant amount of fine particles, which leads to an increase in hydraulic resistance.

The introduction of ultrasonic vibrations in the filtration zone [5], [6] allows not only to regenerate the septum, but also to intensify the filtration process itself. If suspensions or baffles are reciprocated during the filtration process with a frequency of more than 20 kHz, it is possible to carry out a continuous process of separation of the suspension, which will proceed at the highest speed. During the period of full oscillation (forward and reverse), which is carried out by a suspension or partition, the processes of filtration and regeneration take place. During filtration (direct action), solid particles of contaminants are deposited on the surface of the partition. During the return stroke, countercurrent regeneration occurs. As a result, the solid particles are detached from the partition, and then carried by the flow of suspension or deposited in the lower parts of the apparatus, where they are periodically removed. At the same time, the phenomenon of ultrasonic cavitation is observed in the liquid [7]. It is the formation of small bubbles during the passage of a vacuum wave. Such bubbles carry out pulsating oscillations and cause strong local turbulence of the environment. Some of these bubbles during the second phase of the wave, which creates compression, flatten and this leads to significant local temperatures and pressures. All this is a powerful factor in the destruction of solid particles on the walls of the capillaries of the septum and their leaching by flowing liquid.

The main problem of such filters is the destruction of the filter partition over time, due to the destructive action of the cavitation medium. To create technological equipment that implements this technology, it is necessary to choose a material that will not be exposed to the destructive effects of ultrasonic cavitation.

EXPOSITION

For the experimental study, a cylindrical ultrasonic cavitation chamber excited in the radial oscillation mode was used [8]. A special stand was designed and built (Fig. 1). A cylindrical test specimen made in the form of a rod with a diameter of 8 mm was installed along the axis of the chamber.

In the experimental setup, the intensity of the ultrasound could be adjusted within 2...100 W/cm² by the supply voltage of the ultrasonic transducers.

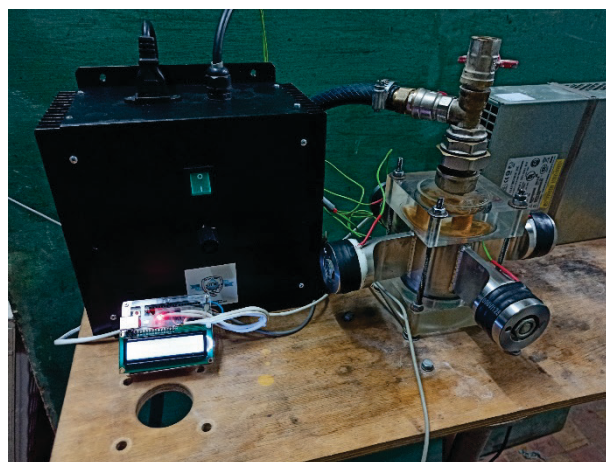


Fig. 1. Appearance of the stand for conducting experimental studies of cavitation erosion of structural materials

To increase the reliability of the results by stabilizing the cavitation mode in the chamber, a closed system of working fluid circulation was created, which provided the maintenance of a constant number of cavitation nuclei (Fig. 2). To investigate the effect of ultrasonic cavitation on structural materials, several different materials and alloys used in mechanical engineering were selected. The following conditions were selected during the tests: liquid - water (H₂O); working fluid temperature 293 K; the pressure in the test chamber was - 0.2 MPa [9]; test time - 0-240 minutes; fluid flow through the test chamber 2 l/min. The amount of material removed during the period of developed cavitation was chosen as a parameter for assessing the erosion resistance of the studied material.

Before each test, the test specimens were thoroughly washed with alcohol and dried in an oven for 30 min at 373 K. Samples were weighed before and after the test using high-precision analytical balances of the AXIS AD50 series. Accuracy class II, which allows to determine the weight of the test sample with an accuracy of 0.001 g. Weighing was performed 5 times to increase accuracy.

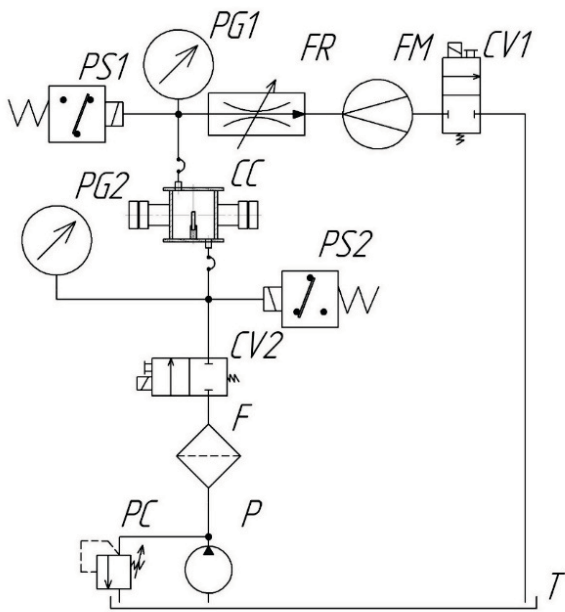


Fig. 2. Hydraulic diagram of the experimental bench. (C - cavitation chamber; CV1 - control valve 1; CV2 - control valve 2; F - filter; FM - flow meter; FR - flow control; P - pump; PC - pressure control; PG1 - pressure gauge 1; PG2 - pressure gauge 2; PS1 - pressure switch 1; PS2 - pressure switch 2; T - tank.)

Experimental studies, some of the results of which are shown in Fig. 3, showed that the mechanism of cavitation erosion mainly depends on the cavitation power (W , W), its duration (t , min) and the structural material of the filter partitions, characterized by the Young's modulus (E , GPa) and described by the function:

$$\Delta V = f(W, t, E) [\%], \quad (1)$$

where W is the power of the cavitation device, W; t is the duration of cavitation, min; E - Young's modulus, GPa; ΔV - relative loss of volume of materials;

The results of research show that further study of the change in the volume of materials during cavitation processes can be carried out by one of the modeling methods. The study of the influence of the above factors on the relative loss of volume of structural materials during one-factor experiments is associated with significant difficulties and volume of work. Therefore, it is expedient to conduct a multifactor experiment to obtain the regression equation for the response function - the relative loss of volume of structural materials.

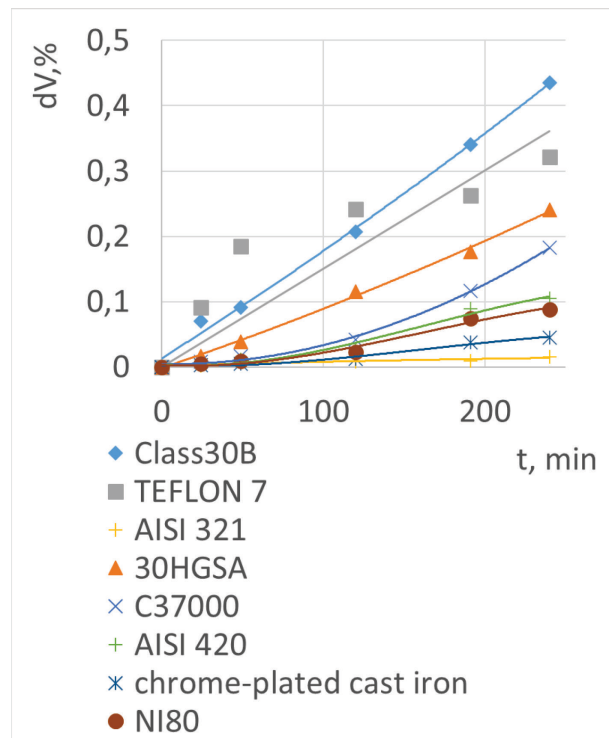


Fig. 3. The dependence of the weight loss of the test sample on the processing time at the power consumption of the ultrasonic cavitator 400 W

Among the existing modeling methods [10] the process of changing the relative volume of the material of the filter partitions of different structural materials during cavitation depending on the cavitation power and its duration can be carried out using one of the algorithms of group argumentation (GDMH), namely GDMH with active neurons [11].

The results of experimental studies were conducted in software GDMH Shell DS 3.8.9 [12], which allowed to obtain relationships between influential quantities.

$$\begin{aligned}
 y &= -0.00665342 + 1.43019 * n_{47} + \\
 &+ 6.46994 * n_{47} * n_{15} - 6.66151 * n_{47}^2 - \\
 &- 0.345979 * n_{15}, \\
 n_{15} &= 0.169846 - 0.00166224 * W + \\
 &+ 0.00419129 * W * n_{47} + 3.50203e^{-6} * W^2, \\
 n_{47} &= 0.0241886 + 15.5951 * n_{92} - \\
 &- 2986.3 * n_{92} * n_{96} + 1524.51 * n_{92}^2 - \\
 &- 15.4387 * n_{96} + 1461.96 * n_{96}^2, \\
 n_{96} &= -0.00206682 - 0.743211 * \sqrt[3]{E} * \\
 &* n_{117} + 4.60507 * n_{117}, \\
 n_{92} &= -0.00406738 + 6.27789 * \\
 &* n_{116} * n_{117}, \\
 n_{116} &= 0.345412 - 0.00154868 * E, \\
 n_{117} &= -0.0460626 + 0.00894853 * \sqrt[3]{t^2}.
 \end{aligned}$$

CONCLUSION

The obtained results allow to evaluate the cavitation stability of structural materials and to make a reasonable choice of materials for use in ultrasonic technological equipment. As a result, among the studied, the most suitable material for use in ultrasonic cavitation filters is steel AISI 321.

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