*International Journal of Engineering Inventions*
*e-ISSN: 2278-7461, p-ISSN: 2319-6491*
*Volume 3, Issue 7 (February 2014) PP: 06-08*

# Sonochemical Reactor with Phase Control

S. Shestakov, T. Shlenskaya, O. Krasulya, T. Baulina
*Moscow State University of Technology and Management, Russia*

**Abstract:** *Describes the ability a managing the symmetric sonochemical reactor for physic-chemical treatment of chemically pure water, true and colloidal aqueous solutions, as well as disperse systems with the speed of sound in them more than at water. Such reactors are useful, for example, in the food industry, where are processed of different concentrations the solutions NaCl. Demonstrated that the development allows you to get the highest acoustic power dissipated on the cavitation and maximum performance of reactor without increasing the electrical power input but by nonparametric control cavitation. Describes the reactor with two tightly fastened by elastic gaskets and flanges at the nodes of the vibration displacement of the acoustic transformers to opposite ends of the housing which distribute in the treated solution coherent plane elastic waves. The distance between the ends of the radiating transformers reactor is multiple of the number of half wavelengths of these oscillations in chemically pure water. Effect is achieved due to the fact that the phases of emitters must always be shifted relative each other in a predetermined angle.*
***Keywords:*** *sonochemical reactor, nonparametric control cavitation.*

## I. Introduction

Here we will talk about sonochemical reactor – apparatus for physical-chemical treatment ultrasound cavitation water, and true colloidal aqueous solutions, as well as disperse systems the speed of sound is higher than that of water. This processing is done in order to change their physico-chemical state the change of dipole-dipole and ion- dipole interactions in their environment and phases for intensification of chemical reactions. In sonochemical reactor the energy transfer into treated liquid has epithermal character and initiates processes characteristic of high-energy chemistry when she on a certain time is exit of the thermodynamic equilibrium. This allows to accumulate, for example, in water, without heating, a certain amount of energy and when returning to an equilibrium state return it as the heat of hydration of dissolved substances and dispersed component or herself by means of creating a molecular structure by hydrogen bonds among its molecules. In the non-equilibrium state the water has a high ability to solubility and intensely hydrates the molecules and ions of dissolved substances, creating them dense hydrate shells [1]. This process of relaxation of nonequilibrium state. Sonochemical reactors are used, for example, in the food industry, pharmaceuticals and production of fuels [2,3].

## II. Short Review Of Technical Literature

There are many designs of sonochemical reactors called still the cavitation reactors. They use as a technological factor elastic energy of the ultrasonic wave in the water which generates the acoustic cavitation. In some of them in creating this acoustic wave participates one ultrasonic transducer and one their reflective element (wall of the chamber, reflector) [4]. But no matter how this reflector is arranged in the acoustic cell of reactor on it dissipated some of the energy of the elastic wave, that reducing the efficiency of conversion to this energy into energy cavitation, ie the efficiency of the reactor. Moreover, from the acoustics theory it is known that the reflection coefficient of the wave reflector is the negative, because the materials from which made reflectors have acoustic impedances are usually higher than that of water. Plane-elastic wave attenuates along a wave beam from the surface of radiation, when some part of energy is dissipates in the water at internal friction and cavitation [5]. Practically acceptable law of attenuating of amplitude wave is described in [6,7]. Therefore are more effective sonochemical reactors have symmetric acoustic cell, which composed of two emitters emitting coherent waves propagating along axis towards each other [8]. The superposition of these waves creates a general wave in reactor. In this case, the general wave has a damping to direction of the geometric center of the reactor. However, the bulk density of erosion power cavitation, more often, in reactors with a length of the beam of up to three half-wavelengths has a maximum value in the geometric center. This is due to the effect of non-parametric amplification cavitation [9]. This effect directionally is used to amplify cavitation without any change of the acoustic parameters of the liquid and the dissolved therein gas [10] in the construction of reactors with several independent waves in volume a fluid. This is done in two ways: by using a special mutual location of the sources of coherent waves, or by controlling the phases of waves of these sources. The second is known only for reactor where there is no superposition of waves initiating of cavitation. Therefore, in a reactor with a two oppositely directed emitters on the same axis, if being processed the liquid, in which the speed of sound is different from the speed of sound in the fluid for which it is designed, a part of energy is lost. Specific acoustic impedance, for example, is water and saturated sodium chloride solution differs by 36%. When processing the last to achieve the same sound pressure amplitude how in the water, which determines the energy of cavitation, required a corresponding increase in the radiation power.

## III. Theoretical Studies

The reactor is symmetric about the center of mass and consists of a supporting body of the working chamber with filling and discharge nipples, two emitters of coherent plane elastic waves, adjointed by flexible gaskets and flanges to each side of the hull at the nodes of the vibration displacement of acoustic transformers. Flanges tightened to each other and form with pipe body and transformers the working volume to skip through the reactor liquid to be treated. Sources vibrations - electro acoustic transducers attaching to transformers by means of pins. (Fig. 1) When the distance between the emitting planes transformers is an odd number of half-waves emitters operate in phase, even number - in opposition phase.

Fig.1. Photo symmetric cavitation reactor on a tripod.

Clearly, to adjust reactor for speed of sound in the specific liquid being processed so that the resulting wave amplitude would be always maximal without increasing the input power one can for example to change the distance between the radiating planes acoustic transformers or change the frequency of the radiation so that the phases of the counterpropagating waves coincided. But it is technically difficult task. Easier set the phase shift of these vibrations on their source , leaving unchanged their frequency , that is, leave them coherent. This would require availability in delay line control circuit, as in [9].

Through holding researching the model multibubble cavitation and the criterion similarity of sonochemical reactors was found that obtaining high power of cavitation and maximum reactor productivity due to optimal superposition of emitted towards each other waves should be set phase shift between the waves of radiation sources. But the cavitation areas adjacent to the radiating surfaces not be should in contact with them so as not to cause of their erosion. Has been found angle $\Delta\phi$ which satisfies these conditions. Its can be expressed by the following additive function:

$$\Delta\phi = \frac{20}{3}\lambda\pi + \frac{1}{2}\pi + 2\left\lfloor \frac{1}{2}N \right\rfloor\pi - N\pi\,, \qquad (1)$$

where: $\lambda$ – wavelength of ultrasound in processed liquid in m; $N$ – the number of half-waves of vibrations on the axis of the reactor chamber between radiating surfaces of acoustic cell in chemically pure water; $\lfloor\ \rfloor$ – lower integer part of number (floor). Under such conditions, cavitation areas which formed near the antinodes of pressure common wave will take the largest volume. This will make the reactor more productive.

## IV. Experimental Studies

Comparison of reactors was by computer experiment with the mathematical model of cavitation reactor and the similarity principle of cavitation processes. To this a reactor was selected, with the design similar to that described in [8]. Number of half-wave of ultrasound in water between the radiating surfaces $N$ = 3. In the comparison was calculated the total volume of cavitation regions. In the reactor without phase offset, he was 331 *ml*, with an offset - 369 *ml*. Average density of power cavitation erosion in the chamber of the reactor when the phase shift is made has increased by 1.18 times.

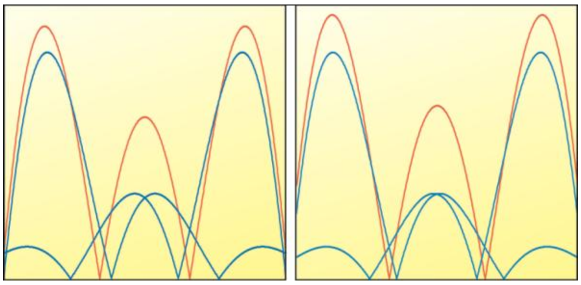

Fig. 2. Graphics sound pressure amplitude on the axis of the reactor in the treated polystyrene latex: □ for each radiator; □ total sound pressure. On the left without phase displacement, on the right with displacement. Numbers on the x-axis shows the lengths of the segments on which acts a cavitation.

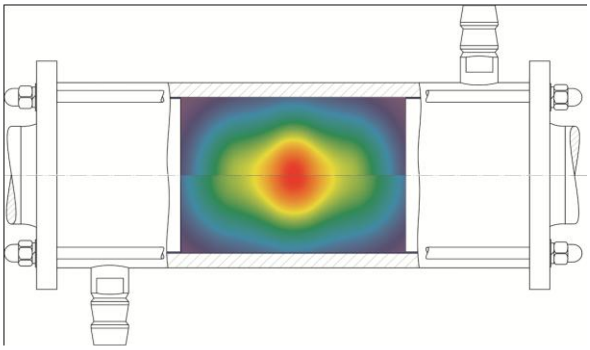

Fig.3. General view with cut by the diameter of the working chamber sonochemical reactor, on which comparative experiments were performed. In the plane of the section through tonal pattern is shown the distribution density erosive power of cavitation in the upper part of the section without phase displacement, at the bottom - with displacement.

In the experiment was carried out comparative dispersion of polystyrene latex. When processing latex by the pressure pulses of cavitation the work is done against the cyclic strength of polystyrene particles which is proportional to the power of cavitation. Modified dispersion of latex can be used as a measure of this work. In the experiment, the control samples of latex were treated in mode of commonmode operation of emitters. A test sample at the same initial temperature was treated during the same time when the phase shift between the emitters was equal to angle 0,127□. By method Geller is found that polystyrene particle diameters the control samples is equal 150 ± 10 *nm* and experienced 120 ± 10 *nm*.

## V. Conclusion

The reactor operates in the following manner. In a treated liquid which passed through fittings with flat surfaces of acoustic transformers spreads elastic waves the pressure amplitude of which decreases with distance from these surfaces. In the resulting in liquid is established the common elastic wave with decreasing amplitude to the center. In that wave, where the amplitude exceeds the threshold of cavitation, arise zones of cavitation with pulsating bubbles which make useful work in the liquid. If in reactor the phases oscillation of emitters are offset, which allows them to shape the resulting wave with the maximum amplitude, and sizes of the cavitation areas increase too. As a result, the average bulk density of the erosive power of cavitation in the reactor chamber and the reactor performance are also obtained more.

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