Ultrasonic Chemical Reactors

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Abstract—The article is devoted to different types ultrasonic chemical reactors for laboratory and industrial using. Experimental results are given.

Index Terms—ultrasonic, sonochemistry, ultrasonic reactor, cavitations.

I. INTRODUCTION

The present-day industrial enterprises continuously increase tempo of industrial production. Usually, for this purpose it is necessary to modernize or completely to change the process flowsheet. It is widely known, that using of high intensity ultrasonic oscillations allows intensifying many technological processes, such as impregnating of composite materials, drilling of brittle and extra-hard materials, dissolution, extraction, emulsification, washing and clearing. [1,2]

A plenty of researches being carried out at present moment specify that speed of passing the majority of chemical reactions increases under action of an acoustic field and that some reactions do not pass without action of ultrasonic oscillations [3-5].

Cavitation is considered as a major factor which influences on reaction speed. The temperature inside cavitation bubbles while collapsing attains approximately 5000 K, pressure attains approximately 100 MPa and velocity of a collapse attains about 400 km/h. At such bubble collapsing the powerful shockwave [3] is created.

Providing of similar requirements is possible at intensity of ultrasonic action from 100 W/cm2. Since the acoustic oscillations of audio frequency and high intensity providing is rather difficult, using of ultrasonic frequency oscillations (above 20 kHz) obtains wide extending.

For implementation of such technological processes there is a special class of technological apparatus called ultrasonic reactors; and for providing researches of reaction passing under action of acoustic oscillations there is a science called acoustic chemistry.

II. ULTRASONIC REACTORS FOR LABORATORY

Now there is a lot of ultrasonic reactors types, which differ from each other with intensity of ultrasonic oscillations introducing into a fluid and possibility or impossibility of the flowing processing [4,6] (fig. 1).

The peak of ultrasonic action provides with the ultrasonic reactor represented in figure 2.

Such reactors are able to process about 300 ml of liquid
with intensity up to 200 W/cm².

In cases when for experimental purpose it is enough to process several tens of milliliters the ultrasonic apparatus for processing liquid in test tubes is used. Distinguishing feature of such apparatus is presence of two replaceable working tools for a ultrasonic oscillatory system. One working tool is intended for direct input of oscillations in the test tube, and another one is for noncontact processing of liquids. The working tool has shape of the hollow cylinder in which test tube with reagents is placed, in space between walls of test tube and the working tool there is a liquid through which transmission of oscillations to test tube walls is carried out (figure 3).

Due to small volumes of the processing liquid it is possible to achieve the intensity of ultrasonic action about 300 W/cm².

III. ULTRASONIC REACTORS FOR INDUSTRIAL APPLICATION

The major drawback of the foresaid reactors is the small processing volume per unit of time. For laboratory it is not a major drawback, but for the industrial applications the other embodiment of the reactor is required. In this case, the optimal solution is the flowing processing of liquid.

The laboratory of ultrasonic processes and apparatus designs a lot of apparatus for the flowing processing of liquid mediums with power from 400 VA up to 6000 VA (fig. 4).

Distinguishing feature of apparatus with power more than 2000 VA is use of the working tool with the extended radiating surface. The working tool is the series joined several step-radial concentrators; such form of the working tool allows to extend the radiating surface in several times in comparison with classical single- and two-half-wave oscillatory systems. (fig. 5)
For providing super intensive action on liquid mediums, it is promising to design the embodiment of ultrasonic reactor for the flowing processing in form of truncated dodecahedron with piezoceramic assemblies on its hexagonal sides. Using of such radiator embodiment will allow achieving the intensity of 500 W/cm² [7] (fig. 6).

IV. EXPERIMENTAL RESEARCHES

The experimental researches on processing milk and sewage with ultrasonic oscillations of high intensity have been carried out using apparatuses designed.

By means of apparatus «MUSA» examination of influence the ultrasonic oscillations on taste property, biological parameters of milk and its storage stability was carried out. Results of test have shown that the radiated milk is kept longer than not processed one.

Thus the amount of bacteria in milk drops from initial 15000 unities to 5000 in the end of the first processing cycle and to 1000 in the end of the third cycle (table 1).

![Image 6 - the Ultrasonic reactor of ultrahigh intensity](image)

**TABLE 1**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>amount of bacteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>15000</td>
</tr>
<tr>
<td>Milk first cycle 2 minutes</td>
<td>10500</td>
</tr>
<tr>
<td>Milk first cycle 5 minutes</td>
<td>7000</td>
</tr>
<tr>
<td>Milk first cycle 10 minutes</td>
<td>5000</td>
</tr>
<tr>
<td>Milk second cycle 2.5 minutes</td>
<td>1000</td>
</tr>
<tr>
<td>Milk second cycle 7.5 minutes</td>
<td>6500</td>
</tr>
<tr>
<td>Milk third cycle 2.5 minutes</td>
<td>2000</td>
</tr>
<tr>
<td>Milk third cycle 7.5 minutes</td>
<td>1500</td>
</tr>
<tr>
<td>Milk third cycle 10 minutes</td>
<td>1000</td>
</tr>
</tbody>
</table>

Also it is determined that decrease in processing velocity from 1 l/min to 0.5 l/min allows to essentially reduce quantity of milk operation cycles to 1-2 with amount of bacteria in milk 1000-2000 unities without losses of taste properties.

Changing in the amount of bacteria in milk on the second cycle of processing are related with variation of productivity from 1 l/min to 0.5 l/min.

The inoculation of milk was made with Kessler and Kmafanm mediums, produced by Obninsk-city on GOST procedures.

The sewage processing was provided with apparatus «Bulava», model 1000-3 (table 2), the represented results show efficiency of ultrasonic oscillations using for water purification.

**TABLE 2**

<table>
<thead>
<tr>
<th>Water parameters</th>
<th>input</th>
<th>output</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7,6</td>
<td>7,7</td>
</tr>
<tr>
<td>UEP</td>
<td>0,102</td>
<td>0,0577</td>
</tr>
<tr>
<td>Suspended matter</td>
<td>&gt;2000</td>
<td>122,2</td>
</tr>
<tr>
<td>Solid residue</td>
<td>612,2</td>
<td>305,6</td>
</tr>
<tr>
<td>BPK5</td>
<td>276</td>
<td>15,6</td>
</tr>
<tr>
<td>Permanganate oxidability</td>
<td>191,8</td>
<td>18,8</td>
</tr>
<tr>
<td>Ammonium</td>
<td>46,5</td>
<td>19,5</td>
</tr>
<tr>
<td>Phosphates</td>
<td>0,95</td>
<td>0,2</td>
</tr>
<tr>
<td>Sulfates</td>
<td>28,9</td>
<td>10,4</td>
</tr>
<tr>
<td>APAV</td>
<td>3,21</td>
<td>2,23</td>
</tr>
</tbody>
</table>

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V. CONCLUSION

The represented embodiments allow satisfying the requirements both the industrial enterprises and the research organizations. The presented experimental results confirm a possibility and promising of using the ultrasonic technologies both in industrial plants and laboratory researches.

REFERENCES


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