On the mechanism of selective fixation of bubbles under the action of ultrasound in NaCl and KCl solutions during degassing

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Abstract. This paper describes the experimental study of the mechanism of selective fixation of bubbles formed in a liquid under the influence of ultrasound on the surface of plates of various degrees of wettability when the liquid is degassed as a result of ultrasonic action. The experiments used solutions of NaCl and KCl of various concentrations, as well as distilled water. The plates are made of organic glass (wetting angle 51°) and Teflon (wetting angle 118°). As a result of the study, the experimental data on the surface area occupied by bubbles on the surface of plates were obtained, and the mechanism of selective fixation of bubbles under the influence of ultrasound in the conditions of emerging degassing was shown.

1. Introduction

Ultrasonic (US) action on the liquid causes the formation of cavitation bubbles in it, and their collapse leads to a huge concentration of energy in a very limited volume. In this case, the surface and kinetic energy of the liquid is converted into the kinetic energy of the shock wave and electromagnetic energy emitted as energy radiation in the infrared and visible ranges of electromagnetic waves [1-4].

The important parameter that affects the formation of bubbles is the degree of saturation of solutions with atmospheric air or other gas, as well as the content of various gases in the liquid. In industry, foam flotation is widely used - a process based on the attachment of hydrophobic particles to air bubbles passed from below through a mixture of mineral particles with water (pulp), and the removal of these particles to the surface of the pulp, where foam is formed. Hydrophilic particles remain suspended in the pulp [5]. The results of this work can be used to understand the processes of ore dressing by flotation.

The purpose of this work is to experimentally study the relative surface area occupied by vapor-gas bubbles on surfaces of different wettability in liquids under the influence of ultrasound, as well as to study the mechanism of selective fixation of bubbles under conditions of emerging liquid degassing.
2. Experimental setup
The experimental setup consisted of a parallelepiped-shaped cuvette with dimensions of 110×116×160 mm$^3$ (Fig. 1). The cuvette was made of 3 mm thick organic glass. The test plates were fixed vertically in the central part of the cuvette. To visualize the bubbles, a laser knife created by a cylindrical lens and a green KLM-532 laser with a laser wavelength of 532 nm was used. A high-speed camera was used to record the dynamics of bubbles. The ultrasound source was a metal disk with a diameter of 88 mm, placed on the bottom of the cell so that the center of the emitter coincided with the center of the cell bottom. It was connected to an ultrasonic oscillator with a frequency $f=40$ kHz and a maximum power $P=100$ W. The plates under study were made of organic glass (wetting angle 51°) and Teflon (wetting angle 118°).

![Figure 1. Experimental setup: 1) cuvette 110×116 × 160 mm$^3$; 2) high-speed camera; 3) laser, 532 nm; 4) ultrasound source, $f=40$ kHz, $P=100$ W; 5) test plates](image)

3. Results
As a result of US action on the liquid, vapor-gas bubbles are formed in it, which can be fixed on the surface of the plates during drift. Experiments show that the composition of the liquid and the material of the plates can significantly affect the relative area of the bubbles attached to the solid surface. In addition, it is known that the number of bubbles formed as a result of cavitation and drifting in the liquid is affected by the gas concentration in the solution [6, 7].

Figure 2 shows that the relative surface area occupied by the bubbles varies depending on the degree of water degassing, as well as on the addition of salts.
When the gas content in the liquid is normal, fewer bubbles form on the surface of Plexiglas (acrylic glass) plates (Fig. 3 a) than on the surface of Teflon plates (Fig. 3 b). This is due to the varying degree of wettability of the plate surfaces.

At a reduced gas concentration in the liquid, bubbles are selectively attached: they are practically absent on acrylic glass (Fig. 3 a), but on Teflon (Fig. 3 b) there are, although a smaller amount, compared to the normal gas concentration in the liquid.

4. Conclusion and discussion
At normal gas content in the liquid (Fig. 4), bubbles are practically not fixed on the surface of hydrophilic particles, as a result of which they are not attached to large bubbles and are not carried to the surface of the liquid. Bubbles are attached to hydrophobic particles that were initially untreated by ultrasound and push the particle to the surface of the liquid. However, if the particles are initially treated with ultrasound, may appear on hydrophobic particles. In the future, the chance that other bubbles will attach to a particle that initially has small bubbles will be much higher. Small bubbles are practically not formed on hydrophilic particles after US exposure.
Figure 4. Type of particles of different wettability in the liquid before and after pre-treatment with ultrasound at: a) normal gas content; b) reduced gas content.

When the gas concentration in the liquid is reduced (Fig. 5), fewer bubbles form on the surface of the particles. There is a selective attachment of bubbles: they are practically absent on hydrophilic particles, but on hydrophobic particles there are, although less, compared to the normal concentration of gas in the liquid. However, when the particles are initially treated with ultrasound, the chance of attachment of the
bubble to the particle increases significantly. However, this does not affect selectivity, since hydrophilic particles are still devoid of additional bubbles on the surface formed as a result of US exposure. Thus, it is expected that US will have a positive effect at the flotation stage when processing potash ores. With the help of pre-US processing, it is possible to increase the % yield of a valuable product after the first flotation, as well as to reduce the total number of ore flotation cycles. Potentially, this can reduce the area of equipment, energy consumption, and reduce the consumption of reagents for flotation.

The graph of the relative surface area (Fig. 2 a) shows that there are relatively large fluctuations for Plexiglas, which are associated with a small wettability angle of the plate surface. Large bubbles are periodically fixed to the plate, but when a certain diameter is reached, they are detached and brought to the surface of the liquid.

A significant decrease in the relative surface area occupied by the bubbles on the surface of the plates during degassing is due to the fact that the liquid contains less gas than before the use of ultrasonic degassing. However, on the surface of Teflon, there are several zones in which stable attachment of bubbles was observed, possibly due to air diffusion from the open surface of the liquid in the cuvette.

As a result of the study, experimental data were obtained on the relative surface area occupied by vapor-gas bubbles on the surface of Plexiglas and Teflon in distilled water and solutions of NaCl and KCl under conditions of ultrasonic degassing. The mechanism of selective fixation of bubbles on the surfaces of plates of different wettability under the action of ultrasound in solutions of NaCl and KCl during degassing is show.

Acknowledgments
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