The gas bubble size distribution control formation in the flotation process

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Abstract
A method for the effective control of the pulp gas phase composition in the flotation process using dynamic effects of high energy ultrasound on the base of phased array technology and determination of its parameters are described.
Key words: PHASED ARRAY, ULTRASOUND, PULP, CONTROL, FLOTATION, BUBBLE SIZE DISTRIBUTION

For the physical processes modeling which determines the flotation it is requires the accurate data on the gas phase characteristics, the most important of which are the concentration and gas bubble size distribution. These parameters are highly dependent on a variety of operational, technical and physical-chemical factors, the effects of which should be considered in flotation process modeling.

The task of research is the control formation of the desired gas bubble size distribution, which would correspond to the pulp solid phase particle size distribution in the flotation process.

To solve this task it is proposed to affect on the pulp flow with high-energy ultrasonic wave with given frequency and amplitude, resulting in a gas bubbles concentration change, and redistribution of their size. Character of redistribution depends on the size of the bubbles themselves, the frequency and amplitude of the incident radiation. To initiate appropriate processes, due to the extreme nature of cavitation in liquids, it is necessary not only to form a certain amplitude and frequency of oscillations, but also to maintain their optimal values when changing the medium parameters and the impact of factors such as: changing the temperature of the medium and the material of the piezoelectric transducer, the damping action of the medium [1-4].

To account for the gas pressure in the bubble, and pressure varying in the liquid, the viscosity and surface tension it is advisable to use a cavitation bubble dynamics equation of Rayleigh-Plesset in which the driving pressure *Pi(t)* given as a short pulse [5].

$$\ddot{R}\left(1-\frac{\dot{R}}{c}\right)+\frac{3}{2}\dot{R}^2\left(1-\frac{\dot{R}}{3c}\right)=\frac{P(t)}{\rho}=\frac{1}{\rho c}\frac{d}{dt}\left[RP(t)\right]$$

(1)

$$P(t)=\left(P_0+-\frac{2\sigma}{R_0}\right)\left(\frac{R_0}{R}\right)^{3\gamma}-\frac{2\sigma}{R}-P_0+P_i(t)-\frac{4\mu\dot{R}}{R}$$

(2)

where P_0 – is static pressure in the liquid, $R(t)$ – is current bubble radius, R_0 – is initial bubble radius, $P_i(t)$ – is pressure in the incident wave, σ – is surface tension, μ- is dynamic viscosity of the fluid, ρ – is density of the liquid, c – is speed of sound in the fluid (water σ = 0.07 N/m, μ = 0.001 N·s/m^2, ρ = 10^3 kg/m^3, c = 1500 m/s), γ – is adiabatic exponent of gas in the bubble (air γ = 1.33). The initial conditions are given as, (t = 0) = 0.

The simulation results of the high – energy ultrasound dynamic effects impact on the pulp gas phase allowed to obtain the dependences of the gas bubbles size distribution function parameters on the frequency and amplitude of the applied ultrasonic action.

The dependence of gas bubbles sizes on the ultrasonic oscillation pressure amplitude for different values of its frequency is presented on Fig.1.

At a constant ultrasound frequency of 0,7 MHz and the formed pressure of 10^2-10^4 Pa the size of the gas bubble remains constant ($5\cdot10^{-5}$ m), at a pressure of 10^4-$2\cdot10^5$ Pa there is a gradual decrease in the bubble size ($5\cdot10^{-5}$ -10^{-5} m), at a pressure of $2\cdot10^5$ -$5\cdot10^6$ Pa the bubble decreases in size (10^{-5} -$1,5\cdot10^{-7}$ m), and when varying the ultrasound frequency from (0,7 - 2,5 MHz) and at a pressure of 10^2 Pa the bubble decreases in size from $5\cdot10^{-5}$ to $1,5\cdot10^{-5}$ m.

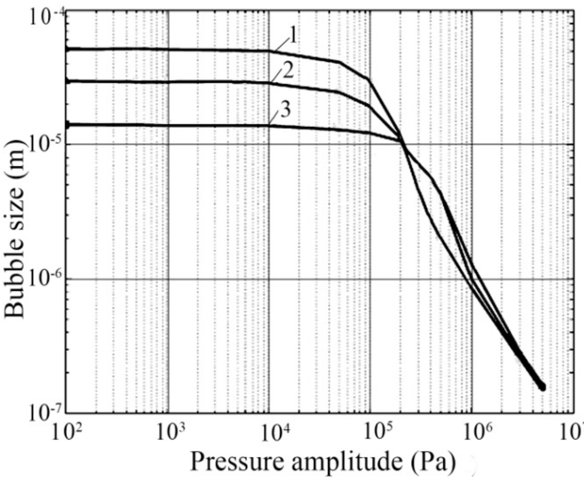

Figure 1. The dependence of gas bubbles sizes on the ultrasonic oscillation pressure amplitude for different values of its frequency: 1 - 0,7 MHz; 2 – 1,5 MHz; 3 – 2,5 MHz.

Let's form the control action based on the dynamic effects of high-energy ultrasound using phased array technology, which have many advantages compared to conventional single-element transducers [6].

When using this approach, the gas bubbles are subjected to elements of the phased array, which having different characteristics. Numerically this effect can be expressed as a weighted sum of the individual bubble size distributions generated by each element of array [7].

$$f(x)=\sum_{j=1}^{N} a_j \cdot f_j(x), \qquad (3)$$

with

$$\sum_{j=1}^{N} a_j = 1, \quad 0 \le a_j \le 1, \quad j = 1.2,...,N, \qquad (4)$$

where N - is the number of array elements, α_j – weighting coefficients, which can be considered as a priori sampling probability of bubbles generated by j-element of array, $f_j(x)$ - is the size distribution function of bubbles generated by j-element of array.

The structure of the gas bubble size distribution automatic control system based on the technology of ultrasonic phased array for realization of proposed method is presented in Fig.2.

The system input receives the information about the solid phase parameters and the estimator determines the gas phase parameters. The signal is then transmitted to the adjusting device, which sets the required amplitude and frequency of ultrasonic vibrations. Then the control action generator transmits the electromagnetic signal to the ultrasonic phased array, whereupon the pulp with the bubbles is exposed to high energy ultrasound emitted from the array elements. That allows to form a predetermined gas bubble size distribution. To maintain or change the required amplitude and frequency the adaptive control algorithm, which control the power for each individual array element is used.

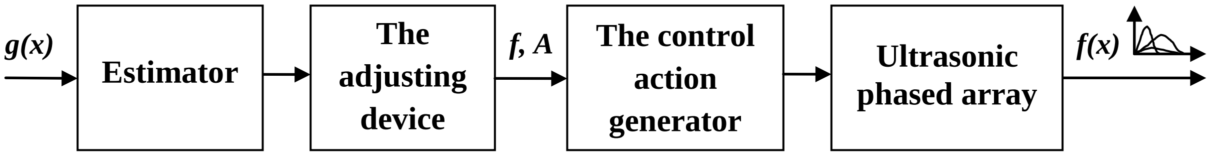

Figure 2. The structure of the gas bubble size distribution automatic control system based on the technology of ultrasonic phased array.

Simulation results of the high energy ultrasound impact on the pulp solid and gas phases allow to form the required gas bubble size distribution function, which would coincide with the pulp solid phase particle size distribution in the flotationprocess.

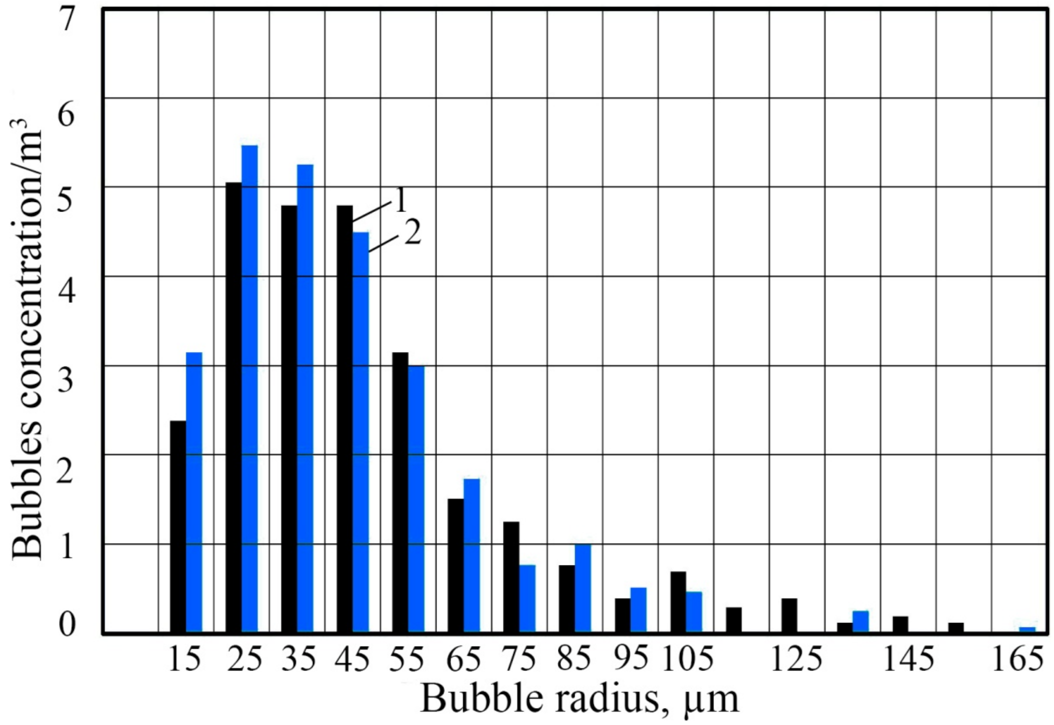

Figure 4. Bubble size distribution: 1- initial; 2 - resulting

Conclusions

The results of experimental studies of the proposed flotation control method based on ultrasonic phased array technology allows to implement the efficient control of the iron ore pulp solid and gas phases composition, to improve the quality of the concentrate and the energy efficiency of the whole beneficiation process.

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