Adaptive control system of the iron ore flotation using a control action based on high-energy ultrasound

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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 is described.
Key words: PHASED ARRAY ULTRASOUND, PULP, CONTROL, FLOTATION, BUBBLE SIZE DISTRIBUTION

One of the most common processes of separation in the mineral processing industry and the most complete and versatile mineral processing operation is flotation. The optimal degree of minerals separation in the flotation process under mineral raw materials characteristics changing is achieved by controlling the amount of air supplied to the float chamber, the froth thickness and pulp level, as well as the impeller performance [1]. The problem of ore minerals fine particles extracting is solved by the microflotation method, which is based primarily on the choice of the optimal gas bubble size and the optimal reagent, and requires the use of small bubbles with a diameter of at least 100 microns and lower [2]. Thus, for each technological variety of minerals in the process of its beneficiation by flotation or microflotation, to obtain a high rate of mineral components extraction, it is required to generate a certain pulp gas phase bubble size distribution, which should be maintained in all modes of technological equipment operation. Existing methods and flotation automatic control systems do not allow to control efficiently the gas phase parameters in the conditions of medium parameters changing and technological equipment state, or are quite costly and complicate the ecological situation.

The aim of research is the development of principles, structure and iron ore flotation adaptive control system using a control action based on high-energy ultrasound with a specified frequency and intensity.

In order to form a specified gas bubbles size distribution, which would correspond to the pulp solid phase particle size distribution in the flotation process, it is necessary to influence on the pulp flow with high-energy ultrasonic oscillations with specified intensity and frequency in the sequence described in [3-5, 8-13]: in the froth flotation process using a granulometric composition sensor the information about the pulp solid phase parameters (concentration and particle size distribution) is continuously received. The signal with this information is supplied to the computing device, which determines the required parameters of the gas phase. Further, from the computing device signal the control device (controller) determines the desired values of the intensity and frequency of electric oscillations, which are then supplied to control action generator block (controlled oscillator). The control action on the basis of the high-energy ultrasound dynamic effects forms focal length and focal spot size using phased arrays having a number of advantages, namely, the ability to set the input angle [6].

The control action generator generates a series of high-frequency electrical oscillations of fixed frequency and intensity, which are then supplied to the distributor designed on the basis of an ultrasonic phased array. The distributor converts received signal in volume ultrasonic oscillations and then the pulp with bubbles is exposed to high-energy ultrasound emitted by several phased array elements, which have different characteristics.

To estimate gas bubbles parameters in the liquid in the process of their free floating and under the influence of external forces the experimental setup was developed [3]. Block diagram of the experimental setup is presented in Figure 1. To fix the bubble sizes and raise velocities, the imaging system comprising a light source (6), a digital video camera GO PRO HERO 3 with 240fps (7) was used. The bubble position is extracted from the video recordings using the image processing procedures in Matlab.

Existing laboratory flotation machines allow users to customize the speed of mixing and flow velocity only manually, after a period of conditioning. Modernization and partial automation of these machines can be done through the application of new components, which can be turned on/off externally and adjusted by means of a PC. For this purpose the parameters of the pulp and formed ultrasonic action by the connecting analog measurement devices (sensors) to the computer was measured [7]. This allowed to register various parameters, such as pH, temperature, flow rate and air flow rate of the pulp (Fig. 2) using the MATLAB extension package - Data Acquisition Toolbox.

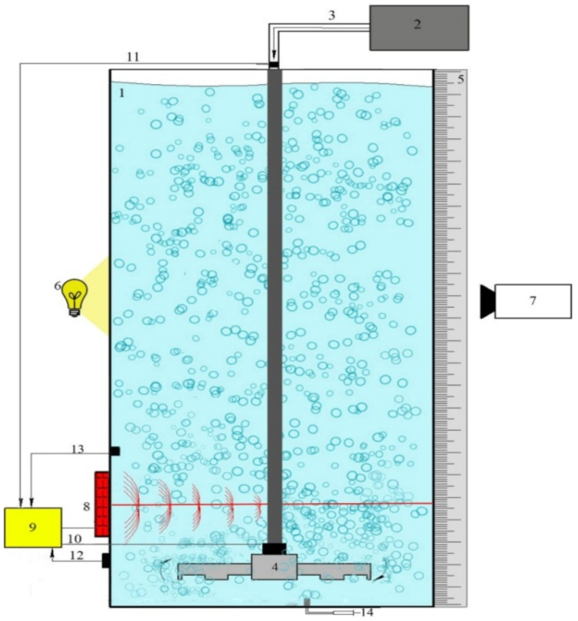

Figure 1. The experimental setup diagram: 1-tank with the liquid; 2-compressor; 3-air duct; 4-the impeller; 5-scale; 6-lamp; 7-video camera; 8-ultrasonic phased array; 9-control system; 10-the impeller rotation speed sensor; 11-mass air flow sensor; 12-infrared thermometer; 13-pH-meter; 14-syringe

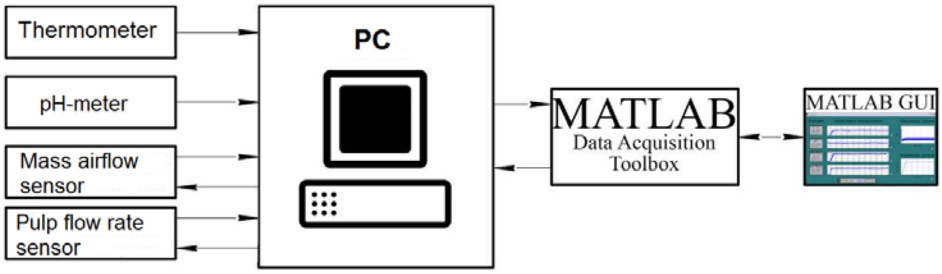

Figure 2. Block diagram of connections and device control

Graphical user interface (GUI) (Fig. 3) was programmed in Matlab in order to simplify the adjustment of parameters, as well as the overall management of the laboratory experimental setup [7]. The program window can be vertically divided into three sectors: in the left sector the average values of the measured parameters are set and displayed, in the middle sector the graphs of measured values of the specified parameters (temperature, pH, flow rate, pulp flow rate) are showed, and the right sector is the results of control system.

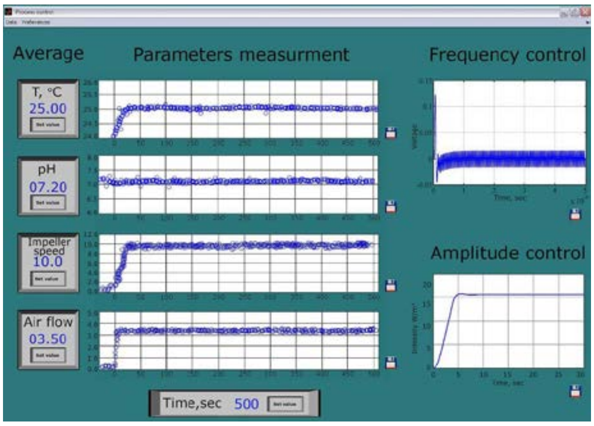

Figure 3. Graphical user interface of gas bubbles size distribution control system

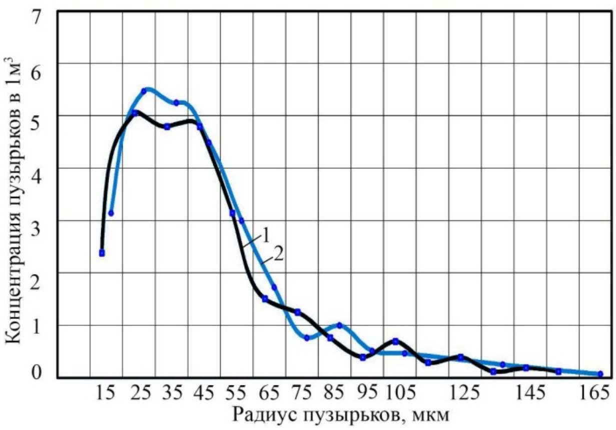

Figure 4. Comparison of the results of the specified gas bubble size distribution (1) and distribution generated with adaptive control system (2)

Fig. 4 shows that the developed system allows forming and maintaining the required gas bubble size distribution with high accuracy.

The proximity of the calculated 1 and experimental 2 data (Fig. 4), confirms the validity of the proposed method of the gas phase parameters automatic control.

The reproducibility of the experiments verified by Cochran's Q test. For all of the experimental data, the calculated value of Cochran's Q test is less than the tabulated values. Thus, the developed method and experimental software and hardware which implements its, allow to reconstruct correctly the gas bubbles size distribution function with an error not exceeding 2.7%.

Conclusions

Proposed automatic control system of gas bubble size distribution based on the ultrasonic phased array technology allows to implement the efficient control of pulp gas phase composition, adjust the aeration degree, increase the flotation speed, increase the concentrate quality and energy efficiency of the entire mineral processing process and can be implemented as a subsystem of the overall APCS flotation circuit following the subsystem foaming parameter optimization control.

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