Automatic control of the ore suspension solid phase parameters

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Abstract
Method of automatic control of ore suspension solid phase parameters, which comprise the forming of gamma rays and low-frequency volume ultrasonic waves in the ore material suspension flow, measurement of the intensity of gamma radiation and low frequency volume ultrasonic waves, is presented.
Keywords. ULTRASOUND, AUTOMATIC CONTROL, ORE, SUSPENSION, SOLID PHASE, GAMMA RAYS

The invention relates to acoustic measurements and can be used for automatic control of the main characteristics of the ore solids in suspension, in particular the concentration of solids, its size distribution and the useful component disclosure degree. The closest technical solution, which is selected as a prototype, is a method of automatic control of the ore suspension solid phase parameters [1]. The disadvantage of this method is that the Love waves intensity in the measuring chamber wall, which contacts with the controlled medium flow varies according to condition of the metal film on the measuring chamber wall, which is in constant contact with the ore suspension abrasive medium. Wear and removing of the metal film leads to ambiguity of measured values, which are determined according to the parameters of the ore suspension solid phase. Thus, the known method requires constant monitoring and determining the state of metal film on the wall of the measuring chamber, and is impossible in the existing production. This fact leads to errors and, consequently, reduces the stability and reliability of measurement results. The object of the invention is to improve a method of ore suspension parameters automatic control by increasing the stability and reliability of measurement results [2-4].

The problem is solved by the method of automatic control of the ore suspension solid phase parameters, which comprise the forming of ore suspension material flow and the reference fluid in the measuring chamber, periodic influence of ultrasonic vibrations on suspension flow, formation of high frequency volume ultrasonic waves in the ore suspension flow, intensity measurement of high frequency volume ultrasonic waves, which have passed a fixed distance in the presence of reference liquid and ore suspension flow in the measuring chamber in the periods of ultrasonic oscillations influence on suspension flow, and in case of its absence, and calculation of measured values ratios, according to which the parameters of ore suspension solid phase are determined [5-9]. According to the invention, gamma radiation and low frequency volume ultrasonic waves in the flow of ore material slurry are formed, the intensity of gamma radiation and low-frequency volume ultrasonic waves is measured.

The method is implemented as follows [10-11]. Firstly, the reference liquid (water) is fed into the measuring chamber. Gamma radiation in the measuring chamber is formed, and passes a fixed distance in it. The obtained result is attenuation of the gamma radiation intensity. This result is reference (basic). In operation condition, the ore material suspension flow in the measuring chamber is formed. Gamma radiation, which passes a fixed distance in the measurement chamber in the presence of ore material suspension flow, is formed. The attenuation coefficient of gamma radiation, which passed a fixed distance in ore suspension material flow, is determined by expression

$$\mu = (1-W)\rho_W \mu_W + W\rho_S \mu_S \qquad (1)$$

where μ_w and μ_s are the mass attenuation coefficients of water and suspension ore material respectively; p_w and p_s are the density of water and suspension ore material particles respectively; W is the volume fraction of ore particles in suspension.

The intensity of gamma radiation, which passed a distance l in ore suspension material flow, can be presented as follows

$$I = I_0 \exp\{-[(1-W)\rho_W \mu_W + W\rho_S \mu_S]l\}, \qquad (2)$$

where I_0 – is the intensity of gamma radiation in the absence of ore material slurry in measurement chamber.

If water is present in the measuring chamber, the intensity of gamma radiation will be determined by the formula

$$I^* = I_0 \exp(-\rho_W \mu_W l) . \qquad (3)$$

Considering (2) and (3), the intensity of gamma radiation can be represented as

$$I = I^* \exp\{-W[\rho_T \mu_T - \rho_W \mu_W]l\}. \qquad (4)$$

This value does not depend on the particle size of solid phase i.e. ore slurry material, and is determined only by the slurry solid phase concentration and its particles density. According to the proposed method, the value S_r for the gamma radiation is formed

$$S_\gamma = \ln\frac{I^*}{I} = AW[(\rho_S \mu_S - \rho_W \mu_W)l], \qquad (5)$$

where A – is the proportionality coefficient.

This expression shows that the density of the controlled medium, which depends on the ore suspension solid phase concentration and its particle density is determined by logarithm of intensity ratio of the gamma radiation in the presence of water flow and ore suspension in measuring chamber. Similarly, the value S_1 is determined for high frequency and S_2 for low frequency volume ultrasonic waves, which passed a fixed distance through the flow of water and ore suspension. Accordingly, the value S_l is determined by

$$S_1 = \ln\frac{I_{w1}^{vol}}{< I_{v1}(z) >} \qquad (6)$$

where ^{vol} - is the intensity of high frequency volume ultrasound waves, which have passed a fixed distance z through the flow of water; and $< I_{v1}(z) >$ - for ore suspension flow. Thus, the value S_1 is determined by the logarithm of intensity ratio of high frequency volume ultrasound waves, which have passed a fixed distance z through the flow of water and ore suspension.

For this

$$< I_{v1}(z) > = I_{w1}^{vol} \exp\left(-\frac{Wz}{\aleph}\int_0^{r_m}\sigma(v_1,r)F(r)dr\right), \qquad (7)$$

where $\aleph = \int_0^{r_m}\frac{4\pi r^3}{3}F(r)dr$; $F(r)$ – is the function of the solid phase particle size distribution in the ore suspension r; r_m – is the maximum solid phase particle size in the ore suspension; σ (v_l,r) – is the cross section of high frequency volume ultrasonic wave attenuation of frequency v on the particle of size r.

The value σ (v,r) for any frequency volume ultrasonic waves is determined by the sum of the absorption cross-sections σ_s (v,r) and scattering σ_c (v,r) of ultrasound

$$\sigma(v,r) = \sigma_c(v,r) + \sigma_s(v,r) \quad (8)$$

In high frequency region ($v_1 \geq 5 \cdot 10^6$) the ultrasound attenuation is caused mainly by scattering of ultrasonic waves on the solid phase particles: $\sigma_1(v,r) \approx \sigma_c(v_1,r)$. Therefore, the signal, which is generated at frequency $v_1 \geq 5 \cdot 10^6$ Hz will be determined by the size and concentration of ore slurry solid phase particles. Thus, value S_1 depends on the ore suspension solid phase particle size and its concentration W

$$S_1 = \frac{Wz}{\aleph} \int_0^{r_m} \sigma(v_1,r) F(r) dr \quad (9)$$

In the low-frequency region $v_2 \geq 5 \cdot 10^5$ Hz the ultrasound attenuation is caused by viscous inertial effects: $\sigma(v_2,r) \approx \sigma_s(v_2,r)$. Therefore, the signal, which is generated at a frequency $v_2 \geq 5 \cdot 10^5$ Hz will be proportional to the concentration of the ore suspension solid phase and independent of its particle size.

Accordingly, the value S_2 is determined by the expression

$$S_2 = \ln \frac{I_{w2}^{vol}}{< I_{v2}(z) >} \quad (10)$$

For this

$$< I_{v2}(z) > = I_{w2}^{vol} \exp\left(-\frac{Wz}{\aleph} \int_0^{r_m} \sigma(v_2,r) F(r) dr \right), \quad (11)$$

Thus the value S_2 depends on the concentration W of ore suspension solid phase and does not depend on its particle size:

$$S_2 = \frac{Wz}{\aleph} \int_0^{r_m} \sigma(v_2,r) F(r) dr \,. \quad (12)$$

If we divide (6) by (10), we can obtain a value S, which depends on the ore suspension particle size

$$S = \frac{S_1}{S_2} \,. \quad (13)$$

Measurement of the useful component content can be reduced to the determination of specific weight (density) of solid phase particles, which are located in the ore suspension. In the measuring chamber section, where the value S is determined, the flow of enriched material suspension is periodically exposed to high intensity ultrasonic waves. Due to the radiation pressure and acoustic flows, there is a displacement of ore suspension solid phase particles from the trajectory of their normal movement in the flow in the direction of high-intensity ultrasonic oscillations influence. Displacement of ore suspension solid phase particles leads to their redistribution by size and concentration in the high intensity ultrasonic oscillations influence zone. The value of this redistribution for the same particle size is determined only by the mineral composition (the ratio of the useful component and gangue) and specific weight (density) of each component. For solid phase particles of the same size, which are crushed to a particle size of useful component inclusions, the value of the displacement is proportional only to their specific weight. Thus, the change value of S parameter under the high intensity ultrasonic oscillations influence depends on the useful component content in the ore suspension solid phase fractions of various size. According to the proposed method the value S_r is determined as

$$S_r = k_1 \frac{S_B - S_0}{S_B} \quad (14)$$

where S_B – is the measured value S in the presence of high intensity ultrasonic oscillations influence; S_0 - is the measured value S in the absence of this influence; k_1 - is the proportionality coefficient.

To obtain a signal which depends on the useful component content of ore suspension solid phase fractions of corresponding size, i.e. disclosure of useful component, the ratio of $S_к$ is calculated

$$S_K = k_2 \frac{S_\gamma}{S_r} \quad (15)$$

All or only certain size classes of the crushed material i.e. a certain solid phase size fraction can be displaced in the measurement zone by increasing the intensity of ultrasonic oscillations from zero to a certain value and with ore suspension constant flow rate.

$$F(r) = \left(\int_0^{r_1} f(r) r^3 dr + \int_{r_1}^{r_2} f(r) r^3 dr + \ldots + \int_{r_{m-1}}^{r_m} f(r) r^3 dr \right) \Big/ \int_0^{r_m} f(r) r^3 dr \,. \quad (16)$$

Thus, the value S_K, which is calculated at a certain ultrasonic oscillations intensity in the ore suspension flow determines the density of solid phase particles or useful component concentration in ore suspension solid phase fractions of appropriate size.

Conclusions

Since all calculations are made on the basis of measurements relative to characteristics of the reference material, the obtained results are protected from various disturbing factors, which reduce the accuracy of measurement parameters of ore suspension solid phase.

Thus a method of ore suspension parameters automatic control allows to increase the stability and reliability of measurement results of ore suspension solid phase.

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