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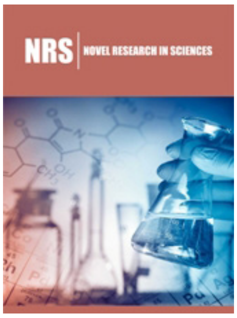
Mini Review

Increasing the Ore Processing Efficiency on the Basis of Raw Material Testing

ISSN: 2688-836X



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Submission: April 08, 2023

Published: July 28, 2023

Volume 15 - Issue 1

How to cite this article: Priadko O* and Muzyka L. Increasing the Ore Processing Efficiency on the Basis of Raw Material Testing. Nov Res Sci. 15(1). NRS.000854. 2023.
DOI: 10.31031/NRS.2023.15.000854

Abstract

A special role in the mineral enrichment belongs to sampling, as a method of obtaining information about the properties of the processed raw materials. However, during the period of delivery dressing plants and during technological processes, the properties of materials may change. This is important information for improving the efficiency of the enrichment process. The purpose of the work is to determine the impact of changing material characteristics during processing on the efficiency of the technological process. In paper the influence of a change in the ore hardness on the increase in sand amount and the possibility of identifying this fact by changing the energy consumption based on the control of the calculation of correlation functions are shown. It has been established that a decrease in inclusions leads to a multidirectional change in the separation output indicators, which is used to control changes in the content of a valuable mineral in the original ore. The change in the average value of the concentrate quality is determined with the help of calculating the integral of the correlation function for a certain time in the stationary mode.

Keywords: Enrichment; Separation; Hardness; Inclusion; Correlation functions

Introduction

The indicator values of enrichment signs are planned by the mining organization and enrichment (dressing) plant at least during the shift when raw materials with known enrichment characteristics are received. However, minerals (ore) are fed into the loading hopper, and the changing moment of these characteristics is not known in advance. At the same time, this is very important information, and it is necessary to know it in order to reduce losses in the control of the technological process.

The purpose

The purpose of the work is to determine the impact of changing material characteristics during processing on the efficiency of the technological process.

Main part

A. **Identification of changes in mineral hardness**

In the enrichment process, ore is divided into enriched material (concentrate) and sands (depleted ore, enrichment waste). Disturbance in the form of ore property changes is shown by a change in the sand load in the first stage of grinding. If the hardness increases, the fineness of grinding increases and a larger amount of crushed material goes into the sand. The load on the mill increases; therefore, the consumption of solids at the entrance of the mill increases, and this further increases the grinding size. But since the grain size of the sand is much smaller than the grain size of the original ore, the average grain size of the original ore stream decreases, which contributes to the reduction of the grinding grain size. Thus, during the change of ore hardness, two conflicting factors simultaneously act: one is aimed at increasing the amount of sand, and the other at reducing their amount. As a result, the transient process is stable, and a new value of the sand load is established.

The sand load in the first stage of grinding is 200-300% of the productivity of the original ore, that is, it is a very powerful load [1]. And the consumption of electricity for its transportation is significant. Thus, the drive of the spirals of the classifier records the change in the amount of sand by adopting new average values of power consumption; therefore, the average value of power consumption by the drive of the classifier corresponds to a certain value of the sand load. By measuring the average value of power consumed by the classifier drive, you can judge the amount of sand.

However, the average value of the amount of sand does not record the moment of appearance of the disturbance and therefore does not allow us to judge it. It is necessary to have a parameter that can record changes in sands over time. Since the process of energy consumption is random, the correlation functions reflect the process dynamics of changing ore properties. This process can be stationary or ergodic. An ergodic process is a random process for which the average value over time, obtained by averaging over a sufficiently large interval, in the limit infinite, for a single implementation of the random process, coincides with a unit probability to the corresponding probability characteristic obtained by averaging over many implementations. We evaluate the possibility of such a fixation of the disturbance appearance.

It is known that for a stationary and ergodic process, the correlation function does not depend on the moment of its reference.

$$K(t_i - \tau) = K(t_n - \tau) \quad (1)$$

Therefore, if we constantly calculate the correlation functions and perform its integration over a certain period of time T, then in the stationary mode we always have a certain constant number close to zero or to $\tilde{N} \geq \mu \to 0$

$$\int_0^T K(\tau)d\tau = C. \quad (2)$$

If at some point of time there is a change in the average value of the sand load, that is, the energy consumption changes, then the energy consumption process becomes non-ergodic, and the correlation function tends not to 0, but to a certain number C_1, which corresponds to the amplitude of the energy consumption jump (Figure 1). At the same time, the integral of the correlation function acquires a larger absolute value than that in the stationary mode.

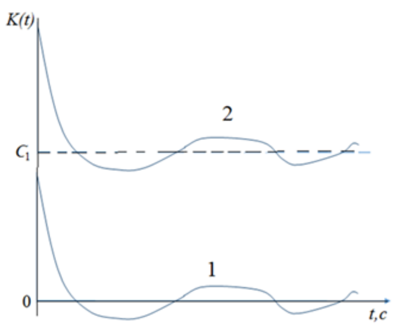

Figure 1: Correlation function for stationary (1) and non-ergodic (2) process.

$$\int_0^T K(\tau)d\tau = C_1. \quad (3)$$

Thus, the time and amplitude of the disturbance will be recorded.

The absolute value of the C_1 parameter must be memorized. A positive increase in C_1 corresponds to an increase in the amount of sand, that is, the hardness of the ore. A negative increase corresponds to an improvement in the grindability of the ore (a decrease in hardness). After the end of the transition process, the stationary conditions are restored again.

B. **Determination of the change in inclusion of a valuable ore component**

We consider this task by analyzing the disclosure of a valuable mineral and its separation. To do this, we consider a separating device with a separation characteristic that corresponds to the best separation, and we change the degree of disclosure [1] of the ore mineral. Let's consider how the disclosure affects the efficiency of separation by means of mathematical modeling based on the separation characteristics and the distribution functions of growths in the source feed [2,3].

Figure 2 shows the distribution functions of growths in two materials obtained for separation.

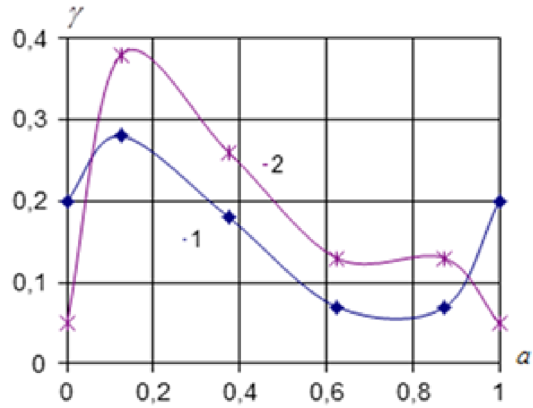

Figure 2: Distribution functions of materials growth.

Figure 3 shows the separation characteristic of the apparatus corresponding to the best separation of the material.

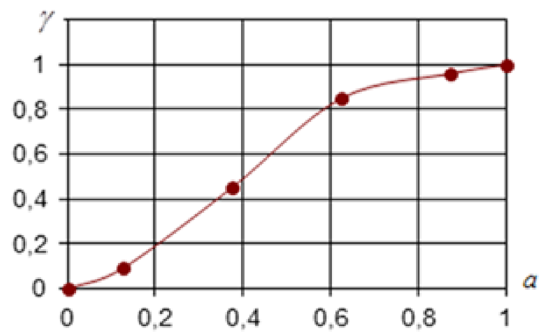

Figure 3: Separation characteristics of the separation apparatus of the ore enrichment process.

Usually, the content of various components is indicated by:

a - in the starting material, β - in concentrates, θ - in tailings (depleted materials). The output of any product is denoted by γ. Extraction (ε) is an indicator that determines what mass part of a valuable component has passed into the concentrate, expressed in % or in fractions of a unit.

The initial and estimated data for the ore are given in the Table 1.

Table 1: Ore indicators.

Content			Separation Characteristic P	Calculated Value					
Valuable Component	Fraction 1 ΔF_1	Fraction 2 ΔF_2		Σ_1	Σ_2	Σ_3	Σ_4	Σ_5	Σ_6
1	2	3	4	5	6	7	8	9	10
0	0,2	0,05	0	0	0	0	0	0	0
0,125	0,28	0,38	0,09	0,035	0,0238	0,025	0,034	0,004	0,004
0,375	0,18	0,26	0,45	0,068	0,098	0,081	0,117	0,044	0,042
0,625	0,07	0,13	0,85	0,044	0,081	0,06	0,111	0,069	0,043
0,875	0,07	0,13	0,96	0,061	0,114	0,067	0,125	0,199	0,067
1	0,2	0,05	1	0,2	0,05	0,2	0,05	0,05	0,12
				0,408	0,391	0,433	0,437	0,276	0,276

We calculate the characteristics of two materials (ore):

$$\gamma_1 = \Sigma_3; \gamma_2 = \Sigma_4; \beta_1 = \frac{\Sigma_5}{\Sigma_3}; \beta_2 = \frac{\Sigma_6}{\Sigma_4}; a_1 = 0,408,; a_2 = 0,391;$$

$$\gamma_1 = 0,433; \gamma_2 = 0,437; \beta_1 = 0,8453; \beta_2 = 0,6316,$$

Where γ_i - output i product,

β_i - The content of the valuable component in the concentrate;

a_i is the content of valuable component i in the initial ore.

Enrichment efficiency is an indicator that characterizes the perfection of the separation process. To assess the technological efficiency of the enrichment process, the Luyken-Hancock formula is most often used, where the technological efficiency indicator is defined in % (4.3) or in fractions of a unit:

$$\eta = 100(\varepsilon_c - \gamma_c) / (100 - a), \quad (4)$$

$$\eta = (\varepsilon_c - \gamma_c) / (1 - a), \quad (5)$$

Where η is the technological efficiency of enrichment;

$\varepsilon_c = \gamma_c \beta / a$ - extraction of a valuable component in the concentrate,

a - the mineral content in the initial ore.

In our case, the values of the criterion are as follows:

$$\gamma_i = 0,433; \gamma_2 = 0,437; \beta_1 = 0,8453; \beta_2 = 0,6316,$$

$$\eta_1 = 0,2747; \eta_2 = 0,1637.$$

Thus, with reduced indicators of mineral disclosure, the efficiency of separation, that is, the efficiency of enrichment decreases.

Let's determine the direction of change of the separation quality indicators when the disclosure of a valuable mineral changes. We use the above data and supplement the calculations by determining the loss of a valuable mineral in the depleted product, that is, in the tails. We summarize the calculations in the Table 2.

Table 2: Calculated data.

α	ΔF_1	ΔF_2	P	1-P	γ_{t1}	γ_{t2}	θ_1	θ_2
1	2	3	4	5	6	7	8	9
0	0,2	0,05	0	1	0,2	0,05	0	0
0,125	0,28	0,38	0,09	0,91	0,255	0,346	0,032	0,043
0,375	0,18	0,26	0,45	0,55	0,099	0,143	0,037	0,054
0,625	0,07	0,13	0,85	0,15	0,011	0,02	0,007	0,012
0,875	0,07	0,13	0,96	0,04	0,003	0,005	0,002	0,005
1	0,2	0,05	1	0	0,0	0,0	0,0	0,0
					0,567	0,564	0,078	0,114

The loss of a valuable component in the tailings (its output) is determined by the formula:

$$\gamma_t = 100 * (\beta - a) / (\beta - \theta),$$

and extraction of the valuable component in the tails is determined according to the formula: $\nu_1 = \gamma_t \theta / a$

In the considered case, these values are:

$$\nu_1 = 0,138; \;\; \nu_2 = 0,202;$$

Therefore, a decrease in the disclosure rate causes the increase in the loss of the valuable component in the tailings.

Studies have shown that a change in the disclosure under unchanged separation parameters leads to a multidirectional change in the quality indicators of the concentrate and tailings [3]. Thus, in one method of separation, when the disclosure of a valuable mineral is changed, it is possible to simultaneously increase the quality of the concentrate and reduce the losses of the valuable mineral in the tailings, and vice versa. If we estimate the correlation between losses in the tailings and the quality of the enriched product at the first separation stage, then a negative correlation indicates that there has been a change in the inclusion of a valuable mineral in the original ore.

So, as it follows from the results of the calculations, a decrease in interpolation leads to a multidirectional change in the initial separation indicators: losses of valuable minerals increase, and the quality of the enriched product decreases; that is, there is a negative correlation between the initial separation indicators.

Thus, if we observe the separation indicators, we have two sequences of numbers: β_i, ν_i. By averaging them over a certain time interval, which smooths out the high-frequency components and isolates the non-random component, it is possible to determine the correlation coefficient between them in time [3]:

$$K_{\beta\nu}(t) = \frac{1}{T}\Sigma(\beta_i - \overline{\beta})(\nu_i - \overline{\nu}). \quad (6)$$

In the stable mode of the technology, the correlation coefficient is equal to zero.

If the sign of the correlation coefficient becomes non-zero and positive, then a change has occurred:

A. The disclosure of a valuable mineral by changing the operating parameters of the devices and the size of the particles in the discharge of the classifier;

B. Or the average content of a valuable mineral in the original product has changed;

C. Or the grindability of the original ore has changed.

D. Thus, the positive correlation does not give an definite answer, which affected the results of the deviation of the separation product quality.

E. If the sign of the correlation coefficient becomes negative, then this clearly indicates that there has been a change in dispersion:

F. If the impregnation has increased, then the quality of the concentrate increases, and the losses decrease;

G. If the dispersion decreases, the quality of the concentrate decreases, and the losses increase.

In both cases, the correlation coefficient becomes negative.

Thus, the appearance of a negative correlation between the change in the content of a valuable mineral in enriched and depleted products clearly indicates a deviation in the dispersion. If at the same time the quality of the concentrate increases, then the dispersion has increased; if the quality of the concentrate decreases, then the impregnation has decreased.

Thus, it is possible to fix the moment of change of the enrichment characteristic with the help of correlation indicators, but the result of its change can be evaluated only after the end of transitional process in the technological line. With the help of mathematical modeling of the equipment operation, it is possible to determine the duration of the transient process, but this is always associated with a certain uncertainty. It is necessary to reliably estimate the moment of the end of the transition process.

The transition process is indicated on the correlation function by the transition from one ergodic state to another. The intermediate state is a non-ergodic process. Thus, if we constantly calculate the correlation functions and perform its integration over a certain period of time T, then in the stationary mode we always have a certain constant number close to zero.

If at some point of time there is a change in the average value of the concentrate quality, then the process of changing the correlation function for the quality of the concentrate tends not to 0, but to a certain number that corresponds to the amplitude of the jump in the change in the quality of the concentrate (Figure 1). At the same time, the integral of the correlation function will acquire a larger absolute value than in the stationary mode. Thus, the time of the end of the transition process (from the moment of the jump of the correlation function from the impregnation to the jump of the correlation function of the quality of the concentrate) and the amplitude of the quality change are recorded.

C. **Determination of changes in the content of a valuable mineral.**

The hardness of the valuable component, for example, magnetite for iron ore, and the host rock differ significantly, and with an increase in the content of magnetite, the hardness of the ore decreases, that is, the crushing ability improves, but within the limits of variable, daily, or even weekly changes, this effect is within the error of determining the content of the valuable mineral. The work [4] gives the results of research on determining the dependence of the iron ore hardness on the content of magnetite in it. This dependence can be linearly approximated by a positive correlation. However, the confidence intervals are quite wide and a change in the content of a valuable mineral within 10% is within the margin of error. It should be taken into account that when the content of a valuable mineral changes, the mode parameters of the grinding unit do not change, but the disclosure changes. This affects the separation indicators: the quality of the enriched product and the loss of the valuable mineral in the tailings change in one direction.

Conclusion

Criteria for identifying changes in the main characteristics of ore during the enrichment process have been established. By the content of the valuable mineral in the enriched product in the crushing-separation enrichment unit, it is possible to determine the change in the content of the valuable mineral in the original ore. It is possible to fix the moment of change of the enrichment characteristic with the help of correlation indicators, but the result of its change can be evaluated only after the technological line has reached a stationary mode. The change in the average value of the concentrate quality is determined with the help of calculating the integral of the correlation function for a certain period of time in the stationary mode.

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