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Optimization of grinding in reverse flotation for bauxite①

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[Abstract] The reverse flotation for desiliconization form bauxite is better than direct flotation, and the grinding before flotation affects the flotation indexes to some extend. The grinding dynamic equation of bauxite based on the data of grinding experiment of diasporic bauxite was derived. The calculated value of the equation is identical with the experiment value. Further the grinding dynamic equation of intermediate grain size range suitable for reversal flotation has also been derived. The grinding time required could be calculated when the mass fraction of intermediate size grain is maximum. The formulation of grinding dynamic equation considerably simplified the grinding experiment, optimized the grinding process.

[Key words] bauxite; grinding dynamics; optimization
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1 INTRODUCTION

The bauxite is the important material for aluminum industry and refractory industry. Bauxite resources in China are rich[1]. The explored reserves are 2.3 billion tons. However, most of them are high alumina and high silicon diasporic bauxite and the ratio of aluminum to silicon is low. The main method of bauxite processing for desiliconization is flotation (including direct flotation and reversal flotation)[2]. On the technological principle and linking with follow-up Bayer's process the reversal flotation for desiliconization is advanced and more reasonable than reversal flotation. It is helpful for reducing mineral processing cost, coarsing the grain size of the concentration, improving dewatering performance of the concentration and avoiding influence of flotation collectors on the Bayer's process. Because dissemination size of diasporite and gangue-aluminum silicate is fine, a certain grinding fineness shall be reached to separate the aluminum silicate from ores. But if grain size of bauxite is too fine, the pulp dispersion is poor. Heter-coagulation will occur and the floatation index will be greatly influenced.

Therefore, the proper grinding time is very important. The present study is to determine the optimal grinding time in order to obtain the suitable particle size range for reversal flotation through establishing the grinding dynamic equation.

2 INVESTIGATION OF GRINDING DYNAMICS

2.1 Basic equation of grinding dynamics

Through the investigation and experiment[3~5] that based on relationship of the reduction of the coarse grain content and grinding time lasting, the following equation was obtained

$$R = R_0 \exp(-kt^m) \quad (1)$$

or

$$R_0 / R = \exp(kt^m)$$

where R is the mass fraction (%) of coarse grain at instantaneous grinding time t, R_0 is the mass fraction of coarse grain of the feed material, and t is grinding time. The value of parameter m and k depends on the feature and grinding condition of the material to be ground. The value of m mainly depends on homogeneity, strength of the ground materials and size feature of grinding medium in a grinding mill. Value k mainly depends on grinding size, the finer the material is ground, the smaller the value k is and the bigger the value m is.

2.2 Determination of parameters in equation

To determine the grinding dynamics equation of diasporic bauxite, values m and k in the basic equation must be determined. The parameters can be determined either with diagrammatic method or calculation method[6]. The paper uses calculation method to determine the parameters of the equation.

If the mass fraction of the product are R_1 and R_2 corresponding to the grinding time t_1 and t_2, then we get

$$R_0 / R_1 = \exp(kt_1^m) \quad (2)$$

$$R_0 / R_2 = \exp(kt_2^m) \quad (3)$$

Taking logarithm from Eqns. (2) and (3) respectively, then

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$$\ln \frac{R_0}{R_1} = kt_1^m \quad (4)$$

$$\ln \frac{R_0}{R_2} = kt_2^m \quad (5)$$

Thus

$$m = \frac{\ln \dfrac{\ln(R_0/R_1)}{\ln(R_0/R_2)}}{\ln(t_1/t_2)} \quad (6)$$

and the value k can be obtained:

$$k = \frac{\ln \dfrac{R_0}{R_1}}{t_1^m} = \frac{\ln \dfrac{R_0}{R_2}}{t_2^m} \quad (7)$$

2.3 Formulation of equation of grinding dynamics

According to grinding experiment of one kind diasporic bauxite, grinding time for mass fraction of 30% and 10% of + 0.076 mm grain is shown in Table 1.

Table 1 Grinding results of bauxite

Grinding time / min	Mass fraction of + 0.076 mm grain	Mass fraction of + 0.076 mm grain in feed ore
930	30%	81.76%
1 370	10%	

Substitute the data in Table 1 to Eqn. (6) we get

$m = 1.91$

Substitute value m in Eqn. (7) we get

$k = 2.14 \times 10^{-6}$

Then grinding dynamics equation of this kind of diasporic bauxite is

$$R = 81.76 \exp(-2.14 \times 10^{-6} t^{1.91}) \quad (8)$$

where R is the mass fraction of + 0.076 mm grain.

To prove accuracy of the above grinding dynamics equation, the calculation values and experimental values are compared (as shown in Table 2). It can be seen that the experimental values and calculated values are well identical.

Table 2 Comparison between experimental values and calculated values

Grinding time / min	Mass fraction of + 0.076 mm grain/ %	
	Experimental value	Calculated value
774	40	40.42
1 152	20	18.14

3 DETERMINATION OF OPTIMAL GRINDING TIME

In order to guarantee liberation degree of diasporic bauxite and gangue-aluminum silicate and avoid sliming, the grain size range suitable for reverse flotation is 10～ 80 μm[7]. The dynamics equation for grain size range of $A \sim a (A > a)$ is needed to be derived to obtain the required grinding time when the grain size range suitable for reverse flotation is the highest[8, 9].

According to the Eqn. (1), the dynamics equations of grinding for sizes A and a are

$$R_A = R_{0,A} \exp(-k_A t^{m_A}) \quad (9)$$

$$R_a = R_{0,a} \exp(-k_a t^{m_a}) \quad (10)$$

Then the grinding dynamic equation of intermediate grain size ($a \sim A$) is

$$R_a - R_A = R_{0,a} \exp(-k_a t^{m_a}) - R_{0,A} \exp\cdot(-k_A t^{m_A}) \quad (11)$$

The guide will be got for t at both sides:

$$\frac{d(R_a - R_A)}{dt} = -R_{0,a} \cdot k_a m_a t^{m_a - 1} \cdot \exp(-k_a t^{m_a}) + R_{0,A} \cdot k_A m_A t^{m_A - 1} \cdot \exp(-k_A t^{m_A})$$

If the value of $(R_a - R_A)$ is the highest, then $\frac{d(R_a - R_A)}{dt} = 0$, and

$$\frac{R_{0,a} k_a m_a}{R_{0,A} k_A m_A} = \frac{t^{m_A - 1} \cdot \exp(-k_A t^{m_A})}{t^{m_a - 1} \cdot \exp(k_a t^{m_a})} \quad (12)$$

Through Eqns. (6) and (7), values m and k in the grinding dynamic equation of the mineral with different grain sizes can be calculated and substitute them in the above equation, the grinding time required when the mass fraction of intermediate size, $(A \sim a)$, grain is the highest.

Giving

$c = \frac{R_{0,a} k_a m_a}{R_{0,A} k_A m_A}$, then

$\ln c = k_a t^{m_a} - k_A t^{m_A} + (m_A - m_a) \ln t$

In case of $m_a = m_A$,

$$t = \sqrt[m]{\frac{\ln c}{k_a - k_A}} \quad (13)$$

Substitute value t in Eqn. (11), the maximum value of mass fraction of $A \sim a$ sizes grain can be obtained:

$$R_a - R_A = R_{0,a} \exp\left[\frac{-k_a \ln c}{k_a - k_A}\right] - R_{0,A} \exp\left[\frac{-k_A \ln c}{k_a - k_A}\right] \quad (14)$$

Eqn. (13) gives the grinding time required, and the maximum mass fraction of the intermediate grain can be calculated through Eqn. (14) when mass fraction of intermediate $(A \sim a)$ grain is the highest[10, 11]. These two equations have been testified as reported elsewhere.

4 CONCLUSIONS

1) Because the dissemination sizes of diasporite and gangue-aluminum silicates are finer, its optimal grinding condition should be determined in order to fully dissociate them and be suited to the reversal flotation.

2) The grinding dynamic equation of diasporite is derived through calculation. The results calculated with this equation are identical with the results of experiment.

3) The calculation formula for grinding time required when the mass fraction of optimal grain suitable for flotation are the highest is derived so it guides the determination of grinding time and optimizes the grinding process.

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