Establishment of the Selectivity Index in Flotation Process

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The flotation process is the process of concentrating the targeted valuable mineral components so it requires the maximum productivity and concentration.

The index, called concentrating efficiency at presence, has been defined as the d recovery difference of values between gangues carried by froth,

$$\eta = \varepsilon_c - \varepsilon_g \tag{1}$$

where η is concentrating efficiency, and ε_c, ε_g are recoveries of valuable mineral and gangue respectively [3]. The concentrating efficiency was introduced in order to consider the recovery of gangue in concentrate because the recovery of concentrate reflects the quantitive aspect only. However the index has some defects. If the valuable component is one, the concentrating efficiency can be written as,

$$\eta = \frac{\varepsilon - \gamma}{1 - \alpha} \tag{2}$$

where γ is concentrate recovery, α is grade of feed. Equation (2) was derived from mass balance equations for the concentrate recovery and gangue one,

$$\varepsilon_c = \frac{\gamma\beta}{\alpha} \tag{3}$$

$$\varepsilon_g = \frac{\gamma(1-\beta)}{1-\alpha} \tag{4}$$

where β is the grade of concentrate. As seen from Eq. (3) and (4), β is involved in both equations. It shows that the quantitative index and qualitative index were not defined strictly. In addition, it is not analytical derivation that the gangue recovery is subtracted from the concentrate recovery. That is subjective intention to estimate the qualitative aspect in the same dimension of concentrate recovery.

There are some attempts to quantitify strictly the separating degree of concentrate from gangue. In the literature [4], omega-transformation applied from the character of flotation process which the lower grade of tailings is, more difficult to decrease that is, or the higher grade of concentrate is, more difficult to increase that is. As reported in literature [4], because

the grade of concentrate and tailing, concentrate recovery and yield are varied at every stage and so the concentrating efficiency value is varied, it is difficult to apply the index to optimization of flotation process.

1. Dynamic Characteristics of Selectivity

In every stage, the values of flotation indices are varied regular because the selectivity of flotation is dynamic variable. The various types of rate equation related to flotation rate in aspect of flotation engineering [5－7]. Based on the parabolic model of flotation rate equation[1], we proposed the flotation rate equation [2],

$$d\varepsilon/dt = k_\varepsilon(1-a\varepsilon)^2$$

$$\varepsilon = \frac{t}{b_\varepsilon + a_\varepsilon t} \tag{5}$$

$$\frac{d\gamma}{dt} = k_\gamma(1-a_\gamma\gamma)^2$$

$$\gamma = \frac{t}{b_\gamma + a_\gamma t} \tag{6}$$

where a_i, b_i are kinetics parameters. $b_i = 1/k_i$ is reciprocal of rate constant (initial rate).

From the Eq. (5), (6),

$$\varepsilon = \frac{\gamma}{B + A\gamma} \tag{7}$$

Eq. (7) shows the change of valuable minerals recovery. Parameter A, B are defined as follow:

$$A \equiv (a_\varepsilon - a_\gamma b_\varepsilon/b_\gamma)$$
$$B \equiv b_\varepsilon/b_\gamma \tag{8}$$

2. The Analytical Basis of Selectivity

The well known equation

$$\varepsilon = K \cdot \gamma \quad (K = \beta/\alpha: \text{grading ratio}, \ \beta: \text{concentrate grade}) \tag{9}$$

shows that the concentrate recovery is a function of the yield and rich ratio, $\varepsilon = f(K, \gamma)$.

From the total differential of Equation (3)

$$d\varepsilon = \frac{\partial\varepsilon}{\partial K}dK + \frac{\partial\varepsilon}{\partial\gamma}d\gamma, \tag{10}$$

the differential of recovery is given by:

$$d\varepsilon = \gamma dK + Kd\gamma \tag{11}$$

The differential form of Eq. (5) is

$$\frac{d\varepsilon}{dt} = \gamma\frac{dK}{dt} + K\frac{d\gamma}{dt} \tag{12}$$

Eq. (6) shows that the flotation rate ($d\varepsilon/dt$) is related to yield rate ($d\gamma/dt$) and the rate of rich ratio change (dK/dt). We define this relationship as the correlation rule of flotation rate.

As Eq. (6) shows, the flotation rate can't be higher than $K\left(\dfrac{d\gamma}{dt}\right)$ because the value of the first term in the right side is negative.

$$\left(\frac{d\varepsilon}{dt}\right)_0 = k = K\left(\frac{d\gamma}{dt}\right)_0 \tag{13}$$

On the other hand, from Eq. (5) the other differential form is given by:

$$\frac{d\varepsilon}{d\gamma} = \gamma \cdot \frac{dK}{d\gamma} + K \tag{14}$$

Eq. (14) doesn't show recovery change vs. yield change, but also how the rich ratio changes with yield in flotation. Eq. (7) represents the kinetics property unlike separating efficiency.

In order to avoid confusion we defined left side of Eq. (7) as grading ratio as follows;

$$d\varepsilon / d\gamma = S_E \tag{15}$$

We called S_E as differential concentrating ratio.

3. Meaning Concentrating Ratio

The grading ratio is a dynamic concept, because of $\dfrac{d\varepsilon}{d\gamma} = \dfrac{d\varepsilon/dt}{d\gamma/dt}$.

The grading ratio is essentially a ratio of flotation rate and yield rate at given time. This variable is related to rich ratio, but is different from it. Consequently, the method that evaluates the reagent systems by comparing the values of rich ratios is reasonable at only initial time.

If the flotation rate and yield rate equation are known, the grading ratio can be calculated easily at arbitrary time and yield using its kinetics parameters. A lot of flotation rate equation model involving the first-order model were proposed.[3-5]

Using the precedent research result that the flotation rate and yield rate are according to parabolic model, the grading ratio can be as follows:

$$\Delta S = \Delta\varepsilon / \Delta\gamma = \varepsilon / \gamma \ \ (t=0,\ t=t) \tag{16}$$

According to parabolic model, recovery vs. time and yield vs. time equation can be written as

$$\varepsilon = \frac{t}{b_\varepsilon + a_\varepsilon t}$$

$$\gamma = \frac{t}{b_\gamma + a_\gamma t}$$

The function $\varepsilon(\gamma)$ converted from Eq. (9) and (10) is given below.

$$\varepsilon = \frac{\gamma}{\dfrac{b_\varepsilon}{b_\gamma} + \left(a_\varepsilon - a_\gamma \dfrac{b_\varepsilon}{b_\gamma}\right)\gamma}$$

The rewritten equation is

$$\varepsilon = \gamma/(B + A\gamma) \qquad (17)$$

where, $A = a_\varepsilon - a_\varepsilon b_\varepsilon / b_\gamma$, $B = b_\varepsilon / b_\gamma$.

Based on the Eq. (12), the grading ratio can be lead as follow

$$S = \frac{d\varepsilon}{d\gamma} = \frac{B}{(B + A\gamma)^2}$$

or

$$S = d\varepsilon / d\gamma = (1 - A\varepsilon)^2 / B \qquad (18)$$

Parameter B means a ratio of initial yield rate and initial recovery rate. On the other hand from Eq. (12)

$$\gamma / \varepsilon = 1 / K = B + A\gamma$$

When value of γ equals 1, ε also equals 1 and so $A + B = 1$. The grading ratio S is ratio of recovery rate and yield rate, so that it is discussed at a given time and overall flotation process can not be evaluated by itself. However, parameter A and B can become indexes that evaluate flotation process. The value of parameter B is in range of $0 \sim 1$ and the smaller its value is, the higher selectivity is. In contrast, the bigger value of A is, the higher selectivity is. Arrangement of Eq. (15) introduced $B = 1 - A$ results in

$$A = (1 - \alpha/\beta)/(1 - \gamma) \qquad (19)$$

where β is the grade of concentrate, α/β is reciprocal of rich ratio, K.

The parameter A is related to both the rich rate and yield and the bigger value of yield and rich ratio are, the bigger its value is. It shows obviously that its physical mean differs from separating efficiency. (See Eq. (2)) We call the parameter A, grading degree and defined it as the selectivity index of flotation process.

Conclusion

We considered the dynamic mean of selectivity and indicated that the selectivity of overall process could not be evaluated by the separating efficiency and rich ratio.

We proposed the concept of grading degree that characterized the dynamic selectivity of flotation based on the parabolic model.

References

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