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OPTIMAL COMBINING PREDICTION FOR BLENDING EFFICIENCY①

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ABSTRACT By means of analysing the mechanism of blending materials, a general blending efficiency model was proposed. Applying this general model to an example, a suitable formula of blending efficiency which is more accurate than those in papers[2-3] was obtained. Finally, a high-precision optimal combining prediction formula for calculating blending efficiency was proposed.

Key words blending efficiency optimal combining prediction correlation fluctuation statistical independence normal distribution

1 INTRODUCTION

The purpose of setting up blending materials systems is to offer the blended ore which conforms with the demands of sintering plant and blast-furnace. In this paper, on the basis of analysing the mechanism of blending materials, we established a formula of blending efficiency for accurate prediction.

2 ELEMENTS DETERMINING THE BLENDING EFFICIENCY

The blending efficiency H is defined as the ratio of the feed standard deviation S_A to the discharge standard deviation S_B, namely,

$$H = S_A / S_B \qquad (1)$$

In accordance with the structure of blending materials system and the process of blending materials operation, the following conclusions were obtained:

(1) The physical and chemical behaviours (including composition, size, water content and stickiness, etc.) of the feed are the main elements determining the blending efficiency. For example, concentrate blending or concentrate burden blending is more difficult than pure fine ore blending; furthermore, the blending efficiency of single material is commonly lower than that of burden blending[1].

(2) The number of material layers is also a determining element. With the addition of the number of material layers and the superposition of raw materials, the fluctuation of raw material compositions will reduce[2].

(3) Unsuitable blending equipments will also directly affect the blending efficiency. For instance, in order to reduce efficiently the cross sectional fluctuation of clean ore blending stack, it is advisable to choose drum-type stacker-reclaimer[2].

As an overall conclusion, the blending efficiency H should be a tribasic function, so the more common model is:

$$H = H_1(N, S_A, C)$$

or $H = H(\sqrt{N}, S_A, C)$

where N is the number of raw material layers; C is the equipment efficiency parameter; S_A is the feed standard deviation.

3 BLENDING EFFICIENCY FORMULAS

3.1 *The Formula of Blending Efficiency in Ideal Case*

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Assuming that raw materials possess the following two ideal behaviours, that is:

(1) The fluctuation of raw material compositions is subject to normal distribution.

(2) The fluctuations of the raw material layers are uncorrelated with each other, i. e., they possess statistical independence.

In such a case, the formula of blending efficiency is as follows[5]:

$$H = S_A/S_B = \sqrt{N} \tag{2}$$

3. 2 *The Formula of Blending Efficiency in Non-ideal Case*

Vander Mooren A L had established the formula of blending efficiency in non-ideal case by introducing a self-correlation function $\Phi_a(K \cdot \Delta t)$[5]:

$$H = S_A/S_B = [1/N + 1/N^2 \sum_{K=1}^{N-1} (N - K)\Phi_a(K \cdot \Delta t)]^{-1/2} \tag{3}$$

Eqn. (3) shows that with the addition of raw material layers the value of $\Phi_a(K \cdot \Delta t)$ increases, thus the value of the term $1/N^2 \sum_{K=1}^{N-1} (N - K)\Phi_a(K \cdot \Delta t)$ increases markedly. As a result H would decrease, which means that the increase of self-correlation will destroy the advantages obtained from the addition of raw material layers.

In practice, Eqn. (2) is often used to calculate H because of the difficulty of obtaining self-correlation function. However, on the other hand, the error of H calculated by Eqn. (2) was so big that several other formulas were proposed. For example, without exact pre-burden, the feed composition fluctuations of blending with varied raw materials will not be subject to normal distribution, and the variation of blending efficiency with number of raw material layers N will be insignificant. In such a case H and S_A will assume approximately linear relationship, i. e., there is the following dual-element(S_A, C) formula[2]:

$$H = K(S_A + 1) \tag{4}$$

In addition to Eqn. (4) there are many other correction formulas, such as dual-element($\sqrt{N}$, C) correction formula[3]:

$$H = a\sqrt{N} + b \tag{5}$$

tri-element(N, S_A, C) correction formula[2]:

$$H = a\sqrt{N}S_A + b \tag{6}$$

where b denotes the equipment efficiency parameter in Ref. [2, 3].

3. 3 *Extended Correction Formula*

In China high-precision burdening equipments are generally set up in the raw material plants, so the composition fluctuation of the raw materials fed to blending stacks is approximately subject to normal distribution, which means the blending efficiency should be in direct proportion to $\sqrt{N}$. But considering that the process of blending is only an approximately ideal case and from the point of view of relations, there should exist interactions among the three elements N, S_A and C. Based on these reasons we proposed a more practical model for the calculation of blending materials efficiency, i. e.,

$$H = H(\sqrt{N}, S_A, C) = a_0 + a_{12}\sqrt{N}S_A + a_{23}S_AC + a_{31}C\sqrt{N} \tag{7}$$

where a_0, $a_{ij}(i, j = 1, 2, 3)$ are coefficients, a_{ij} denotes the correlation degree of dual elements, a_0 denotes the comprehensive correlation degree of all the three elements.

In order to test the reasonableness of the basic model(7), we quoted the test data (see Table 1) of drum-type stacker-reclaimer of the blending yard in Wuhan iron and steel company to carry on regression analysis and obtained the following formula:

$$H = 0.113\sqrt{N}S_A + 0.07\sqrt{N} + 1.1 \tag{8}$$

On the level of significance $\alpha = 0.05$ the regression Eqn. (8) is significant.

3. 4 *Optimal Combining Prediction Formula*

3. 4. 1 Theorem

Assuming that there are n prediction methods and N observed values for the same prediction problem, the weight of the i-th method is k_i, and $\sum_{i=1}^{n} k_i = 1$; E_i is the prediction error of the i -th method; e_i is the prediction error of the combining prediction; e is the matrix of the prediction error, and $e = [E_1, E_2, \cdots, E_n]$. Let $E = \boldsymbol{e}^T \boldsymbol{e} = (\boldsymbol{e}_{ij})_{n \times n}$, $K = [k_1, k_2, \cdots, k_n]^T$, then $J(K) = \sum e_i^2 = K^T E K$; let $R = [1, 1, \cdots, 1]^T$, consequently, the basic model for the calculation of the weights of optimal combining prediction can be written as[4]:

$$\min J(K) = K^T E K \tag{9}$$

$$\text{s.t. } R^T K = 1 \tag{10}$$

If vectors $\boldsymbol{e}_1, \boldsymbol{e}_2, \cdots, \boldsymbol{e}_n$ are of linear independence, then E is a symmetric, positive, definite matrix, thus E is invertible. Applying Lagrangian multiplier rule to Eqns. (9) and (10), the optimal combining weights can be obtained:

$$K = \frac{E^{-1} R}{R^T E^{-1} R} \tag{11}$$

3.4.2 Formula for Calculating H

Using the same data in Table 1, we obtained the following three different formulas:

$$H_1(N, S_A) = 0.113 \sqrt{N} S_A + 0.07 \sqrt{N} + 1.1 \tag{12}$$

$$H_2(N, S_A) = 0.17 \sqrt{N} S_A + 1.2^{[2]} \tag{13}$$

$$H_3(N, S_A) = 0.21 \sqrt{N} + 2.01 \tag{14}$$

To some extent each of these formulas denotes the operation efficiency of the drum-type stacker-reclaimer. Using the sum of error squares to evaluate these formulas, we found that Eqn. (12) possessed the highest exactness. Furthermore, applying the theorem of optimal combining prediction to these formulas, we obtained another formula as:

$$H(N, S_A) = 0.9221 \times H_1(N, S_A) + 0.0651 \times H_2(N, S_A) + 0.0128 \times H_3(N, S_A) \tag{15}$$

The results of the exactness of all the four formulas (12) to (15) are shown in Table 2. From Table 2 we know that J, the sum of error squares of formula (15), is the smallest, thus it is directive and referable to choose blending equipment of the blending yard in Wuhan iron and steel company.

Table 1 Trial data of drum-type stacker-reclaimer of Wuhan iron and steel company

Stack No.	S_A	N	$H^{1)}$	$H^{2)}$
1	0.829	62	3.46	2.400
2	4.235	74	5.35	5.829
3	0.717	55	1.68	2.230
4	1.843	54	2.93	3.173
5	7.507	34	8.05	6.556
6	4.902	63	6.90	6.137

Notes: 1)—actual values;
2)—values calculated by Eqn. (15).

Table 2 Weights and errors of the calculation of blending efficiency

Formulas	K (weight)	J (sum of error squares)
(12)	0.9221	$0.4969E+01$
(13)	0.0651	$0.7191E+01$
(14)	0.0128	$0.3992E+02$
(15)		$0.4598E+01$

4 CONCLUSION

In this paper we proposed a model of blending efficiency.

This model depicts the regularity of synergistic action of several elements and has been proved by the given example that it is more reasonable than other existing models.

Blending materials system is a grey system, and we don't know clearly its global behaviours or mechanism. But based on analysing the function of individual element, we first obtained the approximate formula of blending efficiency, and then the more accurate one by using optimal combining prediction theorem.

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