

# RISK DECISION ON 0.5 ORE BLENDING<sup>①</sup>

Shu, Hang

*Beijing Graduate School, China University of Mining and Technology, Beijing 100083*

Yang, Peng

*University of Science and Technology Beijing, Beijing 100083*

## ABSTRACT

On the basis of research information about the ore blending of a large iron opencast in China, risk of 0.5 ore blending and optimum risk-benefit analysis decision are discussed.

**Key words:** ore blending risk-benefit analysis decision

## 1 INTRODUCTION

Generally speaking, the higher the control level of ore quality is, the more the economic effects will be obtained by the mine. For a certain mine, its production technological and management levels are restricted, hence its ore quality control level is also restrictive. How to make out the optimum ore quality control scheme according to the production situations, objective technological conditions and management level, is the right problem to be studied in this paper.

## 2 POINT OUT PROBLEM

A large iron opencast in China produces five primary ores, then blends commodity ore of  $54 \pm 1.5\%$  grade for sale. According to previous research results, it has been shown that the lower the grade of commodity ore is, the better the mine's economic effect will be. Because iron ore selling price is calculated in the light of grade segments and its nearest integral number, i. e. if the iron grade varies from  $53.5\%$  to  $54.4\%$ , then the grade price is taken as that of  $54\%$ . Hence, the mine makes the iron grade vary from  $53.5\%$  to  $54.0\%$  to gain a good benefits, the reasons are discussed as follows:

(1) The more the grade of commodity ore

closes to  $53.5\%$ , the more the metal be saved, the more the newly increased finished ore output will be, when blended from lower grade ore;

(2) If the grade varies from  $53.5\%$  to  $54.49\%$ , the more the possibility of each ore blending grade lies upon  $53.5\% \sim 54.0\%$ , obviously the more the profit for the mine will be gained.

However, the lower the expectant index of blending grade is, i. e. , the closer the grade index closes to  $53.5\%$ , the more the possibility of reducing to a lower rank of commodity ore selling price will be. Because this will cause a great deal of economic loss, it's not expected or even not permissive for the mine. Fig. 1 shows the variations of corresponding ore blending outputs and output values

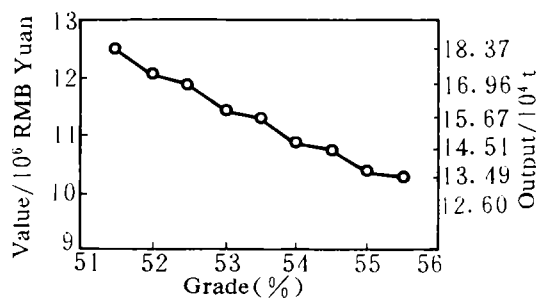


Fig. 1 Relation of different blended grades, finished ore outputs and output values

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for different grade segments.

Obviously, the profits caused by price ascending for grade up is far less than the profits caused by increasing output for grade descent.

Then according to the achieved ore quality control level of the mine, which grade should be selected to obtain optimum economic gain and its risk can be supportable. i. e. utilizing which grade index to organize the production, the risk-benefit is the idealst, it is just the problem to be discussed in this paper.

### 3 MATHEMATICAL DISTRIBUTION OF ORE BLENDING GRADE INDEX

On the basis of statistic analysis of blending informations of the researched mine in 1990, after the frequencies of commodity ore grade blended from various grade segments are treated with sliding-fit method, it's found that random variable  $x$ , which is the actual blended ore grade, accords with normal distribution of right-deviation bogarithm. its possibility density function  $f(x)$  is as follows,

$$f(x) = \frac{1}{(C-x)\sigma\sqrt{2\pi}} e^{-\frac{[\ln(C-x) - \mu]^2}{2\sigma^2}} \quad -\infty < x < C \quad (1)$$

According to maximum likelihood estimation, constant  $C$ , mean square deviation  $\sigma$  and even value  $\mu$  of  $\ln(C-x)$  can be decided as follows:

$$C = 59, \sigma = 0.06379, \mu = 1.65$$

Through the calculation of deviation-peak degree of the logarithm normal distribution, then we have:

$$C_s = -0.3504, C_e = 0.0804$$

And its critical values are:

$$D_s = 0.6188, D_e = 1.2376$$

Obviously,

$$|C_s| < D_s, |C_e| < D_e$$

Test on degree of deviation-peak is passed, the blended ore grade accords with normal distribution of right-deviation logarithm.

It must be explained that the blended ore grade can also pass through the normal distribution checking; but during ore blending, because of an ore blending tendency artificially, the possibility of actual finished blended ore grade inclined to right side of 53.5% should be greater than that of grade

inclined to left side of 53.5%. For this reason, utilizing right deviation mode of logarithm normal distribution will be more suitable for the objective fact.

### 4 RISK POSSIBILITY ANALYSIS

Supposed that  $C_0$  is expressed as expected grade of ore blending, the probable possibility of practical blended ore grade lower than  $C_0$  is as follows,

$$P = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{C_0} \frac{1}{(C_0-x)} \times e^{-\frac{[\ln(C_0-x) - \mu]^2}{2\sigma^2}} dx \quad (2)$$

In fact, the probable possibility, which can not satisfy the expected grade, is the failure rate of ore blending, i. e. it's the risk possibility borne by the mine. As far as guaranteeing to produce qualifiedores go, in the grade zone between 53.5% and 54.49%. The higher the grade, the more the possibility of qualified blended ore(of 53.5% commodity ore grade), and the less the risk held by the mine. We take 54% ore grade as product scheme, 53.5% ore grade as the optimum target, and organize the production in the light of different expected blending grades, the probable risk of failure undertaken by the mine are given as Table 1:

Table 1 Probable risk of failure undertaken by the mine

| Expected blending grade(%) | Possibility of risk failure(%) |
|----------------------------|--------------------------------|
| 53.50                      | 49.56                          |
| 53.60                      | 38.50                          |
| 53.70                      | 28.00                          |
| 53.80                      | 19.94                          |
| 53.90                      | 11.83                          |
| 54.00                      | 6.78                           |
| 54.10                      | 3.42                           |
| 54.20                      | 1.64                           |
| 54.30                      | 0.69                           |
| 54.40                      | 0.24                           |
| 54.49                      | 0.11                           |

From the calculation results above, if the mine is willing to endure greater risk, blending grade can be reduced as much as possible; on the contrary, if the mine is unwilling to bear too much

risk and organizes production according to ore selling contract of 54.0% grade, then only 6.78% of failure risk will be borne, 56.74% of grade carrying rate can be achieved, which is the ratio of grades between 53.5% and 54.0% calculated price in 54.0% grade.

## 5 OPTIMUM DECISION ON RISK-BENEFIT

### FIT

Not only to make the mine to get economic profits as much as possible, but also to ensure the mine to endure the risk, the comprehensive balance of risk and benefit must be involved. Probable-satisfactory degree is introduced to study this problem.

In mathematics, a certain real number  $q$  varying between 0 and 1 is used as the numeral mark of satisfaction for ore blending result. When  $q = 1$ , it's the most satisfactory; when  $q = 0$ , it's the most unsatisfactory according to above the analysis. Grade index 53.5% of ore blending is the best, and 53.6% is the next, 54.49% is the worst. Hence, the satisfactory degree of the finished ore blending grade ( $x$ ) can be expressed in function  $q = q(x)$ , and the expression is as follows:

$$q(x) = 54.5 - x \quad (53.5 \leq x < 54.5) \quad (3)$$

From the satisfactory degree point of view, obviously, when  $x$  equals 53.0%, the mine is the most satisfactory. Because of influence of random factors, a certain error ( $\varepsilon$ ) of the real finished blending grade always exists. For this reason, the expected blending grade ( $C_0$ ) plus random error ( $\varepsilon$ ) is the real finished blending grade, i. e.  $x = C_0 + \varepsilon$ .

From this point of view, if expected blending grade  $C_0$  is taken as 53.5%, the failure possibility of blending grade lower than 53.5% is the biggest, then the mine will bear maximum risk. Therefore when there is influence of random error  $\varepsilon$ , not only the satisfaction but also the realizable possibility should be considered.

It is supposed that expected blending grade is  $C_0$ , square deviation of random error is  $\sigma^2$ , and  $x \in [C_1, C_2]$ , the possibility equation of real blending grade  $x$  can be expressed as follows:

$$P(C_1 \leq x \leq C_2) = \frac{1}{\sigma \sqrt{2\pi}} \int_{C_1}^{C_2} \frac{1}{(C_0 - x)} \times e^{-\frac{[\ln(C_0 - x) - \mu]^2}{2\sigma^2}} dx \quad (4)$$

With the calculation formula of possibility and satisfaction, different blending schemes with influence of random error can be evaluated systematically by means of comprehensive probable-satisfactory degree indexes, and the probable-satisfactory degree is calculated by the following formula:

$$\Phi(x) = \frac{1}{\sigma \sqrt{2\pi}} \int_{-\infty}^{+\infty} \frac{q(x)}{(C_0 - x)} \times e^{-\frac{[\ln(C_0 - x) - \mu]^2}{2\sigma^2}} dx \quad (5)$$

If a certain  $x^*$  makes  $\psi(x)$  to get maximum, then the  $x^*$  is the expected blending grade and can be solved from the integral equation as follows:

$$\Phi'(x^*) = 0 \quad (6)$$

Table 2 listed the different values of  $x^*$  (of which the blending grade changes between 53.5% and 54.49%), the corresponding probable-satisfactory degree  $\Phi(x^*)$  and the relevant profits.

From the results outputted by computer, when optimum expected blending grade  $x^*$  is taken as 53.70%, then maximum probable-satisfactory degree of 0.5844 and 0.1669 million tons of maximum finished blending output as well as 0.123487 million RMB yuans of economic revenue can be gained, compared with the corresponding value of selling construct grade 54%, the mine can increase 3.9 thousand tons of resource extraction and 0.28 million RMB yuans revenue.

**Table 2 Maximum probable-satisfactory degree  $\psi(x^*)$  and economic revenue**

| Blending grade (%) | Maximum finished blending output /10 <sup>6</sup> t | Probable-satisfactory degree $\Phi(x^*)$ | Economic revenue /10 <sup>6</sup> RMB yuan |
|--------------------|-----------------------------------------------------|------------------------------------------|--------------------------------------------|
| 53.50              | 0.1696                                              | 0.5568                                   | 12.5468                                    |
| 53.60              | 0.1682                                              | 0.5742                                   | 12.4473                                    |
| 53.70              | 0.1669                                              | 0.5844                                   | 12.3487                                    |
| 53.80              | 0.1656                                              | 0.5824                                   | 12.2511                                    |
| 53.90              | 0.1654                                              | 0.5669                                   | 12.1545                                    |
| 54.00              | 0.1630                                              | 0.5419                                   | 11.0589                                    |
| 54.10              | 0.1617                                              | 0.5159                                   | 11.9612                                    |
| 54.20              | 0.1604                                              | 0.4992                                   | 11.8705                                    |
| 54.30              | 0.1592                                              | 0.5005                                   | 11.7778                                    |
| 54.40              | 0.1579                                              | 0.5221                                   | 11.6860                                    |
| 54.49              | 0.1567                                              | 0.5583                                   | 11.5953                                    |

This is the optimum decision of blending which has considered the blending risk and its profits comprehensively, according to the present ore blending level.

## 6 INFLUENCE OF RANDOM ERROR ON ORE BLENDING

The influence of square deviation  $\sigma^2$  of random error  $\varepsilon$  on expected blending goal is sensitive. When different probabilities of real blending grade  $x, y \in [53.5\%, 54.0\%]$ , are given, then the corresponding optimum expected blending grades  $x^*$  and successful probabilities  $P$  are obtained as shown in Table 3.

Table 3 shows that the less the value  $\sigma^2$ , the less the value  $x^*$ , it means that more poor ore can be blended, meanwhile, the less the value  $\sigma^2$ , the more the successful possibility  $P$  of blending, the less the blending risk.

Hence, the mine must depend on technological improvements, improve management methods,

and enhance control level of ore quality, then the mine can obtain not only a great deal of profits but also much more poor ore resources. On the other hand, when  $\sigma^2$  decreases, the output grade fluctuation will reduce, it is beneficial for smelting material blending, and the follow-up benefit will be very considerable.

Table 3 Optimum expected blending grades  $x^*$  and successful probabilities  $P$

| $\sigma$ | $x^*$ | $P(53.5 < x < 54.0)$ |
|----------|-------|----------------------|
| 0.1      | 53.61 | 94.16                |
| 0.3      | 53.73 | 59.25                |
| 0.5      | 53.78 | 38.42                |
| 0.7      | 53.82 | 24.60                |

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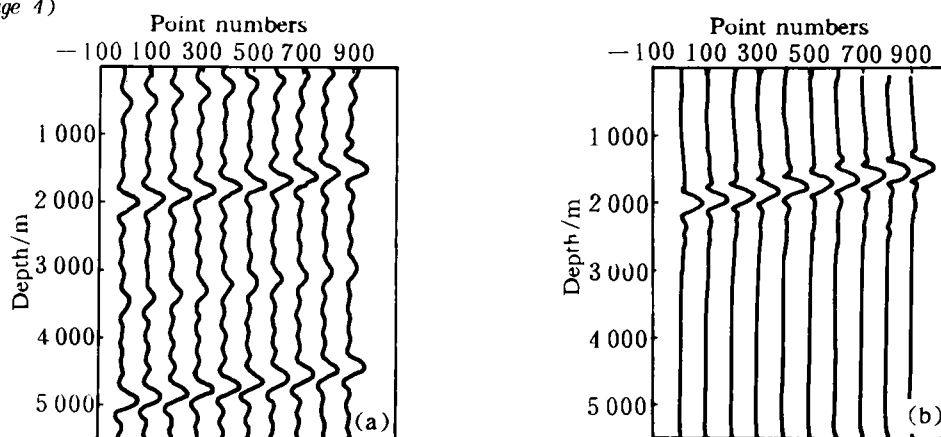


Fig. 3 A 10~50 Hz bandwidth representation of the reflection function  $\beta(x)$  and the wavelet  $|W_s \alpha(x)|$   
(a)— $\beta(x)$ ; (b)— $|W_s \alpha(x)|$

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