Research on Prediction Method of Blasting Block Degree in Open Pit Mine

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Abstract: Because of geological conditions and complexity and transientity of blasting process in open pit mines, at present, there is no unified conclusion on the prediction method of blasting block distribution in open pit mines. In order to explore the prediction method of blasting block degree in open pit mine, this paper introduces the common methods of blasting block, and evaluate the accuracy of the prediction results of the three methods by on-site screening results, then determine the block accuracy prediction method with the highest accuracy. The results show that the Harries model, distribution function prediction model and image analysis prediction model introduced in this paper all have certain accuracy, among them, image analysis prediction model has the highest accuracy, and the method should be widely promoted in engineering practice.

1. Introduction

Blasting is the primary link in open pit mining. The quality of blasting has a great impact on subsequent production and transportation, and thus affects the production efficiency and economic benefits of open pit mines. Among the blasting quality evaluation factors, the blasting block degree distribution is the most important factor in blasting quality evaluation [1-2].

Because of geological conditions and complexity and transientity of blasting process in open pit mines, at present, there is no unified conclusion on the prediction method of blasting block distribution in open pit mines. Early 1980s, Australian famous scholar Harries proposes the classic Harries model, the model assumes that the rock mass is a continuous homogeneous medium, and uses classical mechanics to explore the law of stress wave propagation and predicts the particle size of the rock after blasting [3]. On this basis, Chinese scholar ZOU Dingxiang proposed the BMMC model. Compared with the Harries model, the advantage of the BMMC model is that the influence of joint cracks on the blasting block degree during blasting is fully considered, so the model has stronger practical value [4]. In the following decades, through the constant efforts of many scholars, the blasting block prediction model has made great progress. From the perspectives of stress wave propagation, stress-strain relationship and classical mechanics analysis, various blasting block prediction models have been proposed [5-6]. However, various forecasting models also have certain drawbacks. The predictive models all statically dynamic processes and homogenizes heterogeneous rock masses. However, various forecasting models also have certain drawbacks [7-8]. The predictive models all statically dynamic processes and homogenize heterogeneous rock masses, due to the instantaneousity and complexity of the blasting process and the variability of the mechanical properties and occurrence state of the rock mass, the prediction results are deviated from the actual block degree distribution.

This paper based on the previous studies and combined with the current level of computer development, proposes to use computer image processing technology to analyze and predict the blast block distribution, at the same time, combined with the results of on-site screening in engineering practice, uses mathematical theory to evaluate the prediction method of blasting block degree. The research results of this paper will promote the development of the prediction method of blasting block degree, and it has important theoretical significance and practical value.

2. Blasting block degree prediction method

Select an open-pit oil shale mine stope as the engineering background, mining step height *h*=15m, blasting depth is 15m, the bottom of the hole is not super deep. Blasting with triangular holes, *a*=5m and *b*=8m, single hole charge *q*=150kg, segmented charge and detonation mode is millisecond differential detonation. On the other hand, due to shale refinery equipment requirements, oil shale particles with a blockiness of less than 15mm after blasting cannot be utilized and as tailings disposal, and for oil shale with a particle size greater than 75cm after blasting, secondary crushing is required due to loading restrictions, formally due to this special blasting block degree requirement, it is necessary to determine a reasonable blasting block degree prediction method, thereby reducing resource waste and improving economic benefits. At present, the following prediction models are mainly formed for the blasting block degree.

2.1 Stress wave prediction model

The stress wave prediction model predicts the blasting block from the perspective of stress wave propagation, among them, the Harries model is the most representative of the stress wave prediction model. The model assumes that the surrounding rock around the blasthole is a homogeneous medium with the same identity, and the surrounding rock around the blasthole is approximately simplified to a thick-walled tubular structure centered on the blasthole. During the blasting process, the explosive gas rapidly expands along the vertical plane of the blasthole, producing a tangential tensile stress of uniform diffusion, which causes cracks in the surrounding rock. Based on classical mechanics theory and stress wave propagation law, the blast hole wall strain value can be expressed as:

$$\varepsilon_\theta = \frac{p(1-\mu)}{2\rho(1-2\mu)C_p^2 + 3Kp(1-\mu)} \tag{1}$$

In the formula (1), p is the gas pressure generated by the explosion of unit mass explosive, C_p is the stress wave longitudinal wave velocity, the velocity can be obtained by multiplying both the wavelength and the frequency, ρ is the density of surrounding rock, μ is the Poisson's ratio of the surrounding rock, K is the adiabatic index of the gas, and it can be obtained by the specific heat ratio of the gas, therefore, the wall value of the blasthole hole can be obtained. During the propagation of explosive gas pressure, it should be exponential decay law, the strain value at the center of the blasthole is r can be expressed as:

$$\varepsilon_\theta(r) = \frac{r_b \cdot \varepsilon_\theta}{r} \cdot \exp(-\frac{\alpha r}{r_b}) \tag{2}$$

In the formula (2), r_b is the radius of the blasthole, α is the attenuation index, in order to simplify the operation, generally choose the attenuation index α=0 in the Harries model. So the formula (2) can generally be simplified to:

$$\varepsilon_\theta(r) = \frac{r_b \cdot \varepsilon_\theta}{r} \tag{3}$$

The formula (3) show that surrounding rock strain value at distance r from the center of the blasthole is approximately inversely proportional to the distance r. During the blasting process, the surrounding rock fracture is controlled by both the strain value and the ultimate strain. If the strain value reaches the ultimate strain, the surrounding rock will crack in the vertical plane direction of the blasthole, and the number of cracks generated in the vertical plane direction of the blasthole can be determined by the ratio of the strain value to the ultimate strain, and the rock mass after blasting can be finally determined according to the spacing of two adjacent cracks in the vertical plane direction of the blasthole.

2.2 Distribution function prediction model

The distribution function prediction model is a block prediction model based on blasting experience combined with modern mathematical methods. The model is based on *R-R* distribution function, combines with the rock fracture mechanism, and finally derives the rock mass distribution after blasting. Kuz-Ram model is the most representative of the distribution function prediction model. The model assumes that the blasting block degree is subject to the *R-R* function distribution and combines with the Kuznetson equation to give the rock mass size distribution function after blasting, its expression is:

$$R=1\text{-}\exp[-(X/X_0)^n] \tag{4}$$

In the formula (4), R is the particle size grading cumulative curve, X is the aperture of the screen, X_0 is the characteristic particle size, it corresponds to the particle size of 63.21% in the cumulative curve of the particle size gradation, n is the blockiness distribution uniform coefficient. The Kuznetson equation is used to calculate the characteristic particle size X_0 in the particle size distribution function, so the characteristic particle size expression is:

$$X_0=0.693^n\times 0.01Aq^{-0.8}Q^{0.1667}(115/E)^{0.633} \tag{5}$$

In the formula (5), A is the rock mass coefficient, and it is related to the development of rock mass fissures, q is the explosive unit consumption, Q is the single-hole dose, E is the relative power of the explosive, $2^{\#}$ rock emulsion explosives generally take 100. In order to calculate the block distribution uniformity coefficient n, by the methods of on-site blasting experience and computer simulation proposed an empirical formula for the uniform coefficient n:

$$n=(2.2-\frac{14W}{D})(1-\frac{\delta}{W})[1+\frac{m-1}{2}]\frac{L}{H} \tag{6}$$

In the formula (6), W is the minimum resistance line; D is the diameter of the blasthole; δ is the standard deviation of the blasthole accuracy; m is the blasting hole density coefficient; L is the height of the medicinal column; H is the height of the step. At this point, all unknowns of the rock mass size distribution function in the Kuz-Ram model can be obtained.

2.3 Image analysis prediction model

The image analysis prediction model is a prediction model based on computer technology. The prediction model consists of four parts. The first is the image acquisition system, the small ball is placed at the cross section of the stripping, and the high precision camera is used for image acquisition. The second is the automatic drawing system. The computer image processing technology is used to automatically depict the captured image, and generate a binary image. The third is block calculation system, it performs block analysis calculation based on the information depicted. The last is the result presentation system, it applies the computer graphics software to present the block analysis result in the form of an image, and finally output the particle size [9].

3. Prediction method evaluation

In order to evaluate the accuracy of above three blasting block degree distribution prediction models, the on-site screening results are taken as the true values of the blasting block degree distribution, and the accuracy of the three prediction models is evaluated by the on-site screening results. Select a typical blasting area as the test area, laboratory test indicates that density of oil shale is 2.25g/cm^3, platts coefficient is 2, stress wave longitudinal wave velocity is 2600m/s, Poisson's ratio is 0.35, adiabatic index is 1.5. Blasting uses $2^{\#}$ rock emulsion explosive, the relative power of $2^{\#}$ rock emulsion explosive is 100, explosive grain height is 2.5m, explosive gas pressure is 33000kg/cm^2. During the blasting process, the diameter of the blasthole is 80mm, and the standard deviation of the blasthole accuracy is 0.15m, the blasting block prediction results of Harries model, KUZ-RAM model, image analysis prediction model and on-site screening are shown in table 1.

Table.1. Blasting block prediction results

particle size / percentage under sieve	size 1	size 2	size 3	size 4	size 5	size 6	size 7	size 8
	90	75	60	45	30	15	5	1.5
Harries model	100%	90.3%	81.4%	70.8%	63.6%	28.5%	10.2%	1.9%
KUZ-RAM model	100%	91.3%	80.7%	71.9%	62.4%	29.5%	11.5%	2.1%
image analysis prediction model	100%	92.8%	82.6%	73.9%	64.4%	31.1%	11.2%	2.3%
on-site screening	100%	94.5%	85.4%	77.2%	68.1%	34.4%	12.5%	2.7%

In order to evaluate the accuracy of the prediction model, this paper applies the concept of error rate in the numerical analysis method, takes the on-site screening result as the real value, and uses the prediction result of each prediction model as the experimental value, then the prediction model accuracy evaluation formula can be expressed as:

$$\varepsilon = 1 - \frac{1}{8} \times \sum_{i=1}^{8} \frac{|a_i - b_i|}{a_i} \tag{7}$$

In the formula (7), ε indicates the accuracy of the predictive model, i is the particle size number selected in Table 1, a_i is the percentage under sieve of on-site screening particle size number is i, b_i is the percentage under sieve of predictive model particle size number is i, Apply the formula (7), the Harries model accuracy ε_1=0.889, the KUZ-RAM model accuracy ε_2=0.914, the image analysis prediction model accuracy ε_3=0.938. Obviously, the image analysis prediction model has the highest accuracy, and this method should be widely used in engineering practice.

4. Conclusion

(1) This paper introduces three commonly used methods for blasting block prediction, and evaluates the accuracy of the three prediction methods through on-site screening tests.

(2) Accuracy calculation results show that the Harries model accuracy is 0.889, the KUZ-RAM model accuracy is 0.914, and the image analysis prediction model accuracy is 0.938, all three prediction models have certain accuracy.

(3) The image analysis prediction model is 0.938, it has the highest accuracy, and this method should be widely used in engineering practice.

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