Research on Grey Relational Analysis of Blasting Parameter Optimization

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Abstract: Due to the complexity of blasting parameters and the uncertainty of blasting effect evaluation, how to establish the relationship between blasting parameters and blasting effect is an urgent technical problem in the field of blasting parameter optimization. According to the difference between the control function and the evaluation function in the blasting process, this paper divides the blast parameter variable into the control factor variable and the evaluation factor variable, and establishes the gray correlation degree matrix between each factor by grey correlation analysis method, and determines the influence of blasting parameters on the blasting effect. The method will provide a theoretical basis for the optimization of blasting parameters. At the same time, combines with the on-site blasting tests, evaluates the influence of blasting parameters such as explosive unit consumption, explosive wave impedance, blasthole density coefficient and minimum resistance line on blasting effect. The results show that among the many blasting parameters, the single consumption of explosives has the most obvious influence on the blasting effect. In the parameter optimization, the influence of explosive unit consumption should be considered.

1. Introduction

Blasting is the process of crushing rock mass, which is conducive to excavation and transportation. It is widely involved in water conservancy, hydropower, mining, construction and other fields. The quality of blasting will directly affect the efficiency of subsequent production, and it will have a major impact on engineering efficiency and safe production. In the evaluation of blasting effect, blasting block degree, throwing distance, backlash distance, and bulge height are common indicators for blasting effect evaluation, among many evaluation factors, the blasting block degree is the most important evaluation factor [1].

Research on the evaluation of blasting block degree can be traced back to the middle of the last century. The middle of the last century, with the rapid development of the civil engineering industry, the majority of scholars was aware of the importance of blasting, and did a lot of research on blasting block degree. 1970s, Australian famous scholar Harris and Canadian famous scholar Blaspa proposed the classic Harries model for blasting block prediction, and the model was still widely used today. The model simplifies the rock mass to the cylinder centered on the axis of the blasthole, and assumes that the rock mass is a continuous homogeneous medium. The classical mechanics theory is used to establish the stress wave propagation model to analyze and predict the rock mass size after blasting, but the model is slightly less suitable for mining areas where joint fissures are developed [2-3]. On this basis, in 1984, Anshan mining research institute ZOU Dingxiang and others proposed the BMMC model, which can fully consider the influence of joint cracks on the blasting block during the blasting process, but in the process of stress wave calculation, the model fails to effectively consider the attenuation effect of joints in the face of stress wave propagation [4]. In addition, many models based on stress wave propagation and blasting block distribution functions have been proposed. However, due to the transient nature and complexity of the blasting process, these models fail to fully reflect the dynamics and heterogeneity of the blasting process, so they have certain defects [5].In recent years, with the development of computer technology, the blasting block degree model based on image analysis technology has been gradually improved. The model has the advantages of simple operation and accurate analysis results, and is widely used in engineering practice [6].

Based on the above analysis, this paper uses Split Desktop computer image processing technology to analyze and predict the blasting block degree. At the same time, from the perspective of blasting engineering, the blasting effect is a complex system that is affected by many factors. The system contains both known factors and uncertain factors. In the past, the research generally changed one of the factors, fixed other factors, and used mean comparison, variance analysis, regression analysis and significance test to determine the influence degree of each factor on blasting block degree. This method only reflects the relationship between the single factor and the burst size distribution, and the data is very large, the actual sample collection is limited and has certain dispersion. In order to avoid the influence of limitation and discreteness, this paper adopts the grey relational analysis theory to study the optimization of blasting parameters. The theory has the characteristics of small sample, less data, no need to consider the probability distribution of sample data and apply the methodn into engineering practice and verify the feasibility of the method.

2. Grey correlation analysis

According to the difference between the control function and the evaluation function of the blasting block during the blasting process [7], the blasting parameter variables are divided into two categories: control factor variables and evaluation factor variables. The control factor variable refers to the blasting parameter variable that affects the blasting effect, including the parameters such as explosive unit consumption, explosive wave impedance, minimum resistance line, and blasthole density coefficient. The evaluation factor variable refers to the blasting parameter variable for evaluating the blasting effect, including the parameters such as blasting block degree, block rate, tailing rate, and step height.

After completing the variable classification, define X as a set of control factor variables, $X_i(i=1, 2, \ldots, n)$ indicates the value of the control factor variable of number n, define Y as a set of evaluation factor variables, $Y_j(j=1, 2, \ldots, n)$ indicates the value of the evaluation factor variable of number n. The main factors affecting the blasting effect are studied by s times of blasting test. The data obtained by each control factor variable and the evaluation factor variable in the s times of blasting test form a corresponding sequence, it is:

$$X_i=[X_i(1), X_i(2),\ldots, X_i(k),\ldots, X_i(s)] \qquad i=1, 2,\ldots, n \tag{1}$$

$$Y_j=[Y_j(1), Y_j(2),\ldots, Y_j(k),\ldots, Y_j(s)] \qquad j=1, 2,\ldots, m \tag{2}$$

In the formula (1) and formula (2), $X_i(k)$ indicates the measurement data of the number i control factor variable at the k times test, $Y_j(k)$ indicates the measurement data of the number j control factor variable at the k times test. In the process of calculation, since the units of each parameter variable cannot be unified with each other, the mean value of the parameter variable needs to be changed by the mean operator, and the parameter sequence after the mean value change can be expressed as:

$$X_i'=X_iD_1=[X_i'(1), X_i'(2),\ldots, X_i'(k),\ldots, X_i'(s)] \qquad i=1, 2 ,\ldots, n \tag{3}$$

$$Y_j'=Y_j\mathrm{D}_1=[Y_j'(1), Y_j'(2),\ldots, Y_j'(k),\ldots, Y_j'(s)] \qquad j=1, 2,\ldots, m \tag{4}$$

In the formula (3) and formula (4), mean value X_i'(k) and Y_j'(k) can be calculated by the following formulas:

$$X_i'(k)=sX_i(k)/[X_i(1)+X_i(2)+\ldots+X_i(s)] \qquad i=1, 2 ,\ldots, n \tag{5}$$

$$Y_j'(k)=sY_j(k)/[Y_j(1)+Y_j(2)+\ldots+Y_j(s)] \qquad j=1, 2,\ldots, m \tag{6}$$

Zero process the sequence formed by formula (3) and formula (4), and the resulting zeroed sequence can be expressed as

$$X_i^0=X_i'\mathrm{D}_0=[X_i^0(1), X_i^0(2),\ldots, X_i^0(k),\ldots, X_i^0(s)] \qquad i=1, 2 ,\ldots, n \tag{7}$$

$$Y_j^0=Y_j'\mathrm{D}_0=[Y_j^0(1), Y_j^0(2),\ldots, Y_j^0(k),\ldots, Y_j^0(s)] \qquad j=1, 2,\ldots, m \tag{8}$$

In the formula (7) and formula (8), zeroed sequence $X_i^0(k)$ and $Y_j^0(k)$ can be calculated by the following formula:

$$X_i^0(k)=X_i'(k)-X_i'(1) \qquad Y_j^0(\mathrm{k})=Y_j'(k)-Y_j'(1) \tag{9}$$

According to the definition of gray correlation, the gray absolute relevance of system feature variables can be expressed as:

$$R_{ij} = \frac{1+\left|YS_j\right|+\left|XS_i\right|}{1+\left|YS_j\right|+\left|XS_i\right|+\left|XS_i-YS_j\right|} \quad i=1, 2, \ldots, n \quad j=1, 2, \ldots, m \tag{10}$$

In the formula (10), R_{ij} indicates the gray absolute correlation between the number of i related factor variable and the number of j system characteristic factor. $|XS_i|$ and $|YS_j|$ can be expressed as:

$$\left|XS_i\right| = \left|\sum_{k=2}^{s-1} X_i^0(k) + \frac{1}{2}X_i^0(s)\right| \quad i=1, 2, \ldots, n \qquad \left|YS_j\right| = \left|\sum_{k=2}^{s-1} Y_j^0(k) + \frac{1}{2}Y_j^0(s)\right| \quad j=1, 2, \ldots, m \tag{11}$$

According to the formula (10), the grey absolute relevance matrix can be obtained, and then the degree of correlation between the control factor variable and the evaluation factor variable is determined.

3. Engineering application analysis

The typical domestic highway excavation slope is selected as the engineering background. After the blasting process, for rock mass particles with a particle size of less than 30mm, it is necessary to increase the cost of loading and transportation because it is not suitable for transportation and transportation. For rock particles with a diameter larger than 75cm, secondary blasting is required to increase the blasting cost. Controlling the blasting particle size within this range by parameter optimization is great significance for reducing engineering costs.

In order to research the influence of blasting parameters on the blasting effect during the blasting process, six blasting tests were carried out at the engineering site, and the correlation analysis between the blasting parameters and the blasting effect was carried out by applying the grey correlation analysis theory introduced in the previous paper. Selected explosive wave impedance, explosive unit consumption, blasthole density coefficient, and minimum resistance line in the blasting parameters as the control factor variables, the values of the above parameters in each blasting test were shown in Table 1.

Table.1. Main parameters of blasting tests

parameters	test 1	test 2	test 3	test 4	test 5	test 6
explosive wave impedance ($kg \cdot m^{-2} \cdot s^{-1}$)	3670	3480	3230	3500	3810	3720
explosive unit consumption ($g \cdot cm^{-3}$)	0.164	0.183	0.172	0.151	0.192	0.189
blasthole density coefficient	1	1.7	2	2.2	1.5	2.5
minimum resistance line (m)	5	3	2.5	2.3	3.3	2

For the evaluation of blasting quality, the three aspects of average block, block rate and tailing rate are selected as comprehensive evaluation indicators. After the end of the blasting test, selected a flat area of the stripping cross section in blasting test area and placed a 15cm diameter ball in this area as an image processing size reference and then ensured that the cross section of the stripping was parallel and photographed, and analysed Blasting Block Distribution by using Split Desktop computer image processing technology, the blasting block distribution of each test area were shown in Table 2.

Table.2. Main parameters of blasting tests

parameters	test 1	test 2	test 3	test 4	test 5	test 6
average block (m)	20.3	25.7	23.4	18.5	26.2	25.9
block rate (m)	14.2	10.5	11.2	15.1	10.6	10.1
tailing rate (m)	7.9	8.3	7.5	6.7	9.0	8.1

According to the main parameters in the blasting test and the image processing analysis results, the block distribution data is obtained. Using DPS and MATLAB data processing software to calculate the gray absolute correlation matrix of related factor variables and system characteristic variables [8], the calculation results are as follows:

$$A = \begin{vmatrix} 0.6459 & 0.7969 & 0.7887 \\ 0.8008 & 0.6401 & 0.8083 \\ 0.7421 & 0.5668 & 0.5898 \\ 0.5521 & 0.6847 & 0.5633 \end{vmatrix} \tag{12}$$

Sum the correlation between the control factor variable and the evaluation factor variable, ΣR_{1j}=2.2315, ΣR_{2j}=2.2492, ΣR_{3j}=1.8978, ΣR_{4j}=1.8001, it can be seen that the influence of various factors on the distribution of the blasting block is from primary to secondary in turn is explosive unit consumption, explosive wave impedance, blasthole density coefficient and minimum resistance line.

4. Conclusion

(1)This paper introduces the gray correlation analysis method, and applies it to the engineering practice of blasting parameter optimization, and has achieved good optimization results.

(2)The results of on-site blasting test analysis indicate the distribution of the blasting block is from primary to secondary in turn is explosive unit consumption, explosive wave impedance, blasthole density coefficient and minimum resistance line, in the parameter optimization, the influence of explosive unit consumption should be considered first.

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