Experimental Research on Reasonable Time Difference of Electronic Detonators Based on MATLAB

Jing Wang *
College of Civil Engineering and Architecture Shandong University of Science and Technology, Qingdao, China

*Corresponding author e-mail: 201882040050@sdust.edu.cn

Abstract. At present, there is relatively little research on the selection of reasonable time difference of digital detonators. When choosing delay time in engineering, it mainly depends on engineering experience and empirical formula, which lacks reasonable scientific basis. In this paper, based on a large number of experimental vibration monitoring data, through numerical simulation, the influence of blasting time difference on peak velocity, main vibration frequency and instantaneous energy of blasting vibration waveform is analyzed in detail, and the best time difference is determined comprehensively.

1. Introduction
In the rapid development of Chinese national economic infrastructure construction, blasting engineering has made important contributions to its rapid construction. In order to reduce the blasting vibration effect, which is an additional harmful product in the blasting process, a large number of blasting researchers and blasting workers at home and abroad put forward a large number of effective methods to reduce blasting vibration from the perspective of practical experience and blasting safety. At present, according to the way of controlling the propagation path of blasting vibration, it is generally divided into two categories: first, the blasting seismic wave is passively attenuated in the propagation path by adopting presplitting blasting and excavating damping ditch, thus reducing the intensity of blasting vibration; Second, by adopting reasonable blasting parameters, charge structure, initiation sequence, selecting the direction of the minimum resistance line, increasing the free surface of blasting, and selecting appropriate delay time, the power of explosion is actively weakened at the root of blasting vibration, thus weakening and reducing the intensity of blasting vibration[1]. However, in most blasting projects, it is economical and practical to choose the second method, and it is relatively simple and easy to reduce blasting vibration by changing blasting delay time[2]. In this paper, based on the reasonable time difference test of industrial electronic detonators, the blasting vibration signal is taken as the main research object, the powerful numerical calculation performance of MATLAB numerical simulation software is adopted, and the method of combining numerical simulation with blasting test items is selected, which provides a new method for selecting delay time of industrial electronic detonators.
2. Prediction model

2.1. BP Neural network

2.1.1. BP Overview of Artificial Neural Networks. The Artificial neural network (ANN) is a simulation of micro-physiological structure of biological and human brain nervous system. It is a complex computing network formed by connecting a large number of simple processing units called neurons with each other in a certain way. It is a knowledge processing system based on numerical calculation. The system processes information through dynamic response to external stimuli[3]. Its model based on case learning and adopts parallel reasoning method. It has the characteristics of association, memory and induction.

2.1.2. BP Artificial neural network algorithm. The algorithm of BP neural network is error back propagation, and its basic principle is gradient steepest descent method. The central idea is to adjust the weight to minimize the total error of the network. It is to learn a certain number of samples (input and expected output), that is, to calculate and process the sample information from the input layer through the hidden layer and transmit it to each neuron in the output layer to output the corresponding predicted value. If the error between the predicted value and the expected output does not meet the accuracy requirements, Then the error is "shared" to the weights and thresholds of each neuron by backward propagation from the output layer. By adjusting and correcting the connection weights and thresholds between neurons in each layer, the error is weakened until the requirement that the mean square error between the actual output value and the expected output value of the network is minimized is met [4].

2.2. Wavelet theory

Wavelet transform is a new development of time-frequency analysis based on Fourier transform. The signal is transformed discretely in time domain and analyzed spectrally in frequency domain [5].

Wavelet transform overcomes the contradiction of short-time Fourier transform in time and frequency resolution. It is a multi-scale signal analysis method and a powerful tool for analyzing non-stationary signals. In time-frequency and two-domain signal processing, the ability to characterize local features of signals has higher frequency resolution and lower time resolution in low frequency part-, and higher-time resolution and lower frequency resolution in high frequency part, so it enjoys the laudatory name of "mathematical microscope" [6]. Therefore, wavelet transform analysis method is widely used in dealing with random non-stationary signals with rapid mutation such as blasting vibration signals.

The principle of wavelet discrete transform is: let \( f(x) \) be the collected blasting vibration signal, and the scaling function is \( \varphi_{jk}(x) = 2^{-j/2} \varphi(2^{-j}x - k) \). The sub-wave function is \( \psi_{jk}(x) = 2^{-j/2} \psi(2^{-j}x - k) \). \( \varphi_{jk}(x) \) and \( \psi_{jk}(x) \) is a set of two orthogonal basis functions.

With \( P0f=f(x) \), One-dimensional discrete wavelet transform on the th stage is transformed by orthogonal projection \( Pjf \) and \( Qjf \) will \( Pj-1f \) decompose into:

\[
P_{j-1}f = P_jf + Q_jf = \sum_k c_k^j \varphi_{jk} + \sum_k d_k^j \psi_{jk}
\]

In the formula: \( c_k^j = \sum_{n=0}^{p-1} h(n) c_{2k+n}^{j-1} \), \( d_k^j = \sum_{n=0}^{p-1} g(n) c_{2k+n}^{j-1} \) \( (j = 1, 2, \ldots, L; k = 0, 1, \ldots, N/2^j - 1) \);

- \( h(n) \) —— Low pass weight coefficient;
- \( g(n) \) —— High pass weight coefficient;
- \( P \) —— Length of weight coefficient;
- \( C_n^0 \) —— Input data of signals;
- \( N \) —— The length of the input signal;
- \( L \) —— The required number of stages.
3. Engineering survey

3.1. Test site
The experiment was conducted on a platform in No.5 site of a mine in Shandong Province. The whole site is mainly limestone, which belongs to soft rock, with light gray color and layered structure, poor fracture structure and good regional integrity, with density of 2000-2600kg/m$^3$ and compressive strength of 20-120Mpa, which is mainly used as raw material of cement. See figure 1 for the surrounding environment map of the test site.

![Fig. 1 Environmental map of test site](image)

3.2. Experimental scheme
This test is mainly divided into three parts, namely, single-hole blasting field test, double-hole simultaneous blasting test and multi-hole delayed initiation test. It mainly uses electronic delay device to carry out limestone field blasting test, and determines the influence of different delay time of each hole and different charge on the superposition effect of blasting seismic waves. Blasting vibration meter is used to collect data, which compares the results of numerical simulation, and finally verifies the unity of the two.

3.3. BP Prediction of blasting vibration by neural network
The 40 groups of single hole vibration data are grouped, the first 30 groups of data are used as training data, and the last 10 groups of data are used as detection data. The trained blasting vibration prediction model is used to predict blasting vibration. The maximum relative errors between the vibration velocity measured by BP neural network and the measured data are 1.89%, 1.26% and 1.96%, and the average relative errors are 0.8%, 0.63% and 0.76%. The maximum relative errors between the vibration frequency calculated by BP neural network and the measured data are 2.02%, 1.29% and 0.87%, and the average relative errors are 0.74%, 0.65% and 0.48%, respectively.

4. Superposition analysis of blasting vibration signal

4.1. Selection of superimposed signals
Based on the vibration signals of single hole blasting, the superposition of single hole vibration signals is carried out by using MATLAB program platform to predict the superposition waveforms of group holes with different delay times. Therefore, in order to obtain vibration signals at different distances, it is necessary to combine the BP neural network model in this paper. The specific operation steps are as follows: first, the single hole charge and explosion center distance are substituted into the BP neural
network model to predict the vibration velocity, and then the superimposed waveforms at different time
differences are obtained by signal superposition. Finally, the feasibility of superposition model is
evaluated by comparing it with the measured delay signal.

Compared with the measured blasting vibration velocity in each time difference, the predicted
superimposed vibration velocity is mostly larger than the measured vibration velocity, and the error is
basically kept below 30%. The detailed results are shown in Table 4.1. It can be seen that the predicted
value obtained by the superposition analysis of blasting vibration signal with MATLAB software is
close to the real value, which proves that the simulation prediction result of this method has good
reliability.

4.2. Signal time-frequency analysis

HHT transformation is carried out on superimposed signals under different time differences by using
the programmed program, and the relationship between signal power spectral density and frequency—
PSD power spectral diagram and two-dimensional Hilbert energy spectral diagram are obtained, in
which Figure 3 shows the power spectral diagram and Hilbert energy spectrum of blasting vibration
superimposed signals with delay time difference of 10ms. It can be seen from fig. 2 and fig. 3 that the
energy of blasting vibration is basically in the low frequency region of $30 \sim 60$Hz, and is more
concentrated in the frequency band of $40 \sim 50$Hz. The peak value of PSD appears at 41.6Hz and 46.3Hz
respectively. Combined with the velocity time history curve in Figure 2, this frequency is the main
vibration frequency of blasting vibration signal at this time difference. According to the power spectrum
diagram, the corresponding main vibration frequencies are obtained, and the radial main vibration
frequency variation curves of superimposed signals under different time differences are drawn, and the
tangential and vertical main vibration frequency variation curves are obtained in the same way, as shown
in Figure 3

![Figure 2](image1.png)

**Fig. 2** The power spectrum of delayed 10ms blasting vibration signal (left)
and Hilbert energy spectrum (right)

![Figure 3](image2.png)

**Fig. 3** Power spectrum diagram (left) and Hilbert energy spectrum (right) of blasting vibration signal
delayed by 20ms
Fig. 4 variation curves of radial, tangential and vertical main vibration frequencies of superimposed signals under different time differences

It can be seen from Figure 2~ Figure 4 that the delay time difference has great influence on the main vibration frequency of blasting vibration. With the increase of delay time difference, the main vibration frequency of the superimposed signal shows a periodic change rule, while the curve shows a step-by-step decrease.

For the graph of radial main vibration frequency change in the figure, take the first period as an example. When the delay time difference is in the range of 0~11ms, the main vibration frequency gradually decreases, which is lower than the main vibration frequency of single-segment waveform by 45.6Hz; When the delay time difference is 11ms, the main vibration frequency decreases to the lowest value of 39.6Hz; ; When the delay time difference is within the range of 11~12ms, the main vibration frequency increases sharply, and the maximum main vibration frequency is 49.22Hz; When the delay time difference is within the range of 12~22ms, the main vibration frequency of the superimposed signal decreases gradually. The main vibration frequencies of tangential and vertical superimposed signals also have similar characteristics, but the time difference is different.

5. Conclusion
At present, with the wide application of digital electronic detonators, the problem of low accuracy due to delay time difference of detonators in delayed blasting has been greatly improved. In view of the problems existing in the selection of reasonable time difference of industrial electronic detonators at present, this subject uses MATLAB numerical analysis software as the basic tool, and uses BP neural network model to analyze the attenuation law of blasting vibration by measuring a large number of vibration monitoring test data in the reasonable time difference test of industrial electronic detonators. Then, according to the superposition principle of elastic waves, MATLAB software is used to simulate the superposition of multi-hole signals under different time differences, and Hilbert-Huang transform of wavelet analysis in signal analysis is used to process the superimposed signals, so as to analyze the blasting vibration speed and main frequency and draw the following conclusions:
1. According to the linear elastic superposition theory and the simple attenuation coefficient processing method for topographic and geological conditions, the measured vibration signal of single-hole blasting is predicted by double-hole delayed blasting vibration signal. By comparing with the measured peak velocity of blasting vibration under various time difference conditions, the error between the predicted superposition vibration velocity and the measured vibration velocity is basically kept below 30%, thus confirming the reliability of the simulation prediction results of this method.

2. Using wavelet analysis and Hilbert-Huang method to analyze the spectrum characteristics, it is found that the main vibration frequency of the superimposed signal shows a certain periodic change regularity with the increase of delay time, and the graph shows a step-by-step decline. Due to the principle that the lower the main vibration frequency of blasting vibration is, the closer it is to the natural frequency of buildings, and the greater the damage to surrounding buildings, the best time difference is 12 ~ 16 ms.

References

[1] Sun Jianyong. Application of Smooth Blasting Technology in Class III Horizontal Surrounding Rock of Tunnel [J]. Railway Building Technology, 2010(03):91-95.

[2] Wang Junyue. Blasting vibration signal superposition method and its application in open pit mine [D]. Wuhan University of Technology, 2007.

[3] Fan Chunli. Study on Blasting Vibration in West Bank Treatment Project of Buzhaoba Open-pit Mine [D]. Kunming University of Science and Technology, 2011.

[4] Guo Jianhong. Research on intelligent control of structure based on neural network [D]. Lanzhou University of Technology, 2005.

[5] Fei Zhichao. Analysis of blasting vibration effect and safety evaluation of open-pit mine [D]. Inner Mongolia University of Science and Technology, 2014. Xu Xueyong. Study on wavelet analysis method of blasting vibration signal [D]. Wuhan University of Technology, 2006.

[6] Cui Jihong. Numerical Simulation of Blasting Vibration in Tunnel Excavation [D]. Shandong University of Science and Technology, 2005.