Article

Study on vibration effects of decked charge in bench blasting

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Abstract

By analyzing the vibration signals of three different decoupling decked charges measured in a mine, the vibration effect is discussed by Fourier analysis and wavelet (packet) analysis. From the time-frequency analysis, it is found that the vibration effect of three charge structures is different. The vibration effect decked with rock powder is the most intensive; while that with water is inferior, and that with air is the minimum. As a result, the method decked with water or air is of benefit to the improvement of blast quality and the protection of slope.

Keywords: decoupling decked charge; blasting vibration effect; time-frequency analysis

1. Introduction

The technique of decouple decked charge is frequently adopted in open pit blasting. The charge method varies from the decked medium, such as the rock powder produced by drilling, water or air. Up to now, the research on decouple charge mainly aimed at improving the blasting quality, but not enough had been done in decreasing the vibration effect [1) 2) 3)]. Now along with the deepening of open pit mine, the water hole is becoming more. Thus how to use the water to improve blasting quality and decrease the vibration effect on the high slope and the mine surroundings has become an urgent problem to be settled. In this paper, the blasting vibration effects of different charge structures are researched in order to increase the utilized effective of explosive energy; decrease and control the vibration effect along with improve blasting quality.

2. Blasting test of decked charge and its seismic effect

The decoupling charge decked with water or air can reduce the initial detonation pressure of blast hole wall brought by bursting of explosive, decrease the energy loss which can lead to blasting vibration in far section and initial excessive crush rocks in close section, prolong the time of bursting gas, and increase the utilized effective of explosive energy.

Decked charge structure: according to different geological conditions, there are two or three segments charges. The charge ratio is as follows; bottom: top=8:2 for two segments, or bottom: middle: top=7:2:1 for three segments. The typical charge structure is shown in Fig. 1. The length of water (air) column is about 1-2 meters, commonly 1.5 meters. The chosen reason is on the premise of ensuring that the clogged length of blast hole top is not less than the minimum row distance, all the places is used to deck except that used to charge. In order to distribute the explosives in rocks more reasonable and average, the middle charge columns of neighboring blast hole should be interlaced in space. 30 to 40 experiments were carried out.

The experiment site is in Heisan Iron Ore Mine of Chengde City in Hebei Province in China. The site is flat, and the rock is quite homogeneous without obvious geologic structure. The diameter of hole is Φ200mm, the depth of hole is 14m, the interval distance between holes is 4m, the bottom burden is 6.5m, and the height of bench is 12m, rocks are gabbro of which mechanical properties are that volume weight is 28.2kNm, Young's modulus is 48GPa, Poisson's ratio is 0.23, cohesion is 20MPa and friction

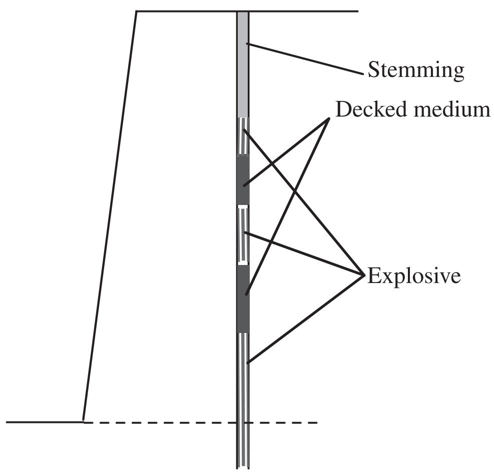


Fig.1 Charge structure of different decked medium.

angle is 45° and every blast hole is filled in 175Kg emulsion explosive distributed in three intervals. The decked medium of each of the three holes is rock powder, air, and water respective. The interval length is 1.5m at bottom and 2.0m at top.

In order to ensure the blasting parameters to be the same as possible so that the exploding conditions and parameters in every holes are unanimous, at the same time the seismic waves don't affect by each other, in the experiment, the high precision millisecond non-electric detonator is used. The delayed interval time is 400ms, and the precision of detonator is ±3ms. The seism monitoring points are placed on lateral back of holes. All the three points are the same distance of 40m to respective hole, so that the seismic effect can be easily compared and analyzed.

Producing practices have proved that decked charge method makes the blasting quality improved considerable, big rock rate decreased obviously, efficiency of excavator raised 35% and consumption of explosive decreased 10% average. The experiments of normal blasting had been conducted before, the results measured the vibration signals indicated that they were 1.5 times larger than the method with decked media.

3. Seismic signal analysis of different decked charge

3.1 Time-frequency analysis based on Fourier transform

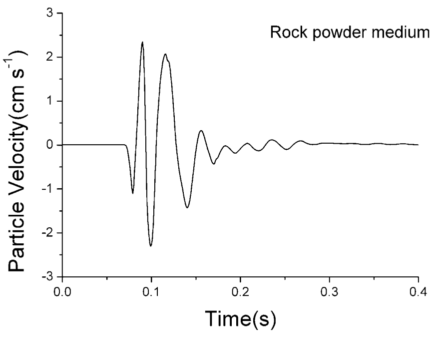
The particle vibration velocity, frequency and the continuance time of vibration are three main factors to describe blasting vibration effect. By analyzing the factors comprehensively, the effect will be more scientific obtained. The time and frequency domain figures are as Figs. 2, 3, 4 shown. The monitor system is mainly composed of seismograph, detector, and analog signal cable. The seismograph is Strata ViewTW produced by American company named EG &G. Before monitoring, all detectors were inserted into the earth, and keep them coupling with the earth well. When, blasting, at the moment touching off the touching cable, signal could be captured.

From the time domain signal of the seism wave with three different charge structures, it is not difficult to find that the PPV of that decked with water is a little larger than that of decked with rock powder and air, but the difference is not obvious.

The main vibration wave is mainly used as the appraising criterion of vibration continuance time. The seism wave from the initial wave to its amplitude attenuated to $A = A_{max}/e$ is defined as main vibration wave [4]. e is natural logarithms. The amplitude of the seism wave decked with air, that is $A_{air} = A_{max\,(air)}/e = 0.743\text{cm s}^{-1}$ is adopted to determined the continuance time of the different main vibration wave so that fairly compare the continuance time of the main vibration wave. As a result, the continuance time of that decked with rock powder is 75.9ms, while that with water is 70ms, and that with air is 62.5ms.

From the Fourier transform, the frequency domain figures can be obtained. From these figures, the frequency distribution can be found out. As to the determination of the frequency width, in order to make the comparison have a unified criterion, the frequency with amplitude larger than 0.0025cm/s is adopted as the main frequency region. From the figures, it can be seen that the main frequency with three different charge structures is almost at the same value of 27Hz, while the difference of the distribution of the frequency region is much large. The frequency region decked with rock powder is rather wide between 1.79-74.16Hz, and the low frequency is abundant. The distribution of the frequency decked with water is between 14.23-79.05Hz, and the low frequency is rather little, while the high frequency is rather abundant. The distribution of the frequency decked with air is between 13.89-88.24Hz, and the low frequency is rather little, while the high frequency is rather abundant. The crush circle of deck charge with rock powder is bigger than that with air and water, the lose of high frequency signal is more than that with air and water.

From the comprehensive analysis of the three factors, it can be seen that the difference of time region is rather little while that of the vibration continuance time and frequency region are obvious. To the average civilian buildings and the open pit high slopes, the self-frequency is almost between 10-15Hz. From this sense, the vibration effect decked with rock powder is the most intensive; while that with water is inferior, and that with air is the minimum. Therefore, Charging decked with air and water are in favor of reducing the blasting vibration and protecting the surrounding environment and the stability of the open pit slope.



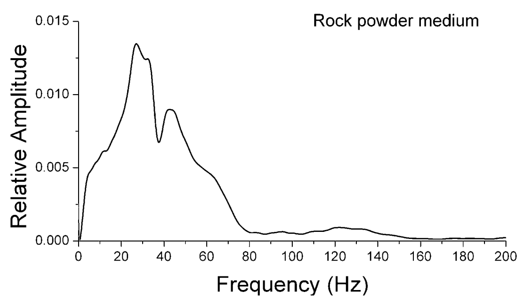


Fig.2 Time and frequency domain figures decked with rock powder.

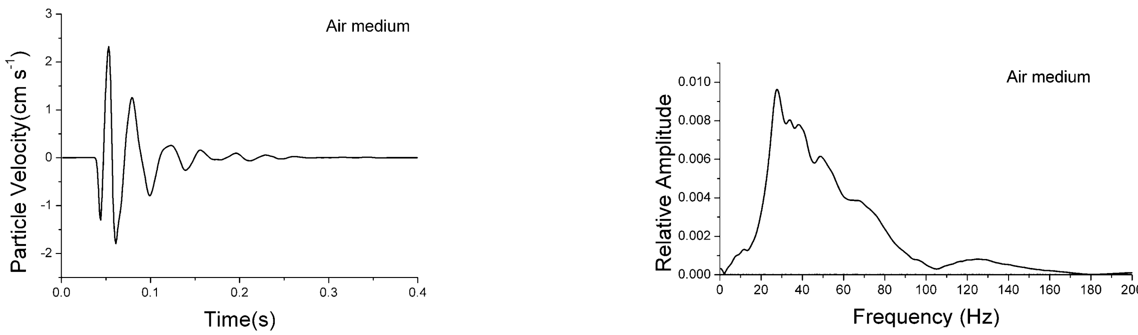


Fig.3 Time and frequency domain figures decked with air.

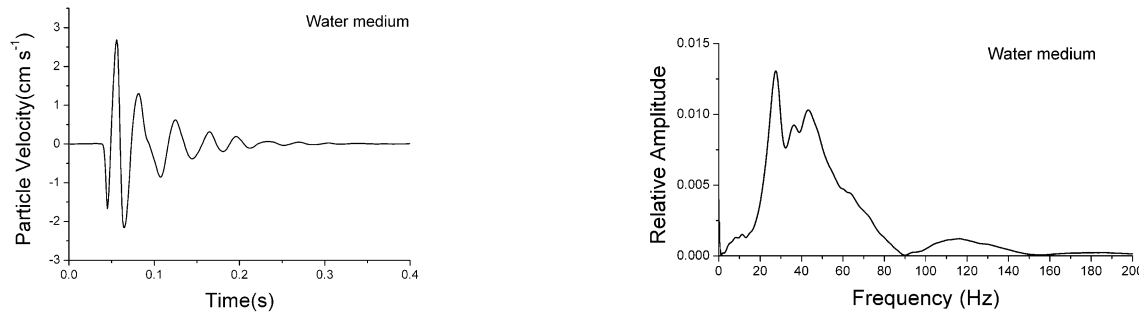


Fig. 4 Time and frequency domain figures decked with water.

3.2 Time-frequency analysis based on wavelet transform

In order to analyze the detail localization information of blasting vibration signals, the wavelet transform is used to analyze the waveform of different decked charge. First, the wavelet decomposition transform is used to find the dominant bands and decide the wavelet decomposition levels. And then, the wavelet method is used to analyze the detail signal. According to the principle of choosing wavelet base, Daubechies wavelet series hold better strict support subset, a certain smoothness and approximate symmetry. It has better local analysis ability and higher waveform reconstruction precision for analyzing blasting vibration signal. The wavelet series can be chosen according to the correlation between the oscillation characteristic of waveform and the oscillation numbers of Daubechies wavelet series[5]. Thus, the db7 wavelet series is adopted to analyze the wave signals from the experiments. The error between reconstructed signal and original signal is above 10^{-11} orders. It can be considered that they are highly consistency so the wavelet analysis result can ensure the authenticity of signal character.

3.2.1 Wavelet analysis of different decked charge

By using the wavelet function provided by Matlab toolbox, the waveforms of different charge structures are decomposed to 7 levels and the whole signals are divided into 8 bands. Their energy statistics relative ratio and energy distribution of each of them are shown as Table 2.

From the table it can be seen that the dominant band of that decked with rock powder is between 15.625-31.25 Hz, and that with water is between 31.25-62.5 Hz. The dominant band of that with rock powder has a rather low frequency. If the relative power spectrum value of water is 1,

Table 2 Energy relative ratio and distribution in different bands respective.

No.	ω / Hz	$(E_k / E_0)/(\%)$		
		Rock powder(1.3)	air(0.7)	water(1)
1	0-3.90625	0.47	0	0.03
2	3.90625-7.8125	3.34	0	0.20
3	7.8125-15.625	21.93	0.19	0.98
4	15.625-31.25	59.53	30.65	24.46
5	31.25-62.5	24.29	57.56	70.81
6	62.5-125	9.90	10.97	2.91
7	125-250	0.18	0.58	0.58
8	250-500	0	0	0

the value of rock powder is 1.3 and that of air is 0.7. This indicates that the blasting decked with rock powder brings more seism energy and the utilized effective of explosive energy is relative low. From the energy distribution of each, the method decked with rock powder has more energy in lower bands about 21.93% from 7.8125-15.625. The self-frequency of high & whole construction as like open pit slope is general between 10-15 Hz. Then the dominant band and energy distribution of rock powder are more close to the self-frequency of slope, so it has more vibration effect and destroys than the other two do. Based on the analysis, it can be concluded that the method decked with rock powder is the worse to the slope stable than that with water and air are.

3.2.2 Time-frequency wavelet packet analysis

The wavelet packet transform is a more detail method than wavelet transform. By using wavelet packet transform, the more detail dominant band and dominant frequency can be obtained. Here the three different decked charges will be analyzed by using it. The least Shannon standard is adopted in the decomposition arithmetic. The decision of dominant band and dominant frequency is according to the power spectrum value of corresponding band [6]. The time-frequency spectrum of that with rock powder, air and water is shown as Fig. 5. From left to right, it takes turns to be the time-frequency spectrum of rock powder, air and water. From the figure it can be seen that the amplitude of dominant frequency of rock powder is the largest, and that of the air is the minimum.

Afterward, by reconstructing the detail signal and comparing among the value of power spectrum of each of them, the detail reconstructed waveforms and corresponding power spectrum figures are found out. They are shown as Table 3. The dominant bands of waveform decked with rock powder are between $S_{7,5}$, $S_{7,8}$, that decked with air are between $S_{7,6}$,$S_{7,13}$, and that decked with water are between $S_{7,6}$, $S_{7,13}$, $S_{7,14}$. Thus, we can conclude: 1) The power spectrum value of dominant bands accounts for a large percent, and it acts an important function on the waveform character: 2) All the waves have two or more dominant frequencies, and compared among them, the frequency of that decked with rock powder is the minimum than the other two are.

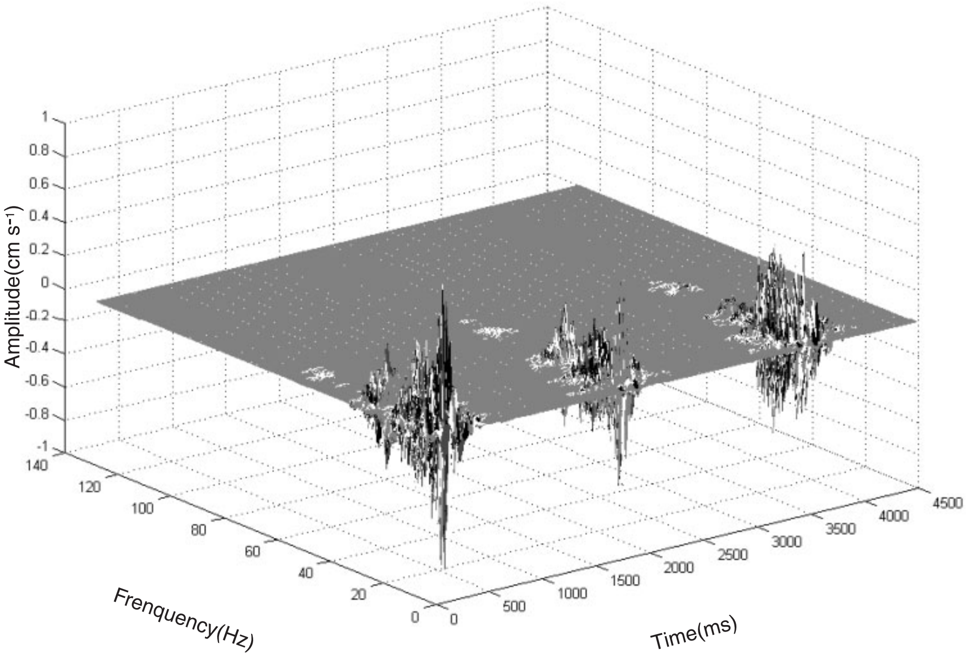


Fig. 5 Time-frequency amplitudes of three decked media.

Table 3 Typical wavelet packet time-frequency analysis results of different decked charges.

Decked medium	Dominant band	Dominant frequency (Hz)	PPV corresponding to Dominant frequency (cm s-1)	$(E_k / E_0)(\%)$
Rock	$S_{7,5}$	17	0.8	27.46
powder	$S_{7,8}$	29	0.67	14.79
Air	$S_{7,6}$	21	0.55	20.00
	$S_{7,13}$	48	0.5	18.63
Water	$S_{7,6}$	21	0.51	14.68
	$S_{7,13}$	48	0.49	14.68
	$S_{7,14}$	52	0.5	14.68

4. Conclusion

1. The dominant bands and energy distribution of rock powder are more close to the self-frequency of slope, so it has larger vibration effect and destroys than the other two do.

2. All of the three different decked methods have two or more dominant frequencies, and compared among them, the dominant frequency of rock powder is the smallest, and that of the water is the largest.

3. Through the comprehensive analysis, the vibration effect decked with rock powder is the most intensive; while that with water is inferior, and that with air is the minimum.

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