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Blasting Vibration Analyses of Millisecond Blasting Model Experiment with Multicircle Vertical Blastholes

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1 Introduction

Cutting blasting is the key to improving blasting advance by providing second free surface for later blast holes detonating. Perpendicular to the working face, the depth of Cutting blast holes is not limited by vertical shaft section and sinking platform is safe for shot throwing distance.

To investigate the rock breaking mechanism of explosive stress wave generated in vertical shaft excavation, millisecond blasting model tests with multi-turn vertical blast holes, such as two circle cutting holes in the middle of concrete model and two circle cutting holes plus one circle auxiliary holes in the middle of concrete model have been conducted in various millisecond delay conditions.

2 Millisecond blasting model tests

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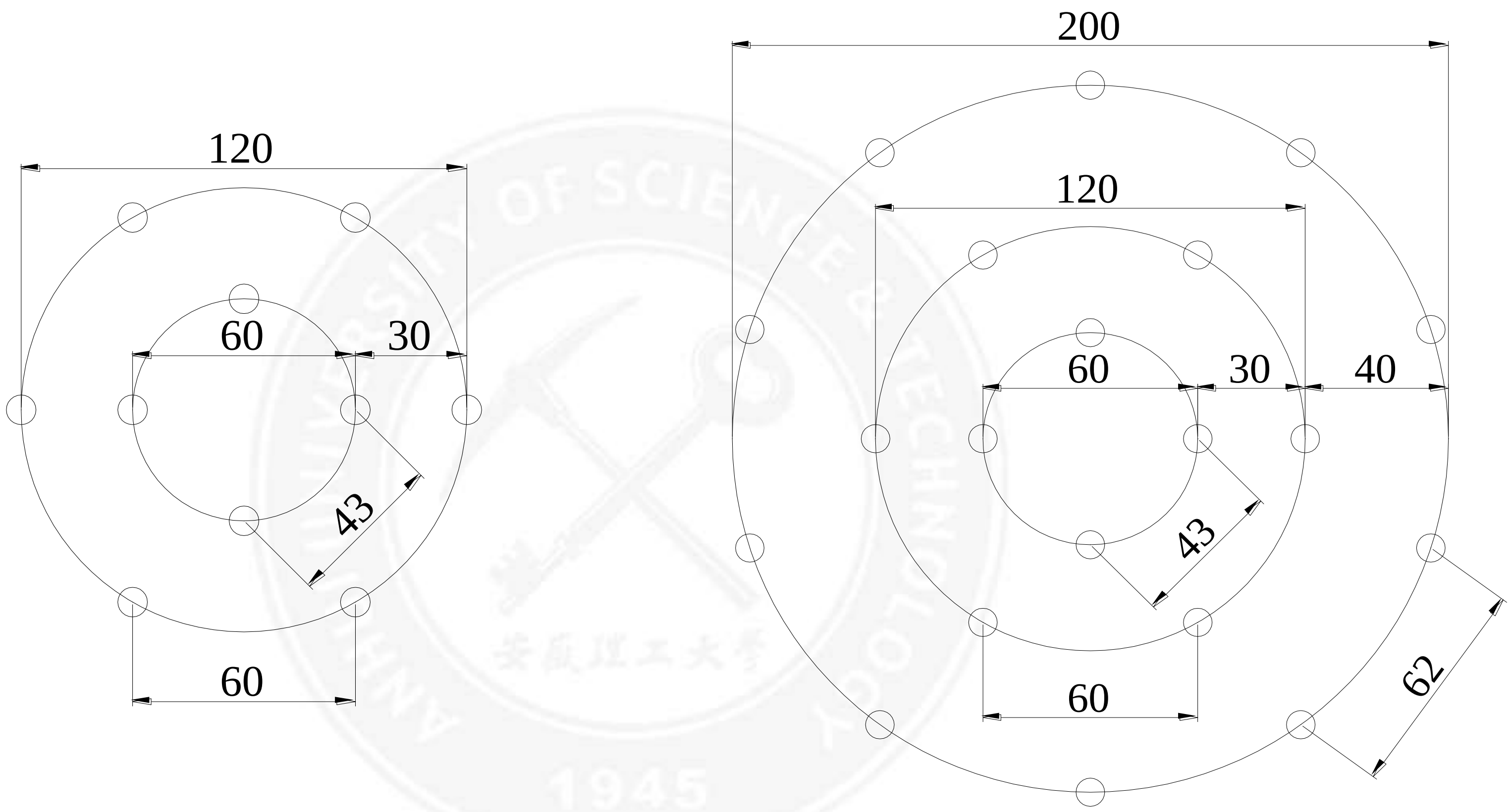
2 Millisecond blasting model tests

With cutting blasting in vertical shaft as the prototype, millisecond blasting model tests have been conducted with multi-turn vertical blast holes. For two-circle vertical blastholes, there are 4 blastholes uniformly distributed in the first circle, 6 blast holes uniformly distributed in the second circle. For three-circle vertical blast holes, there are another 10 blastholes uniformly distributed in the third circle. The diameters of first circle, second circle, and third circle vertical blast holes are 60mm, 120mm, and 200mm respectively. The depth of both first circle and second circle vertical blast holes is 180mm, and the depth of third circle vertical blast holes is 160 mm. The diameter of vertical blast holes is 8mm, and each blast hole charges one electric detonator.

2 Millisecond blasting model tests



Two-circle blastholes

Three-circle blastholes

Fig.1 Layout of multi-turn circle blastholes (mm)

2 Millisecond blasting model tests

Two-circle blast holes

Three-circle blast holes

Fig.2 Pictures of multi-turn circle blast holes

2 Millisecond blasting model tests

Table 1 Millisecond blasting model test schemes

Test Number	CME-1	CME-2	CME-3	CMS-1	CMS-2	CMS-3	CMS-4	CMS-5
Detonation delay	0ms	25ms	50ms	25ms	50ms	100ms	25ms	50ms
First circle charge	electric detonator segment I	electric detonator Segment I	electric detonator Segment I	electric detonator Segment I	electric detonator segment I	electric detonator segment I	electric detonator segment I	electric detonator segment I
Second circle charge	electric detonator Segment I	electric detonator segment II	electric detonator segment III	electric detonator segment I	electric detonator segment I	electric detonator segment I	electric detonator segment II	electric detonator segment III
Third circle charge	—	—	—	electric detonator segment II	electric detonator segment III	electric detonator segment V	electric detonator segment III	electric detonator segment V

2 Millisecond blasting model tests

In millisecond blasting model tests, C40 concrete is adopted as model material and various millisecond delay electric detonators are also employed as explosive material. The length, width, and height of square concrete model are 1000mm, 1000mm, and 600mm respectively. After curing 28 days, the cubic compressive strength of model concrete is 42.8MPa, the splitting tensile strength is 2.58MPa, and the elastic longitudinal wave velocity is 4209m/s.

During the blasting model test, the explosive strain wave signals in concrete model have been measured by super-dynamic strain testing system, and blasting vibration signals on top surface of concrete model have been recorded by the intelligent blasting vibration monitor.

2 Millisecond blasting model tests

Fig.3 Concrete models for millisecond blasting model tests

2 Millisecond blasting model tests

Two-circle blastholes *Three-circle blastholes*

Fig.4 Concrete models after millisecond blasting model test

3 Explosive strain wave analyses

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3 Explosive strain wave analyses

Explosive strain wave signals in concrete model are measured by super-dynamic strain testing system, seen in figure 5.

Fig.5 Super-dynamic strain testing system

3 Explosive strain wave analyses

There are 4 measure points, marked as A, B, C and D, arranged in a space of 80mm on the top surface of one strain brick. Strain brick is made by cement mortar with length of 350mm, width of 70mm, and height of 40mm. Moreover, its embedded depth is 160mm to make the measure points and center of electric detonators in the same level. Each measure point gets 2 strain gauges along the radial direction and tangential direction, and strain gauge in radial direction is marked as R, and strain gauge in tangential direction is marked as T. The distance between measure point A and center of two-circle or three-circle blastholes is 180mm, so the distance for measure point D is 420mm, seen in figure 6.

3 Explosive strain wave analyses

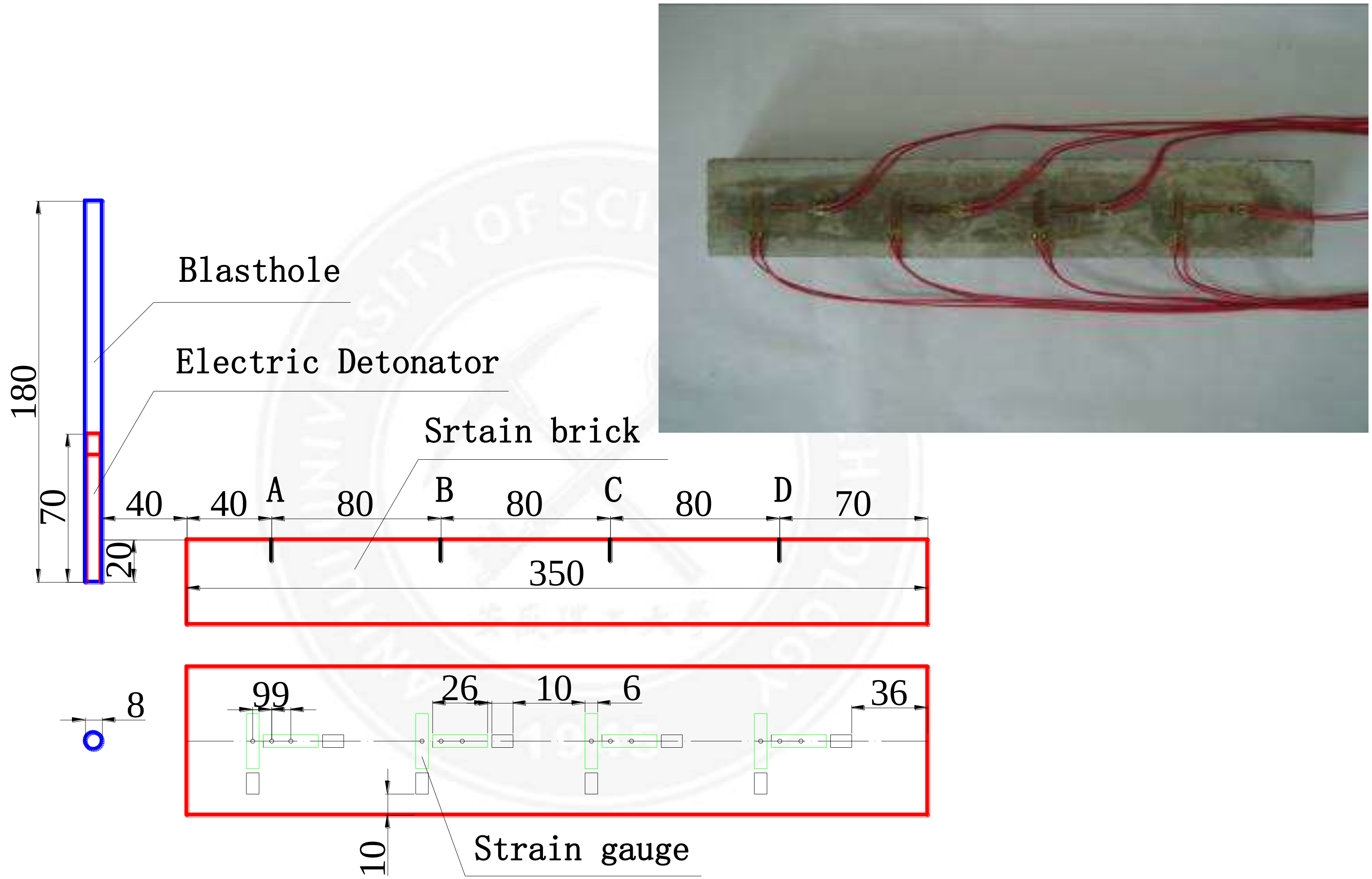

Fig.6 Arrangement of explosive strain wave measure points

3 Explosive strain wave analyses

The actual measured explosive strain wave signals are shown in figure 7.

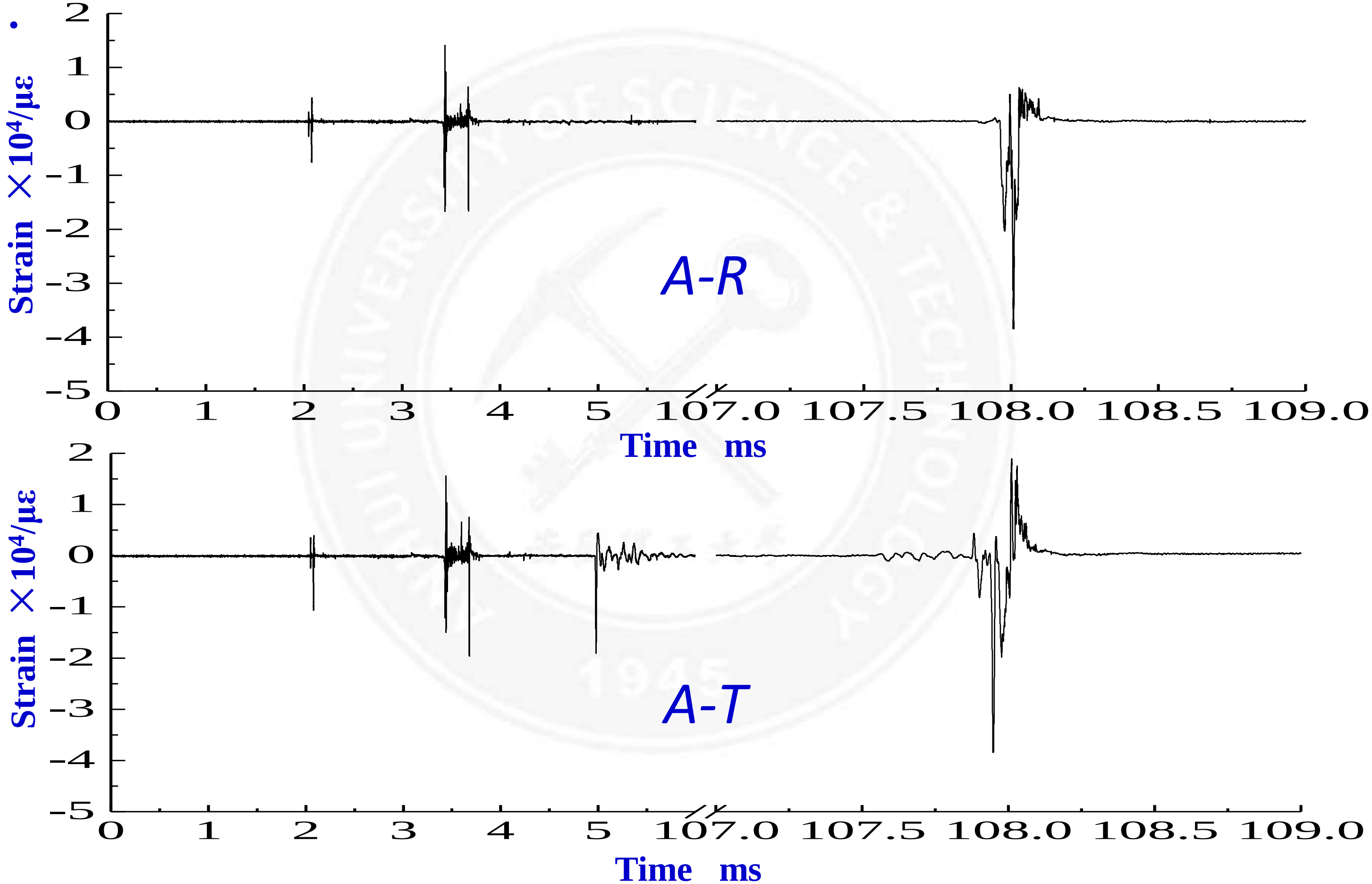

Fig.7 Actual measured explosive strain wave

3 Explosive strain wave analyses

Seen from figure 7, the explosive strain wave can be positive and negative corresponding to tensile strain and compressive strain respectively. Each signal consists of complete tensile phase and compressive phase.

Moreover, the peak points and peak intervals in dynamic strain signal basically correspond with the segments of electric detonators and the delay time. Explosive strain wave signal displays an obvious segmentation phenomenon and the segmentation is closely related to millisecond blasting parameters.

4 Blasting vibration signal analyses

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4 Blasting vibration signal analyses

Blasting vibration signals on the top surface of concrete model are recorded by the intelligent blasting vibration monitor, seen in figure 8.

Fig.8 UBOX-5016 intelligent blasting vibration monitor

4 Blasting vibration signal analyses

There are also 4 measure points, marked as 1, 2, 3 and 4, arranged the top surface of concrete model, seen in figure 9. The distance between measure points and center of two-circle or three-circle blastholes is 400mm.

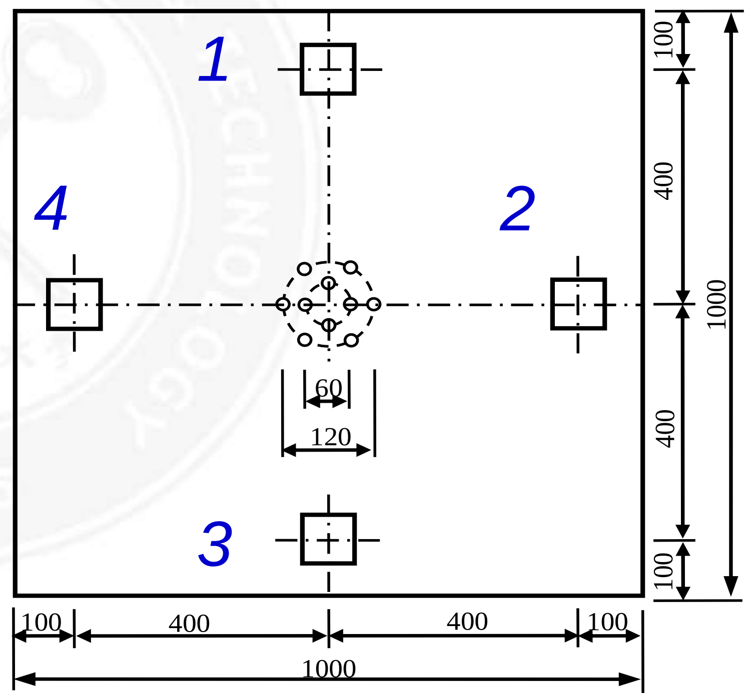
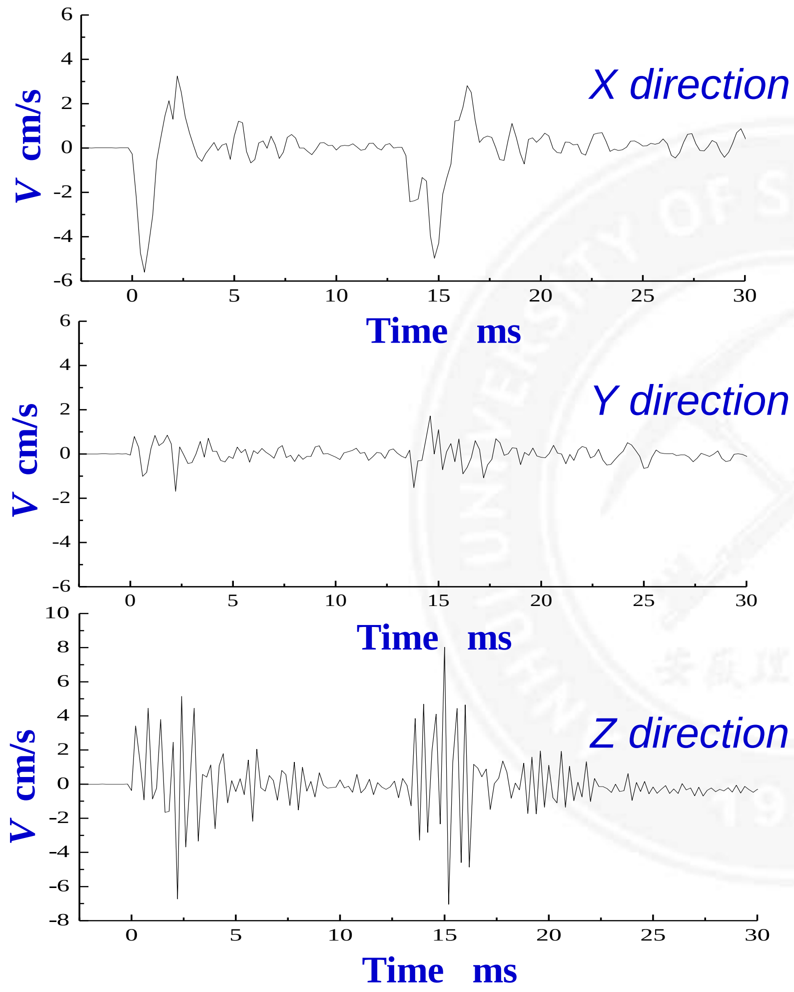


Fig.9 Arrangement of blasting vibration measure points

4 Blasting vibration signal analyses



The actual measured blasting vibration signals in three directions are shown in figure 10.

Fig.10 Blasting vibration signals in three directions

4 Blasting vibration signal analyses

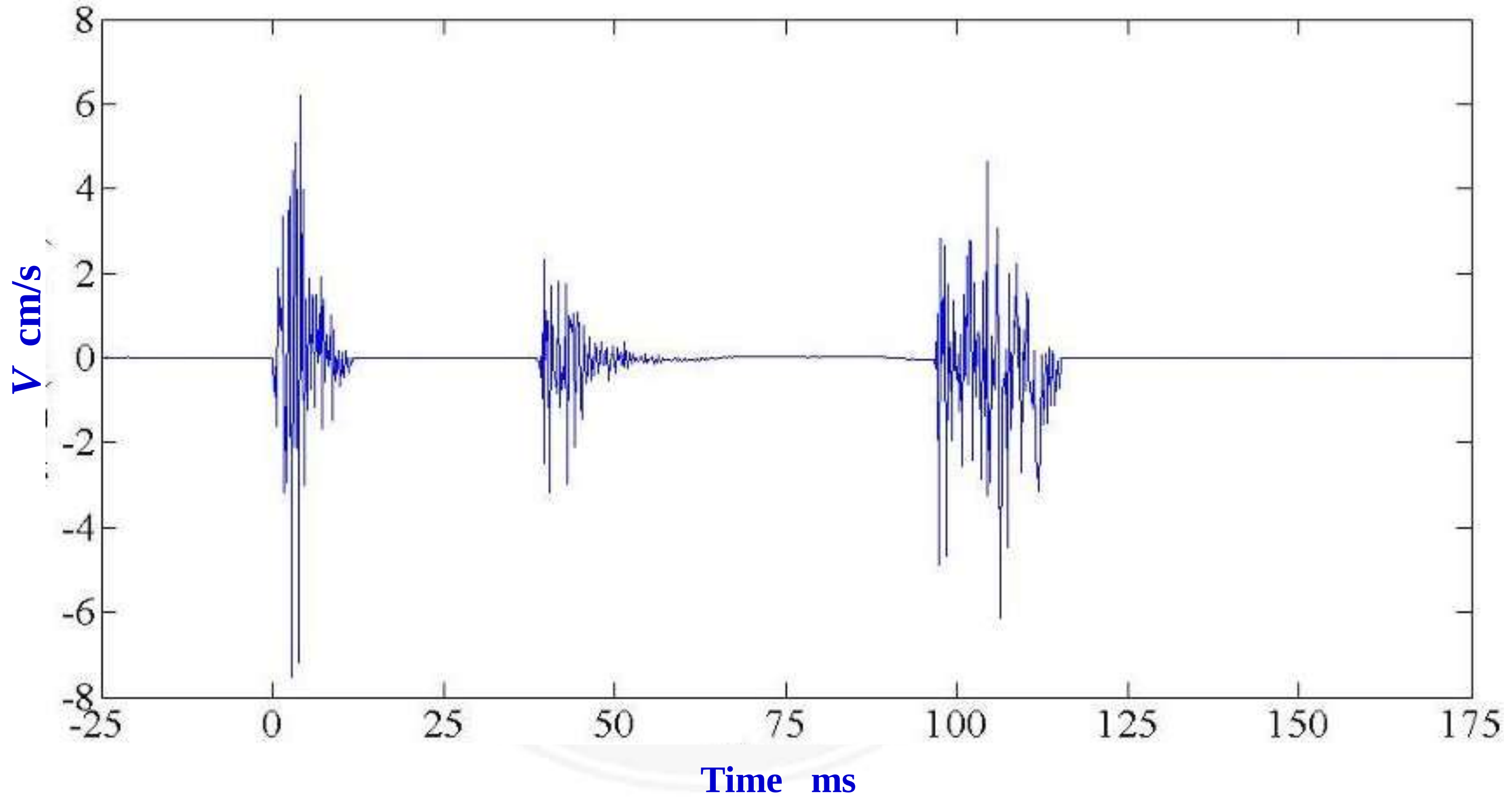


Fig.11 Blasting vibration typical signal(CMS-5)

4 Blasting vibration signal analyses

Seen from figure 10,11, blasting vibration signals present big values in both Z direction and Y direction, blasting vibration signal in X direction is the smallest of all.

5 Blasting effect analyses

5 Blasting effect analyses

After detonating, the blasting cavity is cleaned and blasting fragments are gathered. Then the depth and volume of cutting cavity are measured, and blasting fragmentation analyses are conducted.

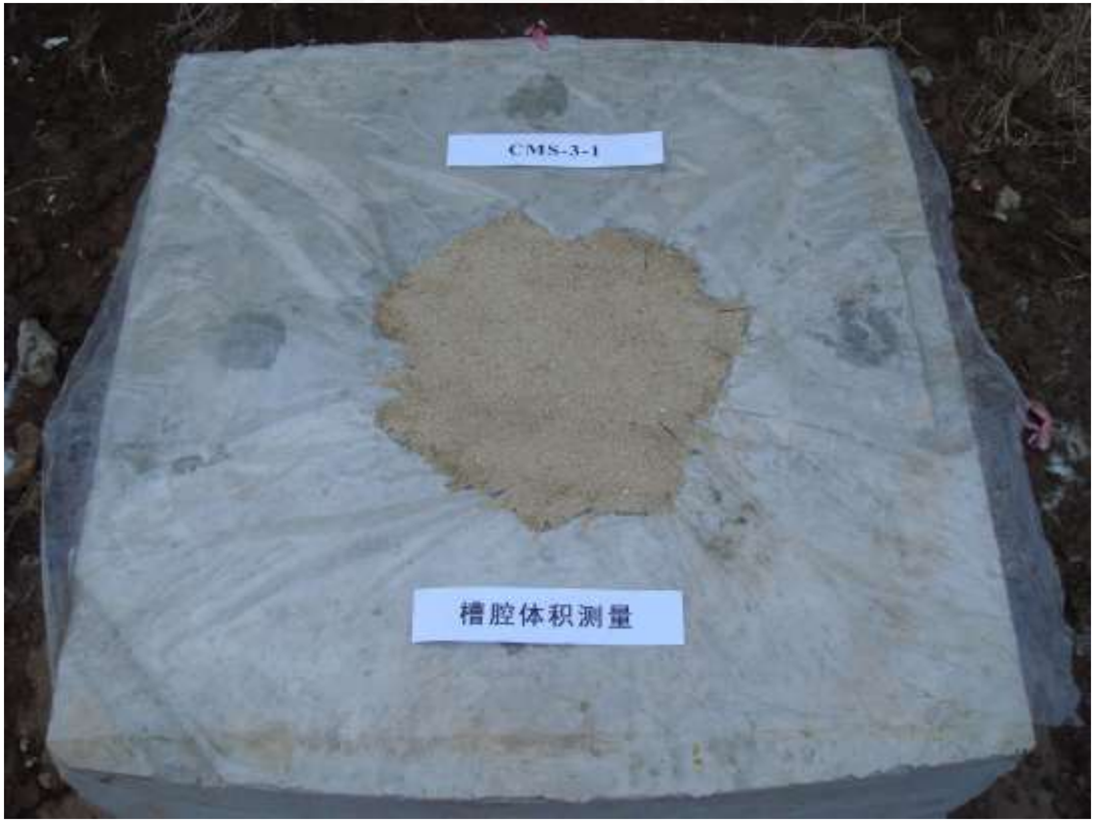


Fig.12 Volume measurement of blasting cavity

5 Blasting effect analyses

By comparing the blasting effects, such as cutting depth, cutting radius and cutting volume, the reasonable delay time for first and second circle blastholes initiated simultaneously and third circle blastholes initiated in millisecond delay is 50ms, and the reasonable delay time for first circle blastholes, second circle blastholes and third circle blastholes initiated in millisecond delay is also 50ms. Thus, the optimal blasting scheme for multiturn cutting blasting is multiturn blastholes initiated in millisecond delay and the reasonable delay time is 50ms.

5 Blasting effect analyses

Considering the size of blasting fragments, Rosin-Rammler distribution function is adopted for blasting fragmentation analyses.

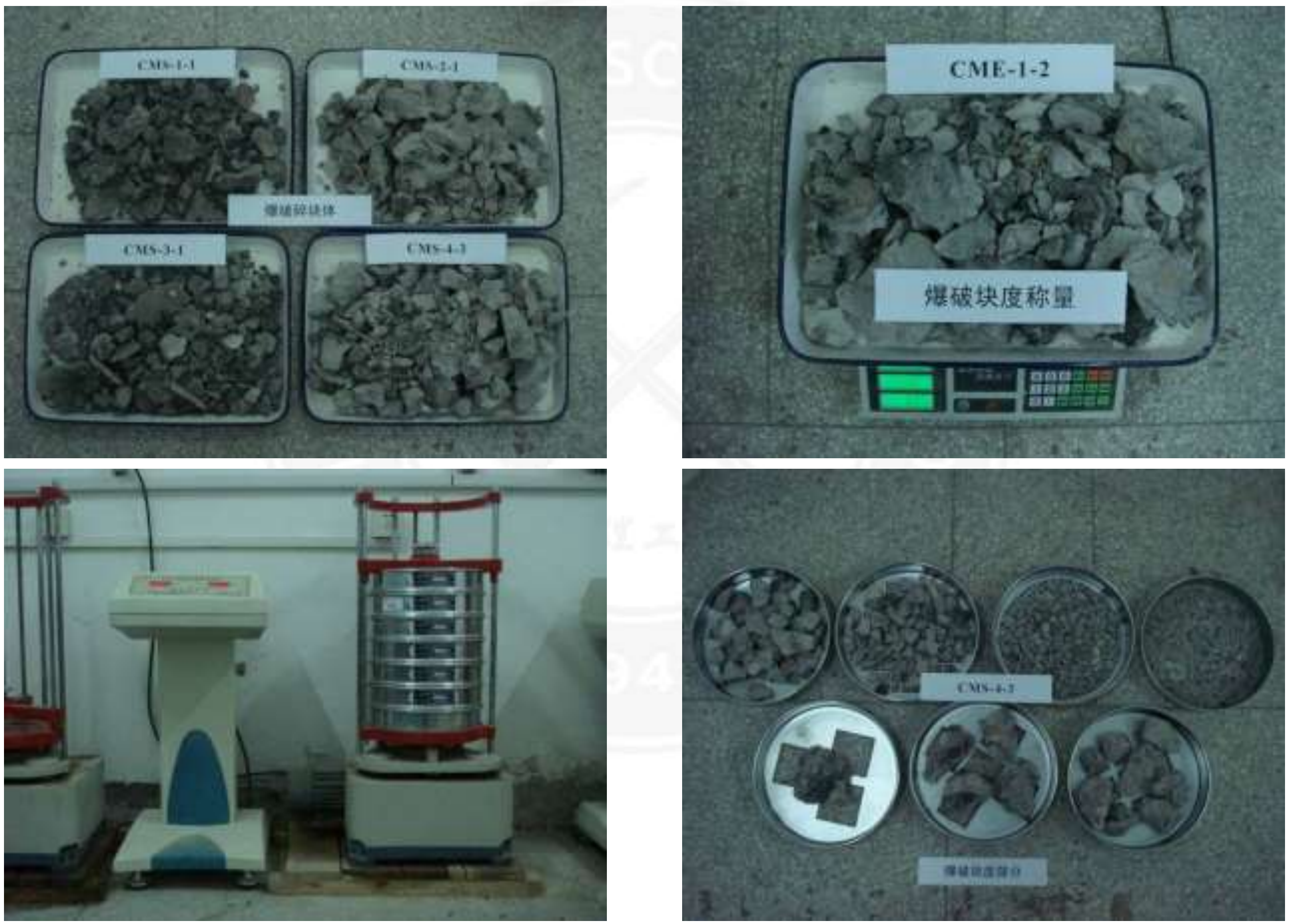


Fig.13 Blasting fragmentation analyses

5 Blasting effect analyses

The blasting fragmentation analyses show that the biggest average blasting fragmentation of all blasting model tests is CMS-4 and its value is 57.0mm. While the smallest average blasting fragmentation of all blasting model tests is CMS-1 and its value is just 27.7mm. The average blasting fragmentation of CMS-2 and CMS-5 are close to each other and their value are 53.2mm and 51.0mm respectively.

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6 Case Study

The renovation and extension projects of Anhui Hengyuan coal electricity group is located in Anhui province, China. There are two vertical shafts, north auxiliary shaft and north air shaft.

During north auxiliary shaft excavation, the above researches have been employed for blasting parameters design. The net diameter of north auxiliary shaft is 7.0m, and the depth of shaft is 1019m. Freezing method and grouting technique have been used. The freezing depth is 316m.

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FJD-6G umbrella drilling derrick has been employed with 6 rock drilling machine.

Button bits with diameter of 55mm are used for cutting blastholes, and bits with diameter of 42mm are used for periphery blastholes.

T220 anti-freezing water-gel explosives are selected.

Electric detonators from segment Ⅰ to segment Ⅸ are chosen.

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Double cutting blasting has been adopted. The inner two circle blastholes are cutting holes and their depth is 5.0m. While the depth of other blastholes is 4.8m.

Table 2 Blasting paramters

Circle	Blasthole number	Dameter of circle /m	Hole angle	Hole depth /m	Space /mm		Charge			Charge coefficient	Segment of detonator
					Hole space	Circle space	Each hole: Number of explosive	Each hole: Charge mass /kg	Charge mass per circle /kg		
1	12	1.7	90°	5.0	440	850	8 Φ45	5.6	67.2	0.64	I
2	16	3.4	90°	5.0	650	1000	8 Φ45	5.6	89.6	0.64	III
3	22	5.4	90°	4.8	750		7 Φ45	4.9	107.8	0.58	V
4	30	7.4	90°	4.8	750	1000	6 Φ45	4.2	126.0	0.5	VII
5	46	8.8	87°	4.8	600	700	4 Φ45	2.8	128.8		IX
Sum	126								519.4		

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Blasting vibration measure points in circular vertical symmetrical form are placed in freeze groove of north auxiliary. Seen from figure 15, Gypsum is chosen to fix the velocity sensors, and let the X direction point to shaft centre.

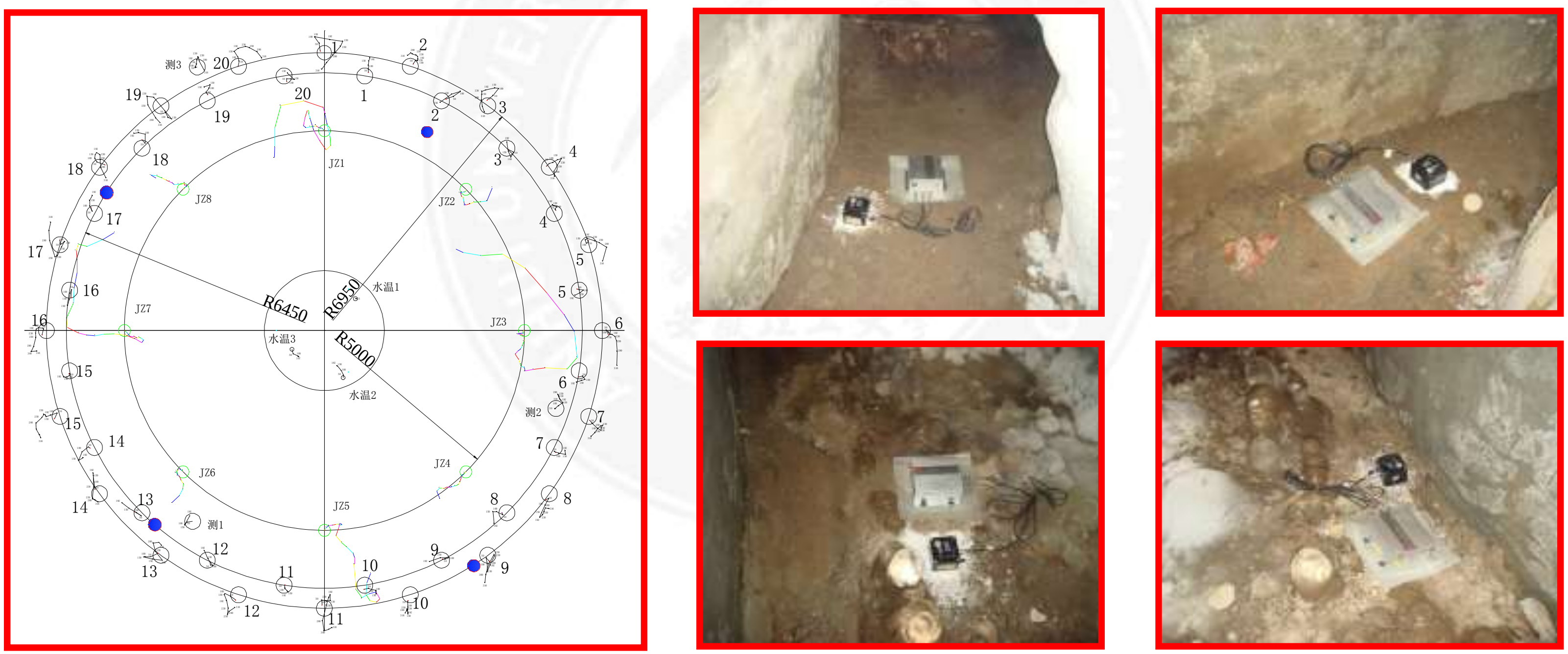

Fig.15 Measure of blasting vibration

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With the optimized blasting scheme, the blasthole utilization factor can reach 91%.

Table 3 - Blasting results

Section height /m	Advance /m	Segment of electric detonator and charge of explosives										Charge mass /kg	blasthole utilization factor /%
		Ⅰ		Ⅲ		Ⅴ		Ⅶ		Ⅸ			
		Hole number	Number of explosive	Hole number	Number of explosive	Hole number	Number of explosive	Hole number	Number of explosive	Hole number	Number of explosive		
275~279	4.5	12	8	14	7	18	7	24	7	53	6/7	614.1	93.7
279~283	4.3	12	8	13	7	19	7	25	7	58	6/7	654.6	89.6
283~287	4.6	12	9	13	8	18	8	26	7	62	6/7	678.9	95.8
287~291	4.3	12	8	13	6/7	18	6/7	26	6/7	60	6	587.0	89.6
291~295	4.4	12	8	12	6/7	21	6/7	25	6/7	60	6	583.4	91.7
295~299	4.3	12	8	14	6/7	21	6/7	29	6/7	57	6	557.0	89.6

Thank you.