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Numerical Simulation of Hole Distribution Blasting with Different Distribution Forms

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ABSTRACT

According to the vibration of cut blasting, the number of holes and the location of holes are reasonably designed by using finite element software LS-DYNA. The rectangular holes and hollow holes in straight cut are simulated respectively. Of the hole in the straight-cut undercut blasting vibration law. The analysis shows that the larger the diameter of the hole is, the better the vibration reduction is. The more the number of holes is, the more obvious the damping effect is. The best blasting effect of the large diameter hollow hole and the large diameter rectangular hole is 0.93cm/s Reduce the blasting vibration speed, buffered the blasting time; get both a good blasting effect and effective rapid damping effect.

Keywords: Undercutting; Blasting; Void; Vibration law; Vibration reduction

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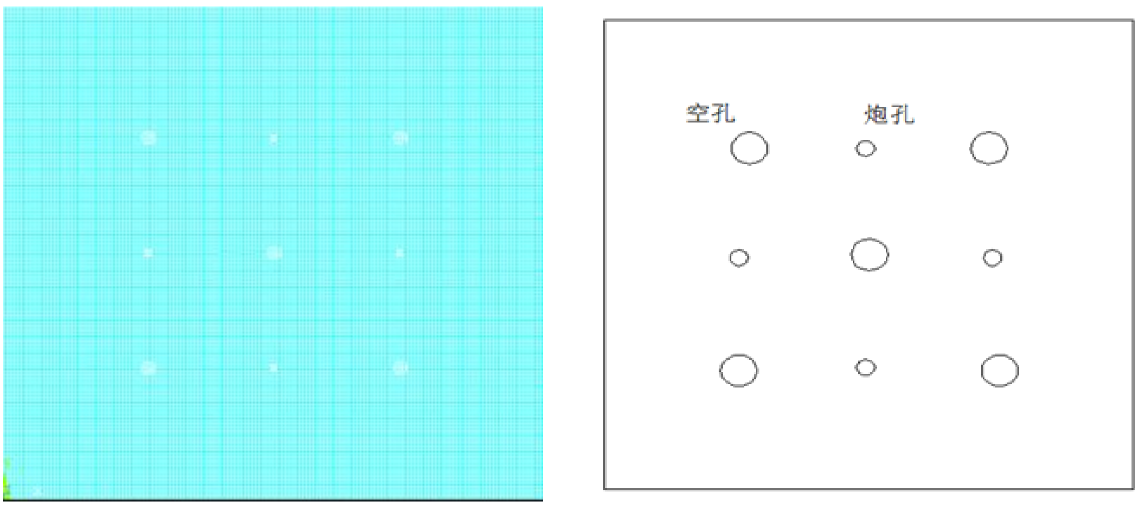
Preface

Drilling hollow holes in cutting blasting can effectively increase the utilization rate of cutting and improve the speed of excavation. Among them, many scholars have conducted research and analysis on the effect of the hollow hole of the straight hole cutting, the relationship between the depth of the blast hole and the hole area [1], and the mechanism study of the hollow hole of the straight hole blasting [2], using LS-DYNA finite element software conducts multi-direction and multi-angle exploration on straight-cut blasting [3,4]. Straight-hole cutting blasting is also well applied in bored piles, roadways and tunnels [5-8]. While meeting the tunneling effect, the influence of blasting vibration on surrounding rock and surrounding rock should be considered in many cases. In order to reduce the damage to surrounding rock and surrounding rock caused by vibration generated by cutting blasting, large diameter empty hole is drilled to effectively reduce vibration damping effect [9-11]. It is very important to reasonably design the number of empty holes and correctly arrange the location of empty holes when vibration is harmful to surrounding rock damage, especially to buildings above ground.

1. Calculation Model

1.1 Modeling method

ANSYS / LS-DYNA software was used to simulate the cutting form of different diameter and number of empty holes, and the 300cm × 300cm × 250cm (XYZ) model was established（As shown in Figure 1. The filling part of the blast hole was 80cm, the distance between the four holes was 70cm, and the distance between the rectangular hole and its two adjacent holes was 70cm. Among them, the diameter of blast hole is 40mm, the diameter of small hole is 40mm, the diameter of large hole is 90mm, and the depth of empty hole is 20cm deeper than that of blast hole. In order to approach the actual effect and avoid adverse effects caused by too large density difference between blasting materials, Lagrange method is used for rock and filling part, ALE method is used for explosive and air part. 720000 grid elements are divided in the model, and non-reflection boundary is adopted for side and bottom surface.



（a） (b)

Fig. 1 rectangular hole and hollow hole joint undercutting model

1.2 Material model and parameters

(1) Explosives. The initial density, detonation velocity and detonation pressure of the explosive are $\rho_0 = 1.2 g \bullet cm^{-3}$ 、 $D_e = 4000 m \bullet s^{-1}$ 、 P_{c-j}

=1.2×10[4]MPa. The JWL equation of state defines the pressure as a function of the initial energy E of relative volume and unit volume V.

$$P = A(1-\frac{\omega}{R_1 V})e^{-R_1 V} + B(1-\frac{\omega}{R_2 V})e^{-R_2 V} + \frac{\omega E}{V} \quad (1\text{-}1)$$

Where: parameters ω, A, B, R1 and R2 are constants characterizing the characteristics of explosives. The equation of state can accurately describe the pressure P, Volume V and energy characteristics of detonation products in the process of explosion.

Table 1 explosives parameters and JWL equation of state parameters

density /(Kg/m)	detonation velocity /(m/s)	A /GPa	B /GPa	R1	R2	ω	E^0 /GPa	V
1200	4000	285	6.44	4.9	1.95	0.52	7	1

(2) Rock and packing materials. The cuttings in the filling part can be made of MAT_SOIL_CONCRETE material. The damage process of rock under the action of explosion stress wave can be taken as *MAT_PLASTIC_KINEMATIC model, and controls material failure by yield stress limit and failure strain. The strain rate factor is 1+ $(\frac{\varepsilon}{C})^{\frac{1}{p}}$ introduced into the yield stress, and the relationship between yield stress δ_y and strain rate ε is as follows:

$$\delta_y = [1 + (\frac{\varepsilon}{C})^{\frac{1}{p}}](\delta_0 + \beta E_p \varepsilon_{eff}^p) \quad (1\text{-}2)$$

$$E_p = E_o E_{\tan} / (E_o - E_{\tan}) \quad (1\text{-}3)$$

Where: δ_0 is the initial yield stress of rock mass; E_0 is young's modulus; ε is the loading strain rate; C is Cowper-Symonds strain rate parameter; E_o is the plastic hardening modulus of rock; $E_{\tan}$ is the tangent modulus; β is the hardening parameter contributed by isotropic hardening and kinematic hardening, 0≤ β ≤1; E_p is the plastic strain component of rock, and the rock mechanical characteristic parameters are shown in Table 2.

Table 2 Rock mechanics characteristics parameters

	ρ /($g \bullet cm^{-3}$)	E_o /GPa	μ	σ_0 /MPa	$E_{\tan}$ /GPa	β	C
hard rock	2.7	69	0.23	100	4.5	0.5	2.63
Gun mud	2.6	19.3	0.38	80	2.1	0.5	2.63

(3) Air. The constitutive behavior of air is represented by an empty material constitutive model and a linear polynomial equation of state, and its density is 1.2929×10^{-3} g·cm^{-3}, and the relevant parameters are shown in Table 3. In the table 3, $C_0 \sim C_6$ are the parameters of the equation; E_0 is the internal energy per unit volume in the initial state of air; V_0 is the initial relative volume.

Table 3 Air state equation parameters

C_0	C_1	C_2	C_3	C_4	C_5	C_6	E_0/GPa	V_0
-10^{-6}	0	0	0	0.4	0.4	0	2.5×10^{-6}	1

2. Analysis and results

Take points at the same position on each model (as shown in Fig. 2). If the sampling points encounter empty holes, take one point around the hole above the same line, and five sample points are A, B, C, D, E, and obtain the vibration law diagram of the sample points under the cutting mode of different aperture and different number of empty holes.

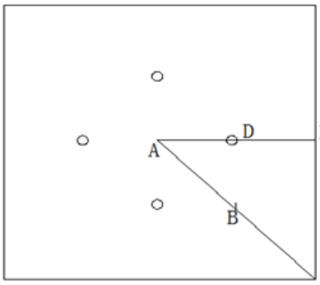


Fig.2 sample location map

2.1 Comparative analysis of small diameter empty hole and large diameter empty hole cutting

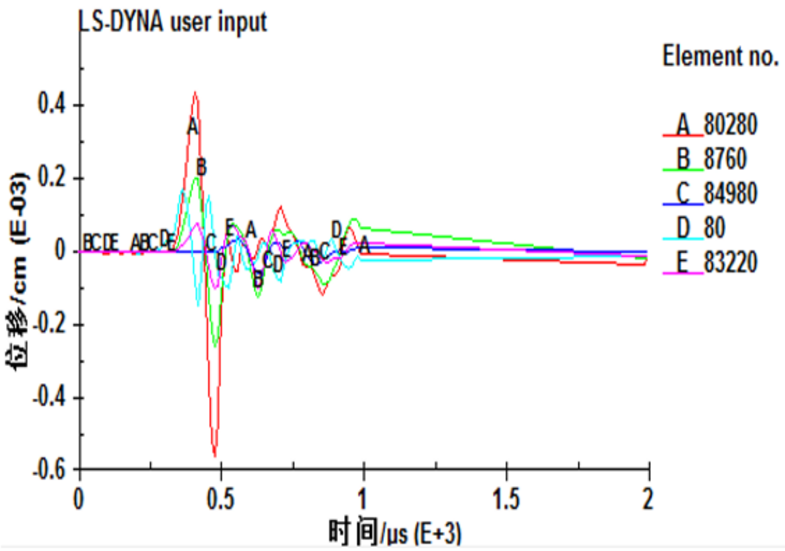
From the vibration diagram of (a) and (b), (c) and (d) in Fig. 3, it is concluded that the vibration velocity of large diameter hollow hole is smaller than that of small diameter hollow hole, and that of large diameter rectangular hollow hole is smaller than that of small diameter rectangular hollow hole. Through comparative analysis, increasing the diameter of empty hole is equivalent to increasing the free surface, and increasing the diameter of empty hole can obviously improve the blasting vibration effect.

2.2 Comparative analysis of hollow hole and rectangular hollow hole cutting

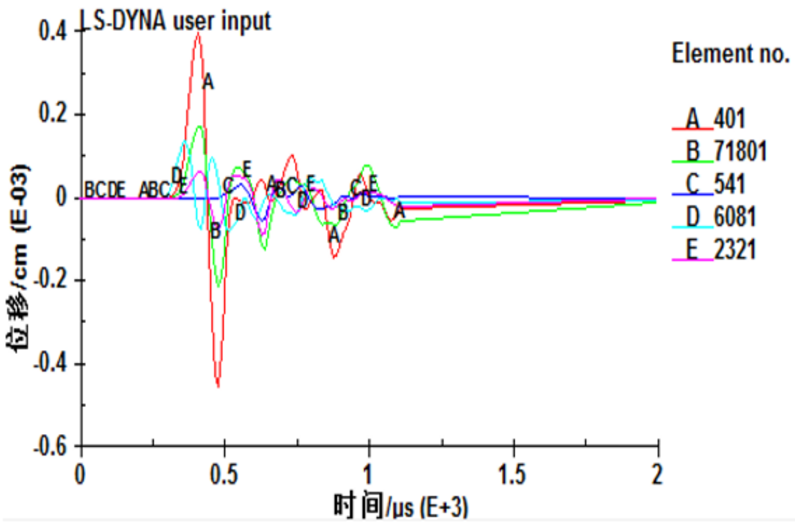
It is not difficult to see that the blasting vibration effect of rectangular hole cutting blasting is better than that of middle hole cutting blasting, and the blasting vibration of large diameter rectangular hole cutting mode is the least. Compared with small diameter rectangular hole cutting blasting and middle large diameter empty hole cutting blasting, the cutting volume is the same, the number of empty holes is different, the distribution position is not consistent, the effect is not consistent, the vibration effect of the former is better than the latter. In the cutting blasting, the empty hole can act as a guide hole, so that the energy of stress wave can be converted and released in the hole, which delays the continuous propagation of stress wave and reduces the transmission energy of stress wave. In addition, due to the existence of empty holes, the stress wave surface in the rock appears breakpoints, and the waveform is distorted, which is equivalent to changing its propagation frequency instantaneously, which plays the role of dispersing energy frequency band, which is conducive to reducing blasting seismic effect and preventing its damage to surrounding rock and surrounding buildings.

2.3 Analysis on cutting blasting of hollow hole and rectangular hole

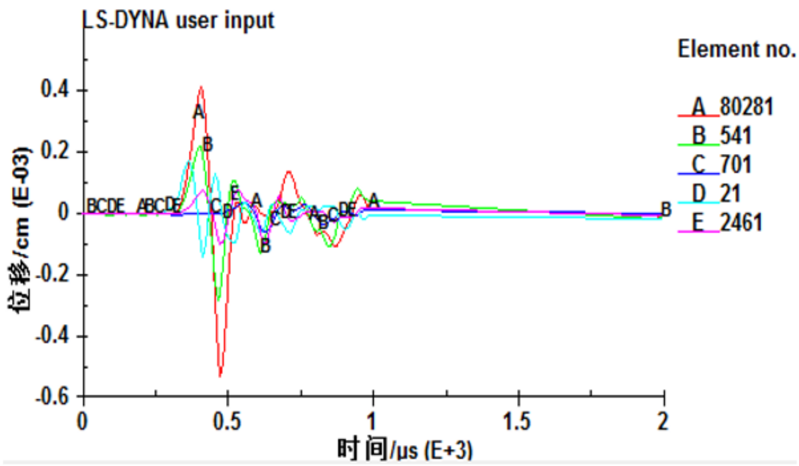
The open hole is taken as the free surface and the expansion space of broken rock. The hollow hole is deeper than the blast hole, and the axes are parallel to each other, and the resistance line is consistent. The distance between the hollow hole and the rectangular hole is the same as that of the adjacent hole, which means that the three empty holes adjacent to the blast hole are all regarded as the free surface and have double shock absorption effect. Therefore, its vibration velocity is much smaller than that of hollow hole and rectangular hole cutting blasting, which has a good protection effect on surrounding rock and surrounding buildings.



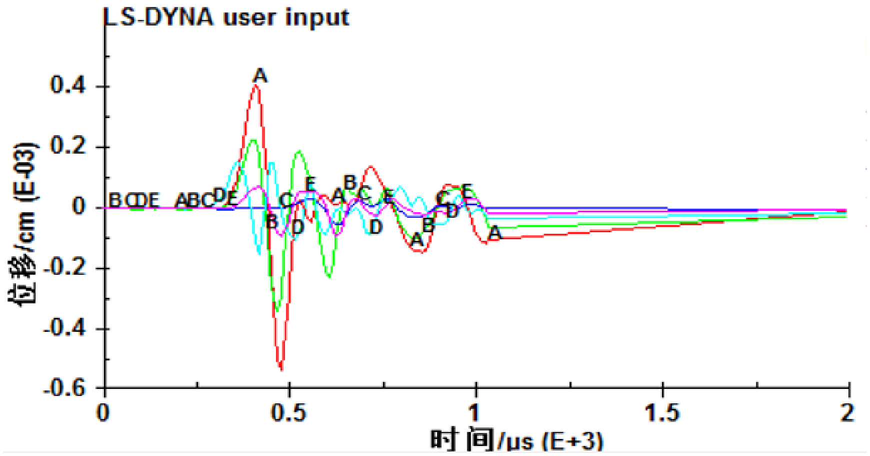
(a) Small diameter hollow hole



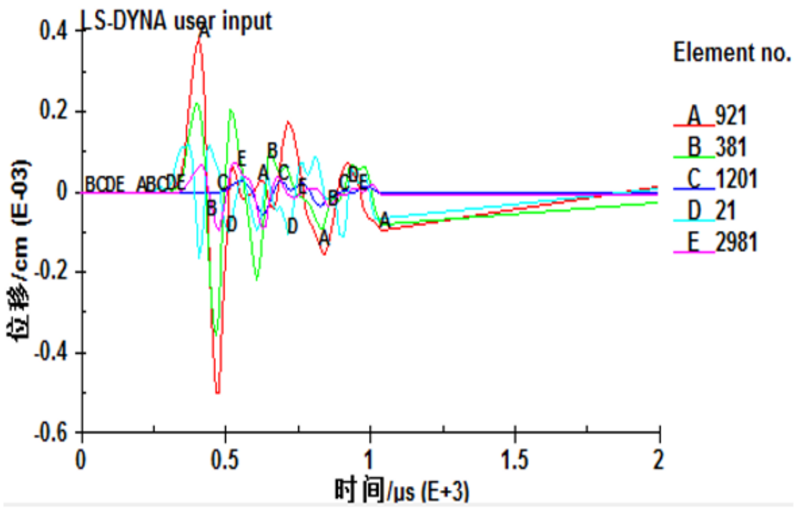
(b) large diameter hollow holes and rectangular holes



(c) Small diameter rectangular holes



(d) large diameter rectangular holes



(e) Large diameter hollow hole

2.4 Result analysis

The analysis above shows that the highest peak of vibration velocity is at point A regardless of the size and arrangement of empty holes. During the initiation, the energy of blasting part meets and interacts at point A, so the peak of vibration velocity appears at point A. In the cutting blasting of hollow hole, the empty hole is regarded as the free surface, and most of the energy in the blast hole propagates to the direction of the hollow hole. Due to the inconsistent propagation direction, part of the shock wave energy offsets each other. This method has a good vibration reduction effect and avoids the problem of too large block at the empty hole. When rectangular hole cutting blasting is carried out, the rectangular hole is taken as the free surface, and the shock wave compresses the air at the empty hole Some energy is dissipated and the vibration velocity is reduced. In figures (a), (b), (c), (d) and (e), the maximum blasting vibration velocity of middle small diameter empty hole cutting is 1.25cm/s, that of rectangular small diameter hole cutting is 1.17cm/s, that of middle large diameter hole cutting is 1.14cm/s, that of rectangular large diameter hole cutting is 1.01cm/s, and that of hollow hole and rectangular hollow hole is 0.93cm/s. As shown in Fig. 4, the large diameter hole is smaller, the free surface of the hole is larger, and the vibration velocity of the small diameter hole is larger than that of the large diameter hole at the same position, and the results show that the free surface size of the small diameter rectangular hole is consistent with that of the large diameter empty hole, and the maximum vibration velocity of the small diameter rectangular hole is small, and the vibration speed is related to the number of empty holes; the vibration effect of the combination of large diameter rectangular hole and large diameter rectangular hole is the best.

3. Conclusion

(1) The diameter of the empty hole is equivalent to the free surface. The larger the hole diameter is, the smaller the vibration velocity is. The free surface is inversely proportional to the vibration velocity.

(2) When the size of the free surface is fixed, the vibration velocity is related to the position and number of empty holes. The position of empty holes can guide the blasting energy. The more the number of empty holes, the less the peak value of vibration velocity.

(3) In cutting blasting, reasonable design of empty hole number and correct layout of empty hole position can effectively protect surrounding rock and above ground buildings. The combination of hollow hole and rectangular hollow hole can effectively "shunt" the vibration peak value of blasting energy. This kind of empty hole distribution can effectively reduce blasting vibration, which can be considered in the protection of important buildings.

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