

Damage to Rocks by Eccentric Uncoupled Charge Explosion Loads

Mingxiao Bai^{1,*}

¹ School of Civil Engineering, Henan Polytechnic University, Jiaozuo 454000, China

* Corresponding author: Bai Ming-xiao (Email: 1409950099@qq.com)

Abstract: In the process of tunnel excavation, the blasting technology is one of the commonly used tunnel excavation methods. The blasting technology is mainly divided into smooth blasting and presplitting blasting. In the process of blasting, in order to prevent excessive damage caused by explosive blasting, the blasting is often carried out by means of uncoupled charging. In the previous studies, the explosive and the blast hole were mainly placed concentrically, while in the actual engineering, the charge often exists in the form of eccentricity. In this study, LS-DYNA is used to establish three-dimensional models of concentric charge and eccentric charge respectively for numerical simulation of blasting, and the whole process of uncoupled charge blasting is reproduced. Based on the damage cloud diagram, hole wall pressure and hole wall vibration velocity obtained by simulation, the damage caused by blasting under two different charging conditions is analyzed and compared.

Keywords: Eccentric uncoupled charge, Blast, Decoupling coefficient, LS-DYNA.

1. Introduction

So far, the drilling and blasting method is a common excavation method in the process of tunnel excavation. In the process of blasting construction, only 20-30% of the energy is used to break the rock, and the rest of the energy is often consumed with surrounding rock vibration and gravel throwing ⁽¹⁾. Therefore, drilling and blasting excavation has always been the object of attention.

In the process of blasting, in order to prevent excessive damage caused by explosive blasting, uncoupled charge is often used for blasting. In the previous studies, the explosives were mainly placed concentrically with the blast holes ⁽²⁻⁴⁾, while in the actual engineering, the charge often exists in the form of eccentricity. In view of this, this paper uses ANSYS / LS DYNA finite element software to establish three-dimensional numerical models of eccentric and concentric uncoupled charges respectively, and study the influence of eccentric uncoupled charges on rock damage under explosion load, in order to provide technical support for the improvement and optimization of eccentric uncoupled charges.

2. Establishment of Blasting Numerical Model

2.1. Model Establishment

The model is established by using ANSYS / LS-DYNA numerical simulation software, as shown in Fig. 1. In order to study the impact of eccentric coupling charge and concentric uncoupling charge blasting on surrounding rock, two working conditions are considered in this paper. The uncoupling coefficient of the two working conditions is the same, $k = 3$. The first working condition is concentric uncoupling charge, as shown in Fig. a, and the second working condition is eccentric uncoupling charge, as shown in Fig. B. A cylindrical rock is established, with a rock radius of 1m, a height of 0.1M, a charge length of 0.5m and a charge radius of 0.045m. Considering the interaction of rock, explosive and air, the

fluid solid coupling algorithm is adopted, that is, the Lagrange algorithm is adopted for rock, the ALE algorithm is adopted for explosive and air, and the keyword * constrained is used_LAGRANGE_IN_Solid couples the solid domain with the fluid domain, and the non reflective boundary condition is used to simulate the infinite rock region around the rock mass.

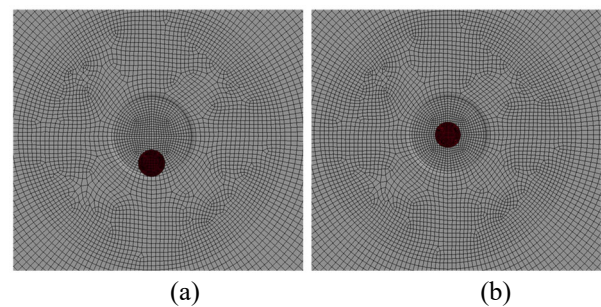


Figure 1. Model diagram

2.2. Material Model and State Equation

2.2.1. Explosive Material Model and Equation Of State Parameters

For explosive materials: The explosive constitutive *MAT_HIGH_EXPLOSIVE_BURN (material type 8) provided by the ANSYS/LS-DYNA software material library was used to simulate rock emulsified explosives No. 2, and the Jones-Wilkins-Lee equation of state (*EOS_JWL) was used to simulate the functional relationship between the pressure volume and energy of the detonation products during the explosion process, which has the following function equation:

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

Where P is the explosion pressure; V is the relative volume; AJ, BJ, R1, R2 are equation of state parameters. The specific parameters are shown in Table 5:

Table 1. Explosives material model and equation of state parameters

ρ_0 Kg·m ⁻³	D_J m·s ⁻¹	A_J GPa	B_J GPa	R_1	R_2	ω	E_0 J·m ⁻³
1050	4000	540.9	9.4	4.5	1.1	0.35	8×10 ⁹

2.2.2. Air Material Model and Equation of State Parameters

For air materials: In LS-DYNA, air materials are typically defined by the keyword *MAT_NULL with *EOS_LINEAR_POLYNOMIAL equation of state, which is:

$$P = C_0 + C_1\mu + C_2\mu^2 + C_3\mu^3 + (C_4 + C_5\mu + C_6\mu^2)E$$

Where: μ is the specific volume, which is the volume parameter used for calculation, $\mu = \rho_a / \rho_0 - 1$; ρ_a is the current moment density of the air; ρ_0 is the initial moment density of air; E is the internal energy density. For specific parameters, see Table 2.

Table 2. Air material model and equation of state parameters

ρ_0 Kg·m ⁻³	C_0	C_1	C_2	C_3	C_4	C_5	C_6	E KJ·m ⁻³	V
1.293	0	0	0	0	0	0	0	235	1

2.2.3. Model of Rock Materials

At present, in dyna software, there are Mohr-Coulomb models and Drucker-Prager models for constitutive models of rock materials in geotechnical engineering. However, for rock materials, it is necessary to consider both strain rate effect and damage on rock strength and failure strain, and the JOHNSON_HOLMQUIST_CONCRETE damage constitutive model used in this paper is an ANSYS/LS-DYNA software, which is numbered 111. Proposed by Holmquist et al. in 1993, the model takes into account simulations of concrete and rock at high strain rates and large deformations, model evolution equations and parameter references.

(1) Strength model, which is described in terms of equal effect forces, considers the effects of strain, strength, strain rate, etc., and its expression is:

$$\sigma^* = [A(1-D) + BP^{*N}] \left[1 + C \ln \left(\frac{\dot{\epsilon}^*}{\epsilon^*} \right) \right]$$

(2) Damage model, which describes the degree of damage to the model, and its expression is:

$$D = \sum \frac{\Delta \epsilon_p + \Delta \mu_p}{D_1 (P^* + T^*)^{D_2}}$$

(3) Equation of state, the equation of state of the HJC model is used to describe the relationship between hydrostatic pressure and volumetric strain, and the whole process can be divided into three stages: elasticity, plasticity and compaction.

Elastic Phase:

$$P = k_e \mu$$

Plastic stage:

$$P = P_{crush} + K_{crush} (\mu - \mu_{crush})$$

Compaction Phase:

$$P = K_1 \mu + K_2 \mu^2 + K_3 \mu^3$$

3. Analysis of Simulation Results

3.1. Damage

As shown in Fig. 2, a is the damage cloud diagram caused by concentric charge blasting of explosive and blast hole, and B is the damage cloud diagram caused by eccentric charge blasting of explosive and blast hole. It can be seen from the figure that the damage caused by concentric charging blasting

of explosives and blast holes is evenly distributed, and there are damages around the blast holes. However, the damage caused by eccentric charging blasting of explosives and blast holes starts from the rock near the explosives, and the damage to the rock near the explosives is more serious.

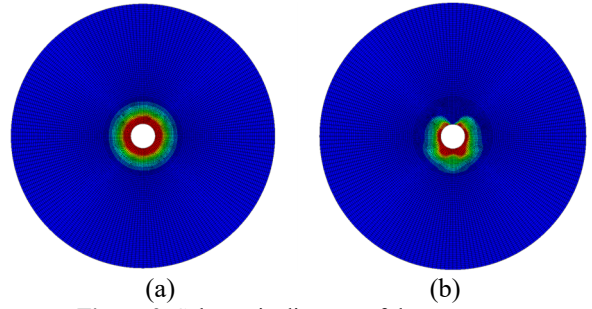
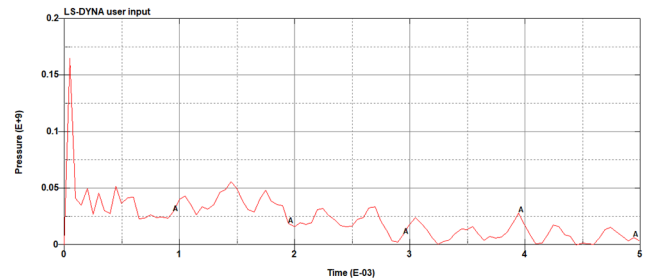


Figure 2. Schematic diagram of damage

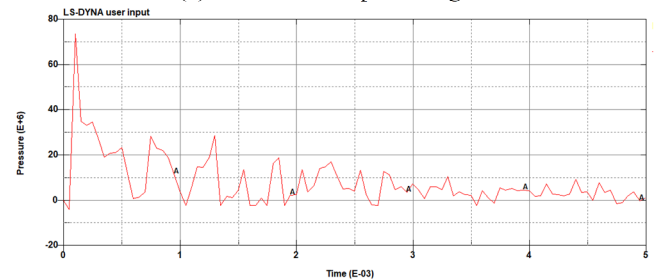
3.2. Hole Wall Pressure

In order to study the influence of eccentric uncoupled charge and concentric uncoupled charge blasting on the pressure of rock, the monitoring points are selected at the same location to analyze the pressure of the point under two different conditions, as shown in Fig. 3.

Fig. a shows the hole wall pressure after blasting when the concentric uncoupled charge is applied. It can be seen from the figure that the maximum value is 73.8mpa; Fig. B shows the hole wall pressure near the explosive position after blasting when the eccentric uncoupled charge is applied. It can be seen from the figure that the maximum value is 165.4mpa. It can be seen that under the same other conditions, the eccentric uncoupled charge is subject to greater pressure than the concentric uncoupled charge at the rock close to the charging position.



(a)Eccentric uncoupled charge



(b)Concentric uncoupled charge

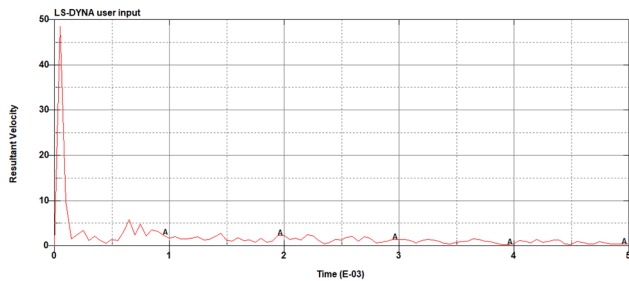
Figure 3. Pressure-time plot

3.3. Vibration Speed of Hole Wall

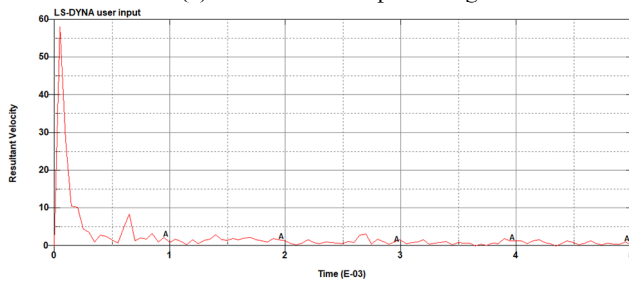
In order to study the influence of eccentric uncoupled charge and concentric uncoupled charge blasting on the vibration velocity of rock, monitoring points are selected at the same location to analyze the vibration velocity of the point under two different conditions, as shown in Fig. 4.

Fig. a shows the vibration velocity of the hole wall after

blasting when the concentric uncoupled charge is applied. It can be seen from the figure that the maximum value is 48.6m/s; Fig. B shows the vibration velocity of the hole wall near the explosive position after blasting when the eccentric uncoupled charge is applied. It can be seen from the figure that the maximum value is 58.2m/s. It can be seen that, under the same other conditions, the eccentric uncoupled charge has a larger vibration velocity at the rock where the charging position is closer than the concentric uncoupled charge.



(a)Concentric uncoupled charge



(b)Eccentric uncoupled charge

Figure 4. Velocity-time plot

4. Conclusion

The three-dimensional numerical models of concentric uncoupled charge and eccentric uncoupled charge are established by LS-DYNA and the numerical simulation is carried out to reproduce the whole process of blasting. It is concluded that under the same conditions, the damage caused by concentric charge blasting of explosive and blast hole is evenly distributed, and there is damage around the blast hole, However, the damage caused by eccentric charge blasting of explosive and blast hole extends outward from the rock near the explosive, and the damage of rock near the explosive is more serious; Compared with the concentric uncoupled charge, the eccentric uncoupled charge has greater pressure and vibration velocity at the rock near the charging position. Therefore, the rock damage effect caused by the concentric uncoupled charge and the eccentric uncoupled charge blasting is different.

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