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Physical scale modelling of roadway advance with wedge cut blasting for South Wing Rail at Tunliu Mine

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PHYSICAL SCALE MODELLING OF ROADWAY ADVANCE WITH WEDGE CUT BLASTING FOR SOUTH WING RAIL AT TUNLIU MINE

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ABSTRACT: Blasting with wedge cut is the key to the efficiency of roadway excavation in coal mines, particularly where the rock face is highly laminated. The quality of the wedge cuts can directly affect blasting results. A series of model experiments were carried out in the Blasting Laboratory of Henan Polytechnique University, China, in order to improve the quality of wedge cuts and increase roadway development rates in the South Wing rail of Tunliu mine. Three groups of twelve wedge cut model experiments were conducted, which showed that the wedge cutting boreholes angle can affect the depth and volume of blasted zone. It was found that; symmetrical cut pattern was beneficial, and effective stemming of the blasting holes can enhance explosive energy efficiency and ensure effective blasting. Suitable roadway wedge cut blasting parameters were determined through the analysis of test results.

INTRODUCTION

Blasting with a wedge cut is the key to the efficiency of roadway excavation in coal mines. The quality of wedge cut can directly affect the blasting results. The depth of the wedge has a direct impact on the length of the face advance. The quality of the wedge cut is related to the geological conditions of the host rock and the type and quantity of explosives and the detonation sequence (Xiaolin and Yu, 2009; Huateng, 1984; Shouzhong, 1988). Wedge cut blasting design model experiments were conducted in the Blasting Laboratory of Henan Polytechnique University in order to improve the quality of blasting with wedge cut and increase roadway development rate in South Wing rail of Tunliu mine. According to the physical and mechanical parameters of rock South Wing rail of Tunliu mine, three groups of tests, comprising a total of twelve wedge cut blasting model experiments were conducted to determine suitable roadway cutting blasting parameters.

BLASTING WITH WEDGE CUTS

Various drilling patterns have been developed for blasting solid rock faces for development mine drifts, ramps and roadways. One of these patterns is the V type wedge cut. In this pattern, the blast holes are drilled at an angle to the face forming a uniform wedge in the middle of the rock face. Upon blasting, the wedge cut is effectively ejected from the rock face, and the wedge is further widened to the full width of the drift in subsequent blasts, each blast being fired with detonators of suitable delay time. This type of cut is particularly suited to coal mines, where the rock is well laminated (Gabshen, 2009; Zhongjie, 2010). In effect, the ejection of the wedge creates a new free surface that helps produce better quality fragmentation when the rest of the blast holes are fired. The number of blast holes needed to form a wedge is usually two to four pairs, and they should be symmetrically drilled with respect to the rock face; see Figure 1. The spacing between the holes is 0.2 to 0.3 m at the wedge bottom. The wedge strike can be either vertical (Figure 1a) or horizontal (Figure 1b). The wedge apex angle is 60° to 30°, which makes the angle of the drill holes with the rock surface in the range of 60° to 75° respectively. When the rock is particularly strong and brittle and the required depth is more than 2 m deep, the wedge pattern can be repeated as shown in Figure 1c to form a double wedge (Yu, 2009).

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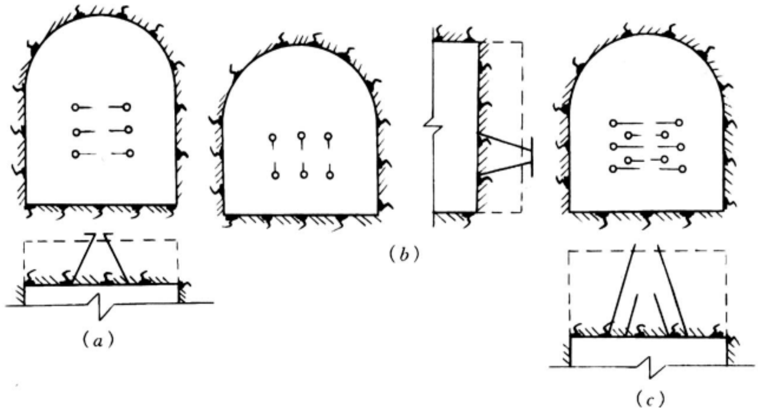


Figure 1 - Wedge cut patterns, (a) Vertical wedge (b) Horizontal wedge (c) Double wedge

MODEL EXPERIMENTS

Objectives

The main goals of the experimental study were:

- Investigate the effect of wedge apex angle or the inclination angle of the blast holes with respect to the rock face;
- Determine the most suitable wedge cut pattern;
- Verify the role of blast-hole block;
- Verify the rock blasting mechanism.

Experimental design

According to the rock physical and mechanical properties of South Wing rail of Tunliu min, the roadway rock strength was divided into three groups at 38.5 MPa, 50 MPa and 25 MPa. The 38.5 MPa strength group accounted for 80% of the roadway rock. According to the criteria of "similarity", as specified by the Chinese Academy of science (1986), the physical scale and model dimensions were 1:20 and 300×300×300 mm (actual engineering 6000×6000×6000 mm) respectively. The models were made from a mixture of water, cement and sand. Three materials were prepared with the following proportions of water: cement: sand - 1:1.9:8.4, 1:2.3:7.2 and 1:2.5:8.0. The cement strength grade used for the models was 32.5 (R) ordinary Portland cement. Testing was carried out in the Blasting Laboratory of Henan Polytechnique University, China. Twelve physical scale models were made. All models were given a curing period of 28 days. Nine models were used to examine the effect of angle of inclination of blast holes with respect to the model face (Table 1). The number of blocks tested which were used to verify the role of blast-hole block is three. The split surface of each model tested was observed.

Table 1 - Experimentation design of physical scale models

Number	Strength (MPa)	Depth of hole (mm)	Hole inclination (°)				Dose per hole (g)
			1	2	3	4	
1	38.5	70	70	70	70	70	0.1
2			75	75	75	75	0.1
3			80	80	80	80	0.1
4			70	70	80	80	0.1
5			80	80	80	70	0.1
6	50	70	70	70	70	70	0.1
7			80	80	80	80	0.1
8	25	70	70	70	70	70	0.1
9			80	80	80	80	0.1

Experimental methods

The holes were made with an electric drill (diameter of 5 mm). A protractor and ruler were used to ensure the accuracy of the hole angle, the type of explosive matching the material should used was in accordance to the impedance principle. Taking into account the smaller size of the model dimensions and drill hole size, and in order to more easily observe blasting effect, a high detonation velocity elemental RDX explosive was used. Each hole charge was 0.1 g, determined according to the model of rock mass strength calculation, and taking into account misfire factors. The detonation means of model was by a gunpowder head. The major risk factors for the model blasting experiment were based on noise, blast shock wave and flying rocks. Because of the small amount of explosive, the noise and blast shock wave were at a safe range for the laboratory use. In order to protect laboratory personnel and facilities from flying rocks, a rubber cover was used. The cutting depth was measured after each blast. The volume of cut cavity was determined by placing a plastic bag in the cavity, and then pouring water into it. The volume of water needed to fill the cavity was recorded. After model blasting, the filling effect of blast-hole and the split plane of fracture and damage model were directly observed.

Figure 3 - Physical scale model

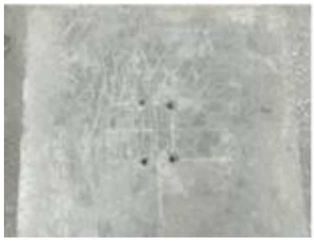


Figure 4 - Blast-hole pattern

Figure 5 - Measuring wedge cut cavity volume

Figure 6 – Measuring the cavity depth

Experimental results

Experimental results parameters include wedge cut cavity depth, volume and blast-hole utilisation and fragmentation. The recorded results are shown in Table 2. Figure 7 shows the groove cavity depth and volume comparison chart (model strength 38.5 MPa). Figure 8 is groove cavity depth comparison for the inclination angles of 70° and 80° for three different strength models. Figure 9 to Figure 13 present the model blasting effect diagrams. Figure 14 presents a comparison between stemming and no stemming of blast holes. Figure 15 shows the split surface of the blasted model.

Table 2 - Experimental results

Model	Groove depth (mm)	Groove cavity volume (ml)	Hole utilization (%)	Degree of stemming	Remarks
1	61	150	92.8	1	a wide range of fragments around the eight models groove cavity.
2	65	190	96	1	
3	68	220	98	1	
4	60	180	91	1	
5	61	140	87	1	
6	54	110	85	1	
7	66	130	94	1	
8	60	180	81	2	
9	63	190	86	1	

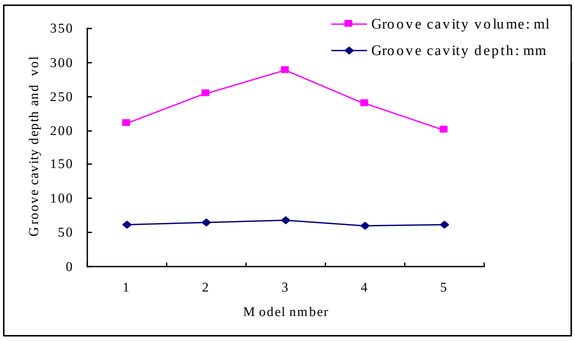


Figure 7- Groove cavity depths and volume comparison chart of model (38.5 MPa)

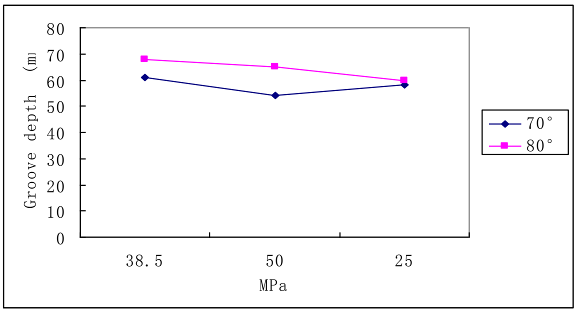
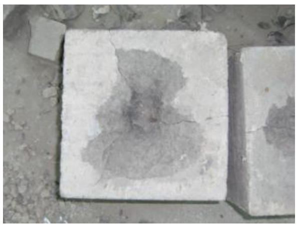


Figure 8 - Model groove cavity depth for different hole inclinations and material strength


(a)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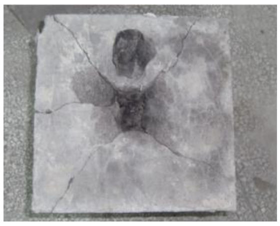
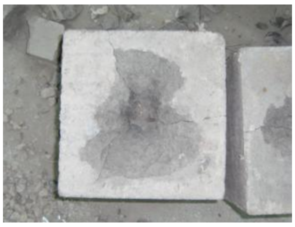

(c)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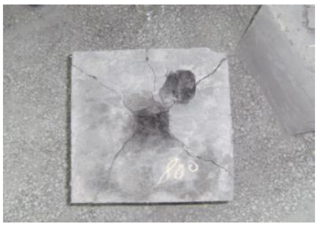

(e)

(f)

Figure 9 - Fragmentation pattern (38.5 MPa)

Figure 10 - Fragmentation pattern (50 MPa)

Figure 11 - Fragmentation pattern (25 MPa)

Figure 12 - Fragmentation pattern (50 MPa)

Figure 13 - Fragmentation pattern (25 MPa)

(a) Stemming **(b) No stemming**

Figure 14 - Blasting effect comparison chart

Figure 15 - Split surface of the basted area

MODEL EXPERIMENTAL FINDINGS

The effect of inclination angle on groove cavity depth and volume was shown in Figure 7. As can be seen, Model 3 (38.5 MPa) with an inclination angle of 80° shows the maximum cavity volume of 220 ml. Meanwhile, as can be seen from the groove cavity volume results reported in Table 2, the asymmetric inclination of the wedge cutting angle (Models 4 and 5) are less efficient than symmetric models with groove cavity volumes of 140 ml and 150 ml for Models 4 and 5 respectively. Figure 8 shows that for the same cutting angle, the groove cavity depth of varies for different strength models. However, as the cutting angle increases from 70° to 80°, the groove depth has increased. The fragmentation patterns of selected samples are shown in Figures 9 to 13 for the three rock types tested. Figure 14 demonstrates the difference between the fragmentation pattern of a block with stemmed blast-hole (Figure 14a), and another with no stemming (Figure 14b). Clearly, fragmentation is much more effective with stemming. Figure 15 shows that there is a smaller range of crush area around the blast holes and some traces caused by the detonation gas splitting into the surrounding area.

CONCLUSIONS

In the light of the results obtained from this experimental study a number of conclusions can be drawn. It appears that the best cutting angle for maximum cavity volume is 80° for the 38.5 MPa rock. The angle of inclination affects the cutting depth and volume; the ideal angle is 80°for the 38.5 MPa rock group, 70° for the 50 MPa rock group, and 85° for the 25 MPa rock. The tests show that asymmetric wedge cut produces shorter groove depth and less cavity volume, and therefore symmetrical cutting must always be used in field applications. In order to enhance the explosive energy efficiency, the blast-holes need to be well stemmed. Detonation gases will not work effectively if the holes are not stemmed to provide full fragmentation potential of the stress waves and detonation gases. Finally, it was found that there was a small crushed area around the blast holes and some shattering caused by the blast detonation.

REFERENCES

Huateng, C, 1984. *Technology of Controlled blasting* (in Chinese). Liaoning Science and Technology Press, pp 33-36.

Institute of Mechanics, Chinese Academy of Sciences. *Compilation of summaries of research reports and information* (in Chinese), China Science Press, pp71-73.

Shouzhong, Z, 1988. *Main Principles of Blasting* (in Chinese). National Defense Industry Press, pp 10-15.

Zhang, Ganshen, *Mine blasting* (in Chinese), Coal Industry Press, pp 141-145.

Xiaolin, Y and Yu, Y, 2009. Underground blasting (in Chinese). Wuhan Polytechnic University Press, pp 94-98.

Zhongjie, Z, 2010. *New Technology of Rock Blasting* (in Chinese). China Railway Press, pp125-136.