Study on pre-splitting blasting technology of hard roof face

Huaifu Liu\textsuperscript{1,2,3} and Zunyu Xu\textsuperscript{1,2}

\textsuperscript{1}China Coal Technology Engineering Group Chongqing Research Institute, Chongqing 400037, China;
\textsuperscript{2}State Key Laboratory of the Gas Disaster Detecting, Preventing and Emergency Controlling, Chongqing 400037, China
\textsuperscript{3}Email: 948247177@qq.com

Abstract. In order to solve the problems of hard roof caving and overhanging area in 220116 working face of Xinji No.2 Coal Mine, deep-hole pre-splitting blasting overburden technology is adopted to destroy the integrity of roof in advance so as to make it collapse as soon as possible, reduce the apparent strength of rock pressure of initial weighting, and slow down the destructive effect of initial weighting on support. The numerical simulation shows that the first collapse step of the basic roof is obviously reduced after the forced roof caving, which greatly reduces the impact disaster caused by large area roof weighting, is conducive to the stability of the support and roof safety management, and is of great significance to the safety production of the working face.

1. Preface

Hard roof refers to the roof with high strength, large thickness, strong integrity, which can be exposed in a large area in goaf after mining and is not easy to fall naturally in a short time [1]. Because of the high strength of the hard roof and the undeveloped cracks, the uniaxial compressive strength and elastic modulus are very large, which often lead to the failure of the working face to collapse in time after mining, resulting in a large area of suspended roof. The first weighting step of the working face is generally greater than 30m, and the maximum is 160m, resulting in the sudden release of a large amount of energy accumulated before collapse, resulting in violent dynamic phenomena, and slightly destroying the supporting equipment and equipment. The instantaneous air pressure injures people, and the serious one causes the dynamic disaster of rock pressure. Therefore, the problem of hard roof is a difficult problem in the safe mining of coal mine, and it has always been a key subject of roof control. At present, many scholars have done relevant research, and have achieved some theoretical and practical results [2-4]. However, the study on comprehensive treatment of high gas coal seam with hard roof by deep hole pre-splitting blasting technology needs further development and improvement [5-7]. In this paper, by using deep-hole pre-splitting blasting overburden technology and UDEC numerical simulation software, the overburden movement law after mining under the original hard roof and the overburden movement law after pre-splitting blasting in the initial mining stage in 220116 working face of Xinji No. 2 Coal Mine are simulated respectively. The simulation results are of great significance to the safety production of working face.
2. Principle of forced roof caving in deep hole blasting

Deep-hole blasting, that is, in semi-infinite medium, after explosion of explosive in the borehole, produces strong shock wave and a large number of high temperature and high pressure explosive gas. Because the explosion pressure far exceeds the dynamic compressive strength of the medium, the medium around the borehole is intensely compressed, crushed and formed a compressive crushing zone. In this area, a considerable part of the blasting energy is consumed on the excessive crushing of the medium, and then the shock wave transmits to the interior of the medium and propagates to the interior of the rock mass in the form of stress waveform. Under the action of stress wave, the radial displacement of the medium particle is generated, and the radial compression and tangential tension are produced in the medium near the compression zone. When the tangential tensile stress exceeds the dynamic tensile strength of the medium, radial cracks will occur and expand with the propagation of stress waves. When the stress wave attenuates below the tensile strength of the medium, the crack ceases to expand. While the stress wave propagates forward, the detonation gas expands rapidly and enters the radial crack generated by the stress wave, and the crack continues to expand due to the wedge action of the gas. With the continuous expansion of cracks, the explosive gas expands and the gas pressure decreases rapidly. When the pressure drops to a certain extent, the elastic energy accumulated in the medium will be released, forming an unloading carrier wave and propagating to the center of the borehole, resulting in annular cracks in the medium (usually fewer annular cracks). The area where radial and circumferential fissures intersect each other is called fissure area. When the stress wave further propagates forward, it has been attenuated enough to cause damage to the medium, but can only cause vibration of the medium particles, which propagates in the form of seismic waves until it disappears.

In the process of crack propagation, detonation gas enters first into the large crack with large opening width, more straight and less resistance to gas wedging, and then into the small crack with which it communicates, until its pressure drops to the point where it is insufficient for the crack to continue to expand. The quasi-static stress produced by explosive gas in rock mass decreases with the increase of the distance from the center of the borehole, so there is a stress gradient of explosive gas in rock mass. Driven by the pressure of explosive gas, the crack always extends in the direction of low pressure (or stress), that is, far away from the borehole, forming a fracture zone along the borehole axis. The fractured zone destroys the integrity of rock mass, so that the direct roof strata can fall with mining under the pressure of overlying strata.

3. Simulation and analysis of overburden movement law in deep hole pre-splitting blasting

3.1. Numerical model and parameter setting

The strength of hard quartz sandstone in 220116 working face of Xinji No.2 Coal Mine is large and the roof caving step is large. In order to avoid the accidents of personnel injury and equipment damage caused by large area of basic roof suspension and stress concentration in goaf of mining face, deep-hole pre-splitting blasting technology is adopted to force roof caving, which destroys the integrity of roof in advance and causes roof caving as early as possible, so as to reduce the apparent strength of roof pressure and slow down the initial pressure. The destructive effect of weighting on bracket can realize the production safety of 220116 working face in Xinji No. 2 Coal Mine.

The UDEC numerical simulation software is used in this simulation, and the model is established according to the comprehensive columnar map of the coal seam in the 212016 fully mechanized mining face. There are two computational models. Model 1 is a computational model of hard primary roof without pre-splitting blasting, which is used to simulate the movement of overburden after mining under the original hard roof; Model 2 is a pre-splitting blasting of hard roof at the initial mining stage to simulate the movement of overburden after mining. The simulation parameters are shown in Table 1. The size of the model is 200 m *80 M. The left and right boundary and the bottom boundary of the model are all displacement-fixed. The upper boundary of the model is applied with stress of 18 Mpa. The numerical model of model 2 is shown in Figure 1.
### Table 1. Mechanical properties of rock strata in numerical model.

| Strata sequence | Lithology       | Thickness /m | Density /kg/m³ | Shear modulus /GPa | Bulk modulus /GPa | Cohesion /MPa | Internal friction angle /º |
|-----------------|-----------------|--------------|----------------|--------------------|-------------------|--------------|--------------------------|
| 1               | Quartz sandstone| 20           | 2873           | 20                 | 22                | 4.92         | 37                       |
| 2               | Medium sand     | 9            | 2830           | 16                 | 20.4              | 2.8          | 30                       |
| 3               | Siltstone       | 7            | 2741           | 12                 | 16                | 4.8          | 40                       |
| 4               | Coal up         | 2            | 1380           | 1.6                | 3.0               | 1.20         | 28                       |
| 5               | Mudstone        | 0.6          | 2600           | 4.8                | 8.0               | 2.3          | 34                       |
| 6               | Coal seam       | 2.6          | 1420           | 1.8                | 3.6               | 1.12         | 35                       |
| 7               | Mudstone        | 4.8          | 2530           | 3.6                | 7.2               | 2.2          | 32                       |
| 8               | Sandstone       | 5            | 2803           | 10                 | 18                | 6            | 33                       |
| 9               | Siltstone       | 29           | 2766           | 5.0                | 7.5               | 2.1          | 30                       |

**Figure 1.** Numerical model of pre-splitting blasting.

### 3.2. Analysis of numerical simulation results

Figure 2 shows that the direct roof of the working face gradually collapses with the advance of the working face when no caving measures are taken under the condition of hard roof. However, the basic roof of the working face is not easy to break down and collapse, and the length of the suspended roof is very large. When the basic roof reaches the ultimate strength, it is easy to produce huge impact load, and the working face is prone to frame and hurricane impact accidents. From Figure 3, it can be seen that when roof caving measures are adopted, roof strata will immediately cave in and fill the goaf, which can play a buffer role to the overlying roof to a great extent, thus greatly reducing the weighting strength; and with the continuous advance of the working face, the main roof periodically collapses, the hanging roof length is small, the old roof can be cut off in time, and it is not easy to cause the death of the support and hurricane impact accidents.

The calculation shows that the first weighting step is 64m and the periodic weighting step is 26m in 220116 working face without blasting measures, and the first weighting step is 39.5m and the periodic weighting step is 21m after adopting blasting measures. The initial and periodic weighting step of the working face is greatly reduced compared with that without forced roof caving, thus reducing the weighting strength of the working face.
Figure 2(a). Working face advance 20m.
Figure 2(b). Working face advance 60m.

Figure 2. Movement law of roof strata under the condition of hard roof.

Figure 3(a). Working face advance 20m.
Figure 3(b). Working face advance 60m.

Figure 3. Movement law of roof strata after pre-splitting blasting of hard roof.

At the same time, the combination of Figure 2 and Figure 3 shows that the initial weighting of the basic roof without the forced caving measures of deep hole pre-splitting blasting is in the form of vertical "O-X" plate breakage, as shown in Figure 4(a). After the forced roof caving by deep-hole pre-splitting blasting, a fracture yield zone is formed vertically on the basic roof of the Cut-hole side, which makes the form of first roof breakage by weighting similar to periodic weighting, showing a "D" cantilever breakage form, and the basic roof collapse and subsidence at the Cut-hole side is large, as shown in Figure 4(b).

Figure 4(a). "O-X" type breakage without forced roof caving.
Figure 4(b). D-shaped breakage after forced roof caving.

Figure 4. Fracture form of primary pressure plate of pasic roof before and after forced roof loading.
The UDEC discrete element simulation shows that the first collapse step of the basic roof can be significantly reduced by using forced roof caving, which is conducive to reducing the impact disaster caused by large area roof weighting.

4. Conclusion
(1) Through explaining the principle of forced roof-caving in deep-hole blasting, the integrality of rock mass is destroyed by forced Roof-caving in deep-hole blasting, so as to achieve the goal of direct roof hard strata falling with mining under the pressure of overlying strata;
(2) By using UDEC numerical simulation software, the movement law of overburden after mining under the original hard roof and after pre-splitting blasting in the initial mining stage are simulated respectively. It is concluded that the initial and periodic weighting step distance of working face is greatly reduced compared with that without forced roof caving, and the basic roof breaking form before and after forced roof caving is obtained.
(3) Through simulation, it is found that after deep-hole pre-splitting blasting technology is adopted in 220116 working face of Xinji No. 2 Coal Mine, the impact disaster caused by large-area roof pressure is greatly reduced, which is conducive to the stability of support and roof safety management, and is of great significance to the safety production of working face.

Acknowledgments
This work was financially supported by the national key research and development program of China(2017YFC0804209),Chongqing science and technology innovation project of social undertakings and people's livelihood guarantee (este2017shmsA90008),Special fund for science and technology innovation and venture capital of China Coal Science and Technology Group Co., Ltd.(2018MS011),General project of Chongqing Research Institute of China Coal Industry Group Co., Ltd. (2017YBXM31),Special fund for science and technology innovation and venture capital of China Coal Science and Technology Group Co., Ltd.(2018-TD-MS076).

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