Applied Research of Deep-hole Presplitting Blasting Technology in Coal

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Abstract: Deep-hole presplitting blasting is a method to solve the problems of gas outburst and low recovery rate in thick and hard coal seam. After explosion, the coal seam permeability is higher than before, and the mass of coal-dropping is increased in result of the local stress change caused by loose blasting. Blasting parameters and cracking zone is calculated based on the theory of explosion. The application indicated that the gas content of the coal seam decreased and the recovery rate increased. The experiment result is in concordance with the result of calculation by theory.

1. Introduction
China's coal resources are characterized by rich storage, wide distribution, complex geological conditions and high gas content in some coal fields. The realization of safe and efficient coal mining is the development trend of the coal mining industry, the gradual perfection of blasting theory provides the necessary conditions for the development of coal mining industry.

Deep-hole presplitting blasting technology is widely used in gas drainage and top-caving mining in coal mines. Because of the poor permeability of coal seams in many coal mines, the gas flow in coal seams is not smooth in the process of gas drainage, the deep-hole blasting technology is applied to presplitting coal seams, at the same time, because of the low recovery rate in the hard and thick coal seam mining, it is necessary to loose blasting the top coal to improve the recovery rate [1].

2. Principle and function of deep hole presplitting blasting
According to the theory of blasting, the fracture zone, the fracture zone and the elastic vibration zone are formed in the rock after the explosive is embedded in the infinite rock. The instantaneous stress wave of explosive explosion acts on the surrounding medium, because there is original damage crack in the Rock, the crack begins to expand under the action of stress wave, and the high temperature and high pressure gas produced by explosive explosion acts on the crack tip, the radial stress in this region increases, and when the Stress intensity factor at the crack tip is larger than the fracture toughness of the rock material, the crack further expands, causing the crack range to widen again. The fractures near the explosives run through each other, the rock is broken into blocks to form the fracture zone, and the fracture zone is far from the fracture zone [2].
The gas exists in the coal seam in the state of Free State and adsorption state. Under the joint action of the gas self-pressure and the disturbance of explosive gas, the gas gushes out along the crack produced by presplitting blasting, reducing the gas content existing in coal seam. In the deep-hole blasting of coal mine, the local stress of the coal seam is changed because of the large charge in the primary blasting, and a weak surface is formed in the blasting action area. For the hard thick coal seam, the weak surface produced by blasting is favorable for caving.

3. Theoretical calculation of deep hole presplitting blasting parameters

According to the Mises criterion, if the stress intensity at any point in the medium is I satisfy (1) or (2), the rock will fail [3].

\[
\sigma_i \geq \sigma_0 \quad (1)
\]

\[
\sigma_0 = \begin{cases} 
\sigma_{cd} & \text{(Crushing Ring)} \\
\sigma_{td} & \text{(Fracture ring)} 
\end{cases} \quad (2)
\]

In the formula, \(\sigma_0\) is the failure strength of rock under uniaxial loading, MPa; \(\sigma_{cd} , \sigma_{td}\) is the uniaxial dynamic compressive strength and uniaxial dynamic tensile strength of rock, MPa.

Under the condition of uncoupling charge in infinite medium, the pressure of transmission shock wave is [4]:

\[
p = \frac{1}{2(1+\gamma)} \rho_0 D^2 K^{-2} l, n \quad (3)
\]

In the formula, \(p\) is the initial shock pressure transmitted through the Rock, MPa; \(\rho_0\) is the density of the explosive, kg•m\(^{-3}\); \(DV\) is the detonation velocity of the explosive ,m•s\(^{-1}\); \(K\) is the radial uncoupling Coefficient of charge, \(K = \frac{d_b}{d_c}\), \(db, dc\) is the bore radius and charge radius, respectively, mm; \(l_c\) is the axial coefficient of charge, \(l_c=1\) means that there is no axial column of air; \(\gamma\) is the expansion adiabatic index of detonation product, general \(\gamma=3\); \(n\) is the pressure increase coefficient when the explosive product expands and collides with the wall of the hole, general \(n=10\).

The transmission shock wave in the rock continuously propagates outward and attenuates, the attenuation index in the crushing area is \(\alpha\), \(\alpha = 2 + \frac{\mu_d}{1-\mu_d}\); outside the crushing ring, the explosive load continues to propagate outwards in the form of stress wave, and its attenuation index is \(\beta\), \(\beta = 2 - \frac{\mu_d}{1-\mu_d}\).

Where \(\mu_d\) is the dynamic poisson's ratio of the rock. According to formulas (1) and (2), at the interface between the crushing zone and the fracture zone, there are:

\[
\sigma_n = \frac{\sqrt{2} \sigma_{cd}}{B} \quad (4)
\]

In the formula, \(B = \left[ (1+b)^2 + (1+b^2) - 2 \mu_d(1-\mu_d)(1-b)^2 \right]^{\frac{1}{2}}\), \(b\) is the lateral stress Coefficient, \(\bar{b} = \frac{\mu_d}{1-\mu_d}\); \(\sigma R\) is the radial stress at the interface between the crushing zone and the fracture zone, MPa.

Because of the uncoupling charge and the small uncoupling coefficient, the expression of the radius of the fracture ring is:

\[
R_p = \left[ \frac{\sigma_{cd} B}{\sqrt{2} \sigma_{cd}} \right]^{\frac{1}{2}} \left[ \frac{\rho_0 D^2 n K^{-2} l, n B}{2 \sqrt{2(1+\gamma) \sigma_{cd}}} \right]^{\frac{1}{2}} r_b \quad (5)
\]

Among them, \(r_b\) is the radius of the hole, mm[5-6].
4. Test and result analysis

4.1. Test Condition
Coal Mine Profile: The thickness of coal seam is about 12m, the coal seam is hard and the hardness coefficient is 2~3, which is disadvantageous to caving mining. The gas content is $9.43 \text{m}^3 \text{t}^{-1}$; the gas pressure is $1.4 \text{MPa}$; and the permeability coefficient is $0.4 \text{m}^2 \text{(MPa}^2 \text{d})^{-1}$. The attenuation Coefficient of natural gas emission is $0.033 \text{d}^{-1}$. The mechanical properties of coal are shown in Table 1.

| Density / kg•m$^{-3}$ | Dynamic Poisson ratio | Uniaxial dynamic compressive strength / MPa | Uniaxial dynamic tensile strength / MPa |
|-----------------------|-----------------------|------------------------------------------|---------------------------------------|
| 1620                  | 0.26                  | 30.0                                     | 9.3                                   |

Blasting equipment: because of the high gas content in coal seam, the permitted water-gel explosive is used in grade 3 coal mine. According to the size of the hole, the roll is made according to the design size Table2.

| Roll length / m | Unit dose / kg•m$^{-1}$ | Roll diameter / mm | Density / kg•m$^{-3}$ | Detonation velocity / m•s$^{-1}$ |
|-----------------|-------------------------|--------------------|-----------------------|---------------------------------|
| 1.0             | 3.6                     | 63                 | 1200                  | 3800                            |

4.2. Test Plan
In order to make full use of gas resources and reduce gas pollution to the environment, the gas will be extracted and reused. In order to make the best use of the gas in the coal body, a technological roadway is dug in the coal body, and the technological roadway is parallel to the working face and connected with the machine roadway and the air roadway. The technology roadway is 2.5 m high, and the distance between the top of the technology roadway and the roof is 2 m. drilling holes are arranged from the technology roadway to the two sides and 1 m from the bottom of the technology roadway. The diagram of drilling holes is shown in Fig. 1.

According to experience, the best diameter range of drill hole is 75 ~ 95mm in deep-hole blasting in coal mine, and the diameter of blasting hole is 75mm because the diameter of explosive roll is 63mm. The parameters of Table 1 and table 2 are substituted into equation (5), and the radius of fissure circle is calculated finally $R_p=1.62 \text{m}$. due to the existence of original damage crack in coal seam, it is easy to determine drilling parameters, and the distance between blasting holes is 4M. The guide hole is arranged in the middle of two adjacent blasting holes, and the drilling parameters of the blasting hole and the guide hole are obtained, which are shown in Table 3.
4.3. Results and analysis

After drilling, the gas drainage pipe is inserted into the pilot hole for gas drainage, so as to ensure that the environmental conditions and boundary conditions of the gas drainage area are basically the same before and after blasting, the parameters of gas concentration and mixed gas flow were recorded before and after blasting. According to the production data of blasting area, the average length of coal mining and the average coal mining quantity are recorded, and the recorded parameters are shown in Table 4.

| Table.4 Comparison of gas drainage and recovery parameters |
|----------------------------------------------------------|
| Average gas concentration/ % | Mixed gas flow/m³/min⁻¹ | Average length of footage per month/m | Average coal yield per month/10³t |
|-----------------------------|--------------------------|--------------------------------------|---------------------------------|
| Before the blast            | 9.6                      | 0.092                                | 30                              | 75                              |
| After the blast             | 35.1                     | 0.126                                | 40                              | 113                             |

From the result of Table 4, the gas drainage increases, which shows that the fracture after blasting is favorable for gas escaping. Because of the action of blasting, the range of fracture is enlarged and the
area of extraction is enlarged. The increase in daily average footage shows that the gas emission from the working face after blasting is reduced, and the amount of gas stored in the coal body is greatly reduced, which provides a safety guarantee for mining, because of the action of blasting, the coal falling amount of top coal caving increases, and the effect of loose presplitting blasting is achieved, and the recovery rate is increased.

After blasting, the guiding hole is kept in good condition, and cracks are formed between the guiding hole and the blasting hole, so as to achieve the blasting effect. Because of the large ground pressure near the blasting hole, it can be regarded as the explosion of the explosive in the infinite coal seam [11].

5. Conclusion
The fracture produced by deep hole presplitting blasting increases the permeability of coal and provides the condition for gas extraction. The loosening of blasting can redistribute the stress of coal body, reduce the drag of drainage, and benefit the caving mining of thick and hard coal seam. The reasonable determination of blasting parameters ensures the blasting effect, reduces the production cost and improves the mining efficiency.

The technology of deep-hole presplitting blasting provides a way to solve the problem for the safe and efficient mining of coal mine.

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