AGH Journal of Mining and Geoengineering • vol. 36 • No. 3 • 2012

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AN EXPERIMENTAL STUDY OF DEEP BOREHOLE PRE-CRACKING BLASTING FOR GAS PRE-DRAINAGE ON A MINE HEADING ROADWAY IN A LOW PERMEABILITY SEAM[**]

Coal and gas outburst is the phenomenon that it sprays a large number of coal (rock) from coal and rock layer to the mining space within a very short time, during the coal mine underground mining process [1, 3–5].With the increase of mining depth, coal seam gas pressure and gas content increases significantly, and the risk of gas disaster also increases. Heading roadway in the outburst coal seam, the outburst risk must be eliminated in advance, with drillings through strata pre-drainage the coal seam gas, in order to make the coal seam pressure and gas content within the control range of roadway reduce to below the specified value of the provisions of coal and gas outburst prevention and treatment, however, because of low permeability seam in Huainan coal mine, gas pre-drainage effect is not good, leading to eliminate the outburst risk for a long time, thereby affecting the mine mining. In order to improve gas extraction in the control area of coal and seam, and improve the speed of the roadway excavation, in this paper, deep borehole pre-crack blasting was proposed, strengthening to increase the permeability of dug coal seam, and improving the gas drainage efficiency, to achieve the rapid safety excavation of outburst coal seam roadway.

1. Test area summary

In Huainan mining area, the average thickness of 11–2 coal seam in a face roadway heading region of a mine is 2.6 m, the bottom contains a thin layer of mudstone or carbonaceous

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[**] The National Natural Science Foundation-funded Project (51004003,50974004); Anhui University Provincial Natural Science Research Key Project (KJ2010AO91)

mudstone partings, 11–1 coal seam is developed in floor, the elevation of face floor is –890 – –900 m, higher in the west and lower in the east overall, the angle of seam is 0–6°. In the area, the gas pressure of 11–2 coal seam is 1.4 MPa, the average of gas content is 5.65 m^3/t. The lithological characteristics of the roof and floor are shown in Table 1.

TABLE 1
The lithological characteristics of the roof and floor

Roof and floor name	Rock name	Thickness, m	Lithological characteristics
Old roof	Fine-grained Sandstone	9.6~10.85	Light gray ~ gray, sorting general, calcium cementation, clip banded argillaceous thin layer
Direct roof	11-3 coal seam	0~0.88	Black, massive, the metal luster, the bright coal
	Sandy Mudstone	1.5~3.1	Gray, more dense, massive, sandy and argillaceous structure, partly mudstone
False roof	–	–	–
Direct floor	Sandy Mudstone	2.2~3.1	Gray, more dense, massive, sandy and argillaceous structure, clipped siderite tuberculosis, irregular-shaped fracture
Old floor	Sandy Mudstone	3.7	Gray, rich in plant debris, partly with siderite tuberculosis

2. Mechanism analysis of deep borehole pre-crack blasting increase permeability and outburst prevention [2]

Special coal seam gather-energy explosive column developed by our group blasting in low permeability original coal seam, could produce a large number of cracks under the detonation stress wave. The broken circle that is 5–10 times blast hole diameter around the blast hole was formed. Secondly, when the detonation gas spread to the control hole neighboring with the blast hole (drainage hole no explosive), since the existence of the control hole leading to the stress wave reverse stretching and reflection action, the cracks were promoted to further expansion. When detonation stress wave attenuation after all, coal of the blasting far region was subjected to detonation stress wave disturbance, damage to the gas pressure balance, promoting to generation of the cracks. Deep borehole pre-crack blasting damage to the balance state of original coal stress, coal around the blasting hole with a substantial displacement and stress change, promoting to re-distribution of coal stress, stress concentration area transferring to depth away from broken coal, effective stress was reduced. Meanwhile,

as the generation of new cracks and reduced stress broken in dynamic balance of adsorption and desorption gas in the coal, making the most of adsorption gas transfer to desorption gas, desorption gas migrated through the cracks and being extracted with borehole, the elastic potential energy of coal and gas inflation energy were released to a great extent, the permeability was increased significantly, to further improve gas drainage rate, increase coal plastic, decrease brittle, and reduce desorption speed of the coal residual gas. Therefore the formation of a certain range of relief and gas drainage region in coal, in the safety area, the fundamental conditions of coal and gas outburst occurrence were destroyed, effectively playing effect on outburst prevention and treatment.

3. Experimental program on borehole through strata deep borehole pre-crack blasting increase permeability

1) Test program on the loosen radius of 11–2 coal seam deep borehole pre-crack blasting. In order to optimize 11–2 seam drainage borehole design within the control range of heading roadway, and implementation of deep borehole pre-crack blasting, the loosen influence radius of 11–2 seam caused by blasting explosive column was tested in the first place, the test program layout of loosen radius was shown in Figure 1, and the borehole parameters shown in Table 2.
2) Test on deep borehole pre-crack blasting coal seam loosen radius of 11–2 coal seam. Special seam blasting explosive columns developed by the group in advance were put into No. 1 borehole, explosive column is 1m long, 75 mm diameter, 4 m long explosive column were put in borehole seam segment in all, coal seam loosen radius was judged through the investigation on gas drainage concentration and volume of drainage holes adjacent to blasting hole, such as the gas drainage pure quantity of borehole adjacent to drainage hole was increased by more than 10% before the blasting, thus, coal seam loosen radius could be judged. After No. 1 borehole blasting, gas drainage concentration and pure quantity of each drainage borehole are shown in Figure 2 and 3.

   Through the analysis of Figure 2 and 3, it can be obtained that borehole gas drainage concentration and pure quantity are all 2–3 times than before blasting when drainage borehole away from blasting hole 4m, and borehole gas drainage concentration and pure quantity are approximately 1.5 times than before blasting when drainage borehole away from blasting hole 5 m, thus, loosen radius 5 m of deep borehole pre-crack blasting coal seam can be judged.
3) Optimization design on deep borehole pre-crack blasting borehole through the strata of 11–2 coal seam.

   According to the test deep borehole pre-crack blasting coal seam loosen radius 5 m, combined with the actual situation, 40 boreholes in all were designed in each borehole field, the borehole diameter was 113 mm, drainage boreholes were constructed to 11–2 coal seam floor 1 m. 6 boreholes were exploded each time, blasting hole parameters were

shown in Table 3, and special explosive column performance parameters were shown in Table 4.

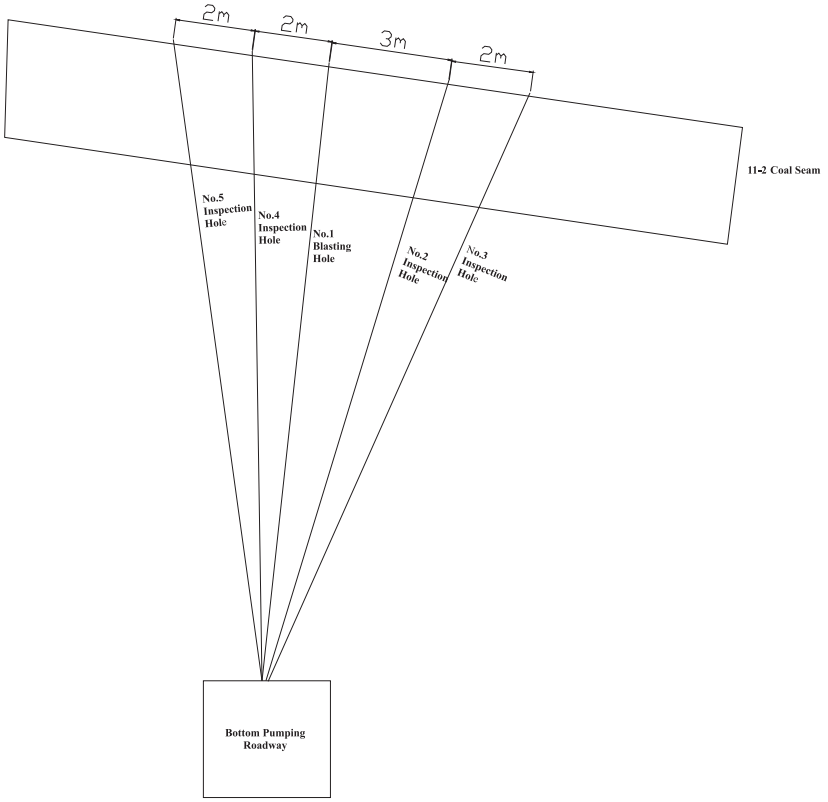

Fig. 1. The loosen radius test borehole layout of 11–2 coal seam

TABLE 2

The loosen radius test borehole layout parameters of 11–2 coal seam

Borehole number	Titled angle, °	Azimuth angle, °	Borehole length, m	Distance from blasting hole, m	Remark
No. 1	84	vertical roadway	28	0	blasting hole
No. 2	73	vertical roadway	31	2	inspection hole
No. 3	66	vertical roadway	33	3	inspection hole
No. 4	89	vertical roadway	30	4	inspection hole
No. 5	82	vertical roadway	31	5	inspection hole

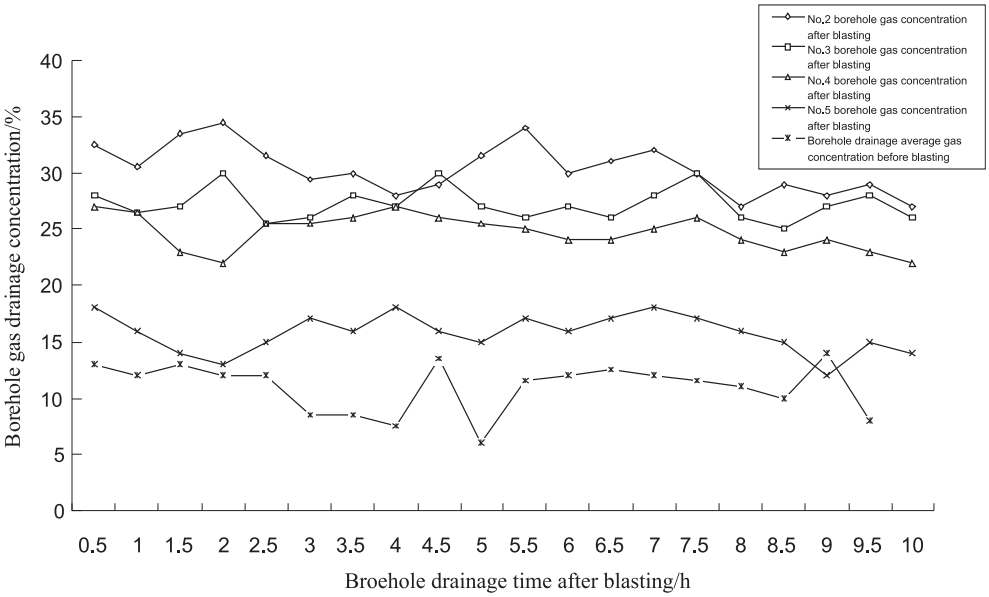

Fig. 2. Gas concentration change comparison curve of each drainage borehole before and after the blasting

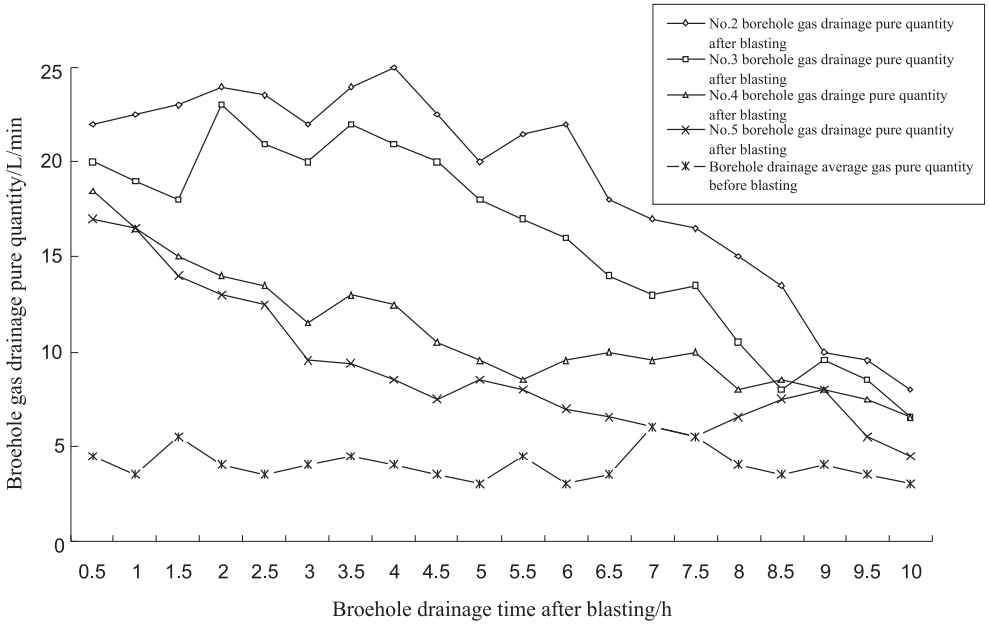

Fig. 3. Gas drainage pure quantity change comparison curve of each borehole before and after the blasting

TABLE 3
List of blasting hole borehole parameters

Borehole field	Borehole number	Azimuth angle, °	Titled angle, °	Borehole diameter, mm	Depth meeting 11–2 coal seam, m	Borehole depth, m	Length meeting coal seam of actual borehole, m	Explosive length, m
No. 30	Y126-3	L 1.3	40	94	34.5	37.5	3	4
	Y126-8	L 14.1	61	94	30.5	33	2.5	3
	Y128-3	R 18.8	38	94	35.1	38	2.9	3
	Y128-8	R 29.9	58	94	32	35	3	3
	Y130-3	L 1.3	40	94	34	37	3	3
	Y130-8	L 14.1	61	94	31	34	3	3

TABLE 4
Special explosive column technique performance indicators

Performance	Indicator
Density	0.95~1.1 g · cm^{-3}
Explosive length	φ 42 mm
Detonation velocity	2400~2700 m · s^{-1}
Viagra force	≥ 250 ml
Brisance	≥ 10 mm
Induced detonation	≥ 3 cm
Explosion transferring length	≥ 50 m

4. Deep borehole pre-crack blasting technology

According to actual conditions, drainage borehole firstly was constructed, combined with drainage borehole extracting, until the construction of drainage borehole, then Blasting hole was constructed, azimuth angle, bow angle, and borehole length were well recorded, to determine the length of explosive. Implementation of deep borehole pre-crack blasting, special explosive column was only installed in seam segment. Charge structure is that each borehole is installed with explosive using special explosive column and adoption in forward charge structure, and forward initial detonation. After installing explosive column, blasting borehole was sealed with special sealing hole materials and equipments.

5. Analysis on deep borehole pre-crack blasting increase permeability effect

1) Gas drainage effect of borehole through the strata significantly increased, after blasting gas drainage pure quantity was shown in Figure 4.
   From Figure 4, it can be seen that after blasting gas drainage pure quantity of No. 30 borehole field is up to 3.3 m^3/h, the average flow increases about 8–10 times than before blasting, good drainage effect is obtained, according to the calculation, coal seam permeability is improved by 150 times after deep borehole pre-crack blasting.
2) After deep borehole pre-crack blasting, the maximum gas concentration is 0.3% during coal seam roadway heading process corresponding to drainage, the speed of heading roadway is increased by 2 times.

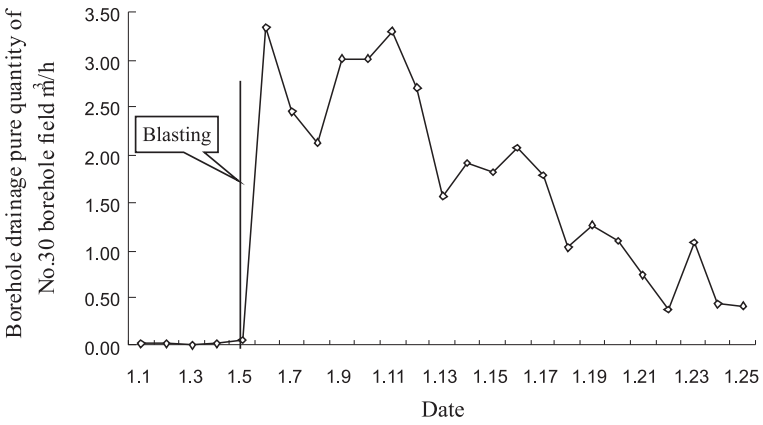

Fig. 4. Gas pure quantity comparison analysis of drainage borehole before and after blasting

6. Conclusion

Through the analysis of deep borehole pre-crack blasting coal seam increase permeability and outburst prevention mechanism, blasting loosen radius 5 m of certain mine 11–2 coal seam was measured, drainage boreholes of each borehole field were optimize designed according to blasting loosen radius. Deep borehole pre-crack blasting increase permeability effect was inspected, deep borehole pre-crack blasting increasing coal seam permeability was obtained, gas drainage pure quantity was increased by 8–10 times than before blasting, coal seam permeability was improved by 150 times, the speed of heading roadway was improved by 2 times, providing a guarantee to mine safety production, and obtaining remarkable economic and social benefits.

REFERENCE

[1] *Qi-xiang Yu*: Mine gas prevention and control [M]. Xu Zhou: China University of Mining and Technology Press, 1992: 108–121

[2] *Jian Liu, Ze-gong Liu, Bi-ming Shi*: Study on the roadway excavation rapidly in the low permeability outburst coal seam [J]. Journal of China Coal Society, 2007, 32(8): 827–831

[3] *Lei Li, Cheng-lin Jiang*: Experimental study on predicting outburst hazards by using ideal crosscut for opening a coal seam[J]. China Coalbed Methane, 2008, 5(1): 41–43

[4] *Shu-xiang Jia, Shou-ren Xu*: Rapid seam opening technology with cross borehole gas drainage in outburst thick seam [J]. Coal Science and Technology, 2008, 36(12): 40–42

[5] *Ping Lu etc.*: Study on proper layout parameters of the gas drainage drills of outburst prevention in rock cross-cut coal uncovering [J]. Journal of China Coal Society, 2002, 27(3): 242–248.