International Journal of Mining Science and Technology 27 (2017) 771–775

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

Coal seam drainage enhancement using borehole presplitting basting technology – A case study in Huainan

Chen Xianzhan [a,b], Xue Sheng [a,c,*], Yuan Liang [a]

[a] School of Mining and Safety Engineering, Anhui University of Science and Technology, Huainan 232001, China
[b] Anhui Coal Mine Safety Supervision Bureau, Hefei 230088, China
[c] CSIRO Energy, PO Box 883, Kenmore, QLD 4069, Australia

ARTICLE INFO

Article history:
Received 25 December 2016
Received in revised form 2 April 2017
Accepted 19 May 2017
Available online 9 August 2017

Keywords:
Coal mining
Gas drainage
Permeability enhancement
Deep hole blasting

ABSTRACT

Xinji No. 2 underground coal mine extracts the coal seams #4 and #5. These two seams are highly gassy and gas drainage is required to control mine gas emission and reduce outburst risk. Because the seam permeability coefficient is very low and around 0.1 $m^2/(MPa^2 \cdot d)$, a number of technologies have been trialled to enhance the seam permeability prior to gas drainage. Of these technologies trialled, the deep borehole presplitting blasting technology has been proven to be quite effective in increasing permeability. In Xinji No. 2 mine it doubled or sometimes tripled gas drainage volume. This paper describes the technology, its application in the enhancement of seam permeability in Xinji No. 2 coal mine, and its effect on gas drainage performance.

1. Introduction

The technique of enhancing coal seam permeability using deep borehole presplitting blasting consists of drilling a deep blasthole in the front of workface, loading the borehole with water-gel explosive, and then setting it off [1–5]. During the blasting process, the stress wave and detonation gas generated by the explosive material in coal blasting hole produce the compression crushing zone in the area near blasting source, which brings about a blasting cavity and creates deformation of coal solid skeleton [6–10]. Then, the initial cracks whose lengths are several times greater than the radius of blasthole come into being on the blasting cavity wall. In the meantime, a connecting fracture network is formed around the blasthole, including the compression crushing circle, crack circle with the radial and ring crossed and the secondary crack circle. Thereby, it is beneficial to the elimination of the non-uniformity of coal structure and the decrease of underground stress [11,12]. Moreover, the permeability of coal body is thus enhanced and the drainage effect is correspondingly improved. Therefore, the aim of both permeability enhancement and outburst elimination is then achieved [13–15]. This paper describes how this blasting technique was applied in Xinji No. 2 coal mine and its effect on seam permeability and gas drainage efficiency.

2. Test site conditions

Xinji No. 2 coal mine commenced coal production in 1996 with annual output of 2.9 million tonnes. The mine extracts two coal seams, namely #4 and #5 seams. The seams are about 2 m thick and seam spacing is about 15 m. Basic tests were undertaken with the seams in order to understand their characteristics. These tests include proximate analysis, seam gas content and pressure, gas adsorption isotherm, borehole gas flow decay, and seam permeability.

The proximate analysis and gas adsorption isotherm tests were undertaken with coal samples from #4 and #5 seams. The absolute and bulk densities and porosity of the coals were also measured. The results are shown in Table 1.

2.1. Seam gas content/pressure and borehole gas flow

Gas content of coal was obtained with the direct measurement method, stated in *The Direct Method of Determining Coalbed Gas Content in the Mine* (GB/T 23250–2009), 2009. The average gas contents of #4 and #5 seams were 5.8 and 6.6 m^3/t, respectively. Gas pressure in the seams was measured with sealed boreholes drilled in the seams. The determined gas pressures of #4 and #5 seams were 0.7 and 0.8 MPa, respectively.

To measure borehole gas flow decay coefficient, one borehole was drilled in each of #4 and #5 seams. The gas flowrate from the borehole was measured for five days immediately after the

---

* Corresponding author at: School of Mining and Safety Engineering, Anhui University of Science and Technology, Huainan 232001, China.
E-mail address: sheng.xue@csiro.au (S. Xue).

http://dx.doi.org/10.1016/j.ijmst.2017.07.015
2095-2686/

Table 1
Results of coal proximate analysis and gas adsorption isotherm tests.

Seam	Proximate analysis			Absolute density	Bulk density	Porosity	Adsorption isotherm	
	Moisture (%)	Ash (%)	Volatile matter (%)	(t/m^3)	(t/m^3)	(%)	Langmuir volume (m^3/t)	Langmuir pressure (MPa)
#4	2.71	22.76	28.32	1.47	1.36	7.48	27.0647	0.758
#5	2.79	16.41	30.88	1.4	1.3	7.14	27.6197	0.728

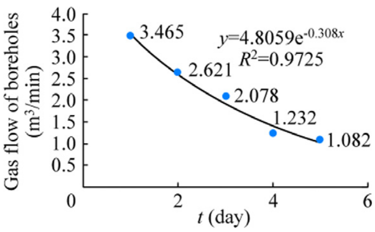

Fig. 1. Borehole gas flow in #4 coal seam.

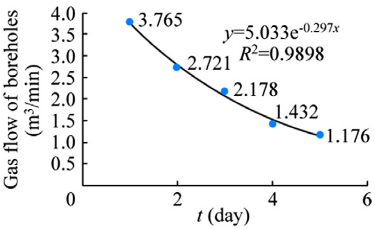

Fig. 2. Borehole gas flow in #5 coal seam.

borehole was drilled and sealed. Figs. 1 and 2 show the results of the measured gas flowrate from these boreholes. It can be seen from Figs. 1 and 2 that the borehole gas flow decay coefficients in #4 and #5 seams were 0.30 and 0.29 d^{-1}, respectively.

2.2. Seam permeability

Seam permeability was estimated by drilling a borehole perpendicular the seam and measuring the borehole gas flowrate. The method assumes that the borehole flow follows Darcy's law. To calculate the permeability of #4 and #5 seams, one borehole was drilled in each of the seams and gas flowrates from the borehole were monitored. Some basic data of the seams and the boreholes are listed in Table 2.

From the basic data, a number of intermediate parameters used for calculating seam permeability were derived. These parameters include gas content coefficient a, internal surface area of the borehole S, gas emission from the internal surface of the borehole q, coefficients A and B, and seam permeability coefficient λ. These parameters are explained below.

Gas content coefficient a

$$a = \frac{X \cdot \gamma}{\sqrt{P}} \tag{1}$$

where X is the gas content of coal seam, m^3/t; γ the apparent coal density, t/m^3; and P the seam gas pressure, MPa.

Internal surface area of the borehole S

$$S = 2\pi r_1 \cdot L \tag{2}$$

where L is the borehole length, m; and r_1 the borehole radius, m.

Gas emission from the internal surface of the borehole q

$$q = q_t/S \tag{3}$$

where q_t is the gas flow of borehole at the time point of t, m^3/d.

A and B

$$A = \frac{q r_1}{p_0^2 - p_1^2} \quad B = \frac{4P_0^{1.5} t}{a r_1^2} \quad q = q_t/S \tag{4}$$

where P$_0$ is the initial seam gas pressure, MPa; and P_1 the borehole gas pressure, MPa.

Seam permeability coefficient λ

$$\lambda = A^a B^b \quad q = q_t/S \tag{5}$$

where a, b are the regression coefficients, depending on gas flowrate.

Once these intermediate parameters are determined, the seam permeability can then be calculated below.

$$\lambda = \frac{K}{2\mu p_1} \quad q = q_t/S \tag{6}$$

where λ is the gas permeability coefficient of coal seam, m^2/(MPa^2·d); μ the dynamic viscosity of gas, 1.08 × 10^{-6} P a/s for methane; p_1 0.1013 MPa; and K the permeability of coal, m^2.

Table 3 lists the intermediate parameters for calculating of the permeability of #4 and #5 seams, and the calculated permeability of the seams. As the borehole flow decay coefficients in #4 and #5 seams were larger than 0.05 d^{-1} and the seam permeability coefficients of both of the seams were less than 0.1 m^2/(MPa^2·d), but gas in #4 and #5 seams was deemed to be hard to drain according to the Chinese standard.

Table 2
Basic data of the seams and boreholes test.

Seam	Gas pressure P_0 (MPa)	Gas content X (m^3/t)	Borehole radius r_1 (m)	Flow q (m^3/min)	Borehole length (L/m)
#4	0.7	5.8	0.047	1.082	10.2
#5	0.8	6.6	0.047	1.176	8.4

Table 3
Intermediate parameters and seam permeability.

Coal seam	X	P	a	q_s	A	B	λ	K (10^{-19})
4	5.8	0.7	8.94	0.30	0.0352	492.37	0.0790	2.01
5	6.6	0.8	9.52	0.39	0.0351	565.15	0.0815	2.06