DONGFANG XU
TAO FENG
JING YANG
and
ZUOYA QIN

Experimental study on prevention and control of coal-bed methane (CBM) through mining of the protective seam of multiple coal seams

This research intends to obtain the pressure relief angle of protective scope through research and study of the protective scope and effects after mining of coal seam No. 2 as the protective seam of coal seam No. 5 in mining area No. 23 of Jinzhushan Mining Co., Ltd. CBM flow attenuation coefficients of taps within protective area are reduced from 0.016 and 0.015 d-1 before mining to 0.008 and 0.011 d-1; and average CBM extraction amount in seven days is raised by two to three times. This research provides scientific basis for mining of protective seams for the mine.

Keywords: *Protective seam, pressure relief angle, attenuation coefficient, CBM flow.*

1. Introduction

Protective seam refers to coal seam or rock formation that is exploited in priority to eliminate the outburst hazard of adjacent coal seams [1-2]. Long-time theoretical and practical research reveals that mining of protective seam is the most economical and effective measure to prevent local outburst [3]. After mining of protective seam, rock formation on top of goaf forms natural arch under caving effect, while rock formation below expands upward after losing its original stress balance [4-6]. The occurrence of caving and expansion enlarges fractures in wall rock, increasing permeability of coal seams accordingly [7]. The technology of protective seam mining was initially adopted in France as early as 1933 to prevent outburst of coal and CBM, and it has been a commonplace in many countries from then on [8-9]. It is stipulated in the Safety Regulations of Coal Mines of our country that: “For coal seam with outburst risk, local prevention and control measures including protective seam mining or pre-extraction of CBM shall be taken”; and “The method of protective seam mining shall be given priority during mining of coal seam groups in outburst mines to prevent and control outburst” [11-12].

Messrs. Dongfang Xu* and Tao Feng, Hunan University of Science and Technology, Xiangtan 411 201 and Jing Yang and Zuoya Qin, Hunan Provincial Coal Science Research Institute, Changsha 410 004, China. E-mail: 94190285@qq.com

2. Discussion of theory about protective AEAM mining

One of the key issues in protective seam mining is selection of the first mining seam; that is because it is hard to control CBM during mining of the first mining seam, which is the most dangerous point, thus coal seam with no outburst risk or with lower risk should be selected as the first mining seam [13-14]. Meanwhile, interlay spacing between the first mining seam and other coal seams, properties of rock formation, etc. should also be noted, so as to improve protective effect. During mining of protective seam, change of fractures in wall rock makes adjacent CBM flow to work face; therefore, CBM extraction should be performed for protected seam simultaneously during mining of protective seam; otherwise, progress of the first mining seam would be affected [15].

Based on relative position between protective seam and protected seam, protective seam can be divided into upper protective seam and lower protective seam [16]. During mining of lower protective seam, the ratio of distance from protective seam and protected seam to the average mining height of protective seam is the relative interlay spacing, which is the key factor that affects the degree of pressure relief of protected seam. Generally speaking, when the mining height of protective seam reaches above 1.4 m, pressure relief height during mining of lower protective seam can reach above 60 m; when the mining height reaches 1.8 m, pressure relief height can reach above 100 m. Pressure relief depth is normally within 60 m during mining of upper protective seam.

3. Field test and research

3.1 Introduction to the mine

Located in Leng Shuijiang City, Hunan Province, X Mine of Jinzhushan Mining Co., Ltd. faces serious CBM hazards, and has suffered over 50 times of outburst of coal and CBM since establishment, with the maximum outburst intensity being 800 t. Minable seams of the mine field are mainly coal seams No. 2, 3, 4 and 5, with coal seams No. 3 and No. 5 contribute the most. Geological structure of the mine is complicated, with coal seams No. 3 and No. 5 combining together, or floor of coal seam No. 5 separating into several parts; and most outbursts happen in these areas. Moreover, coal seam No. 2 is a non-outburst coal seam, and outburst risk of coal seam No. 3 is lower than that of coal seam No. 5. Thus, coal seam No. 2 is exploited as the protective seam firstly in recoverable area (the west side of mining area No. 23 is selected for this test), so as to reduce outburst risk of underlying coal seams No.3 and No. 5, and conduct research of the protective scope and effect of coal seam No. 5.

3.2 Research contents and methods

Contents subject to research for effects of protective seam mining mainly include determination of protective scope and pressure relief angle, change of CBM flow attenuation coefficient of taps within protective scope, and change of single-tap CBM extraction amount. Protective scope covers dip protective scope and strike protective scope, the area of which is largely dependent on dip pressure relief angle, or strike pressure relief angle as well as vertical distance between seams. Please refer to Fig.1 to determine the predicted protective scope along dipping direction, and Table 1 for values of pressure relief angle. Strike protective scope can be fixed in a similar fashion with dip protective scope; for protective seam that is fully depressurized, mining starting line and terminal line of work face and the protective scope of coal pillars preset to protected seam along strike are generally defined based on the pressure relief angle δ of 56º~60º.

However, during research of actual protective scope, we should take predicted protective boundary mentioned above as the center, set pressure taps to both sides evenly, which is shown in Fig.2, so as to determine whether pressure taps are within protective scope or not based on the change of pressure before and after mining of protective seam. For this research of strike protective scope, the author sets pressure taps in No. 2352 floor extraction roadway, takes predicted strike protective

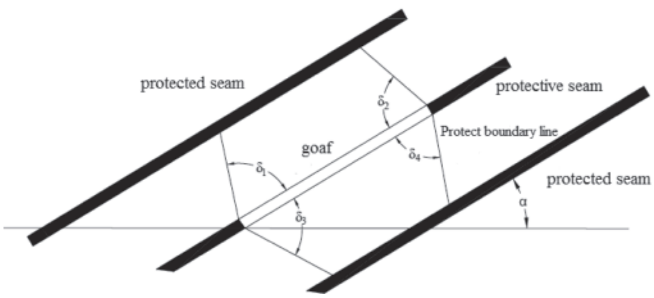

Fig.1 Protective scope of protective seam along dipping direction

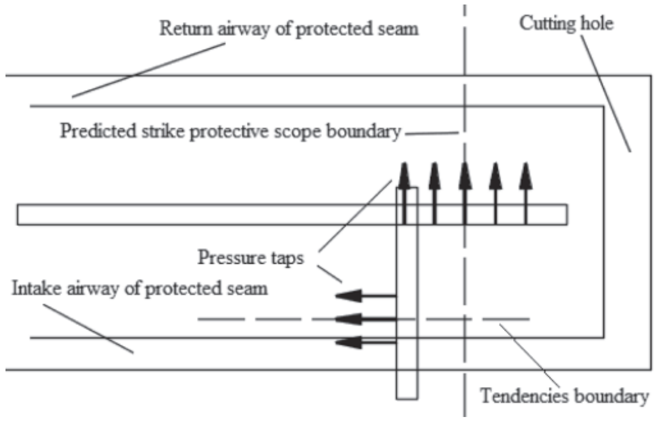

Fig.2 Layout of pressure taps for research of actual protective scope

scope boundary as the center, and arranges 5 pressure taps on each side respectively; pressure taps for research of dip protective scope are set in No. 23 slant roadway, with 3 taps on each side. All pressure taps have the same direction and dip angle, and the spacing of drill-hole finished is 10 m. Numbers of strike pressure taps from the side of open-off cut are from 1# to 10#; and numbers of dip pressure taps from the side of return airway are from 11# to 16#.

With regard to the research of CBM flow attenuation coefficient of taps and single-tap extraction amount, the author selects two groups of extraction taps in 2352 floor extraction roadway near the middle part of the protective scope and at the boundary of corresponding protective scope on the side of terminal line of coal seam No. 2, compares the change of CBM flow attenuation coefficients before and after mining of protective seam. In the meantime, the author also selects one group of extraction taps outside the protective scope, compares CBM extraction amount of the same period to draw the final conclusion.

4. Research results

4.1 Change of pressure

Since many pressure taps are engaged, the author only uses pressure taps 1# to 5# to illustrate the pressure change in this paper, and that of other taps can be represented with the final results.

We can see from the changing process of CBM pressure and final results that pressure tap 2# is within the protective scope; and the calculated side pressure relief angle is 67° based

Table 1: Reference value of pressure relief angles for determination of the protective scope along dipping direction

Dip angle of coal seam α (degree)	δ_1	δ_2	δ_3	δ_4	Dip angle of coal seam α (degree)	δ_1	δ_2	δ_3	δ_4
0	80	80	75	75	50	70	90	80	70
10	77	83	75	75	60	72	90	80	70
20	73	87	75	75	70	72	90	80	72
30	69	90	77	70	80	73	90	78	75
40	65	90	80	70	90	75	80	75	80

TABLE 2: STATISTICAL TABLE ON CBM FLOW AND ATTENUATION COEFFICIENT OF TAPS

Day of test (day)	1	5	10	15	20	25	30	Attenuation coefficient
Before mining of extraction tap in middle part	0.101	0.088	0.079	0.072	0.067	0.064	0.063	0.016
After mining of extraction tap in middle part	0.064	0.063	0.063	0.062	0.059	0.055	0.050	0.008
Before mining of extraction tap at the boundary	0.107	0.093	0.085	0.079	0.075	0.071	0.068	0.015
After mining of extraction tap at the boundary	0.054	0.051	0.048	0.046	0.045	0.043	0.038	0.011

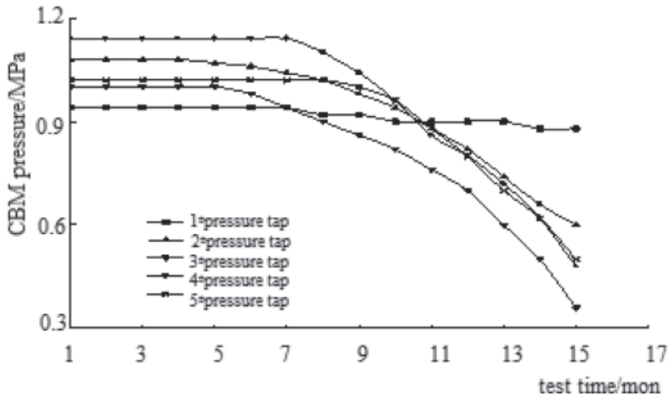

Fig.3 Pressure change of CBM of pressure taps 1# to 5#

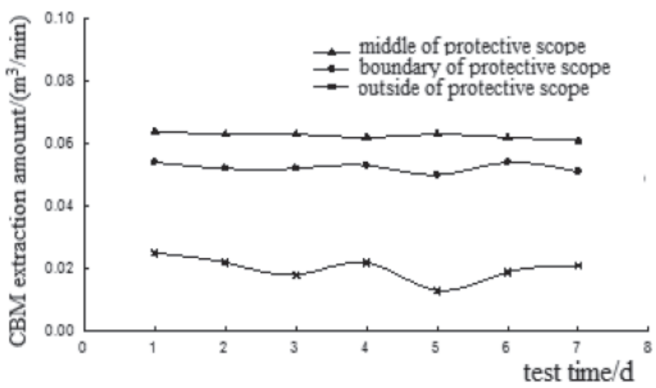

Fig.4 Comparison of single-tap CBM extraction amount of the same period within/outside protective scope

on distance from tap 2# to cutting hole and the interlay spacing between coal seams No.2 and No.5. Similarly, pressure relief angles calculated on the side of mining starting line and terminal line, return airway and intake airway are 59°, 79° and 71° respectively.

4.2 CHANGE OF ATTENUATION COEFFICIENT AND SINGLE-TAP CBM EXTRACTION AMOUNT

CBM flow measured of selected extraction taps and calculation results of attenuation coefficient before and after mining of protective seam are shown in Table 2. Comparison of single-tap CBM extraction amount after mining of protective seam are shown in Fig.4.

5. Conclusions

Through research of the effect of mining of coal seam No. 2 as the protective seam of coal seam No.5 in mining area No.23 of the mine, the following conclusions are reached:

(1) This paper defines the protective scope based on actual research, and calculates pressure relief angles on the sides of mining starting line, terminal line, return airway and intake airway which are 67°, 59°, 79° and 71° respectively. These values are all greater than the theoretical pressure relief angles for reference, which indicates that the pressure releasing scope is larger, and is mainly affected by properties of the rock formation between coal seam No.2 and No.5.

(2) After advance of the work face of protective seam for 5 to 6 months, the authors observe that the pressure of CBM of protected seam starts to be affected, and the falling range of pressure increases constantly with advance of work face and gradual pressurization.

(3) CBM attenuation coefficient of taps in the middle part and at the boundary of the protective scope are 0.016 and 0.015 d-1 respectively before mining of protective seam, and these two values drop to 0.008 and 0.011 d-1 after mining, which indicates that permeability of coal seam is improved and the improvement is more obvious in middle part than at the boundary.

(4) Average CBM amount in seven days of taps in the middle part and at the boundary of the protective scope are 0.063 and 0.052 m^3/min respectively before mining; while the average CBM amount in seven days of taps outside the protective scope is 0.020 m^3/min, the CBM amount of taps is increased by two to three times after mining of protective seam.

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(Continued on page 530)