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Determination of Gas Content in Low Permeability and High Gas Coal Seam

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Abstract. The determination of coal seam gas content is of great significance to the study of coal seam gas occurrence law and gas prevention technology. There are direct and indirect methods for the determination of gas content in coal seam. Both direct and indirect methods have their advantages and disadvantages, but the results of direct measurement have more disadvantage than indirect measurement. In this paper, the gas content in No. 1 coal seam of Weijiadi Coal Mine is determined by indirect measurement method. The gas content in No. 1 coal seam is calculated to be 8.1m³/t, which is important for gas geological division and precise gas extraction.

1. Introduction

Coal seam gas content is an important basis for the prediction of mine gas emission, coal and gas outburst and mine gas prevention and control. At present, there are four main methods to obtain gas content in coal seam, namely, sampling and measuring gas content in exploration boreholes, measuring gas content in underground boreholes during production, indirectly measuring gas content in coal seams, and calculating gas content in reverse from gas emission in coal seams. In order to get the value of coal seam gas content more accurately, many scholars have done a lot of research on the determination method of coal seam gas content, sampling and back calculation in the process of determination [1-5]. However, at present, it is still a difficult problem to accurately obtain atmospheric non-desorbable gas content. Although scholars have done a lot of research on residual gas content, there are no accurate data results.

2. Classification of Methodology for Measuring Gas Content in Coal Seam

The method of gas content determination in coal seam can be divided into direct method and indirect method. According to the application scope, it can also be divided into the method of gas content determination in geological exploration boreholes and the method of gas content determination in underground boreholes.

The direct method is relatively simple. The coal sample is taken directly from coal body, desorbed on site, and then sent to the laboratory. In the laboratory, the gas is extracted by vacuum pump, the gas composition is analyzed, the coal quality industry is analyzed, and the gas content in coal seam is calculated and determined. The advantage of direct method is to avoid many errors in parameter measurement. The disadvantage of direct method is that there is gas escaping in the process of sample taking. Mathematical model is needed to calculate gas loss.



The indirect method for measuring coal seam gas content is to calculate the pressure of coal seam gas according to the actual measurement or known law, and to determine the adsorption isotherm, porosity and industrial analysis results of coal in the laboratory, and finally calculate the gas content of coal seam. The characteristic of this method is that the coal sample does not need to be sealed and the sampling method is simple. The disadvantage of this method is that it needs to measure the gas pressure in the coal seam in the underground. Because there are inevitably some errors in the determination of various parameters, the final calculation results of indirect method may only be approximate values.

2.1. Direct Measurement Method of Coal Seam Gas Content

(1) Measuring Party of Coal Seam Gas Content in Geological Prospecting Period [6]

In geological exploration boreholes, various types of sealed core adopters and gas collecting core adopters have been used successively, and the gas loss (desorption method) is determined according to the variation law of gas desorption with time measured in coal core.

At present, borehole desorption method is widely used to measure gas content in coal seam during geological prospecting period. The characteristic of this method is to determine the amount of gas loss in the sampling process according to the variation law of coal desorption gas amount with time. Compared with the gas collecting core collector, the special instrument is changed to drill the coal core at the bottom of the hole by common coal core tube, and the coal sample tank is used to sample when the coal core is lifted to the orifice. The main advantage is that there is no need for special core adopter, and it does not affect the normal drilling of geological exploration boreholes, and the success rate of coring is high.

(2) Gas content determination method of underground coal seam

Underground desorption method is the application of geological prospecting desorption method in underground mine. Compared with geological prospecting boreholes, the advantages of desorption speed are as follows: firstly, the exposure time of coal samples is short, generally 3-5 minutes, and the initial time of gas desorption of coal samples can be accurately measured; secondly, the gas desorption condition of coal samples in boreholes is basically the same as that in air, without the influence of mud and mud pressure. The disadvantage is that sampling is difficult when boreholes collapse.

2.2. Indirect Measuring Method of Coal Seam Gas Content

(1) Calculating the content of coal seam gas according to the pressure of coal seam gas and the adsorption isotherm of coal

The most commonly used indirect determination method of coal seam gas content at home and abroad is to calculate the gas content of coal seam based on known gas pressure of coal seam and the value of adsorption constant of coal measured in laboratory.

$$X = \frac{abp}{1+bp} \times \frac{1}{1+0.31W} e^{n(t_s-t)} + \frac{10Kp}{k} \quad (1)$$

In the formula, X—the gas content of pure coal, m³/t;

a—adsorption constant, limit adsorption capacity of pure coal at test temperature, m³/t;

b—adsorption constant, MPa⁻¹;

p—coal seam gas pressure, MPa;

t_s—the temperature at which the adsorption test is carried out in the laboratory, °C

t—coal Seam Temperature, °C

W—moisture of coal,%;

n—coefficient;

K—pore volume of coal, m³/t;

k—the compression coefficient of methane is calculated in reference [6].

If the gas content of raw coal needs to be determined, the conversion can be carried out according to the following formula:

$$X_0 = X \frac{100 - A - W}{100} \quad (2)$$

In the formula, X_0 —raw coal gas content, m^3/t .

A —ash content of raw coal, %.

(2) Content Coefficient Method

In order to reduce the errors caused by the differences between laboratory conditions and natural coal seam conditions, Academician Zhou Shining studied and proposed the content coefficient method of underground gas content. Based on the analysis of gas content, it is proposed that the relationship between gas content and gas pressure in coal can be approximately expressed by the following formula [6]:

$$X = \alpha \frac{\sqrt{p}}{\gamma} \quad (3)$$

In the formula, X —the content of raw coal gas is m^3/t .

α —the gas content coefficient of coal, $\text{m}^3/(\text{m}^3 \cdot \text{MPa}^{1/2})$.

p —gas pressure, MPa.

γ —density of coal, t/m^3 .

The gas content coefficient of coal seam can be determined directly in underground mine.

(3) Calculating Coal Seam Gas Content Based on Residual Gas Content of Coal

When using this method, a coal sample is taken from the top and bottom of the coal seam, which is exposed to the coal wall for 30 minutes in the normal working face, and then filled into a sealed tank, and sent to the laboratory to determine the residual gas content of coal. If the measured residual gas content of coal is less than $3 \text{ m}^3/\text{t}$ (combustion), the original gas content of coal is calculated according to the following formula:

$$W_0 = 1.33W_c \quad (4)$$

In the formula, W_0 —coal drying ash-free base original gas content, m^3/t (combustion);

W_c —measuring the residual gas content of coal, m^3/t (combustion).

When the residual gas content of measured coal is more than $3 \text{ m}^3/\text{t}$, the original gas content of coal is calculated according to the following formula:

$$W_0 = 2.05W_c - 2.17 \quad (5)$$

(4) Inversion of Gas Content from Gas Emission

Coal seam gas emission refers to the amount of gas gushing from coal and rock and pumping into pipeline in the process of mine construction and production. The amount of gas emission is closely related to coal seam gas content, mining depth, mining scale, mining technology and other factors. The greater the gas content in coal seam, the greater the gas emission, there is a great correlation between the two. Therefore, the gas content in coal seam can be calculated according to the data of gas emission. The main sources of gas in mining face are gas gushing from the coal seam, gas gushing from adjacent seam and gas gushing from goaf of mining face. The gas emission of this coal seam is mainly composed of two parts: the coal wall of the working face and the continuous falling coal of the working face. The theoretical expression of Q statistics for the amount of gas emission is as follows:

$$Q = K_1 \cdot K_2 \cdot K_3 \cdot \frac{m}{M} \cdot (W_0 - W_c) \quad (6)$$

In the formula, K_1 —surrounding rock gas emission coefficient, K_1 values range from 1.1 to 1.3;

K_2 —the gas emission coefficient of K_2 -face is calculated by the reciprocal of recovery rate.

K_3 —influence coefficient of pre-drainage gas in mining roadway;

m —mining seam thickness, m;

M —mining height, m;

W_0 —coal seam gas content, m^3/t ;

W_c —residual gas content of coal after being transported out of mine;

When the amount of gas emission from the mining seam has been obtained, the gas content in the mining seam can be calculated according to the following formula:

$$W_0 = \frac{Q}{K_1 K_2 K_3} + W_c \quad (7)$$

Accurate determination of some key parameters is the main factor affecting the accuracy of inversion results when calculating coal seam gas content based on coal seam gas emission. These parameters mainly include gas emission from mining seam, gas emission from surrounding rock, influence coefficient of pre-drainage gas in roadway and residual gas content in mining coal.

3. Measurement and Analysis of Coal Seam Gas Content in Weijiadi Coal Mine

3.1. Survey of Weijiadi Coal Mine

Weijiadi Coal Mine is the backbone mine of Jingyuan Coal and Electricity Co., Ltd. In Gansu Province. Its original designed production capacity is 1.5 million tons. It was put into operation on December 15, 1989. After capacity expansion and transformation, its approved production capacity is 3 million tons in 2015. Weijiadi Coal Mine is a dual energy efficient mine with coal and gas co-mining in Gansu Province. Its geological conditions are extremely complex. Five natural disasters coexist. The main coal seams have poor permeability and poor gas permeability. The gas content is high, and all of them have outburst danger.

3.2. Indirect Measurement of Coal Seam Gas Content

The content of adsorbed gas in coal is calculated according to Langmuir equation, and factors such as moisture, ash, temperature and percentage of combustible matter in coal should be taken into account. Coal bed gas content refers to the amount of free gas and adsorbed gas per unit weight (or volume) of coal bed under natural conditions.

The indirect method is used to determine the gas content in coal seam. That is to say, the adsorption constant of coal, moisture, ash content, porosity and bulk density of coal and gas pressure measured in situ are determined by laboratory, and calculated by formula.

The industrial analysis data of geological prospecting coal core are shown in Table 1.

Table 1. Laboratory data

program Sampling locations	Adsorption constant		Water content Wf(%)	Volatile matter VF(%)	ash content Ag(%)	True specific gravity d(g/cm³)	Pseudo specific gravity r(g/cm³)	Porosity f_n(%)
	a	b						
<i>manometry hole</i>	20.6168	0.0529	0.85	26.71	18.75	1.51	1.355	10.6
<i>East three slope</i>	30.1205	0.0335	1.33	31.87	9.31	—	1.41	—
<i>101 Shimen</i>	31.348	0.0219	2.04	19.69	12.74	1.51	1.35	13.3
<i>104 coal roadway</i>	34.3643	0.0359	1.90	25.89	7.2	1.415	—	—
<i>101 coal roadway</i>	26.9542	0.0318	1.21	24.89	6.3	1.45	—	—
<i>East three slope</i>	15.8544	0.04563	1.19	36.65	10.47	1.39	1.29	7.19

Gas content is calculated according to the following formula:

$$W_0 = \frac{abP_0}{1 + bP_0} \times \frac{100 - Wf - Ag}{100(1 + 0.31Wf)} + \frac{f_n P_0}{100\gamma} \quad (8)$$

In the formula: W_0 —Coal Seam Gas Content, m³/t,

a, b—gas adsorption constants;

P_0 —absolute gas pressure of coal seam, Kg/cm²,

W_f —coal moisture, %

Ag—ash content of coal, %

f_n —coal porosity, %

γ —The bulk density of coal, t/m³.

Considering table 1, we can get:

$$W_0 = \frac{26.5433 \times 0.03694 \times 18.8}{1 + 0.03694 \times 18.8} \times \frac{100 - 1.43 - 11}{100(1 + 0.31 \times 1.43)} + \frac{10.717 \times 18.8}{100 \times 1.35} = 8.1 \text{ m}^3/\text{t}$$

Therefore, the gas content is 8.1 m³/t.

4. Conclusion

The main coal seam in Weijiadi Coal Mine has poor gas permeability and high gas content, and the coal seam has outburst risk. The indirect determination of the gas content in the coal seam is 8.1 m³/t, which is of great significance for the implementation of gas prevention and control measures.

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