

Determination Method of Gas Content in Limestone and Its Application

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Abstract: The determination of gas content in coal and rock mass is the basic work to predict the gas emission of working face and mine. Generally speaking, gas exists in coal body in adsorbed state and free state, and the amount of adsorbed gas accounts for a large proportion. In order to explore the gas occurrence of lime rock mass, isothermal adsorption experiments are carried out on K2 and K3 limestone in Yangquan mining area. The experiments show that the gas adsorption capacity of lime rock mass is very small and mainly exists in the rock mass as free gas. When the temperature is constant, the gas content of limestone rock mass is linearly related to gas pressure and pore volume. That is, gas pressure and pore volume are the main factors determining the gas content of lime rock mass. Based on the gas state equation, this paper studies and determines the indirect calculation method of gas content in lime rock mass. The indirect calculation method is used to predict the gas emission of z15104 working face in Sijiazhuang coal mine. The prediction accuracy is about 86%, and a good prediction accuracy is obtained. It has certain guiding significance for mines with similar geological conditions.

Keywords: Adsorbed, Limestone, Gas Content, Gas Emission, Forecast

1. The Question Is Posed

The prediction of gas emission is the basis of guiding mine ventilation design, and its accuracy directly affects the reliability of ventilation design. In the scientific research work of Yangquan mining area, it is found that there is a large error in the prediction of gas emission. The main reason is that the influence of rock gas content on gas emission of working face is not considered.

Gas Content of rock mass refers to the amount of gas per unit mass of rock mass under natural underground conditions which is generally expressed as " m^3/t ".

The experimental results show that the amount of gas adsorbed by limestone is very small but is sealed in the pores of the Rock when the rock pressure relief free gas will flow to the excavation space. The determination of gas content in coal and rock mass is the basic work for predicting gas emission from working face and mine.

Up to now the gas emission from adjacent rocks is not considered in the prediction of gas emission from working face which leads to some errors in the prediction results [1]. Therefore the determination of gas content in rock mass has practical significance and application value.

2. Formation of Gas in Limestone Formation

The Yangquan Mining area is the production base of high-quality anthracite in China.

The coal seams of Taiyuan formation of carboniferous and Shanxi formation of permian are mainly exploited. From top to bottom the three layers of limestone in coal measures strata are respectively K4 K3 and K2 limestone. K4 K3 limestone is not pure K2 is relatively pure hard brittle joints are not developed cracks are filled with calcite pyrite nodules crinoids and other animal fossils.

According to practice there have been dozens of abnormal gas emission phenomena in limestone strata in the process of shaft driving and drilling of which K3 emission is the largest. Limestone is mainly formed in marine environment and there are some karst pores in the process of formation. However the gas from the adjacent coal seams above and below the limestone enters into these pores after a long time migration and forms free gas. In addition a large number of

UNMUDDIED crinoids and other animal fossils have been found in the limestone which can form Alkane gas in the geological age of the limestone [2-4].

3. Analysis of Gas Occurrence State in Limestone Stratum

It is well known that there are two modes of gas occurrence in coal: adsorbed state (adsorbed on the pores and inner surfaces of fissures) and Free State (in the pores and fissures of coal).

Coal is a kind of porous medium the gas in coal mainly exists in adsorption state the adsorption of methane by coal accords with Langmuir equation the ISOTHERMAL adsorption curve of coal to gas is shown in Figure 1. The physical properties of rock are different from that of coal so the occurrence state of gas in coal and rock is also different. In order to further analyze the occurrence state of gas in limestone the adsorption constant of K2 and K3 limestone in Yangquan Mine area is measured by high pressure volumetric method. The results are shown in figures 2 and 3.

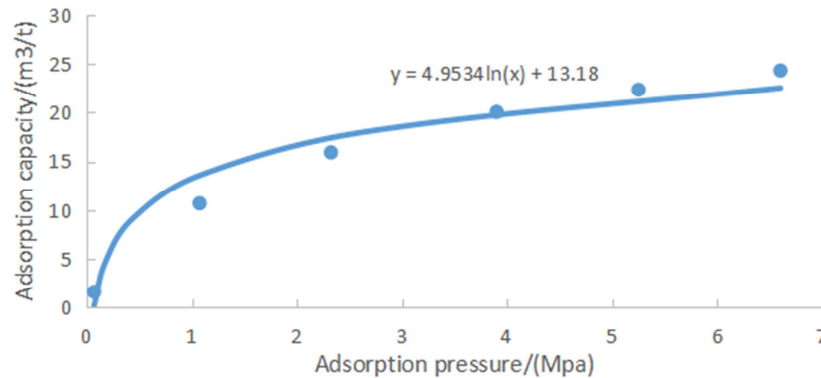


Figure 1. Adsorption curve of coal to gas.

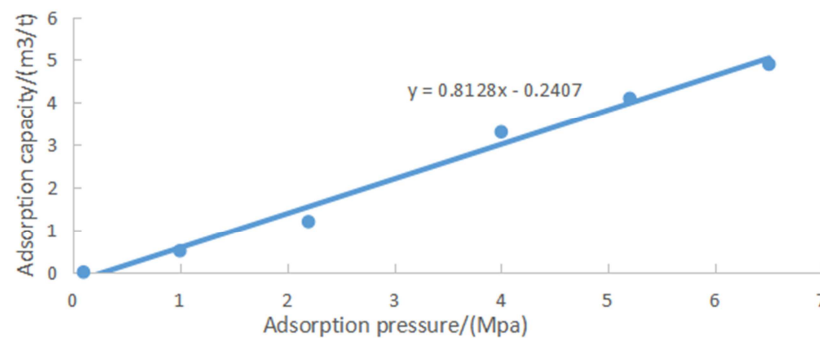


Figure 2. K2 adsorption curves of limestone.

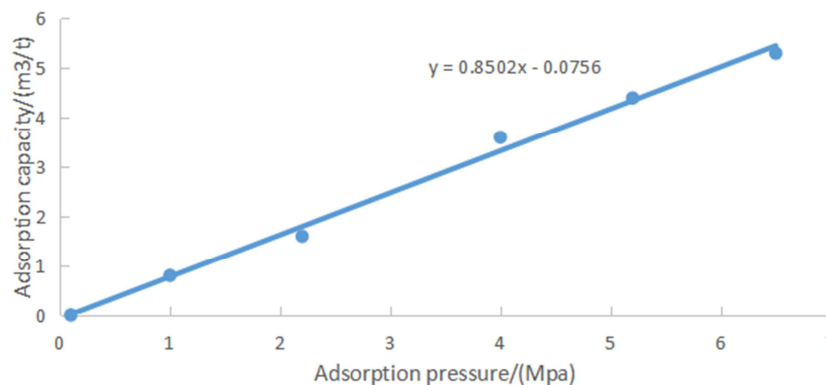


Figure 3. K3 adsorption curves of limestone.

The adsorption capacity of coal is not only restricted by the nature of coal itself but also influenced by many external factors such as temperature pore characteristics gas composition particle size and so on. As can be seen from Figure 1 and Figure 2 when the gas pressure is relatively low the adsorbed gas

amounts to the majority. With the increase of gas pressure the adsorbed gas amounts to saturation gradually and the proportion of free gas increases gradually. The ISOTHERMAL adsorption curve of Limestone is obviously different from that of coal which shows that the gas quantity increases linearly with

the increase of gas pressure. The gas pressure is a force produced by the impact of the free thermal movement of gas molecules in the coal and rock voids which is equal in each direction at a certain point and perpendicular to the voids wall. Therefore the main gas occurrence state of Limestone Body is free state. A large number of production practices also confirm this point namely the Rock itself does not adsorb gas or adsorption amount (in organic matter) is very small.

4. Calculation of Gas Content in Limestone Mass

It can be concluded that Free State is the main gas occurrence state in limestone so it is difficult to determine the gas content directly. In general the free gas content is calculated according to the gas equation of state [5-9], I. e:

$$W_y = \frac{VPT_0}{TP_0\zeta} \quad (1)$$

In the middle of the ceremony: W_y —Free Gas content, m^3/t ;

V —Pore volume, m^3/t ;

P —Gas Pressure in coal seam, MPa;

T_0 , P_0 —Absolute temperature (273K) and pressure in standard condition (0.101325MPa);

T —Absolute temperature of gas, $T=273+t$;

t —The centigrade temperature of the gas, $^{\circ}C$;

ζ —Coefficient of gas compression.

Considering the actual situation of coal mine the temperature of limestone body is $20^{\circ}C$. from formula (1) it can be seen that the temperature of rock body is $20^{\circ}C$ has little influence on the calculation result. For ease of calculation it can be obtained by formula (1):

$$W_y = 10KP \quad (2)$$

In the middle of the ceremony: W_y —Free Gas content, m^3/t ;

K —Constants related to pore volume and gas compressibility;

P —Gas Pressure in coal seam, MPa.

From Equations (1) and (2) it can be seen that the gas content of limestone is linearly related to gas pressure and pore volume at a certain temperature. That is gas pressure and pore volume are the main factors that determine the gas content of limestone.

5. Application Case

5.1. Overview

Z15104 is the first mining face when Sijiazhuang Coal Mine was put into production mining 15# coal seam the average thickness is 5.48 m the coal seam structure is simple in the middle and upper part there is a layer of carbonaceous mudstone or mudstone with gangue; It belongs to half-dark-half-light Briquette and the value F of coal seam's brinell hardness is 0.21~0.52. The roof is Sandy Mudstone siltstone or Mudstone and the floor is mudstone and carbonaceous mudstone. The structure of this mining area is relatively simple the whole is monoclinic structure the dip angle of coal seam is mostly $3 \sim 8^{\circ}$ average 5° .

The Z15104 working face is arranged along the long wall the face length is 240m the strike length is 1800m and the designed annual production capacity is 1.50Mt/a. Mining 15# coal seam by fully mechanized mining method with full height at one time.

During the mining of 15# coal seam the overlying 13#, 12#, 9#, 8# Coal Seam and K2 and K3 limestone will gush out gas to different degrees. According to the analysis and arrangement of the columnar data of the exploration boreholes in the mining areas of these two working faces the coal thickness and the distance to the 15# coal seam of the six upper adjacent coal seams are shown in Table 1.

Table 1. Occurrence parameters of adjacent strata in the first mining face.

The name of the adjacent layer	Upper adjacent layer					
	13#	12#	9#	8#	K2	K3
Distance to 15# coal seam /m	30.8	45.6	63.6	68.7	22.8	35.6
Coal (rock) thickness /m	0.46	0.45	1.0	1.5	6.25	4.6

5.2. Prediction Method and Determination of Prediction Parameters

5.2.1. Prediction Method

Z15104 is the first mining face of the mine the statistics of gas geological data is limited the application of statistical methods to predict gas emission is very limited. Therefore according to the gas emission source and the law of each source emission combined with the technical conditions of coal seam mining coal seam gas storage parameters that is the separate source prediction method to calculate the gas emission quantity of the working face. The gas emission quantity of the working face mainly includes the gas

emission quantity of the mining layer and the gas emission quantity of the adjacent layer [10] [formula (3) formula (4) in the meaning of each parameter see references].

Gas Emission from mining seam:

$$q_1 = k_1 \cdot k_2 \cdot k_3 \cdot \frac{m}{M} (W_0 - W_c) \quad (3)$$

Gas Emission from adjacent layers:

$$q_2 = \sum_{i=1}^n (W_{0i} - W_{ci}) \cdot \frac{m_i}{M} \cdot \eta_i \quad (4)$$

5.2.2. Determination of Gas Content in K2 and K3 Limestone Beds

According to the above analysis the determination method of gas content in limestone formation is to measure its gas

pressure by drilling to test its pore volume by laboratory and to calculate according to formula (2). The borehole parameters and measured results of gas pressure in K2 and K3 limestone beds in Sijiazhuang coal mine are shown in Table 2.

Table 2. K2, K3 borehole parameters for gas pressure measurement in limestone formation.

Hole number	Depth of bore/m	Aperture/mm	Obliquity/°	Azimuth angle/°	Gas Pressure/Mpa	Rock bed
1	42	94	60	90	0.3	K2
2	42	94	60	90	0.85	K2
3	53	94	60	90	0.6	K3
4	57.5	94	60	90	0.7	K3

In order to reduce the error the maximum gas pressure of each limestone layer is 0.85MPa for K2 layer and 0.7MPa for K3 layer. In the measuring process the borehole horizon is controlled accurately and there is no water inrush in the borehole so the measured value of gas pressure is accurate and reliable.

According to Formula (2) the calculated results of gas content of K2 and K3 limestone layers are $0.16\text{m}^3/\text{t}$ and $0.20\text{m}^3/\text{t}$ respectively (the measured results of Pore volume of K2 and K3 limestone layers in laboratory are $0.02\text{m}^3/\text{t}$ and $0.03\text{m}^3/\text{t}$ respectively and the gas compression coefficient is 1.06).

5.2.3. Forecast Parameters and Results

Because the first mining face is along the long wall the coal seam gas content has little change in the process of mining. According to the measured gas content of 15# coal

seam the gas content of 15# coal seam in the first mining face is $8.01\text{m}^3/\text{t}$. The mine roof management mode is all across falling method the designed recovery rate of the first mining face is 90% so K1, K2, K3 in Formula (3) are 1.3, 1.11 and 0.85 respectively [11].

During the advancing process of the working face the relief gas in the adjacent coal seam and the K2, K3 limestone strata will emerge in the excavation space in varying degrees. From the adsorption curve and formula (2) it can be seen that the free gas in the K2, K3 limestone stratum will almost all gush out so the residual gas content of K2, K3 limestone stratum is $0\text{m}^3/\text{t}$. The actual measured values of gas content and the selection of residual gas content in the adjacent coal (rock) beds are shown in Table 3.

Table 3. Gas content table of adjacent coal (rock) seam.

Serial number	Gas Content/(m^3/t)	Residual gas content/(m^3/t)	Notes
13	5.73	0.65	The gas content is measured and the remaining gas content is calculated by langmuir equation
12	5.73	0.65	
9	10.29	0.65	
8	13.58	0.65	
K2	0.16	0	The gas content is the measured value
K3	0.20	0	

According to the predicted parameters the results calculated by formula (3) and formula (4) are shown in Table 4.

Table 4. Forecast result table of gas emission quantity in working face.

Prediction method	Daily output /t	Predicted value of gas emission					
		Mining bed		Adjacent Layer		Total	
		m^3/t	m^3/min	m^3/t	m^3/min	m^3/t	m^3/min
Source separation method	5000	6.15	21.35	5.69	19.76	11.84	41.11

The predicted value of gas emission at Z15104 working face is $41.11\text{m}^3/\text{min}$. It is necessary to explain here that when determining the output and ventilation design of working face we must consider the maximum gas emission of working face that is multiply by 1.2-1.5 times the disequilibrium coefficient of gas emission on the basis of prediction parameters. In this prediction K2 and K3 limestone beds are included in the calculation. The production practice shows that the prediction accuracy of this method can reach about 86% and a good prediction accuracy is obtained [12, 13].

mining area, the prediction parameters are further refined in order to obtain higher prediction accuracy. Better guide mine ventilation.

The fine measurement technology of gas content and gas pressure is adopted to master the abnormal area of gas emission from limestone mass and guide the mine to do a good job of gas prevention and control in advance [14].

Further study the gas occurrence in sandstone and mudstone, and improve the gas emission prediction technical system [15].

6. Future Work Plan

Combined with the geological characteristics of Yangquan

7. Conclusion

1) Free Gas is formed when the gas in the adjacent coal

seams above and below the limestone enters into the pores after a long time migration. In addition a large number of UNMUDDIED crinoids and other animal fossils have been found in the limestone which can form Alkane gas in the geological age of the limestone;

- 2) Laboratory experiments and production practice show that Free State is the main gas occurrence state of Limestone I. E. The rock itself does not adsorb gas or the amount of adsorbed gas (existing in organic matter) is very small;
- 3) According to gas equation of state the gas content in limestone is $W_y = 10KP$ where K is a constant related to pore volume and gas compression coefficient;
- 4) In the face prediction the K_2 and K_3 limestone strata are included in the calculation as the adjacent coal seam. The production practice proves that the prediction accuracy of this method can reach about 86% and a good prediction accuracy is obtained;
- 5) Only a single sample (limestone) has been tested in this test the research scope should be further expanded when the conditions are available in order to improve the accuracy of gas emission prediction in working face and mine and to provide scientific basis for ventilation design.

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