

Experimental Study on Gas Desorption Rules of Residual Coal in Coal Mine Goaf

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Abstract: A large number of coal mining goaf produced by long-time mining in China is rich in coalbed methane resources. If the coal CBM is not used properly, it not only causes the waste of resources, but also affects the safe production of the coal mine, and will pollute the environment at will. However, at present, there are few studies on the gas desorption law of abandoned coal in goaf, which is an important part of gas source in goaf. Therefore, in this paper, a new experimental device is developed for the desorption of large size primary lump coal in the goaf, and a new empirical formula is derived for the desorption test of different particle sizes of raw coal at different temperatures.

1. Introduction

Coal bed methane is a kind of clean energy with high quality and high efficiency, and its combustion heat value is about 36000 KJ/nm^3 , about twice that of coal. On the other hand, the direct release of methane from coal into the ozone layer will cause a greenhouse effect, which will increase the temperature of the earth 25 times more than the same volume of CO_2 [1,2]. At the present stage, the research on the mining area resource assessment technology is still a big problem at home and abroad, especially the research on the desorption law of the residual coal gas in the goaf, which is an important part of the resource source of the goaf. The paper studies the gas desorption and residual content of the residual coal in the coal seam gas resources of the mining area, and simulated the process of gas desorption in the mined out area, and obtained the corresponding law of the desorption of the residual coal gas in the goaf.

2. The research status

2.1 The source of gas in the goaf

The amount of coal seam gas resources in the goaf mainly depends on the content of coal seam gas in the upper and lower part of the goaf, the size of the residual coal pillar in the coal seam, the content of the residual coal gas in the goaf and the volume of the free space in the goaf[3].

2.2 Empirical formula for gas desorption

In the long-term gas control work, domestic and foreign scholars have summarized the empirical formula of coal gas desorption under different conditions[4]. The paper studies the desorption of the residual coal gas in the goaf, and the desorption time is long, which usually reaches a few years or decades. Therefore, under this condition, the calculated value of the cumulative amount of desorption of the selected empirical formula should be a monotone increasing function. When the time tends to infinity, the gas solution absorption tends to be $Q_t = Q_\infty$, and the desorption velocity function formula is monotonous. When the time tends to infinity, the desorption rate tends to 0. When the time tends to infinity, the limit gas solution of Barrell, Sun Chongxu and Uskinov are all

infinite, while the limit gas solution of Bot is $(1-c)Q_{\infty}$. When time tends to be 0, the rate of gas desorption of Vent tends to infinity, which is not consistent with the actual situation. When the time of desorption is more than 1000 minutes, the experimental data of Wang Youan and exponential are close to a fixed value, which is not consistent with the requirements of the experiment, and the error of Wang Youan is larger in the later period of the experiment. Therefore, the original empirical formula can not accurately describe the process of residual coal gas desorption in different grain size and temperature, and can not reflect the influence of temperature and particle size on the desorption. It is necessary to analyze and deduce the experience formula of the gas desorption experience in the goaf.

2.3 Research ideas

According to Chen Xiangjun[4] formula of gas desorption with time in coal samples, the adsorption constant of residual coal in the goaf is generally stable, and the radius of the specific gas is also fixed, and the elastic modulus of the coal is closely related to the degree of coal damage. When the destruction of coal is more serious, the smaller the elastic modulus. In summary, the main factors affecting the gas desorption of coal in the goaf are adsorption equilibrium pressure, coal sample size, type of coal destruction and ambient temperature. In the case of the initial adsorption equilibrium pressure, this paper mainly studies the desorption of large size coal sample desorption test device and the original coal samples with different particle sizes at different ambient temperatures.

3. Test ideas and development of test equipment

3.1 Design of the test plan

In this paper, two kinds of desorption tests are carried out, which are gas desorption test of coal samples of the same size under desorption and temperature change conditions of fixed-temperature and constant-pressure coal samples. The primary coal sample of the coal sample is selected by the test coal sample, and the coal sample size is based on the longest side of the coal sample, and the ratio of the maximum edge to the shortest side can not be more than 1.8. The coal sample adsorption pressure is the original gas pressure of the sampling site. The test conditions are set as shown in Table 1.

Table 1 Test condition setting

Name	Gas desorption test of different sizes of coal samples with constant temperature and constant pressure	Gas desorption test of coal samples with the same particle size under variable temperature condition
Coal sample size and weight	Particle size: 30-150mm weight: 1Kg per group Number of coal samples: 13	Particle size: 40-140mm weight: 1Kg per group Number of coal samples: 6
Test ambient temperature	20°C	20,25,30(°C)
Test time	160 days	160 days

3.2 Problems existing in existing test equipment and development of test equipment

High pressure sealed metal tank is used in the existing desorbing test. It is difficult to calculate dead space, difficult to determine the absorption quantity, large error and not adapt to long time measurement in the process of small solution absorption, long time desorption and large particle size coal sample desorption test.[6] Therefore, the compressible vacuum sealing bag was used as the sealing element of coal sample. The test device is shown in Fig.1.

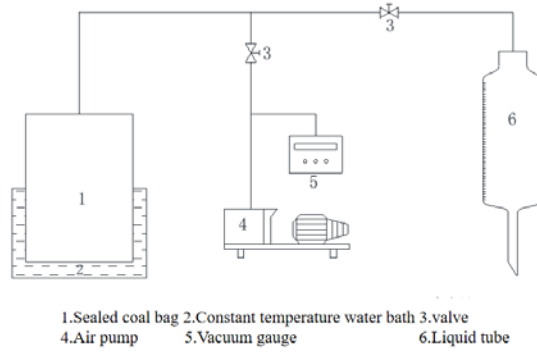


Fig.1 Schematic diagram of the desorption experiment device

4. Analysis of test results and model derivation

4.1 Gas desorption test of different particle size coal samples with constant temperature and constant pressure

The curves of the gas desorption capacity of different size coal samples at room temperature are shown in Fig.2.

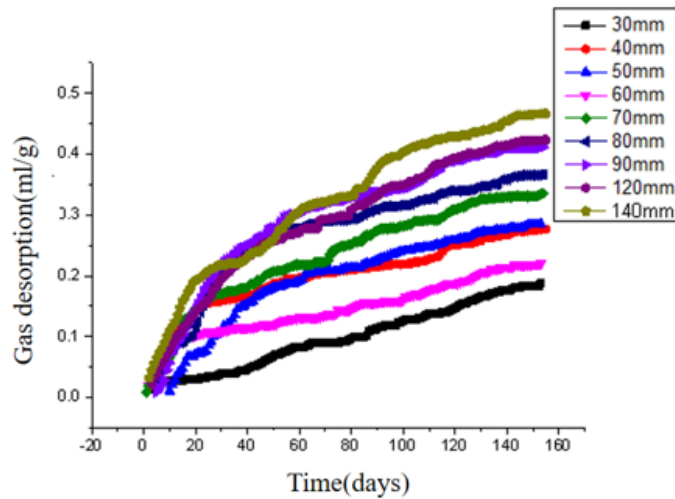


Fig.2 Gas desorption law for coal samples with different particle sizes at the same temperature

Through calculation, it is found that the variation law of gas desorption rate of experimental coal samples with time can be in good accordance with the power function relationship:

$$V_t = \frac{1}{\alpha \times t + \beta} \quad (1)$$

Where V_t is gas desorption rate of coal sample at desorption time t , ml/g.d. t is gas desorption time of coal sample ($t \geq 1$),d. α, β is attenuation coefficient of gas desorption rate with time.

Combined with the desorption data, we can calculate:

$$\alpha = 60.9421 \times 0.7433^t + 4.3575 \quad (2)$$

The coefficient has an average value of 56.754, so it can be concluded that the relationship between the desorption rate of the coal sample and the particle size and time is:

$$V_t = \frac{1}{56.754 + (60.9421 \times 0.7433^t + 4.3575) \times t} \quad (3)$$

Where V_t is gas desorption rate of coal sample at desorption time t , ml/g.d. t is gas desorption time of coal sample ($t \geq 1$), d. r is coal sample size, cm.

4.2 Gas desorption test of coal sample with the same particle size under variable temperature conditions

The gas desorption test results of coal samples with 40mm, 70mm and 130mm particle sizes at different temperatures were analyzed as an example. The gas desorption curve with time is shown in Fig.3.

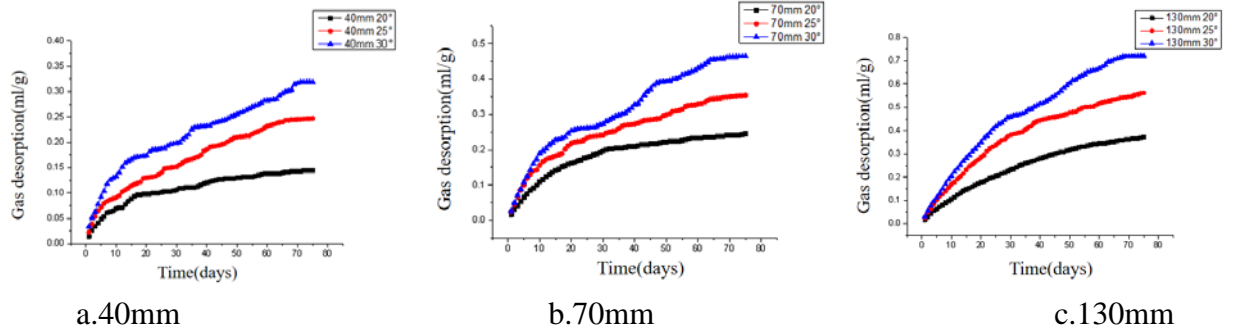


Fig.3 Gas desorption law for coal samples with different particle sizes at different temperatures

The desorption rate V_{20} of the experimental coal samples at different temperatures at 20 °C was selected as the benchmark to investigate the effect of different desorption temperatures on the desorption rate of coal samples. The expressions of the correction coefficient of the gas desorption rate V of coal samples at different temperatures are as follows.

$$\eta = \exp\left(a + \frac{b}{t^2}\right) \quad (4)$$

Where η is correction factor of temperature on coal gas desorption rate. a, b is regression coefficients. T is gas desorption temperature, °C.

According to the test results, the a and b mean values are calculated, so the correction coefficient of gas desorption rate with temperature is:

$$\eta = \exp\left(1.11049 - \frac{441.75074}{t^2}\right) \quad (5)$$

Therefore, it can be concluded that the gas desorption rate formula of coal samples at other temperatures at the same time point is also based on the desorption temperature of the coal sample at a temperature of 20 °C and the desorption rate V_{20} of the coal sample at 20 °C.

$$V_T = V_{20} \times \eta \quad (6)$$

4.3 Derivation of empirical formula

According to the relationship between the desorption rate of coal samples at different particle sizes and temperatures with time, it can be concluded that under the conditions of desorption temperature and coal sample particle size, the cumulative desorption gas quantity of coal sample at time T is as follows.

$$Q_{T(t)} = \int_0^t V_{T(t)} dt = \int_0^t V_{20(t)} \times \eta dt \quad (7)$$

By equation (3), it can calculate as shown in the equation (8).

$$Q_{T(t)} = \eta \left[\frac{\ln\left(1 + \frac{\alpha}{56.754} \times t\right)}{\alpha} \right] \quad (8)$$

4.4 Effect test of empirical formula

The coal samples from different coal mines in the same mining area were selected, and the desorption results and empirical formula calculations were recorded as shown in Table 2.

Table 2 Correlation coefficient between different particle size coal samples and test data

Comparative test coal sample size	Squared correlation coefficient
40mm	0.971
50mm	0.991
70mm	0.995
90mm	0.993
120mm	0.990
130mm	0.996

It can be seen from Table2 that the measured curve of gas desorption with time is more correlated with the fitted curve of the new empirical formula regression, which shows that the new empirical formula can describe the effect of coal sample size and desorption temperature on the gas desorption of experimental coal samples.

5. Conclusion

(1) A set of simulated experimental device for coal gas desorption in goaf has been developed and can be used to study the desorption of coal samples with different particle sizes under different temperature conditions.

(2) Using the newly developed test equipment, the desorption experiments of different size coal samples at different temperatures were carried out and a new empirical model was derived.

(3) The accuracy and rationality of the empirical model has been verified through experiments, and the accuracy of coalbed methane resources evaluation in goaf has been improved to a certain extent.

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