

In-depth Study on the Gas Desorption Law for Abandoned Block Coal in Goaf Under Water Flooding Conditions

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Abstract

China's coal production has formed a large number of goaf, which contains a large amount of coal and coalbed methane resources. If these resources are stored in the goaf, it will not only cause a waste of resources, but also cause environmental pollution if the coalbed methane in the goaf leaks into the atmosphere. Therefore, the utilization of goaf resources is imminent. In order to achieve the purpose of efficient extraction, it is necessary to evaluate the amount of goaf resources. As an important part of goaf resources, the desorption law of abandoned coal is affected by many factors, among which water is an important factor affecting the desorption law of abandoned coal. At present, there are few studies on the desorption law of block coal under different watered-out volumes.

Keywords

Coal Mine; Desorption Law; Water Flooding; Abandoned Block Coal; Goaf.

1. Introduction

In recent years, scholars at home and abroad have done a lot of experimental studies on the law of gas desorption of pulverized coal and lump coal. Zeng Shejiao, Nie Baisheng et al. [1-2] studied the law of gas desorption of pulverized coal with different particle sizes at different desorption temperatures. Wang Yibo et al. [3] conducted a corresponding study on the desorption law of coal samples at ultra-low temperature, and the desorption rate of coal samples at ultra-low temperature significantly decreased. Chen Xiangjun et al. [4] conducted gas desorption experiment for coal with 1mm-3mm particle size under water content, and found that with the gradual increase of water content, coal gas desorption speed gradually decreased. The studies by Yang Qiluan and Wang Zhaofeng et al. [5-6] show that there is a certain limit in the relationship between coal desorption and particle size. When the particle size of coal sample is smaller than the limit particle size, the attenuation coefficient of gas desorption strength increases with the decrease of particle size. Jiang Yongdong et al. [7] studied the desorption law of coal samples under different acoustic fields, and the gas desorption rate accelerated under the action of acoustic fields. Nie Baisheng et al. [8] found that electromagnetic field would promote coal sample gas desorption by adding electromagnetic field influencing factors in coal sample desorption. Wang Ran [9] studied the law of gas desorption of lump coal with different particle sizes under different temperatures and negative pressures.

Through the analysis of existing studies, it is found that the existing gas desorption experimental methods have the following shortcomings in the case of water flooding for the abandoned block coal in goaf:

(1) There are few experimental studies on the desorption law of lump coal, most of which are coal powder with small particle size. There are even fewer studies on the desorption law of lump coal under different volumes of water flooding, which cannot reflect the real situation of gas desorption of coal abandoned in goaf.

(2) Most of the existing desorption experimental devices are filled with coal powder for desorption. In the case of flooding of large coal samples, there are some problems such as inconvenient to inject water into the coal sample tank, imprecise control of adsorption equilibrium pressure and watered-out volume in the coal sample tank, which cannot meet the existing experimental requirements.

(3) The existing empirical formula of gas desorption cannot correctly reflect the calculation of the desorption amount of the left block coal in the case of goaf, which affects the accuracy of goaf resource assessment.

To sum up, it is necessary to trial-produce more suitable experimental devices and methods and deduce a more accurate empirical model of coal gas desorption rate on the basis of existing research and aiming at the desorption situation of coal abandoned in goaf in humid environment.

2. Trial Manufacture of Experimental Equipment

The main purpose of the experimental device is to accurately control the adsorption equilibrium pressure and water flooded volume of block coal. So on the basis of existing coal sample tank, the tank increased the tray can lift device, the dry coal samples placed on the tray, smoking inside the tank to the negative state, open the water valve, under the influence of negative pressure, through measuring cylinder injection of water, water injection coal sample at this time not contact with water, after water injection, by adding mouth filling the gas, Make the coal sample reach the set adsorption equilibrium state, then lower the coal sample tray to soak the lump coal in water, and the soaking volume is controlled according to the experimental requirements. The desorption device is shown in Figure 1.

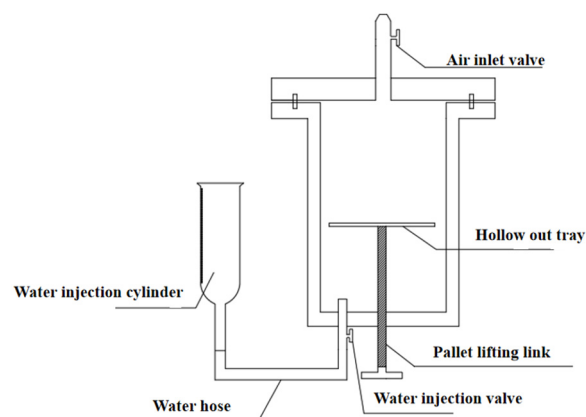


Figure 1. water flooding gas desorption device of lump coal

3. Coal Sample Trial Production and Experimental Parameter Setting

3.1. Physical Parameters of Coal Samples and Trial Production of Experimental Coal Samples

The physical characteristics of experimental coal samples are as follows: true density is 1.4t/m^3 , porosity is 4.01%, solidity coefficient F value is 0.96, initial velocity of gas emission ΔP is 9.

The test coal sample is the original coal sample, which is cut into a cube of about $4\text{cm} \times 4\text{cm} \times 4\text{cm}$. The trial-produced coal sample is shown in Figure 2.



Figure 2. Schematic diagram of coal sample

3.2. Experimental Settings

The determination of about 60 groups of coal samples has been completed. Three groups of coal samples are taken as examples to simulate the desorption under the conditions of 1/3, 2/3 and unflooded coal samples under the conditions of 0.4mpa, 0.6mpa and 0.8mpa respectively. The soaking time of coal samples under the conditions of flooded is 48 hours, and the data of no. 1, 2 and 3 coal are shown in Table 1.

Table 1. Dimensional data of test coal samples

Coal sample No.	Coal sample Volume	Coal sample weight
1	60cm ³	83.6g
2	72cm ³	86.1g
3	65cm ³	85.1g

Before the test, the coal samples shall be dried and degassed for 12h at 70°C to ensure the complete evaporation of water in the coal samples and the accuracy of the experiment. The 9 groups of 3 coal samples are shown in Table 2.

Table 2. Coal sample desorption test scheme

Coal sample number	Desorption temperature	Adsorption equilibrium pressure	Volume of soaking water
1	25°C	0.4MPa	Do not soak
1	25°C	0.4MPa	Submerge the coal body one third of the height
1	25°C	0.4MPa	Submerged coal two-thirds of the height
2	25°C	0.6MPa	Do not soak
2	25°C	0.6MPa	Submerge the coal body one third of the height
2	25°C	0.6MPa	Submerged coal two-thirds of the height
3	25°C	0.8MPa	Do not soak
3	25°C	0.8MPa	Submerge the coal body one third of the height
3	25°C	0.8MPa	Submerged coal two-thirds of the height

4. Analysis of Experimental Data

4.1. Analysis of Coal Sample Desorption Data

Taking the desorption data of three groups of coal samples as an example, the desorption rates of soaked coal samples of different volumes under three adsorption equilibrium pressures are shown in Figure 3~Figure 5. The desorption rates have been converted into the desorption rates per g of coal samples, and counting is stopped when the desorption rates are lower than 0.001L/min.

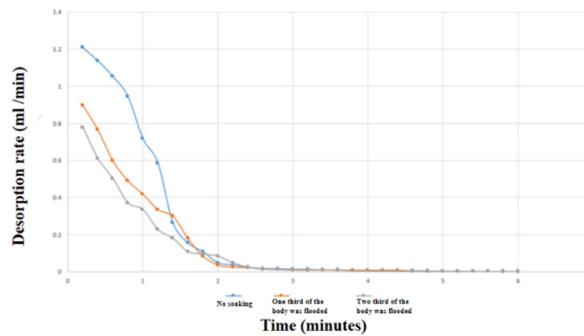


Figure 3. Gas desorption rate curves of coal samples per unit mass at different flooded volumes under the adsorption equilibrium pressure of 0.4MPa

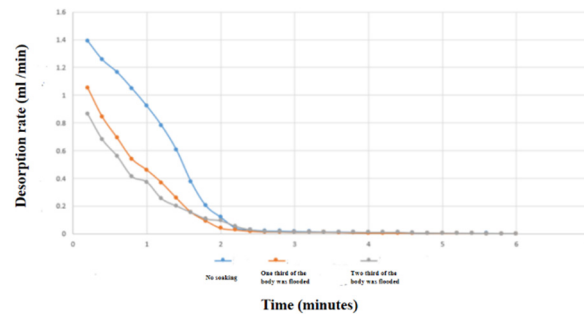


Figure 4. Gas desorption rate curves of coal samples per unit mass at different flooded volumes under the adsorption equilibrium pressure of 0.6MPa

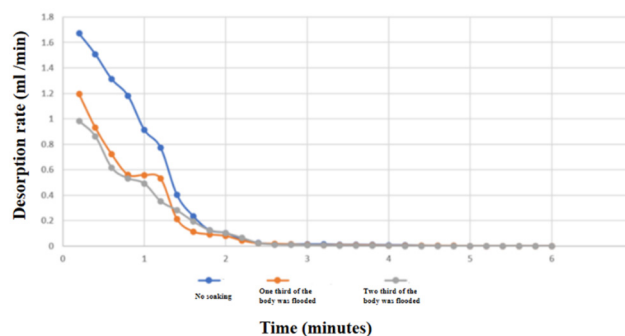


Figure 5. Gas desorption rate curves of coal samples per unit mass at different flooded volumes under the adsorption equilibrium pressure of 0.8 Mpa

It can be seen from the figure that the initial desorption rate of waterlogged coal decreases significantly. Under 0.4mpa adsorption equilibrium pressure, the initial desorption rate of waterlogged coal is 34% higher than that of soaked one-third coal, and 56% higher than that of soaked two-thirds coal. The difference in desorption rate between the two kinds of volumetric soaking coal samples is 22%. Under 0.6mpa adsorption equilibrium pressure, the initial desorption rate of waterless coal is 32% higher than that of immersed one-third coal, and 62% higher than that of immersed two-thirds coal, and the difference of desorption rate of coal

samples under two volume immersion conditions is 30%. Under 0.8mpa adsorption equilibrium pressure, the initial desorption rate of waterless coal is 53% higher than that of immersed one-third coal, and 70% higher than that of immersed two-thirds coal, and the difference of desorption rate of coal samples under two volumetric soaking conditions is 17%. There is a significant difference between the gas desorption rate of the coal sample without waterlogging and that of the coal sample soaked in a certain volume, indicating that different volume waterlogging has a significant impact on the desorption rate of the coal sample with large particle size. However, the desorption rate of the coal sample decreases rapidly in all three cases. After two minutes, the desorption rate of the coal sample in the three cases tends to be flat until the counting stops. From the desorption data, we can see that under the adsorption equilibrium pressure of 0.4mpa, the cumulative gas desorption capacity of No. 1 coal sample is 51.2% higher than that under the condition of 1/3 flooding, and 78.6% higher than that under the condition of 2/3 flooding. Under the equilibrium pressure of 0.6mpa, the cumulative gas desorption capacity of No.2 coal sample is 57.3% and 82.5% higher than that of 2/3 under the condition of no flooding. Under the adsorption equilibrium pressure of 0.8mpa, the cumulative gas desorption capacity of No. 3 coal sample is 63.7% and 89.2% higher than that of no. 3 coal sample under the condition of 1/3 and 2/3 flooding.

To sum up, when the adsorption equilibrium pressure increases, the difference between the desorption capacity of unwaterlogged coal sample and that of waterlogged coal sample further increases. In the case of two volume waterlogging conditions, the difference between the cumulative desorption capacity of coal sample gas under three adsorption equilibrium pressures is 27.4%, 25.2% and 25.5%, respectively, which are relatively close. Therefore, by increasing the adsorption equilibrium pressure, and the difference of gas desorption capacity between waterlogged coal and unwaterlogged coal gradually increases, while the difference of gas desorption capacity under different waterlogged coal volumes is relatively small.

4.2. Derivation of Empirical Formula for Desorption Ratedrilling Equipment

Derived from experimental data under different water volume of coal gas desorption empirical formula, at 0.6 MPa pressure consists of desorption of adsorption equilibrium time t (min), set the volume of water desorption rate influence coefficient for R , water volume factor for p (%), and coal desorption rate under different adsorption equilibrium pressure difference can be calculated by previous research, The formula of gas desorption rate V (mL /min) of coal body (g) with different waterlogged volume is:

$$V = [(1.38 - 0.60 \times t + 0.061 \times t^2)] \times R$$

By analyzing the difference of gas desorption rate of block coal under different soaking volumes and fitting the difference data, it can be deduced that the influence coefficient of water flooded volume on desorption rate is R and the calculation formula is as follows:

$$R = 1.05 - 0.06 \times p + 0.001 \times p^2 - 7.6 \times p^{2.5} + 0.048 \times p^{0.5} \times \ln(p)$$

4.3. Validation of Empirical Formulas

Table 3. Data table of empirical formula verification

Number	Cumulative desorption	Empirical formula fitting quantity	Alignment
1	471.05ml	504.05ml	92.9%
2	369.23ml	421.62ml	85.8%
3	342.11ml	308.36ml	90.1%
		Average:	89.6%

Three groups of new coal samples 1, 2 and 3 were selected to soak 15%, 45% and 75% of their volume respectively into water for desorption, and the empirical formula was first used to fit the desorption data and compare the calculation results and test results. The comparison results are shown in Table 3.

5. Conclusion

(1) In order to verify the law of gas desorption of block coal under different water flooding conditions, an experimental device for gas desorption of block coal was trial-produced. The device could accurately control the adsorption equilibrium pressure, water flooding volume and time, which met the experimental requirements.

(2) on the coal sample processing multiple sets of desorption experiment was carried out at the same time, different volume water can be found through the experiment of big diameter coal desorption exists significant influence, with the increase of water volume, the desorption rate is reduced, at the same time improve the adsorption equilibrium pressure, water and water coal gas desorption amount gap will gradually increase, The difference of gas desorption capacity under different volume flooding is relatively small. The empirical formula of coal gas desorption with different watered-out volume unit and the influence coefficient of watered-out volume on desorption rate are deduced by experimental data.

(3) The empirical formula was verified, and the coincidence degree between the calculated data of the empirical formula and the measured data reached 89.6%, proving the accuracy of the empirical formula, which can well reflect the law of coal gas desorption under different water flooded volumes under experimental conditions.

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References

- [1] Zeng Shejiao, Ma Dongmin, Wang Penggang. Journal of Xi 'an University of Science and Technology, 2024, 29(4):449-453.
- [2] Nie Baisheng, Yang Tao, Li Xiangchun, et al. Journal of China University of Mining and Technology, 2023, 42(6):975-981.
- [3] Wang Yibo, Li Hongtao, Qi Liming. Study on gas desorption law of coal body under low temperature [J]. China Coal,2011,37(5):103-104,107.
- [4] Chen Xiangjun, Cheng Yuanping, Wang Lin. Experimental study on inhibition effect of added water on gas desorption in coal [J]. Journal of Mining and Safety Engineering, 2023, 30 (2):296-301.
- [5] Yang Qiluan. Experimental study on the law of coal dust gas emission [J]. Safety in Coal Mines, 1986, 18 (2):9-17.
- [6] Wang Zhaofeng. Study on gas desorption law and application of coal in air, water and mud media [D]. Xuzhou: China University of Mining and Technology,2001.
- [7] Jiang Yongdong, Xiong Ling, Yang Xingyang, et al. Journal of China Coal Society,2010,35(10):1649-1653.
- [8] Nie Baisheng, He Xueqiu, Wang Enyuan, et al. Study on the mechanism of the influence of electromagnetic field on methane adsorption in coal seams [J]. Natural Gas Industry, 2004, 24 (10): 32-34.
- [9] Wang Ran. Experimental study on residual gas content and desorption law of coal mine goaf [D]. Chongqing: Chongqing Research Institute Co., LTD., China Coal Science & Engineering Group, 2015.