Experimental study on the gas desorption law of lump coal in coal mine goaf

Linchao Dai 1, 2, *
1State Key Laboratory of the Gas Disaster Detecting, Preventing and Emergency Controlling, Chongqing, China
2Chongqing Research Institute of China Coal Technology and Engineering Group Corp., Chongqing, China

*Corresponding author e-mail: dailinchao@126.com

Abstract. In order to accurately predict the coal mine goaf gas emission and evaluate the goaf gas resources, a self-designed atmospheric pressure coal desorption measurement device was used to conduct a long-term (lasting 140 days) gas desorption rule experiment of goaf lump coal, the effect of lump coal size on gas desorption law was analyzed. The research results show that the desorption rate of lump coals of different sizes (3cm, 5cm, 8cm, 13cm) has a negative exponential function relationship with time. And the cumulative amount of gas desorption basically increases with the increase of lump coal size, the initial gas desorption rate basically increases with the increase of the lump coal size.

1. Introduction
The amount of residual gas desorption in coal mines is an important part of the extractable gas resources in the goaf, and the accuracy of its estimation directly affects the reliability of the gas resource assessment results in the goaf [1]. The gas resources of the coal seam in the goaf are mainly determined by the gas content of the upper and lower coal seams in the goaf, the gas content of the remaining coal pillars in the coal seam, and the volume of the free space in the goaf. When the amount of coal pillars or coal left in the goaf is small, the amount of gas resources is mainly determined by the gas content of the upper and lower coal seams affected by mining. Therefore, it is of great significance to carry out the study on the law of gas desorption of the residual coal in the goaf.

In recent years, scholars have studied the influence of adsorption equilibrium pressure, coal sample size, temperature, moisture and other factors on the gas desorption law through a large number of experiments, and have obtained rich results [2-7]. At present, the coal samples selected for gas desorption experiments are mostly small-diameter coal samples with a diameter of less than 6 mm and the test observation time is relatively short. Fu Xiang et al [8] found that in the process of coal gas desorption, there is a limit particle size of coal particles. The limit particle size is the inherent particle size of coal, which is related to the degree of coal destruction and metamorphism, and is 0.5~6mm. Ge Yanyan et al [9] found that under the same temperature and pressure conditions, the adsorption capacity of anthracite powdered coal samples with a particle size of 60~80m was 1.20 times that of 2~5cm granular coal samples, and 1.79 times that of large coal samples. Chi Leilei[10], Chen Xiangjun[11], Liu Yanwei[12], Han Enguang[13] and so on used coal samples with a particle size of less than 6 mm
to study the law of gas desorption. It can be seen from this that there is a big difference between the size of the coal sample selected by the previous research and the size of the coal left in the goaf, which are mostly different sizes (more than 6 mm). Therefore, in order to accurately predict the gas emission from the goaf, the author conducts a long-term experimental study on the desorption law of lump coal of different sizes in the goaf, in order to obtain the gas desorption law of lump coal. It provides a basis for improving the accuracy of calculation of the amount of residual coal gas in the evaluation of gas resources in goaf.

2. Coal sample and experimental device

In order to study the law of gas desorption of lump coal in different sizes, fresh coal samples were collected from working face coal wall in 6 # coal seam of Shihao Coal Mine in Chongqing, China, and transported to the laboratory after sealed to keep the original state of coal samples. In the laboratory, filtered out pulverized coal, classified the coal samples according to the length of their longest side, and divided the coal samples with the longest side length of 3 cm, 5 cm, 8 cm and 13 cm into 4 groups, the weight of each group was 1 ± 0.05 kg. Finally, put into a sealed bag for use in experiments. The self-designed atmospheric pressure desorption experiment device was used. The device consisted of high-pressure gas cylinder, pressure relief valve, coal sample sealing unit, precision pressure gauge, thermostatic water bath tank, gas measurement device and vacuum pump. The cumulative amount of gas desorption of coal sample can be read directly from the liquid level in the burette. Schematic diagram of the experimental device is shown in Figure 1.

![Experimental Device Diagram](image_url)

1- High-pressure gas cylinder; 2- Pressure relief valve; 3- Coal sample sealing unit;
4- Precision pressure gauge; 5- Thermostatic water bath tank; 6- Gas measurement device;
7- Vacuum pump; a-e- valves

Figure 1. Schematic diagram of atmospheric pressure desorption experiment device

3. Experimental program

Experiments were carried out for a long time to observe the law of gas desorption of lump coal in goaf, and the coal samples were removed from the working face and sent back directly to the laboratory, without drying and degassing. The desorption of coal samples was carried in its original gas content, to simulate the true situation of residual coal gas emission in goaf. The detailed test procedure is as follows:

First, put the coal samples after being grouped into coal sample sealing unit, connected the experimental device and checked the air tightness. And then, set the coal sample sealing unit into the thermostatic water bath tank with 25 ℃ constant temperature. Finally, turned on the connection valves c-e, calibrated the liquid level in the burette. Continuously and regularly measured the liquid level for 140 days, the gas desorption volume in the standard state can get through the conversion formula, Eq.
(1). Repeated the above steps, the 3 cm, 5 cm, 8 cm, 13 cm coal samples were respectively tested, the law of cumulative amount of gas desorption with time in different size of lump coal can be obtained.

\[ Q_t = \frac{273.2}{101325 \times (273.2 + t_w)} \cdot \left( P_{atm} - 9.81h_w - P_t \right) \cdot Q'_t \tag{1} \]

Where, \( Q_t \) is the cumulative amount of gas desorption in standard state (cm\(^3\)), \( Q'_t \) is the cumulative amount of gas desorption in experimental state (cm\(^3\)), \( t_w \) is the temperature of water bath (℃), \( P_{atm} \) is the atmospheric pressure (Pa), \( h_w \) is the liquid level in the burette (mm), \( P_t \) is saturated steam pressure in the temperature of \( t_w \) (Pa).

4. The result and analysis

The law of cumulative amount of gas desorption with time in different size of lump coal is shown in Figure 2. It can be seen from Figure 2 that the cumulative amount of gas desorption in different sizes of lump coal increases with time, and the change of its cumulative amount is more obvious in the early stage, and then the gas desorption gradually stabilizes with time. At the same time, it can be seen that the cumulative amount of gas desorption basically increases with the increase of lump coal size.

![Figure 2. The relation curve between gas desorption and time of lump coal](image_url)

The relationship between the desorption rate and time of different sizes of lump coal is shown in Figure 3. As shown in Figure 3, in the long observation time, the gas desorption rate (V) of coal sample in different sizes shows a descending trend as a whole. In the initial stage, the variation of gas desorption rate per unit time is large, and then the variation of gas desorption rate gradually tended to be gentle. The relationship between the gas desorption rate and the time of lump coal in different sizes can be fitted by the following negative exponential form.

\[ V = V_0 e^{-bt} \tag{2} \]

Where, \( V \) is the gas desorption rate in t time (ml/(g·day)), \( V_0 \) is the initial gas desorption rate of the first day in experiment (ml/(g·day)), \( b \) is the fitting parameters, \( t \) is the time of desorption (day).
Figure 3. The relation curve between gas desorption rate and time of lump coal

At the same time, it can be seen that the initial gas desorption rate ($V_0$) basically increases with the increase of the lump coal size. This is because that the experimental coal samples from the work surface to the laboratory to carry on the atmospheric pressure desorption experiment is about spend 50 hours. Although coal samples were sealed in the process, there are gas desorption spillover during coal falling, coal filtering and coal loading, which lead to different residual gas content of different size lump coal at the beginning of experiment. The ratio of desorption of coal samples in different desorption stages can be obtained by comparing the original gas content of coal samples (measured directly in the field at the time of sampling) and the residual gas content after the experiment. The gas desorption amount from the coal sampling to the start of the experiment was taken as the first stage, the desorption amount during the gas desorption experiment was taken as the second stage, the residual gas content was the third stage. Taking the 3 cm and 8 cm coal samples as examples, the gas desorption amount in each stage is shown in Table 1.

The original gas content of different sizes of lump coal is same because they are taken from the same location. As can be seen from Table 1, In the first stage, the gas desorption amount of coal with size of 3 cm is larger than that of 8 cm, which indicates that the gas desorption rate of small size coal sample is relatively large at this stage. This is because that the smaller coal sample has more exposed surface area per unit mass, and it easily released gas desorption. Therefore, the residual gas content of the large-size coal samples is larger at the beginning of the second stage (the beginning of the atmospheric pressure desorption experiment), and the initial gas desorption rate is larger.

| Table 1 | Different stages of gas desorption quantity and proportion |
|---------|-----------------------------------------------------------|
| Size/cm | Gas content/ (ml.g$^{-1}$) | First stage | Second stage | Third stage |
|         | Desorption amount/ (ml.g$^{-1}$) | Proportion/% | Desorption amount/ (ml.g$^{-1}$) | Proportion/% | Desorption amount/ (ml.g$^{-1}$) | Proportion/% |
| 3       | 1.465 | 0.716 | 48.9 | 0.186 | 12.7 | 0.563 | 38.4 |
| 8       | 1.465 | 0.271 | 18.5 | 0.425 | 29.0 | 0.769 | 52.5 |
5. Conclusion
The cumulative amount of gas desorption in different sizes of lump coal increases with time, and the change of its cumulative amount is more obvious in the early stage, and then the gas desorption gradually stabilizes with time. At the same time, the cumulative amount of gas desorption basically increases with the increase of lump coal size.

(1) In the long observation time, the gas desorption rate of coal sample in different sizes shows a descending trend as a whole. In the initial stage, the variation of gas desorption rate per unit time is large, and then the variation of gas desorption rate gradually tended to be gentle. At the same time, the initial gas desorption rate basically increases with the increase of the lump coal size.

(2) The residual gas content of the large-size coal samples is larger at the beginning of the second stage (the beginning of the atmospheric pressure desorption experiment), and the initial gas desorption rate is larger.

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