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**Research Article**

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# Changing law of coal rock permeability under the influence of gas injection pressure

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**Abstract** Gas injection pressure is one of the main factors affecting the permeability of coal rock, and this paper finds that the experimental study of nitrogen seepage under different injection pressure conditions shows that the permeability of coal rock decreases with the increase of injection pressure, and the permeability of coal rock increases more when the injection pressure increases from 0.5MPa to 1MPa compared with that when the injection pressure increases from 2MPa to 3Mpa. The conclusions drawn in this paper help to understand the seepage behavior of coal rock and provide an important reference for engineering applications in related fields.

**Keywords** Injection pressure; Penetration rate; Permeability

## 1. Introduction

Coalbed methane (CBM) is an important renewable energy source, and the permeability of coal rock is a key parameter for controlling CBM production. Gas injection pressure is a major factor that affects the permeability of coal bedrock, so its effect on the permeability of coal rock has been widely studied.

At present, scholars at have carried out a large number of experimental and numerical simulation studies to investigate the mechanism and law of the influence of gas injection pressure on the permeability of coal rock in depth. Bobo Li [1] carried out isothermal adsorption experiments and seepage experiments at different pore pressures to modify the Langmuir model under the influence of temperature and excess adsorption, and the results showed that under adsorption and slip effects, the permeability of the coal rock decreases with increasing pore pressures and increases with increasing temperatures. Zhejun Pan [2] determined the permeability of carbon dioxide, ethane, and helium to sandstone core samples at different temperatures and pressures, and found that when the pressure is the same and the temperature increases, the apparent permeability of all gases gradually increases. Xiangchen Li [3] investigated the permeability and axial strain of coal rock at six different temperatures, and concluded that the permeability change was determined by the internal structural change of coal rock, and the experimental results showed that the permeability of nitrogen and methane varied non-monotonically with the increase of temperature. Jiang Liu [4] investigated the mechanism of permeability enhancement of coal rock after heat treatment, and measured the permeability and acoustic velocity of coal rock by injecting hot helium gas at 50°C, 100°C, 200°C, 400°C, 600°C, and 800°C into the water-bearing coal samples. The results showed that the permeability of the coal rock was increased by 4-14 times from 50°C to 200°C, and the permeability of the coal rock started to be pyrolysed at 400°C-600°C. At 400°C-600°C, the permeability of coal rock started to pyrolyse increased by 79~1600 times. After 800°C, the coal rock is completely pyrolysed and the permeability increases by 20,000 times. Jiangkun Chao [5] studied the permeability evolution process of seven different grain size coal rock under different temperature, pore pressure, and water content conditions. The results showed that the change law of permeability and the change law of axial strain were in a negative exponential relationship, and the porosity of the coal rock decreases with the increase of the grain size of the coal rock. Shuang Wu [6] studied the seepage law of different volatile fraction bituminous coals under different temperatures and pressures in Ordos area, and found that the permeability of coal rock decreased exponentially with the increase of effective stress, and compared the permeability of nitrogen and helium. The results showed that the permeability of nitrogen decreases gradually with the increase of temperature at a faster rate. M.S.A. Perera [7] studied the seepage experiments of coal rock under different injection pressure and temperature conditions. The experimental data showed that the $CO_2$ permeability increased significantly with the increase of temperature under high injection pressure, but the temperature did not have much effect on the $CO_2$ permeability under low injection pressure. The effect of the temperature on the $CO_2$ permeability was more significant when it was around 90°C, but the temperature had less effect on the $N_2$ permeability. Kai Wang [8] studied the permeability of $CH_4$, $CO_2$ and He in anthracite samples at different gas pressures and temperatures. The results show that with the increase of gas pressure, methane and carbon dioxide is a "U"-shaped law of change, carbon dioxide to reach seepage steady state to be longer than that of methane.

Coalbed methane mining practice is a real means to verify the effect of gas injection pressure on coal rock permeability. In recent years, China's CBM mining projects have accumulated rich experience in gas injection pressure control, and it is found that a reasonable gas injection pressure can effectively improve the permeability of coal beds and increase the production of CBM, but exceeding a certain injection pressure will lead to the destruction of coal beds and the loss of resources.

In this paper, the rule of change of coal rock permeability under different gas injection pressure conditions is explored by carrying out under the same temperature conditions, which is of great significance for the gas injection after hydraulic fracturing to drive out the water in coal rock and reduce the blocking effect of water.

## 2. Experimental Equipment and Coal Sample Preparation

### 2.1. Experimental Coal Sample Preparation

The experimental coal samples were taken from Shenmu coal samples in Yulin City, Shaanxi Province, China, and in order to facilitate the experiments, the experiments were carried out by mechanically processing the coal samples as columnar samples with a diameter of 50*100mm. The coal samples are as follows:

*Figure 1: Bituminous Coal in Shenmu City, Yulin City, Shaanxi Province, China*

### 2.2. Experimental set-up

The experimental device adopts the gas seepage system, the experimental device consists of gas device, axial peripheral pressure system and seepage test system. The specific experimental device diagram is as follows:

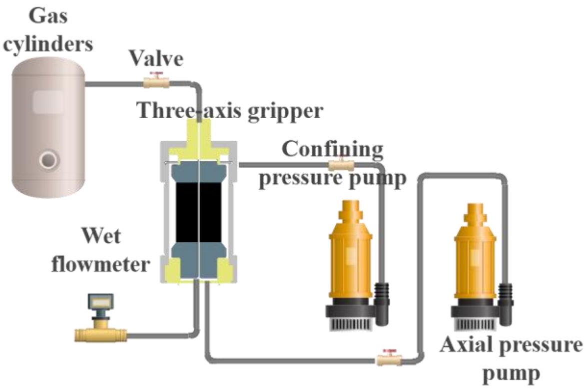


*Figure 2: Experimental setup diagram*

### 2.3. Experimental steps

(1) Place the coal rock into the triaxial holder and adjust the axial and radial strain gauges. At the same time, load the axial pressure to 6MPa and radial pressure to 5MPa. to simulate the axial ground stress conditions.

(2) Heat the nitrogen tank to 30°C at the same time, pressurize to 0.5MPa (1MP, 2MPa, 3MPa) for a certain period of time to stabilise.

(3) Open the valve after gas pressure in the tank is stabilised, and pass the gas into the coal to monitor for 30 minutes.

(4) Change the pressure inside the heating tank and repeat the above steps.

### 2.4. Data processing

Coal rock permeability was calculated using the following formula:

$$K = \frac{2QP_a\mu L}{S(p_1^2 - p_2^2)} \tag{1}$$

Where: $K$ is the gas permeability, mD; $Q$ is the gas flow rate, $cm^3/s$; $P_a$ is the standard atmospheric pressure, 0.1MPa; $\mu$ is the gas viscosity, $\times 10^{-3} Pa \cdot s^{-1}$; S is the permeable area of the coal sample, $cm^2$; $p_1$ is the pressure at the inlet end, MPa; $p_2$ is the pressure at the outlet end, MPa.

## 3. Changing law of coal rock permeability under different pressure conditions

### 3.1 Analysis of the change rule of coal rock permeability under different conditions of gas injection pressure

Gas injection pressure is the pressure at which gas is injected into the coal rock. In the process of gas injection, the injection pressure has a significant effect on the permeability of the coal rock. The following figure shows the change of permeability under different gas injection pressure conditions at 30°C.

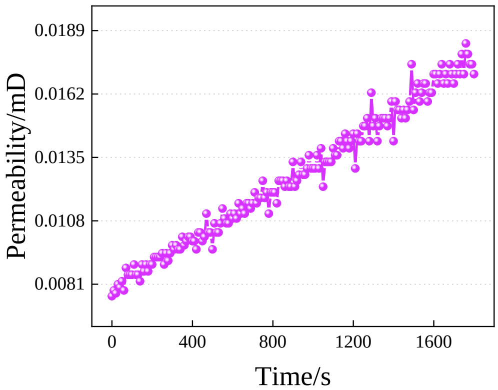


*Figure 3: Changing law of permeability under 30°C, 0.5MPa injection pressure*

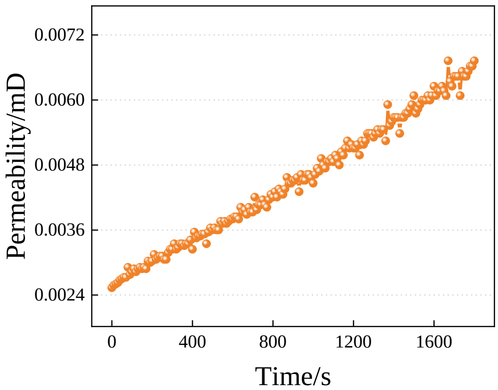


*Figure 4: Changing law of permeability under 30°C, 1MPa injection pressure*

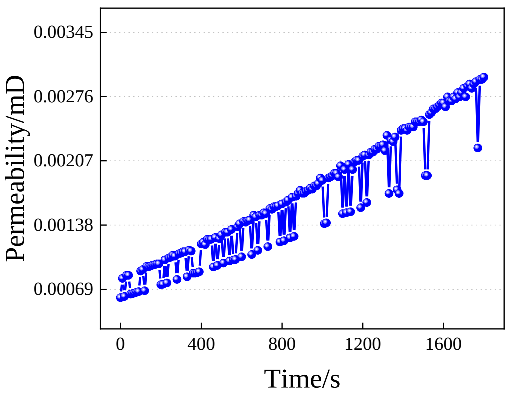


*Figure 5: Changing law of permeability under 30°C, 2MPa injection pressure*

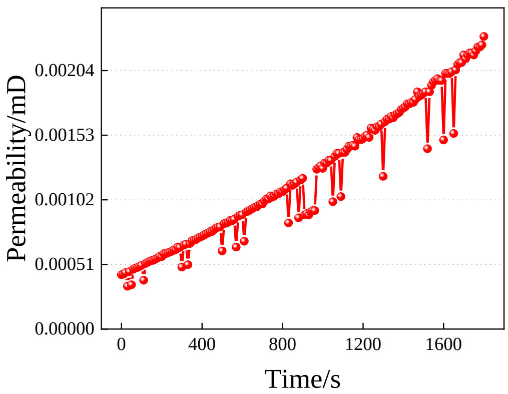


*Figure 6: Changing law of permeability under 30°C, 3MPa injection pressure*

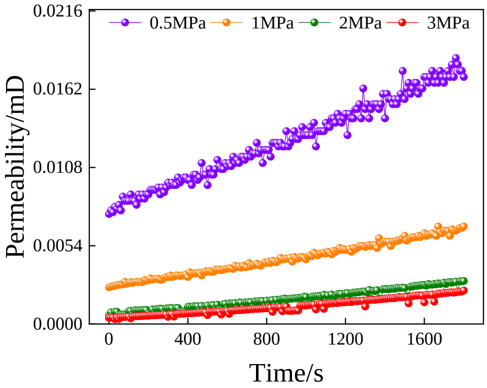


*Figure 7: Change rule of coal rock permeability under different gas injection pressures*

With the continuous injection of nitrogen, the gas pressure in the nitrogen tank decreases, and the permeability of the coal rock under different injection pressure conditions shows an increasing trend change. Under the condition of 0.5MPa gas injection pressure (Figure 3), the permeability of the coal rock increased from 0.007591mD to 0.017047mD with the continuous decrease of the pressure at the upstream end, and it showed a small fluctuating change in the process of permeability increase.

Under the condition of 1MPa gas injection pressure (Figure 4), the permeability of coal rock increases from 0.002534mD to 0.006624mD with the decreasing pressure at the upstream end, and the number of small fluctuation changes in the process of permeability increase is less compared with that under the condition of 0.5MPa gas injection pressure.

Under the condition of 2MPa injection pressure (Figure 5), the permeability of coal rock increases from 0.000807mD to 0.002968mD with the decreasing of upstream pressure, and the number of small fluctuation changes in the process of increasing permeability increases compared with that under the condition of 0.5MPa and 1MPa injection pressure.

Under the condition of 3MPa injection pressure (Figure 6), the permeability of coal rock increased from 0.000428mD to 0.00231mD with the decreasing pressure at the upstream end, and the number of small-scale fluctuation changes in the process of permeability increase was significantly reduced compared with that under the condition of 2MPa injection pressure.

The trend of coal rock permeability change under different gas injection pressure conditions is shown in Figure 7, when the gas injection pressure increases from 0.5MPa to 1MPa, the coal rock permeability decreases more compared with the increase of gas injection pressure from 2MPa to 3MPa. And as the pressure in the nitrogen tank decreases, the permeability under the condition of 0.5MPa injection pressure increases more.

### 3.2. Mechanism analysis of the influence of gas injection pressure on the change of permeability of coal rock

The permeability of coal rock changes under different pressure conditions. Generally speaking, with the increase of pressure, the permeability of coal rock will decrease, and the permeability of coal rock becomes worse. On the one hand, this is because the pores and fissures in the coal rock will be squeezed under pressure, resulting in weakened connectivity of the pores and narrowed channels for fluid penetration. On the other hand, Klinkenberg effect will also lead to the permeability decrease with the increase of gas pressure. In addition, the coal has a certain degree of plasticity, when subjected to pressure, the coal rock will be deformed and compacted phenomenon, so that the pore space is more compact, thus reducing the permeability.

However, it should be noted that the change law of permeability of coal rock has great complexity and is affected by many factors. For example, the permeability of different coal types varies greatly, and the characteristics of the pore structure, fracture system and permeable medium of coal rock will also have an impact on the permeability. In addition, environmental factors such as temperature, water content, and ground stress will also have an impact on the permeability of coal rock.

Therefore, when studying the change rule of permeability of coal rock, it is necessary to comprehensively consider a variety of factors and conduct experimental research to obtain more accurate results. At the same time, the rule of change of permeability of coal rock under different coalfields and geological conditions may be different, so it is necessary to analyze specific problems.

## 4. Conclusion

According to the results of the study, the permeability of the coal rock is affected by the injection gas pressure. The following are the conclusions about the influence law of gas injection pressure on the change of permeability of coal rock:

1. With the increase of gas injection pressure, the permeability of coal rock shows a decreasing trend. This is because the pores and fissures in the coal rock will be squeezed under pressure, leading to weakening of the connectivity of the pores and narrowing of the channels for fluid penetration. In addition, Klinkenberg effect will also result in the permeability decrease with the increase of gas pressure.
2. There is a non-linear relationship between the permeability of coal rock and the injection pressure. With the increase of gas injection pressure, the rate of increase of permeability gradually decreases, showing a decreasing trend. This indicates that the benefit of increasing the gas injection pressure will gradually diminish.
3. For different types of coal rock samples, there are differences in the response of permeability to gas injection pressure. Some factors such as the pore structure and gas content of the coal rock will affect the trend of permeability and saturation pressure.

In summary, in our experiments, we observed that the permeability of coal rock decreases as the gas injection pressure increases, and the rate of increase gradually decreases as time goes by. These conclusions help to understand the seepage behavior of coal rock and provide an important reference for engineering applications in related fields. However, further studies are still needed to better reveal the influence law of gas injection pressure on the change of coal rock permeability.

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