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The relation of gas seepage and coal body damage under the true three dimension stress

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Abstract

The law of gas flow is the basis of coal and gas outburst prevention and gas drainage rate increase. Thus the relation of gas seepage and coal body damage under the true three dimension stress is studied. The research results show that when volume stress is not change with the change of pore pressure the permeability of coal body change with the parabolic law. The relation of damage and permeability of coal body is established. It can be known that during load of coal body the greater the damage occur, the more the permeability of coal body after unload decrease than primary permeability of coal body.

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Keywords: coal body; seepage; damage; gas

1. Introduction

The permeability of coal is an important parameter of studying gas flow in coal seam[1-17]. When the coal seam is mined there is the stress decrease area, the stress increase area and the original stress area in front of working face. With the mining of working face and the continued re-distribution of stress in coal seam the coal seam will experience the process of loading and unloading in order to make coal permeability changes. Thus, the study of the relation of gas seepage and coal body damage has the

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important meaning for the mechanism of coal and gas outburst, gas flow and gas drainage. Thus, with the seepage equipment of the test system of gas and liquid relative permeability in coal body the relation of gas seepage and coal body damage under action of true three dimension stresses is studied.

2. Experiment system

2.1 Experiment system

The seepage equipment of the test system of gas and liquid relative permeability in coal body of CGMS is used. It can be seen in Figures 1 and 2.

2.2 Main technical parameters

Maximum working pressure: 40MPa	*Maximum horizontal pressure: 40MPa*
Maximum Vertical pressure: 40MPa	*Maximum axial pressure: 20MPa*
Maximum lateral pressure: 32MPa	*Maximum Flooding pressure: 26MPa*
Seepage equipment size: out diameter: 186mm, length: 410mm	*Maximum sample size : 60 mm×25mm×25mm*
	Working temperature: -5℃-85℃

Fig. 1 The test system of gas and liquid relative permeability in coal

2.3 Coal sample

The coal samples is collected from Qidong coal mine and processed into the specimen of 25mm×25mm×60mm in Institute of Geological and Mechanics, Chinese Academy of Sciences (Fig.3).

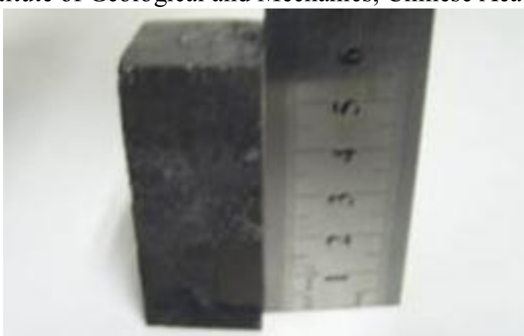

Fig.3 Coal sample

2.4 Experimental program and procedure

(1) Experimental content

① The change of the permeability of coal sample is studied by use of the seepage equipment of TY-7 under the same pore pressure and the different volume stress.

② The change of the permeability of coal sample is studied by use of the seepage equipment of TY-7 under the same axial, confining pressure and the different pore pressure.

Because methane is dangerous and the absorption characteristic of carbon dioxide is similar with methane carbon dioxide is used in the experiment.

(2) Experimental procedure

① Coal samples are processed into size of 25mm×25mm×60mm.

② Coal samples is placed in a vacuum drying oven and heated to 50℃. After the temperature is kept 24h coal samples is cooled to room temperature. Then coal samples is removed and sealed.

③ Coal sample is placed into the seepage equipment and pipeline is connected.

④ Axial pressure of coal sample is loaded to setting value. Then lateral pressure and pore pressure of coal sample is loaded. During loading pore pressure must be less than lateral pressure which prevent the gas of coal sample spill because of the larger pore pressure.

⑤ After the exhaust speed of gas in coal sample is stable gas seepage content is measured and the permeability of coal sample is calculated.

3. Experimental results and analysis

3.1 Calculation formula

The most of study think that gas flow in coal obey Darcy's law, which can be expressed as follows

$$q = -\frac{K}{\mu} \cdot \frac{\partial p}{\partial x} \tag{1}$$

where q is gas flow velocity, m/s; $\frac{\partial p}{\partial x}$ is pressure gradient, Pa/m.

According to equation (1) calculation formula of coal permeability can be gained as follows

$$K = \frac{2Q_0 P_0 \mu L}{(P_1^2 - P_2^2)A} \tag{2}$$

where K is permeability, m^2; P_0 is atmospheric pressure of measurement point, Pa; Q_0 is gas flow content, m^3/s; μ is gas viscosity, Pa·s; L is the length of coal sample, m; P_1 is gas pressure of import of coal sample, Pa; P_2 is gas pressure of export of coal sample, Pa; A is cross-sectional area of coal sample, m^2.

3.2 Experimental results

The relation between pore pressure and coal permeability can be seen in Figure 4. Figure 4 show that volume stress of three curves is 47.34MPa, 53.61MPa, 59.88MPa respectively from up to down. It can be known from Figure 4 that with the change of pore pressure the permeability of coal body change with the parabolic law. The reason is that when pore pressure is very low, the influence of pore pressure to the coal deformation, the opening degree of the cracks and pore is very small. The influence of gas adsorption layer thickness in coal body is very large. With the increase of gas adsorption layer thickness the effective flow path area decrease which result into the increase of gas molecular migration resistance significantly and the decrease of the speed of gas flow velocity. Because the opening degree of the cracks and pore is less than the increase of gas adsorption layer thickness the permeability of coal body reduces.

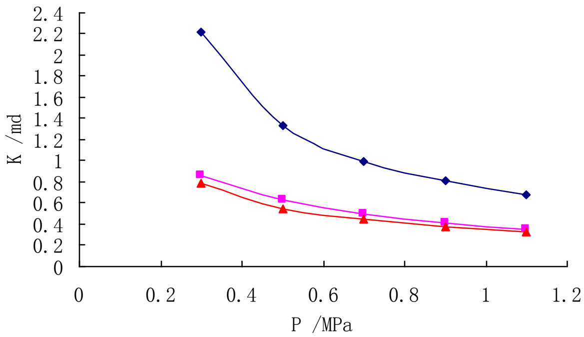

Fig.4 The change of permeability with pore pressure

4 The relation of damage and permeability of coal body

Coal contained gas will deform continuously under the force, during the transformational history, since the coal exists a lot of weak structural planes, such as micro-pores、micro-fissure、granular cementation surface、joints and stratification which damage the coal constantly, thus, the coal will generate new micro-defect, or the native defect will expand, or the coal will produce micro-crack, all the effect will change the permeability of the coal in the end. Therefore, it is necessary to analysis the relationship between the damage of the coal and its permeability when it experiences the loading and unloading. According to the theory of damage mechanics, the one-dimensional linear elastic damage model of the material can be known as follows[18]:

$$\varepsilon = \frac{\sigma}{E(1-D)} \tag{3}$$

where σ is stress; ε is strain; E is modulus of elasticity; D is damage variable.

The relationship between the permeability of the coal and its strain can be shown as follows[19]:

$$k = 1.03 \times 10^{-0.31\sigma} \tag{4}$$

where k is permeability.

Put the equation (3) into (4), the result is as follows:

$$k = 1.03 \times 10^{-0.31\varepsilon E(1-D)} \tag{5}$$

The equation (5) is rightly the relationship expression between the permeability of coal body and its damage. it can be seen that, the strain of the coal will increase with the damage variable, so does the permeability of the coal. It can be seen that during load of coal body the damage and deformation of coal body increases and with the increase of stress the permeability of coal body decrease. During unload of coal body with the decrease of stress the permeability of coal body increase. But the permeability of coal body can not come back to primary value. This is because coal is not elasticity and coal deformation can not come back absolutely. Thus, the permeability of coal body after unload is lower than primary permeability of coal body.

5. Conclusions

(1) When volume stress is not change with the change of pore pressure the permeability of coal body change with the parabolic law.

(2) The relation of damage and permeability of coal body is established. It can be known that during load of coal body the greater the damage occur, the more the permeability of coal body after unload decrease than primary permeability of coal body.

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