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Research on gas irradiation feature of tectonic coal

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Abstract

Using gas-diffusion experimental installation created by Chongqing institute of coal science research institute, in different pressure conditions, studied the rule of gas diffusion in tectonically coal. Got the characteristics of the gas diffusion in tectonically coal by analysis of the experimental data, and provided the basis for the gas outburst prediction and estimate the gas emission on the working face.

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1. Introduction

There were some tectonic coal seam variation in thickness in the coal and gas outburst seam. Tectonic coal was the product of geotectonic movement in the last period of formation of coal. The bedding of the tectonic coal was very inordinate, behaved crushed acute-angled grain powdered. Some domestic and international academics had a think of the point that tectonic coal was the necessary condition of the coal and gas outburst. So we made use of the self-manufactured system exercises carrying on the diffusion experiment, researched on gas irradiation feature of tectonic coal, looking forward to provide the theory thereunder for the fatalness forecast of coal and gas outburst and abundance of methane.

2. System exercises

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Chongqing Research Institute of China Coal Technology &Engineering Group CORP triturated a gas diffusion system exercises based on the measuring method for measuring gas absorbance promulgated by Ministry of coal industry in 1997. The system exercises were composed of vacuum degassing system, gas adsorption-diffusion system and high pressure gas system.

![Sketch of diffusion experimental device](image_url)

**Fig.1 Sketch of diffusion experimental device**

### 3. Principle

Coal was a kind of complicated porous medium, gigantic pore system was the occurrence space and migration channel of gas. It is generally recognized that gas diffusing in the pore according with Fick law. Thus the coal was a kind of adsorbent, so its gas diffusion coefficient was variational in the process of diffusion. Some scholar found that the diffusion $Q_t$ in time $t$ had a connection $Q_t/Q_\infty = K \sqrt{t}$ with diffusion $Q_\infty$ in time $t \to \infty$, accounted for that the time-varying diffusion process had a similar laws with constant diffusion coefficient. So come up with a few scientific hypothesis as follows:

1. Pea coal was homogeneous isotropy spherical particle;
2. The motion of gas followed the law of conservation of mass and continuity of mass law;
3. The solution of timevariant diffusion model was the product between solution of constant diffusion coefficient and time function $X_t$. 


Fig. 2 Diagram of gas diffused in coal

On account of the diffusion with constant diffusion coefficient, the diffusion equation and boundary condition:\[1\]:

\[
\frac{\partial c}{\partial t} = \left( \frac{1}{r^2} \right) \frac{\partial}{\partial r} \left( r^2 D \frac{\partial c}{\partial r} \right)
\]

\[
c(r, 0) = c_0; c(R, t) = c_1
\]

\[
\left. \frac{\partial c}{\partial r} \right|_{r=0} = 0
\]

in the equation (1), \(R\) was the radius of pea coal; \(c(r, t)\) was the concentration in the radial direction. Solution can be expressed as:

\[
\frac{c - c_1}{c_0 - c_1} = \frac{2R}{\pi r} \sum_{n=1}^{\infty} \frac{(-1)^n}{n} \sin \frac{n\pi r}{R} \exp \left( -\frac{n^2\pi^2 D t}{R^2} \right) n = 1, 2, 3, \cdots
\]

Also got:

\[
\frac{Q_t}{Q_\infty} = 6 \left( \frac{D t}{a^2} \right)^{\frac{1}{2}} \left\{ \frac{1}{\pi} + 2 \sum_{n=1}^{\infty} \text{erfc} \left( \frac{na}{\sqrt{D t}} \right) \right\} - \frac{3D t}{a^2}
\]

Ignored the error function in the (3), the equation can be reduced to

\[
\frac{Q_t}{Q_\infty} = 12 \frac{\sqrt{\frac{D t}{\pi}}}{d} = \frac{12D}{d^2} t
\]

Thus the numerical value \(D\) was very small, generally \(10^{-8} \sim 10^{-13} \text{ cm}^2/\text{s}\), ignored the second in the (4), set \(K = \frac{12}{d} \sqrt{\frac{D}{\pi}}\)

\[
\frac{Q_t}{Q_\infty} = 12 \frac{\sqrt{\frac{D t}{\pi}}}{d} = K\sqrt{t}
\]

In the equation (5), \(d\) was the radius of pea coal.
\[
\frac{c_{at} - c_1}{c_0 - c_1} = X_t \left( \frac{6}{\pi^2} \right) \sum_{n=1}^{\infty} \frac{1}{n^2} \exp \left( -\frac{n^2 \pi D_t t}{R^2} \right) \quad (6)
\]

Deal with the equation (2), then got:
\[
\frac{c_{at} - c_1}{c_0 - c_1} = X_t \left( \frac{6}{\pi^2} \right) \sum_{n=1}^{\infty} \frac{1}{n^2} \exp \left( -\frac{n^2 \pi D_t t}{R^2} \right) \quad (7)
\]

or \[
\frac{c_{at} - c_1}{c_0 - c_1} = X_t \left\{ 1 - \left( \frac{6}{R} \left( \frac{D_t}{\pi} \right) \right)^{1/2} \left[ 1 + 2\pi \sum_{n=1}^{\infty} \text{erf} c \frac{nR}{\sqrt{D_t t}} \right] + \frac{3D_t t}{R^2} \right\} \quad (8)
\]

In the equation (8), \( c_{at} \) was the average concentration on condition time \( t \) and radius \( R \); \( c_0 \) was the average concentration at the initial time, \( c_1 \) was the average concentration on the surface of peal coal; \( X_t \) was a time function, had some connection with concentration, time and coal adsorptivity; \( D_t \) was the diffusion coefficient corresponding with the \( t \) and \( c_{at} \).

For some special time \( \tau \), we can got the \( (9) \) when the diffusion time tend to \( \tau \), based on the continuity of diffusion curve.
\[
X_t \rightarrow X_\tau, D_t \rightarrow D_\tau \quad (9)
\]

Description on the diffusion curve based on the equation:

Diffusion time \( t \)
\[
\frac{c_{at} - c_{at}}{c_1 - c_0} = X_{\tau} \left( \frac{6}{R} \right) \left( \frac{D_\tau}{\pi} \right)^{1/2} \left( t^{1/2} - \tau^{1/2} \right) \quad (10)
\]

In the equation (10)
\[
X_{\tau} = \left( 1 - \frac{Q_\tau}{Q_\infty} \right) + X_{\tau} \left( \frac{6}{R} \right) \left( \frac{D_\tau}{\pi} \right)^{1/2} \tau^{1/2} \quad (11)
\]

\[
\frac{Q_\tau}{Q_\infty} = \frac{c_{at} - c_0}{c_1 - c_0} \quad (12)
\]

The last item of equation (12) was the intercept of line between \( c_{at} - c_{at}/c_1 - c_0 \) and \( t^{1/2}, Q_\tau/Q_\infty \) was the relative diffusing capacity at the time of \( \tau \).

On condition that diffusion time was long \( \ln \frac{c_1 - c_{at}}{c_1 - c_{at}} = \frac{-\pi^2}{R^2} D_\tau (t - \tau) \quad (13) \)

We can got the diffusion coefficient \( D_\tau \) at the featured time \( \tau \) and numerical value \( X_\tau \), according to the line relationship. Got the diffusion coefficient and \( X_\tau \), by using the same method.

4. Experimental method

Experimental coal sample was taking in 6# coal seam Yu tianbao coal mine Nantong mining bureau, there was a obvious seam of tectonic coal. Firstly, grinding the coal sample to the granularity...
0.2~0.25mm, doing the drying process, and then loading the tank. Pouring the 99.99% concentration gas into a vessel at last. Using the copper tube connecting the tanks, for assurance the pressure of tectonic coal and non-tectonic coal was same. Opening the exit end after the coal sample captured gas balance, then the gas absorption equilibrium system was broken, so the gas can diffuse. Measuring the gas diffusing capacity at the different desorption time.

5. Experimental result and analysis

Measuring the gas diffusing capacity at the different desorption time on condition of pressure 0.41Mpa. The fig 2 shows that diffusion coefficient of tectonic coal and non-tectonic coal render the “upend Z” variation, diffusion coefficient did not change very obviously at the initial deabsorption stage, diffusion coefficient changed tempestuously after some time. The diffusion coefficient did not changed very obviously at the terminate deabsorption stage.

Fig.3 Curve of desorption at adsorption equilibrium pressure 0.41Mpa

The pore system of tectonic coal was very developed, the condition of connectivity was very complicated. The gas adsorption of tectonic coal was more than the non-tectonic coal. Gas spread from interior to outside of the pore, under the concentration difference. The gas density of the coal died down gradually in the process. It is generally recognized that the deformation generated by adsorption had an effect on the porosity, then changed the encumber property of coal for the gas movement spread. So the diffusion coefficient was in a state of flux under absorbance change influence. The pore diameter of coal was proximal with gas molecular free path, pore diameter got smaller after adsorption equilibrium, so the diffusional resistance was large at the incipient stage. As the gas density getting lower, the pore diameter got larger gradually, but the change degree of pore diameter was still small compared with the gas molecular free path, the diffusion coefficient did not changed very obviously. The affect of gas diffusion was more and more obvious, to cause that the diffusion coefficient increased obviously. The pore
diameter changes smaller at the last time, the specific value of change degree and gas molecular free path was very small, essentially a constant. The complicated pore structure of tectonic coal made the diffusion coefficient vary with absorbance have a huge skin.

6. Conclusion

(1) On account of the Fick diffusion for gas, lead in indeterminate function for describing the diffusion process with time-varying diffusion coefficient, derived formula for solving the time-varying diffusion coefficient on the base of constancy of diffusion coefficient.

(2) The experimental result shows that the diffusion coefficient of tectonic coal was larger than the non-tectonic coal, and behaved the same law in the desorption process.

(3) The complicated pore structure of tectonic coal made the diffusion coefficient vary with absorbance have a huge skin.

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