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Research Article

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Mine Gas Occurrence and Flow Law

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Abstract: China is a country with coal as its main energy source. For a long time to come, coal will still occupy a major position in China's energy system. Coal mine methane, as a companion to coal, coexists with coal and is stored in coal and surrounding rock, and it is usually emitted in the form of gushing during coal mining. Under certain time and space conditions, accidents such as gas explosions and coal and gas outbursts may occur, causing major casualties and property losses. Therefore, how to prevent and control gas disasters has become an urgent problem for the coal mining industry. Studying the occurrence and flow law of gas is of great significance to prevent and control safety accidents caused by coal and gas disasters.

Keywords: gas prominence; the law of endowment; flow laws

1. Introduction

In recent years, with the increase of the depth of coal mining and the continuous increase of the intensity of mechanized mining, the amount of gas gushing out of the mine has been increasing, and the danger of coal and gas outburst has also increased. The gas problem has become a prominent problem that hinders the safe and efficient production of mines, and the survival characteristics of coal seam gas are the basis for mine gas gushing and prominent hazard prediction. Only by mastering the characteristics of the relevant factors of coal seam gas survival and summarizing the law of gas survival can we scientifically guide the prevention and control of gas disasters and achieve the purpose of predicting gas disasters in advance [1].

The survival state of coal seam gas today is the result of the complex geological and historical evolution of coal-containing formations and is controlled by the comprehensive geological effects of gas generation, migration, and preservation conditions. Studying the survival status of gas in coal seams is an important part of mine gas research. Years of practice have proved that only by using the theory of plate tectonics, the theory of regional geological evolution, and the theory of step-by-step control of gas accumulation structures can the mechanism and law of gas accumulation be revealed.

2. Coal Seam Gas Survival Theory

The amount of gas stored in the coal body not only affects the size of the coal seam gas content but also has a great impact on the flow of gas in the coal seam and the risk of disasters. Therefore, the study of the survival status of gas in coal seams is an important part of mine gas research.

Adsorption of coal to gas

Coal is a natural adsorbent with good adsorption properties. The adsorption of coal to gas is physical adsorption, that is, the force between the gas molecules and the coal molecules is the remaining surface free force (Van der Waals gravity). Under certain conditions, gas can also be desorbed from coal, and adsorption and desorbed are reversible.

The main influencing factors of adsorption content: ① the influence of gas pressure. ② for every 1℃ increases in temperature, the ability to absorb gas decreases by about 8%. ③ the increase in moisture reduces the adsorption capacity of coal.

The storage state of gas in coal

Coal body is a complex porous solid containing a large number of voids and cracks, so that there will be a lot of free space and voids formed on the surface. Therefore, the gas in coal generally exists in two forms: the free state and the adsorbed state. Coal forms an adsorption effect on gas through physical adsorption. Its adsorption effect is the result of mutual attraction between gas molecules and carbon molecules. The adsorption of gas is divided into absorption of gas and absorption of gas. Usually, absorption of gas refers to the gas entering the inside of the coal body, and absorption of gas refers to the gas attached to the surface of the coal body.

Vertical sub-zone of coal seam gas accumulation

When the coal seam has an outcrop or is directly covered by a fourth-series alluvial layer with good breathability, the gas in the coal seam will migrate in two different directions. One is that the gas generated during the coalification process is continuously transported from the deep part of the coal seam to the surface through the coal seam, the overburden and the fault. The other is that the ground air and the biochemical and chemical reactions in the topsoil produce the gas to penetrate and diffuse to the deep part of the coal seam, so that the gas present in the coal seam exhibits vertical zoning characteristics.

Coal seam gas can generally be divided into: gas weathering zone and methane zone along the vertical direction.

Generally, coal seams are divided into four zones from the top to the bottom of the outcrop: CO_2－N_2, N_2 and N_2—CH_4, CH_4 zones. The first three zones are collectively referred to as gas weathering zones, and those located below the lower boundary of the gas weathering zone belong to the methane zone. Not only are the gas components different in each zone, but the gas content is also different. The ribbon distribution of coal seam gas is the basis for the prediction of coal seam gas content and roadway gas gushing volume, and it is also the basis for a good job in gas management.

3. The Main Factors Affecting the Survival and Content of Coal Seam Gas

The current research results believe that the main factors affecting the gas content of coal seams are: the depth of burial of coal seams, the breathability of coal seams and surrounding rocks, the degree of coal deterioration and coalification, and the regional geological structure.

The burial depth of the coal seam

In the methane zone under the coal seam gas weathering zone, there is a positive correlation between the gas pressure, gas content and mine gas gushing volume of the coal seam and the buried depth of the coal seam, that is, it increases with the increase of the buried depth [2].

The increase in the buried depth of the coal seam will not only reduce the breathability of the coal seam and the surrounding rock due to the increase in ground stress but also increase the distance of gas migration to the surface. The changes in both are in a direction that is conducive to the storage of gas, but not conducive to the release of gas. Development. Studies have shown that when the depth is not large, the coal seam gas content basically increases linearly with the increase of the burial depth; when the burial depth reaches a certain value, the coal seam gas content will tend to be constant.

Breathability of coal seams and surrounding rocks

The lithology combination of coal strata and their breathability have a significant impact on the gas content of coal seams. The surrounding rock conditions directly affect the size of the coal seam gas storage stock and determine the lithology of the top and bottom slab of the coal seam and the strength of its breathability. The looser the top plate rock formation, the larger the particles and porosity, the more conducive it is to gas migration and escape. The less breathable the coal seam and its surrounding rock, the easier the gas is to store, and the higher the gas content of the coal seam.

The degree of coal deterioration and coalification

The increase in the degree of coal deterioration has increased the amount of coal seam gas generated, and the adsorption capacity of coal to gas has been enhanced. Therefore, the high degree of coal deterioration has created favorable conditions for the generation and enrichment of coal seam gas. Under normal circumstances, in the gas belt, if other factors are the same and the degree of coalification is different, the gas content is not only different, but also the amount of gas content increases with the increase of depth is also different [3-4].

Coal is a natural adsorbent, and the higher the degree of coalification of the coal seam, the stronger its ability to store gas. In the methane zone, under the same conditions as other factors, the gas content of coal with different degrees of coalification is not only different, but also the gas content increases with the increase of depth; for high-metamorphic anthracite coal (volatile content less than 120mL/g), the gas content does not obey the above law [5-6].This is because the structure of this kind of coal has undergone qualitative changes, and its gas content is very low, and it has nothing to do with the depth of burial. For example, in the Wenhua Village mine in the coalfield mining area of Hunan, the coal has deteriorated close to graphite (the volatile content is only 3.14%), and the coal seam gas content is very low.

4. Geological Structure

The geological structure can not only change the survival form and coal body structure of the coal seam but also change the permeability of the surrounding rock of the coal seam. Specifically, fracture movement occurs along with tectonic movement, and the type of fracture has an important impact on gas preservation [7].

The current state of coal seam gas accumulation and the geological conditions affecting coal and gas outburst are the result of the evolution of coal-bearing formations through successive tectonic movements. During each tectonic movement period, plate activity, collision extrusion, rotational shear, stretching and tensioning will affect the mining area and the area where the mine is located. Tectonic uplift, trapping, wrinkling, fracture and other activities will affect the deep formation and metamorphosis of the coal seam or the gas generation conditions under the thermal metamorphosis of magma, the gas preservation conditions under the conditions of uplift, weathering, and erosion, and the development characteristics of tectonic coal formed by the destruction of the coal seam structure under the action of tectonic extrusion and shear [8].

Gas accumulation is mainly affected by the depth of coal seam burial and tectonic zoning. The gradients of the gas content of different gas geological units with the depth of coal seam burial and the depth of the gas weathering zone are different, resulting in different degrees of gas enrichment in the units, and the distribution of gas is controlled by the geological structure [9].Within the current level of exploration and mining, due to the control effect of small faults and pleated structures on gas dispersal, the gas content in the control area is generally higher than that of coal seams with the same buried depth.

Coal seam gas migration theory

A coal seam is a pore-cracking medium filled with tiny pores and cracks, while a coal body is a collection of pores and cracks. When the mining space enters the coal seam, the gas is transported from the inside of the coal seam to the roadway space in a very complex manner. The influencing factors are not only the original conditions of the natural coal seam, but also mining work, underground stress fields and rock formation movement. Due to the uneven pore size and fracture size of the coal seam, there is still diffusion in the micropores that is divided into slipway, turbulence may occur in the large fracture zone, and laminar flow movement in the micro-fracture. Based on the determination of the gas flow law in the field and laboratory, it can be considered that the flow law mainly follows Darcy's law, that is, laminar flow movement.

Classification of coal seam gas flow status

The researchers divided the flow state of gas in the coal seam into two flow types: stable flow and unsteady flow according to time factors. Among them, the stable flow field does not change with time, while the unsteady flow field will change with time.

The flow state of gas in coal seams is classified according to the spatial flow direction, which can be divided into three types: one-way flow, spherical flow and radial flow.

① One-way flow-After analyzing the flow state of gas in the coal seam in three-dimensional space, the researchers concluded that the flow rate in two directions is zero, and the flow state where the flow rate exists in only one direction is set as one-way flow.

② pheric flow-After the researchers analyzed the flow state of gas in the three-dimensional space of the coal seam, they called the state of motion with partial velocities in all three directions spherical flow.

③ Radial flow-After the researchers analyzed the flow state of gas in the three-dimensional space of the coal seam, they called the flow state with partial velocity in two directions and zero partial velocity in the third direction radial flow.

5. Gas Flow Theory

The size of the pores and cracks of the coal seam is uneven, so turbulence may occur in the large fracture zone, while in the micro-fracture it is laminar flow movement, and there is also diffuse molecular slipflow in the micropores. The diffusion movement of gas in coal seams is to study the diffusion process of material molecules gradually reaching equilibrium from a high-concentration system to a low-concentration system. This diffusion process conforms to the law of diffusion, also known as Fick's Law.

Coal seam gas flow theory is a theory that specializes in the distribution of gas pressure in coal seams and the law of gas flow changes. Depending on the scope of application and conditions of use, there are the following theories of coal seam gas flow：

Linear gas flow theory of linear gas seepage believes that the migration of gas in coal seams basically conforms to the law of linear penetration-Darcy's Law. In 1856, the French hydraulicist Darcy summed up the famous Darcy's Law through experiments. This law is an experimental law that reflects the law of water seepage in the pores of rock and soil [10].

$$v = -\frac{K}{\mu} \cdot \frac{dp}{dx}$$

v —Flow rate, m/s

μ —Gas dynamic viscosity coefficient, Pas

K —Permeability of coal seam, m^2

dx—a very small length consistent with the hydrodynamic direction, m

dp—Differential pressure within the length of dx, Pa

Linear penetration (Darcy's Law). When the flow of gas in the coal seam is linear penetration, that is, when the flow rate of gas is proportional to the gradient of gas pressure in the coal seam, it is linear. In line with Darcy's law. A large number of gas penetration tests conducted by China University of Mining and Technology on cylindrical artificial coal samples pressed with pulverized coal in the laboratory showed that when gas flows in coal samples with large pore diameters, it completely obeys Darcy's law.

This law shows that the speed of water passing through a porous medium is proportional to the size of the hydraulic gradient and the permeability of the medium. This theory also applies to the flow of gas in each layer. Gas is like water, and the pores of coal seams are like porous media

Nonlinear gas flow theory, Darcy's law was used to describe the experiment of gushing gas from a uniform solid (coal sample), and the result led to a conclusion that was inconsistent with actual observations. Judging from the determination of the gas permeability of coal samples by varying pressure difference, Darcy's law is not in line with the gas flow law.

Reynolds number (Re) is a dimensionless number that can be used to characterize fluid flow. The Reynolds number can be used to distinguish whether the flow of a fluid is laminar or turbulent, and it can also be used to determine the resistance of an object to the flow of a fluid. When the Reynolds number is greater than a certain value, the flow of gas in the coal seam is in a nonlinear seepage, which does not obey Darcy's law.

The low Reynolds number region, Re<1~10, has the dominant viscous force and belongs to the linear laminar flow region, which conforms to Darcy's law.

In the Reynolds number region, the upper limit of Re is 100, which is a nonlinear laminar flow region and obeys the law of nonlinear permeability.

The high Reynolds number region, Re>100, is turbulent flow, inertial force dominates, and the flow resistance is proportional to the square of the flow rate.

Gas diffusion theory, coal is a typical porous medium. According to the study of the diffusion mechanism of gas in the porous medium, the Northen number Kn, which represents the relative size of the pore diameter and the average free path of molecular motion, can be used.：

$$K_n = \frac{d}{\lambda}$$

d—Average pore diameter, m

λ—The average free path of the gas molecule, m

Diffusion is divided into general Fick type diffusion, Northen type diffusion and transition type diffusion.

Fick diffusion: When Kn≥10, the pore diameter is much larger than the average free path of gas gas molecules. At this time, the collision of gas gas molecules mainly occurs between free gas gas molecules, and the chance of collision between molecules and the capillary wall is relatively small. This kind of diffusion still follows Fick's theorem and is called Fick diffusion.
Northen diffusion: When Kn≤0.1, the average free path of the molecule is greater than the pore diameter. At this time, the collision between the gas molecules and the pore wall dominates, while the collision between the molecules takes a secondary position. This kind of diffusion no longer follows Fick diffusion, but Northen diffusion.
Transitional diffusion: When 0.1<Kn<10, the pore diameter is similar to the average free path of gas molecules. The collision between molecules is as important as the collision between molecules and surfaces. Therefore, the diffusion at this time is a transition diffusion between Fick diffusion and Northen diffusion.

6. Conclusion

The survival of coal seam gas is the result of long-term geological tectonic changes, interference by man-made extraction, and the control of comprehensive factors such as gas generation and migration in the coal seam. At present, coal and gas outburst accidents in coal mines in our country occur frequently, and the number of deaths seriously affects the safe production of coal mines. The law of gas flow is of great significance for the prevention of coal and gas outburst, the improvement of coal seam gas extraction rate and the development and utilization of coal bed methane. Therefore, the theory of coal seam gas flow needs more in-depth research, and how to prevent and control gas disasters has become an urgent problem in the coal mine industry.

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