Numerical simulation research on gas migration with Y type ventilation

Yanan Gou, Xuezheng Han*
College of Mechanical and Electrical Engineering, Zaozhuang University, Zaozhuang 277160, China

*Corresponding author e-mail: zzxyh5909@126.com

Abstract. The ventilation way of the working face has a great influence to goaf flow field and gas migration, the existing U-shaped ventilation face wind serious overrun, Y type ventilation mode is put forward, and the mathematic control equation of the gas moving rule is established. Put the Gaozhuang coal mine west five mining area as the model, set up calculation model. And the gas concentration is simulated, the simulation results show that the Y type ventilation ways can intercept goaf gas into the corner on the working plane and return air lane, effectively avoid the work of top corner gas accumulation.

1. Introduction
Gas is the first killer of coal mine safety production in China, as the increase of the coal mining production and mining depth in our country, 80% of the gas must be discharged through the underground ventilation system. Typical U-shaped ventilation way, due to the effect of wind field, easily causes to work top corner gas overrun, thus put forward the Y type ventilation way, according to characteristics of goaf gas flow, the mined-out area is regarded as continuous flow space, based on darcy law and mass conservation law, using fluent numerical simulation and application software to study gas concentration distribution under Y type ventilation way.

2. The mathematical model of the goaf gas migration pattern
2.1. The basic assumptions of the mathematical model
The basic law of the goaf gas flow is consistent with the Darsy law

\[ \vec{v} = -\frac{k}{\mu} \cdot \nabla p \]  

Among them: \( \vec{v} \) is the average flow velocity of flow over the cross section (\( cm/s \) ); \( k \) is the permeability of the coal seam; \( \mu \) is the absolute viscosity coefficient (\( Pas \) ); \( \nabla p \) is the gas pressure gradient (\( Pa/cm \) ). Considering the complexity of the goaf flow field, make the following assumptions about the flow field:

(1) The goaf gas initial pressure is the same, or it varies linearly with distance.
(2) The goaf permeability coefficient of gas is a function of space or time.
(3) The temperature does not change when the goaf gas flows.

2.2. Gas flow control equation

Mass conservation equation

In the flow field, take a closed space, which is called the control body. The difference between the quality of inflow and outflow per unit time is equal to the incremental fluid mass of internal control body in same time intervals. Then

$$\frac{\partial (\rho u)}{\partial x} + \frac{\partial (\rho v)}{\partial y} + \frac{\partial (\rho w)}{\partial z} = 0$$  \hspace{1cm} (2)$$

Among them: $\rho$ is the flow field density; $k$ is the permeability of the coal seam; $u, v, w$ are the velocity components in $x, y, z$ direction.

Momentum conservation equation

In a certain fluid system, the change rate of its momentum is equal to the sum of the forces acting on it, the simplified model equation.

$$\frac{\partial (\rho u u^2)}{\partial x} + \frac{\partial (\rho v v^2)}{\partial y} = \frac{\partial (\rho u u)}{\partial x} + \frac{\partial (\rho u v)}{\partial y} - n \frac{\partial p}{\partial x} + \frac{\mu}{\rho}$$  \hspace{1cm} (3)$$

The gas component transport equation

$$\frac{\partial (\rho C_s u)}{\partial x} + \frac{\partial (\rho C_s v)}{\partial y} = \frac{\partial}{\partial x} \left[ D_s \frac{\partial (\rho C_s )}{\partial x} \right] + \frac{\partial}{\partial y} \left[ D_s \frac{\partial (\rho C_s )}{\partial y} \right] + S_s$$  \hspace{1cm} (4)$$

The standard $k - e$ equation

$$\frac{\partial (\rho k)}{\partial x} + \frac{\partial (\rho v k)}{\partial y} = \frac{\partial}{\partial x} \left( \rho u \frac{\partial k}{\partial x} \right) + \frac{\partial}{\partial y} \left( \rho v \frac{\partial k}{\partial y} \right) + G_k - \rho e$$  \hspace{1cm} (5)$$

Among them: $u, v$ are components of the velocity vector in the $x$ and $y$ direction, $m / s$; $\rho$ is the air flow density in goaf, $m^3 / s$; $p$ is the gas pressure in goaf, $Pa$; $n$ is the porosity of porous medium; $e$ is the permeability of porous media; $\mu_{ef} = \mu + \mu_s$ is the dynamic viscosity coefficient; $u$ is the viscosity turbulent coefficient; $S_s$ is the component production rate; $D_s$ is the diffusion coefficient of each component; $k$ is turbulent kinetic energy, $m^2 / s^2$; $e$ is the dissipation rate of turbulent kinetic energy, $m^2 / s^3$; $G_k$ is generation item of the turbulent kinetic energy which caused by the average velocity gradient; $C_{1e} C_{2e} C_u \sigma_k \sigma_{2e}$ is fixed value; the value of the points are 1.44, 1.92, 0.09, 1.00, 1.30.

Diffusion motion equation
The coal rock is a porous medium composed of fissures, and the flow of gas is mainly diffusion motion.

\[ \frac{\partial}{\partial t} (\rho Y) + \nabla \cdot (\rho \mu Y) = \nabla \cdot (\nabla Y + m^n) \]  

Among them: \( Y \) is the leak gas mass fraction of the \( i \) group; \( D \) is the leak gas diffusion coefficient of the \( i \) group; \( m^n \) is the leak gas unit volume production rate of the \( i \) group.

3. The numerical simulation model

3.1. Working face schematic diagram
Put Zaozhuang Mining group Gaozhuang coal mine west five mining area 1101 face as the simulation object, the mining area includes three down mountains, the three respectively are: track down the mountain, tape machine down the mountain, return air down the mountain. Among them, the length of the track down mountain is 750m, the length of the section is 10.8, the average slope is 16, and they are arranged along the three coal seams. X axis means the working face points to the depths of the goaf, the Y axis means intake entry points to outtake entry along the working face, Z axis points to the direction of roof. Taking X axis length as 240 m direction along the goaf, taking Y axis length as 140 m along the working face, the size of the roadway is 20 x8m. Y type ventilation system model is shown as figure 1.

![Figure 1. Y ventilation system working face schematic diagram.](image)

3.2. The boundary conditions and parameter settings
The wind lane entrance is set as the speed entrance, the inlet average wind speed is 3 m/s, the inlet oxygen volume fraction is 21%. The outlet of backwind and the end lane are the pressure outlet, and the inside of the mining area is porous medium, and the flow of porous media is pressure.

4. The analysis of numerical simulation results

4.1. The gas concentration distribution of the working face
Taking \( z = 2m \) the gas concentration profile, each point changing curve of gas concentration is obtained from \( y = 2m \ x = 5m \), and the concentration distribution law is shown in figure 2.
Figure 2. The gas concentration distribution of the type Y ventilation work face.

As shown in figure 2, the gas concentration in the backwind lane is lower when the type Y ventilation is adopted, and the gas concentration increases as deep into the goaf. It shows that adopting the type Y ventilation way can effectively intercept the gas flow to the working face and the backwind lane.

4.2. The air leakage diagram along the interface of the working face and the mined-out area f in the Y-type ventilation mode

The air leakage diagram along the interface of the working face and the mined-out area in the Y-type ventilation mode is shown in figure 3.

Figure 3. The distribution of air leakage velocity along the length of the working face.

From figure 3, the wind speed has increased sharply in the mined-out area, because the turbulent wind flow is almost straight into the area in the lower corner. The wind speed first rises and then down, because the velocity is larger and the radius of curvature is smaller over turning point. Because of the inertial action the vortex appears in the inner layer of the working face, the existence of vortex zone makes the wind speed of air leakage still very high; After this, the pressure difference gradually decrease along the working face and vacant lane, so the air leakage decreases gradually.

4.3. The gas distribution of the goaf

Taking $z = 2m$, the distribution of the gas concentration section is shown in figure 4.
Figure 4. The gas concentration distribution of the y-type ventilation

From figure 4, in plane, the distance from the working face is about 20m, the gas concentration is 6%, with the deep to the goaf, the gas concentration achieves to 40%, from wind lane entrance to outlet of backwind, gas concentration increased gradually, from the diagram, few gas of the goaf surge upward the top corner, avoid the top corner of the working face gas accumulation.

5. Conclusion

The pressure difference between the working face and the goaf of the Y type ventilation system is lower than that of the U type, which reduces the gas concentration limit of the top corner, and inhibits the leakage of air in the working area. The paper establishes calculation model of the goaf, and through numerical simulation, get around 20 m from working face, the gas concentration is 6%, with the deep to the goaf, the gas concentration achieves 40%, it shows that using Y type ventilation can effectively intercept gas into working face and backwind lane.

References

[1]   Hu Qianting, Liang Yunpei, Liu Jianzhong, J. CFD simulation of goaf gas flow patterns. Journal of China Coal Society. 7, 32(2007).
[2]   Yang Ming, Gao Jianliang, Feng Pujin, J. Numerical simulation of the gas distribution in the gobs of U-type and Y-type ventilation mining working faces. Journal of Safety and Environment. 5, 12(2012).
[3]   Ding Houcheng, J. Numerical simulation and experiment research on gas migration in goaf under U + L type ventilation. Journal of Natural Disasters. 6, 21(2012).
[4]   Miao Leigang, J. Study on methane emission and movement in mining space with quasi E-type ventilation system. Anhui University of Science and Technology. 2, 23(2009).
[5]   Chen Chonhchong, Zhang Xuebo, Yan Chao, J. Numerical simulation for the impact of gas emission location on the gas distribution in the goaf. Journal of Safety and Environment. 5, 15(2015).
[6]   Yang Mingdong, Li Yingming, Zhang Han, J. Numerical simulation of gas concentration field in the partial W-type ventilation system. Journal of Safety and Environment. 6, 13(2013).
[7]   Yang Ming, Feng Pujin, Gao Jianliang, J. Numerical Simulation on Air Distribution in Mining Goaf with One Intake and Two Air Returning Y Type Ventilation. Coal Science and Technology. 9, 40(2012).
[8]   Zhang Jianye, Chen Jushi, Sun Xin, J. Gas drainage technology numerical simulation of coal mine. Coal science and technology magazine. 4(2015).