

Influence Factors of Two Holes Drainage for Cleat Coal Gas

Xiaotong Li and Ming Gao ^{a, *}

College of Mining and Safety Engineering, School of Shandong University of Science and Technology, Qingdao, Shandong, China

^{*, a} Corresponding author e-mail: lxgaom@163.com

Abstract. Coal occupies a very important position in the national energy strategy. Gas drainage from seam is the most effective technical measure to prevent gas accident. Mathematical model and numerical analysis method are new methods for the study of gas flow. The LB method can be used for solving the problem of gas seepage, which is a simplified computational model based on the microscopic scale. This paper based on LB method, simulated the gas pressure, flow track and speed vector diagram in terms of the topic for cleat coal gas drainage through symmetrical holes. It analyzed the position of the holes influence the gas leakage; summarized and concluded the drainage performance under the controllable subjective factors during the cleat coal gas drainage process.

1. Introduction

Gas Disaster is one of the most serious hazards in coal mines. Gas could occur dynamic phenomenon of coal and gas outburst in migration process and cause the gas disaster. It is important to study the law of coal seam gas seepage in coal seam gas drainage boreholes and be optimal layout of gas drainage boreholes, which is of great significance in effective gas drainage and ensuring the implementation effect of regional outburst prevention measures.

With the continuous deepening of the coal gas seepage mechanics and the modernization of research methods, the application of computer to study the pressure distribution and the flowing change in the gas flow field is the mainstream of the gas seepage mechanics research means to realize the modernization [1]. In the early 80s, Wei Xiaolin[2] and Li Yingjun[3] took the lead in studying the results of gas flow by computer. The numerical simulation of gas seepage is realized by using the Finite Element Method (FEM) and the Boundary Element Method (BEM) in the literature in foreign research [4,5].

The LB method (Lattice Boltzmann Method) is a simplified computational model based on the microscopic scale at the end of the 1980s, it is not a direct discretization of the macroscopic continuous equation but studying on the microscopic model and some mesoscopic kinetic equations. Under the course graining approximation, these mesoscopic kinetic equations can be reduced to the macroscopic fluid mechanics equations. This method can establish the model of porous media seepage theory and be numerically simulated. It has made great progress in parallel computing, boundary condition processing, analysis of accuracy and stability, comparison with typical numerical examples and traditional numerical methods and specific applications. The LB method provides a new way of thinking and method which simulate migration law of gas flow field.



2. Brief Introduction to LB Method

The LB method is developed and improved by the Lattice Gas Automata (LGA) theory. In 1976, the HPP model was proposed by Hardy et al. and the simple flow phenomenon was simulated. In 1986, Frisch et al got the FHP model [6], and Humieres et al. put forward the HLF model [7] for three dimensional problems. Once we get the symmetry grid, the only remaining problem is to determine the rule of particle motion(evolution). There are two ways to deal with this problem, namely the LGA method and the LB method.

The main idea and calculation procedure of LB method is extremely similar to LGA. The main difference is that LB method uses the mesoscopic real number variables--- particle distribution function $f_\alpha(x,t)$, instead of Boole type variables $n_\alpha(x,t)$ of LGA. Here $f_\alpha(x,t)$ represents the probability which there is one moving particle along the e_α direction at t time in x node. That is:

$$f_\alpha(x,t) = \langle n_\alpha(x,t) \rangle$$

In this way, the LB method no longer needs to calculate the microscopic amount, but directly calculates the microscopic quantity according to the lattice boltzmann equation.

$$f_i(\bar{x} + c\bar{e}_i\Delta t, t + \Delta t) - f_i(\bar{x}, t) = \Omega_i(f(\bar{x}, t)), (i = 0, 1 \dots, b)$$

Then use

$$\left\{ \begin{array}{l} \rho(x,t) = \sum_{i=0}^n f_i(\bar{x}, t) \\ \rho(x,t)u(x,t) = \sum_{i=0}^n \bar{e}_i f_i(\bar{x}, t) \\ \rho(x,t)\varepsilon(x,t) = \frac{1}{2} \sum_{i=0}^n (\bar{e}_i - \bar{u})^2 f_i(\bar{x}, t) \\ p = c_s^2 \rho \end{array} \right. \quad (1)$$

to calculate macroscopic quantity. That is to say, the LB method uses the lattice boltzmann equation to simulate the macroscopic phenomena.

The LB method represents the collision term as a function of the particle distribution function. Higuera, Succi and Jimenez (1989) [8-9] to represent the collision term as a matrix by the linearization method. Elements in the matrix only depend on the angle between the colliding particles. These models effectively eliminate statistical noise, but other problems still exist because they still belong to the Fermi-Dirac distribution. In 1991, Chen S Y and Chen H D [10] abandoned F-D[11] distribution and used Maxwell-Boltzmann distribution, so that symmetry, invariance and pressure independent of velocity and other issues were met. In 1992, a very simple model D2Q9 [12] appeared, it makes collision matrix simplification. Lattice BGK(LBGK) model, which is proposed to use the relaxation time to make the distribution function approximate to the local equilibrium distribution function by Bhatnager [13], Gross[14] and Krook[15], is widely used at present. The corresponding LBGK equation is

$$f_\alpha(\bar{x} + e_\alpha, t + \Delta t) - f_\alpha(\bar{x}, t) = -\frac{1}{\tau} (f_\alpha(\bar{x}, t) - f_\alpha^{eq}(\bar{x}, t)), (\alpha = 0, 1 \dots, b) \quad (2)$$

The LB method is used to simulate the flow field, which is actually attributed to the iterative solution of the equation (2.2). After the particle distribution function of each grid point is obtained at every moment, the macromechanical quantity can be calculated by (2.1).

3. Building Gas Flow Field Model

An 80 x 80 grid is used to replace the flow area of the fractured coal body, and the gas is discharged by a double hole on the right side of the flow area. The air permeability of the coal seam roof and floor is much lower than that of the coal seam. Therefore, it is assumed that the surrounding rock of the coal seam roof and floor is an impermeable layer and does not contain gas. Gas flow field model as shown below:

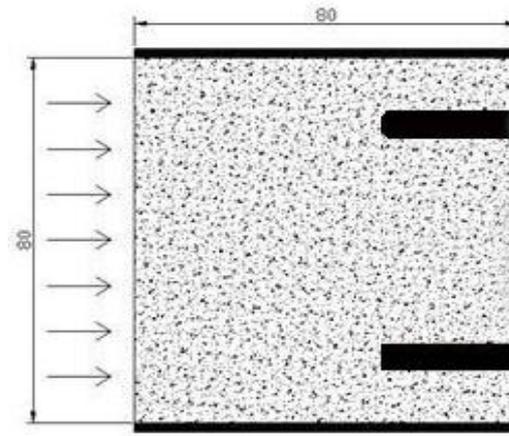


Figure 1. Gas flow field model

There are various factors that affect gas drainage, the effect of gas drainage is different in different condition. The main factors affecting gas drainage include natural factors, equipment factors and technical factors. The main factors affecting gas drainage are natural factors, equipment factors and technical factors. This paper mainly discusses the influence of some technical factors on gas drainage without considering natural factors and equipment. Due to the fact that natural factors are not controllable, there is still no real efficient drilling rig in China at present. The efficiency of drilling rig widely used in coal mines is generally not up to the design requirements, which affects the quality of drilling holes and then affects the effect of gas drainage. Drilling parameters which influence on the effect of gas drainage are bore diameter, borehole angle, drilling length, the space between bores, drilling number, the negative pressure of suction, material and technology of hole sealing. Therefore, the parameter setting must be reasonable. In this paper, we mainly discuss the influence of hole depth on the effect of gas drainage.

4. Comparison and Analysis of the Model's Pressure Chart, Streamline Diagram and Velocity Vector Chart

When the hole depth is 40, the pressure on the left side is 1.01, the free flow pressure on the right side is 1, and the drainage pressure at the opening is 0.96. With different opening positions, the pressure change of the model is shown below:

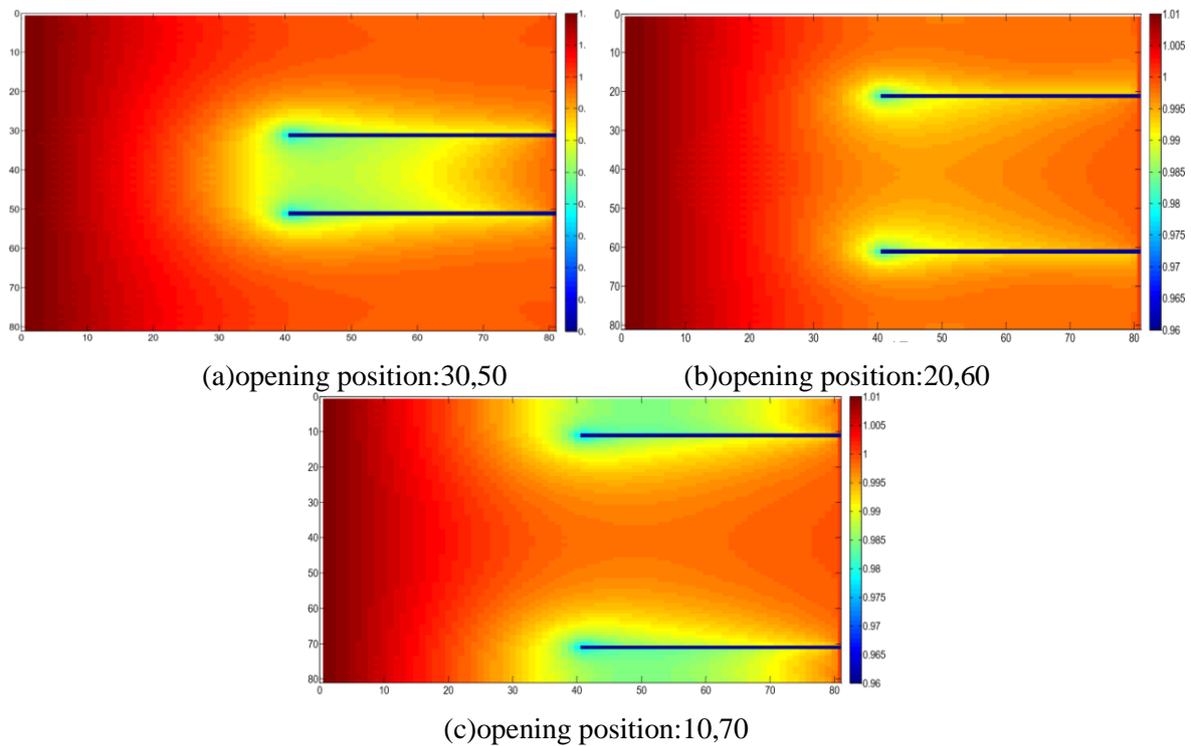
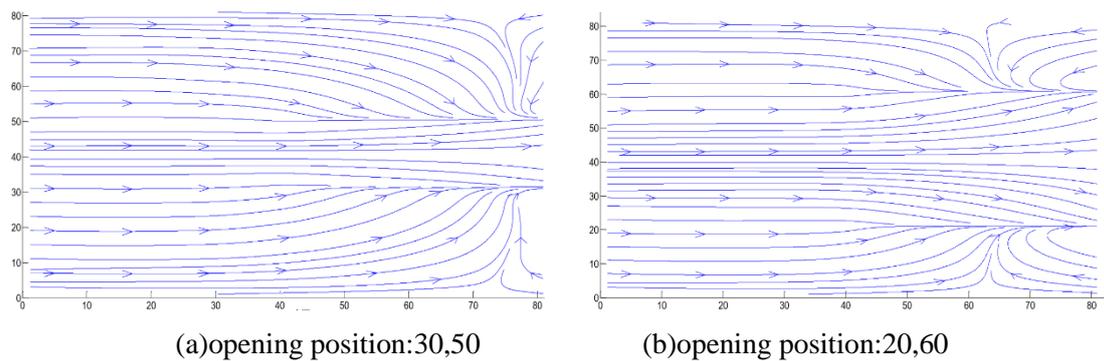


Figure 2. Pressure charts of different opening positions

It can be obtained by comparing the above pressure charts that the pressure is relatively large far away from the hole and the pressure is small at the hole. As time goes on, the change of gas pressure tends to be linear. The smaller the distance between two holes is, the greater the pressure change of gas in the whole flow field is, the vice versa. The farther the distance between two holes, the greater the pressure at the center of the right boundary, the smaller the pressure gradient at the center of outlet boundary is.

The left side pressure is 1.01, the right side free seepage pressure is 1, and the hole depth is unchanged, which is 40. The velocity streamline diagrams of the different opening positions are as follows:



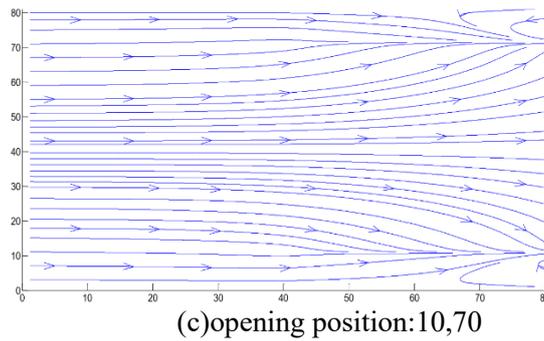
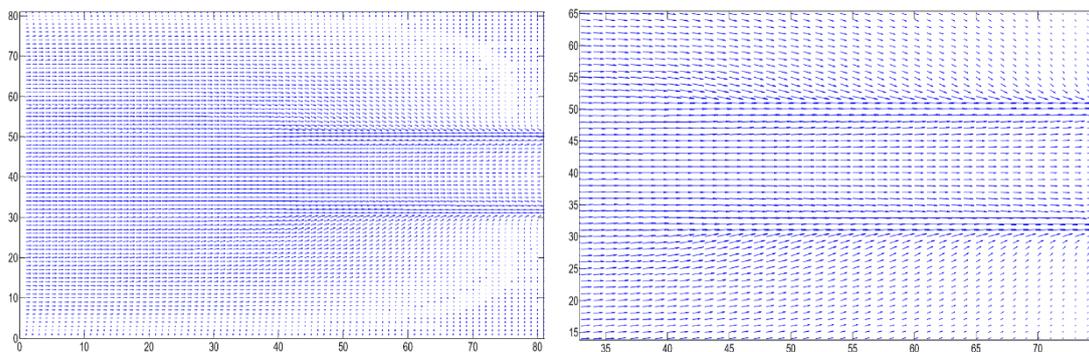


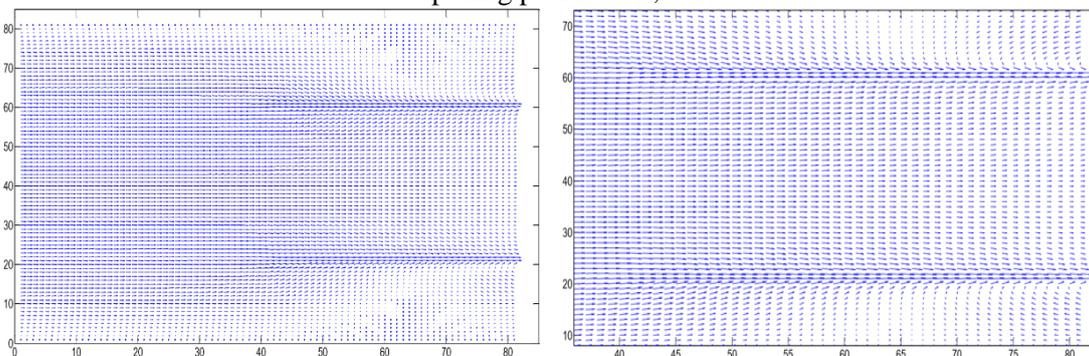
Figure 3. Streamline diagram of different opening positions

From the above charts in different position opening conditions, comparison of gas trace in the flow field of two holes, away from the orifice gas flow is relatively sparse even in the orifice gas traces were dense, relatively large gas flow; double distance is smaller, more dense gas flow trace. The larger the distance between the two holes, the thinner the trace of gas flow in the middle of the flow field, that is, the gas exudation in the center of the right boundary decreases with the increase of the distance between the two holes. When the depth of opening reaches a certain depth, there will be eddy current in the upper and lower sides of the right boundary. When the opening depth is the same, the larger the distance between the two holes is, the more obvious the vortex phenomenon is in the upper and lower sides of the right boundary.

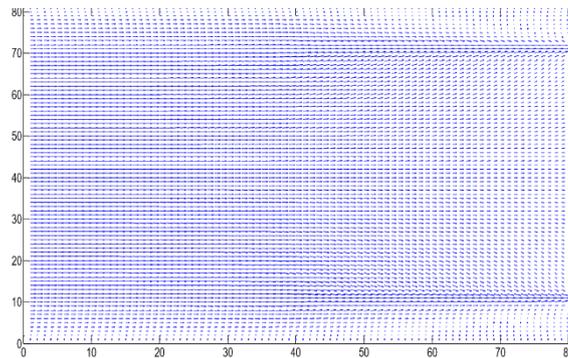
The left side pressure is 1.01, the right side free seepage pressure is 1, and the hole depth is unchanged, which is 40. The gas velocity vector of the different opening positions are as follows:



opening position:30,50



opening position:20,60



opening position:10,70

Figure 4 .Velocity vector chart of different hole depth

From the above pressure, streamline and vector three photos in the different position of opening conditions, comparing the gas velocity vector in the flow field of two holes, the velocity vector of gas flow is basically the same in the left boundary, the velocity vector of gas is larger at the hole, and the flow of gas is radial flow around the hole. The smaller the distance between two holes is, the larger the velocity vector of gas flow. With the increase of dual hole distance, the vector change of gas velocity in the middle of the flow field basically approaches to zero, and it increases gradually in the upper and lower boundary.

5. Conclusion

In this paper, the LB method is used to simulate the gas flow during the gas drainage in the fractured coal body according to the model of the gas seepage. The different hole depth gas flow is simulated in the condition of double hole symmetry. The simulation results mentioned above can be summarized as follows:

With the same opening depth, the smaller the double hole distance is, the more obvious the gas flow pressure is, the more dense the flow trace is, the better the drainage effect is.

In the case of the above analysis, the opening position of the hole is 30 and 50, and the best pumping effect is achieved.

References

- [1] Peide Sun, Xuefu Xian. Research Progress on seepage mechanics of coal seam gas[J]. Journal of Jiaozuo Institute of Technology, 161-167, 2001.
- [2] Xiaolin Wei. Study on the experimental and numerical methods of gas flow in coal seam[J]. Coal technology in Guangdong Province,(2): 35-41,1981.
- [3] Yingjun Li. Study on the distribution of gas pressure in coal seam[J]. Coal mine safety,(5):32-36, 1980.
- [4] C.Yu, X.Xian. Analysis of gas seepage flow in coal beds with finite element method [A]. Symposium of 7th international conference of FEM in flow problems, Huntsvill, USA, 1989.
- [5] C.Yu, X.Xian. A boundary element method for inhomogeneous medium problems [A]. Proceedings: 2nd world congs. On computational mechanics, Stuttgart, FRG. 1990.
- [6] Frisch U, Hasslacher B, Pomeau Y. Lattice-gas automata for the Navier-Stokes equations[J]. Phys. Rev. Lett. 56: 1505-1508, 1986.
- [7] D'Humieres D, Lallemand P, Frisch U. Lattice gas model for 3D hydrodynamics[J]. Europhys. Lett. 2: 291-297, 1986.
- [8] Higuera F J, Succi S. Simulating the flow around a circular cylinder with a lattice Boltzmann equation[J]. Europhys. Lett. 8: 517-521, 1989.
- [9] Higuera F J, Jemenez J. Boltzmann approach to lattice gas simulations[J]. Europhys. Lett. 9: 663-

- 668, 1989.
- [10] Chen S, Chen H, Martinez D, et al. Lattice Boltzmann model for simulation of magneto hydro dynamics[J]. *Phys. Rev. Lett.* 67:3776-3779, 1991.
 - [11] Chen H, Chen S, Matthaeus W H. Recovery of the Navier-Stokes equations using a lattice-gas Boltzmann method[J]. *Phys. Rev. A* 45:5339-5342, 1992.
 - [12] Qian Y H, d'Humières D, Lallemand P. Lattice BGK models for Navier-Stokes equation[J]. *Europhys. Lett.* 17:479-484, 1992.
 - [13] Qian Y H, Orszag S A. Lattice BGK models for the Navier-Stokes equation: nonlinear deviation in compressible regimes[J]. *Europhys. Lett.* 21: 255-259, 1993.
 - [14] Rakotomalata N, Salin D, Watzky P. Simulations of viscous flows of complex fluids with a Bhatnagar, Gross and Krook lattice gas[J]. *Phys. Fluids* 8:3200-3202, 1996.
 - [15] Bhatnagar P L, Gross E P, Krook M. A model for collision processes in gases. I. Small amplitude processes in charged and neutral one-component system[J]. *Phys. Rev.* 94:511-525, 1954.