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Research on the position of gas single hole drainage borehole based on Lattice Boltzmann Method

Ruyue Zhao [*], Shaotong Fu

Shandong University of Science and Technology, Qingdao, China

*Corresponding author e-mail: 862855374@qq.com

Abstract. Gas has been a serious threat to the safety of coal mine production, especially in high gas and gas outburst mines. As the most effective way to avoid safety accidents caused by gas outburst, the location of boreholes in the process of gas drainage is particularly important to determine the effect of gas drainage. Based on the perfect LBM gas seepage model and using MATLAB to process the simulation data, this paper completes the pressure, gas flow track and gas flow velocity vector diagram of the gas flow area under various simulation conditions. Under the condition that the depth of gas drainage hole is invariable, the influence of different hole position on gas seepage field is analyzed in turn, and the influence of different hole position on gas drainage effect is summarized. The conclusion is very instructive to the selection of borehole location for gas drainage in fractured coal.

1. Introduction

At present, gas-bearing mines account for the vast majority of coal mines in China. The proportion of high gas mines and coal and gas outburst mines has reached 47%. The mine gas problem seriously threatens the production safety of coal mine enterprises and the safety of personnel. With the increasing depth of coal mining today, the potential hazards caused by mine gas have increased dramatically. Due to the low permeability of coal seams in China, the underground well drilling and gas extraction has become a major technical measure to prevent gas outburst in underground wells due to its simple and wide application process. How to rationally optimize the drainage position of gas wells on the basis of fully understanding the gas seepage law is of great significance for the efficient extraction of coalbed methane, prevention of gas outburst and safety of coal mines.

2. Introduction to the LBM method

The lattice Boltzmann method is a computational model based on the microscopic level of molecular motion theory and statistics that can be used to simulate the motion of a fluid. From the microscopic point of view, the continuous medium is regarded as a large number of discrete fluid particle particles located on the mesh nodes. The particles move on the mesh according to their respective migration laws, and the statistical average of the fluid points and motion characteristics of each mesh fluid is obtained. In order to finally obtain the macroscopic motion law of the fluid.

Based on the simple D2Q9 model, if the particle distribution function is f(r, e, t) drde, the particle distribution function can be expressed as:

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

f^{eq} represents the distribution function of the equilibrium state, the subscript α represents the direction of motion of a given particle, and Δt is the time step.

The fluid density ρ and the momentum ρu are:

$$\begin{cases} \rho = \sum_\alpha f_\alpha^{eq} \\ \rho u = \sum_\alpha e_\alpha f_\alpha^{eq} \end{cases} \qquad (2)$$

Through continuous iteration of equation (1), the particle distribution function of different grid points can be obtained, and the required mechanical parameters can be obtained by using equation (2).

3. LBM gas seepage model

There are many factors affecting gas drainage. Under different conditions, the gas drainage effect is different. 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 under certain conditions of natural factors and equipment. In this paper, we mainly discuss the following factors affecting the effect of gas drainage: (1) opening position;(2) opening depth;(3) drainage pressure;(4) central opening, right boundary slitting.
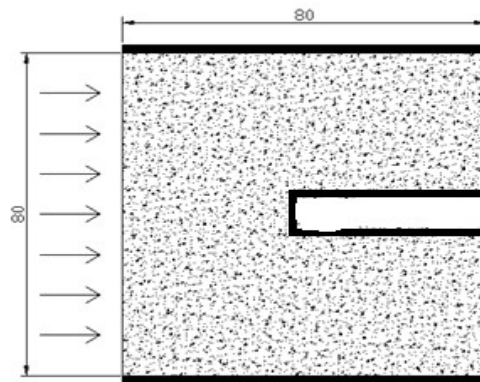
Figure 1. Gas flow field model.

Using the gas seepage dynamics model shown in Figure 1, the model size, gas velocity and gas pressure are dimensionlessly processed, and the gas seepage field is divided into 80× 80 square grids. Since the top floor of the coal seam is much less gas permeable than the coal seam, it is assumed that the surrounding rock of the coal seam roof is airtight and the gas content is zero. When t=0, the left side of the boundary condition is the input pressure, the right side is the output pressure, and the upper and lower sides are the airtight boundary. The subjective controllable factors were changed separately to simulate the gas flow law during the gas drainage of fractured coal.

The main steps of numerical simulation of gas flow:

Using the established gas flow field model of fractured coal body and the C language program compiled for he model, simulate the gas flow law during gas drainage under different subjective controllable factors, and then use Matlab software to fracture coal. The simulation results of the flow law during body gas drainage are plotted to analyze the gas drainage effect.

## 4. Single hole drainage gas seepage simulation

This section mainly discusses opening the hole at the right edge of the flow field, and only under the condition of opening a hole, the diameter of the hole is a grid, the depth of the hole is 40 grids, the left

boundary enters the pressure P_{in} =1.01, the right boundary freely seeps the output pressure P_{out} =0.96, changes the opening position, simulates the flow law of the gas in the flow field when simulating the gas drainage, and the simulation results respectively use the pressure distribution map, the velocity vector diagram and the flow streamline The way the graph analysis is summarized is given.

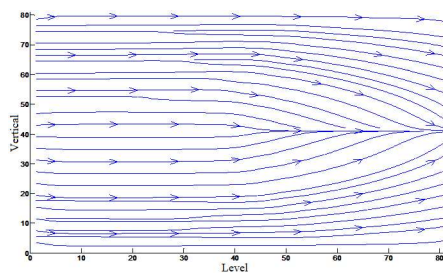*4.1. Opening position:40;opening depth:40*
The following figure shows the distribution of gas seepage pressure during gas drainage in fractured coals at the opening position of 40, the distribution of gas seepage flow in Fig. 3, and the distribution of seepage velocity in gas in flow field.

As shown in Fig. 2, when opening a hole at the right boundary 40-41 grid, it can be seen from the simulation result Fig. 1 that as time passes, the pressure gradually increases and the linear distribution, and at the opening The pressure gradient changes greatly. When the gas enters the flow field, the fluctuation of the pressure fluctuation is relatively large, and as time goes by, the change of the gas pressure becomes more stable as it approaches the outlet.
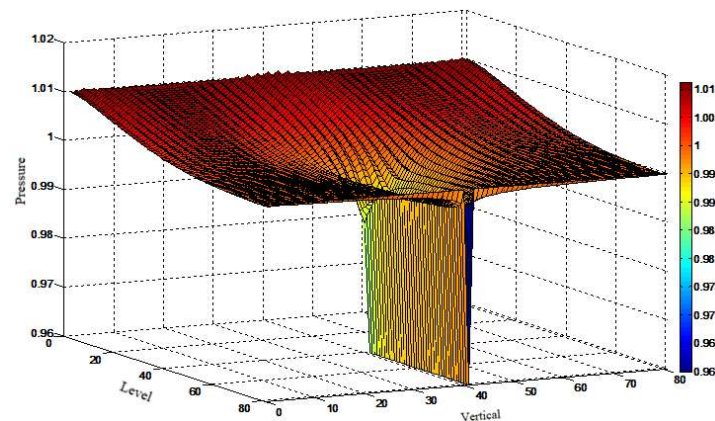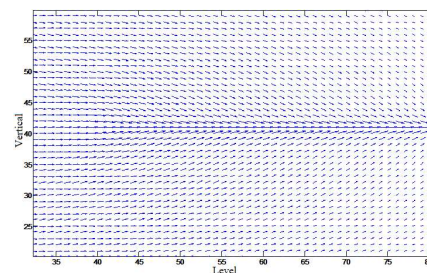

Figure 2. The opening position is 40 gas seepage pressure distribution maps.
(x:Number of grids; y:Number of grids; z:Gas osmotic pressure)

As shown in Figure 3 below: the gas flow is relatively stable at the inlet of the flow field, the gas flow is laminar, and the closer to the opening, the flow direction of the gas is basically radial flow, and at the opening position, the gas flow distribution More intensive.

Figure 3. The opening position is 40 gas seepage flow stream line distribution map.
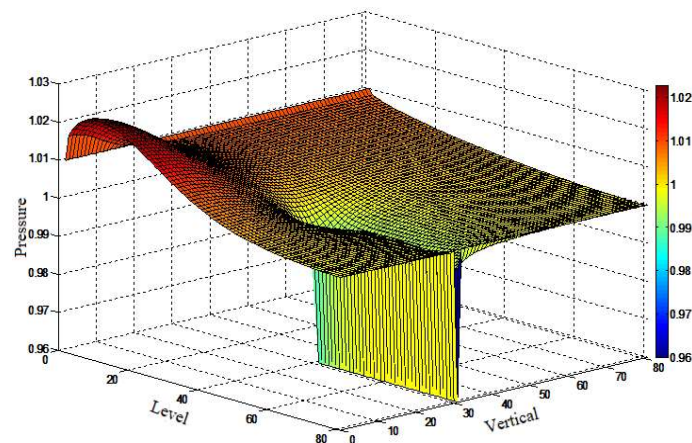

Figure 4. The opening position is 40 gas seepage flow velocity distribution map.

As shown in Fig. 4, at the opening, the gas flow rate is large, and the gas leakage amount is relatively large; while around the edge of the orifice, the gas flow velocity is smaller than that at the orifice, and the gas leakage at the boundary is relatively less.
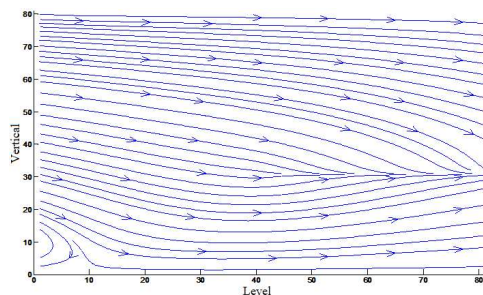
4.2. Opening position:30 ;opening depth:40

The following figure shows the distribution of gas seepage pressure when the gas is discharged from the fractured coal body at the opening position of 30. Figure 5 shows the distribution of the flow path of the gas seepage flow and the distribution of the flow velocity of the gas in the flow field.

As shown in Figure 5 below: when opening a hole at the right boundary 30-31 grid, it can be seen from the simulation results in Fig. 5 that as time passes, the pressure tends to increase linearly with the flow rate, and the pressure gradient at the opening Larger; when the gas enters the flow field, the pressure fluctuations above the left boundary are relatively large, and the pressure gradient changes significantly; as time goes by, the change of gas pressure tends to change linearly as it approaches the outlet.
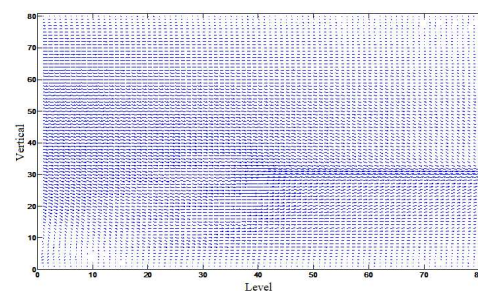

Figure 5. The opening position is 30 gas seepage pressure distribution map.

It can be concluded from Fig. 6 and Fig. 7 that the gas flow line is dense near the opening position, the gas flow velocity is large, the flow rate is large, and the gas velocity changes significantly as it approaches the opening position; near the left boundary The gas flow at the location exhibits eddy currents and the flow rate is slow.

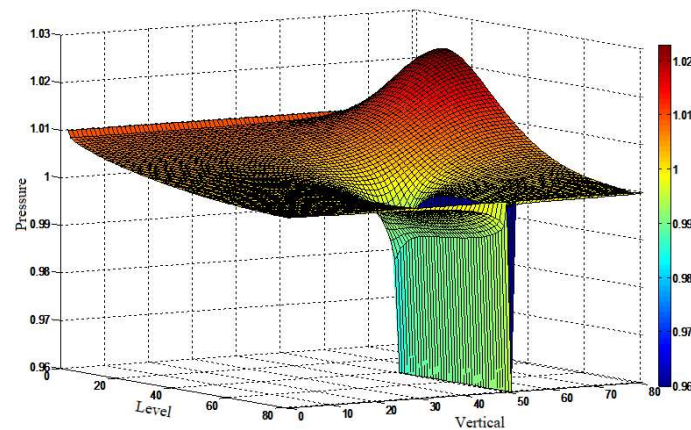**Figure 6.** The opening position is 30 gas seepage flow stream line distribution map.

Figure 7. The opening position is 30 gas seepage flow velocity distribution map.

### 4.3. Opening position:50;opening depth:40

When the opening position is 50 and the opening depth is 40, the gas seepage pressure distribution during the gas drainage of the fractured coal body is shown in Fig. 8. The flow trajectory distribution of the gas seepage flowFig. 9 and the flow velocity vector distribution of the gas in the flow field are shown in Fig. 10.
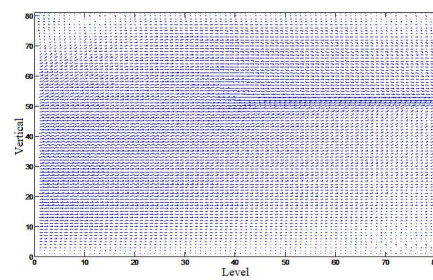
Figure 8. The opening position is 50 gas seepage pressure distribution map.

Comparing Figure 5 and Figure 8, it can be seen that the pressure change is symmetrical about the center of the flow field. When the hole is opened at the upper right (lower right) boundary, the pressure changes at the upper left (lower left) boundary, and there is a greater pressure there. Gradient; the closer to the opening position, the more the pressure changes toward and linearly.
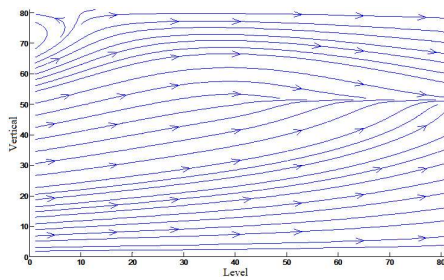
Figure 9. The opening position is 30 gas seepage flow stream line distribution map.

Figure 10. The opening position is 30 gas seepage flow velocity distribution map.

Comparing Figure 9 with Figure 6, the flow line in the flow field is symmetrical about the center of the flow field. When the hole is opened at the upper right (lower right) boundary, eddy current appears at the upper left (lower left) boundary; near the opening Position, the flow stream line is dense; the edge of the opening position, the flow stream line is sparse, and the flow rate is relatively small.

Comparing Fig. 10 with Fig. 7 above, the flow rate vector change is symmetric about the center of the flow field. When the hole is opened at the upper right (lower right) boundary, the flow velocity vector is smaller at the upper left (lower left) boundary; the closer to the opening position, the flow rate The bigger the vector.

Therefore, it can be concluded that the upper and lower symmetric openings have the same effect on gas drainage.

*4.4. Opening position:20;opening depth:40*
The following figure shows the distribution of gas seepage pressure during gas drainage of fractured coal body in the opening position of 20 and the depth of opening 40. Figure 11. Flow distribution of gas seepage flow in Fig. 12 and flow velocity vector distribution of gas in flow field 13.
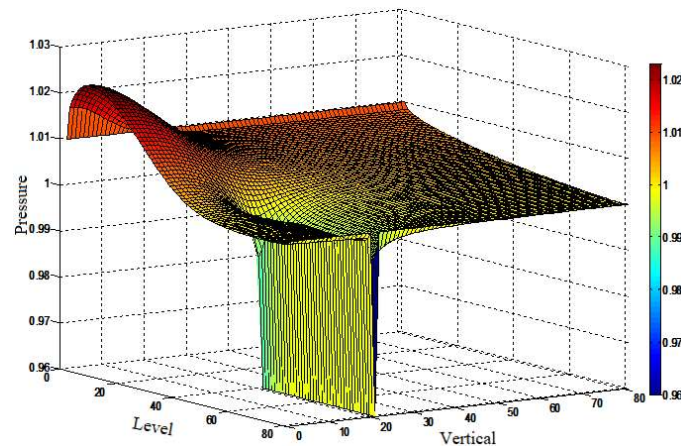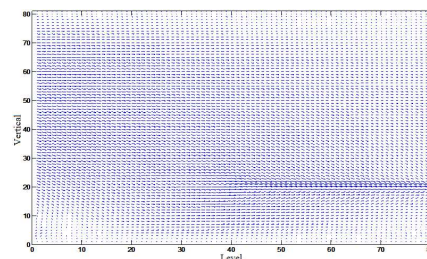
Figure 11. The opening position is 20 gas seepage pressure distribution map.

Figure 11 shows a comparison of the gas seepage pressure distribution map when the opening position is 20: as time passes, the gas flow velocity increases, and the pressure is raised when the opening position is 20,and the pressure is raised. The positional pressure gradient is large and the pressure gradient changes significantly at locations far away from the hole.

Figure 12 and Figure 13 show the comparison of Figure 3 and Figure 4 when the opening position is 40. When the opening position is 20, the gas flow rate of the gas flow near the opening position is 40 compared to the opening position. Sparse, denser when leaving the hole far away, and the flow rate of gas seepage is relatively small. When the opening position is 20, eddy current is generated above the left boundary, which affects the flow of gas, and the drainage effect is relatively poor when the opening position is 40.
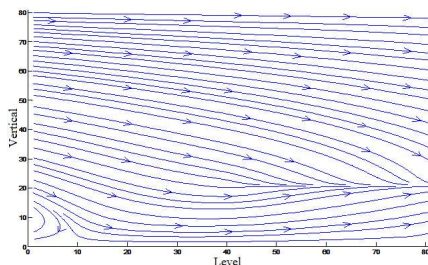
Figure 12. The opening position is 20 gas seepage flow stream line distribution map.

Figure 13. The opening position is 20 gas seepage flow velocity distribution map.

5. Conclusion

In this paper, by establishing a gas flow model and using a single-hole gas drainage simulation method, only the opening position is changed for simulation. The above simulation results can be summarized as follows:

(1) The effect of the hole in the symmetric position on both sides of the center of the right boundary is the same.

(2) The farther the opening position is from the center of the right boundary, the worse the pumping effect is.

(3) When the pumping pressure is the same and the opening depth is the same, if the eccentric opening is on the upper side (lower side) of the right boundary, eddy current appears in the upper left (bottom right) of the flow field, indicating that there is a higher gas pressure gradient.

(4) Opening the hole at the center of the right boundary of the flow field, the gas pressure gradient at the opening position is smaller than that of the eccentric opening, and the drainage effect is better than the eccentric opening.

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