The Seepage Simulation of Single Hole and Composite Gas Drainage Based on LB Method

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Abstract. Gas drainage is the most effective method to prevent and solve coal mine gas power disasters. It is very important to study the seepage flow law of gas in fissure coal gas. The LB method is a simplified computational model based on micro-scale, especially for the study of seepage problem. Based on fracture seepage mathematical model on the basis of single coal gas drainage, using the LB method during coal gas drainage of gas flow numerical simulation, this paper maps the single-hole drainage gas, symmetric slot and asymmetric slot, the different width of the slot combined drainage area gas flow under working condition of gas cloud of gas pressure, flow path diagram and flow velocity vector diagram, and analyses the influence on gas seepage field under various working conditions, and also discusses effective drainage method of the center hole slot on both sides, and preliminary exploration that is related to the combination of gas drainage has been carried on as well.

1. Introduction

Coal mine gas outburst is one of the most severe natural disasters occurred in the process of coal roadway drivage. The outburst will fill the roadway with adverse airflow, and the outburst gas will make people suffocate or cause gas explosion, causing serious casualties and mine damage accidents. The gas in the coal seam exist in free and adsorption state, in the area that does not affected by excavation, the coal seam gas is in equilibrium, and the gas does not flow, but due to mining destroys the balance of the original gas pressure, the formation of gas flow will be caused and gas flow field will be formed, Studying the pressure distribution of gas flow field has important practical significance to prevent and control the gas dynamic disaster in coal mine [1]. Because of the low permeability of coal seams and complex terrain conditions on the ground in our country, downhole drilling extraction becomes the primary technical measure to prevent gas outburst, therefore, the study of coal seam gas seepage law of gas drilling drainage, optimize the layout of gas drainage drilling, coal seam gas drainage, guarantee for the effective regional outburst prevention measures of the implementation of the effect is of great significance, and the gas drainage is still the most effective way to solve the problem of coal mine gas [2].

In the early 1980s, Wei Xiao-lin[4]and Li Ying-jun[5] were the first to use computer to study the results of gas flow. Especially in literature [4], in combination with the practical problems of coal mine, using finite difference method (DEM) for the first time, the gas flow field in has realized the numerical simulation of the pressure distribution and flow rate are successfully predicted the gas

pressure variation law of gas flow field. [6-7] are foreign studies, they used the finite element method (FEM) and the boundary element method (BEM) to simulate the gas seepage.

Lattice Boltzmann Method is developed and improved by Lattice Gas Automata, the Boltzmann equation is used to simulate macroscopic phenomena. LB method of parallel computing, boundary condition processing, precision and stability analysis, comparing a typical numerical example with the traditional numerical method and concrete application research have made great progress, showing strong vitality. After practicing for nearly two decades, LB method is proved to be one of the most effective numerical tools of fluid mechanics and seepage mechanics, and using the LB method for the simulation study of gas seepage is feasible. What's more, it provides a new train of thought and method for gas migration regularity of flow field simulation study.

2. Gas Flow Field Model

Based on the basic principle of LB method, considering actual characteristics of fractured coal gas drainage, we set up 80 fissure grid fissure flow area of the coal, coal and puckering in the flow area on the right side of the drainage gas. The flow field and lower boundary are the coal seam roof and the bottom plate, the left boundary is the coal seam, and the right boundary is the extraction working face. The gas flow field model is shown in figure 1. When t = 0, the left boundary is the input pressure, and the right boundary is the output pressure, and the boundary conditions are set respectively. Change the extraction method to simulate the gas flow in the fissure coal gas drainage.
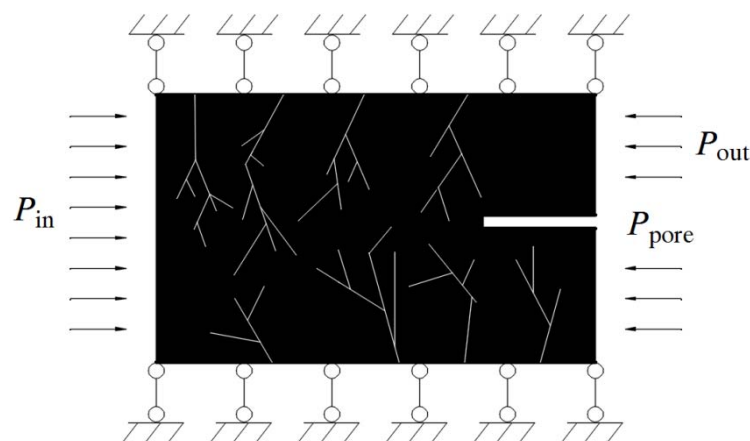

Figure 1. Gas flow field model

3. Single Hole Pumping Gas Seepage Simulation

Single-hole gas extraction has the characteristics of simple operation, open hole at 40 lattice points in the center of the right boundary, and the depth of the hole is 40 grids. Input pressure on the left edge P_{in}=1.01, and right boundary free seepage pressure 1, suction pressure P_{out} =0.96, and simulate. Figure 3~5 is the gas seepage pressure cloud diagram, gas flow diagram and gas flow velocity vector diagram for fissure coal gas drainage.

In figure 2(a), the horizontal and vertical coordinates represent the grid number, and the vertical coordinate represents the gas pressure. Known as time goes on, the simulation results with the velocity increasing, the pressure distribution and linear fractional trend, and pressure gradient change in the hole is big, when the gas gets into the flow field, the pressure changes and volatility is larger, but as time goes on, when the closer it gets to the export, the change of gas pressure is more steady.
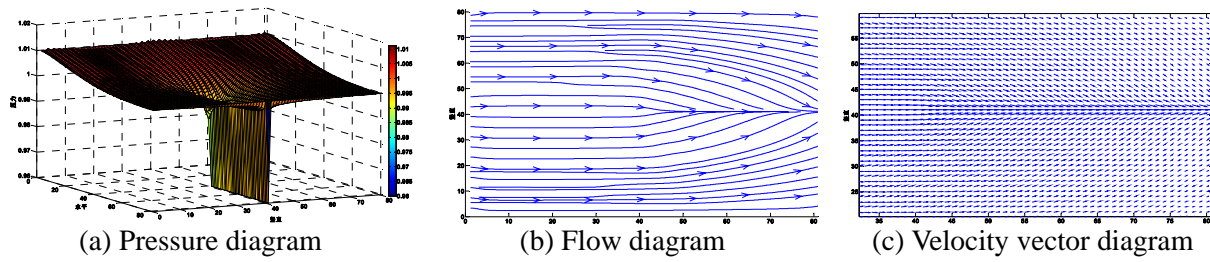
| (a) Pressure diagram | (b) Flow diagram | (c) Velocity vector diagram |

Figure 2. Gas seepage diagram of single hole pumping gas

As is shown in figure 2(b), the gas flow at the entrance of the flow field is more stable, the gas flow is laminar flow, and the closer it gets to the hole, the direction of gas flow is the basic of radial flow, and the opening location, gas flow is increasing.

It can be seen from figure 2(c) that the gas flow velocity is large and the gas seepage is relatively large. At the edge of the orifice, the gas flow velocity is smaller than that of the hole

4. Combined Pumping Gas Seepage Simulation

Opening hole and slotting combination gas drainage is often better than open - hole pumping effect ideal. The hole depth is 40 mesh, and the width of the slit in the center of the right boundary center is taken. The same extraction parameters are used for effective contrast with single-hole gas extraction. Input pressure on the left edge P_{in}=1.01, and right boundary free seepage pressure 1, Bleed pressure P_{out}=0.96.The cutting length and position of the slit affect the pumping effect. For this reason, the extraction effect of different cutting joints of different slit length and the same length of slit is simulated.

4.1. Symmetrical Cutting Gap with a Width of 5 Mesh

In the center of the opening hole, the hole is 40 mesh, and the width of the 5 meshes is at 25-30 and 50-55. The total length of the slit is 10 meshes. Figure 3(a)~(c) is the flow chart of the flow in the flow field and the velocity vector diagram of gas in the flow field respectively.
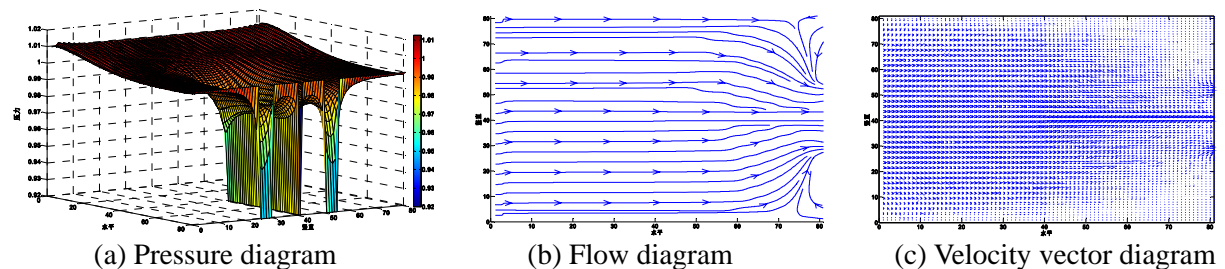

| (a) Pressure diagram | (b) Flow diagram | (c) Velocity vector diagram |

Figure 3. The gas seepage diagram of the symmetric slit width is 5

From the analysis of figure 3(a), with the pass of time and increasing gas flow rate, pressure distribution tends to be linear distribution, in the opening position and slotted pressure gradient is big, and it is good for gas drainage; When the gas enters the flow field and gets near the hole position and slotted edge pressure changes in great fluctuation, but as time goes on, The change in the position of opening and cutting gas seepage pressure tend to be more stable.

As shown in figure 3(b): the gas flow at the entrance of the flow field is more stable, the gas flow is laminar, and the closer it gets to the open hole and slot position, the direction of gas flow is basic to the radial flow, and in the hole and slot position, gas flow line distribution is relatively concentrated.

As is shown in the above figure 3(c): according to the analysis of gas flow velocity vector distribution diagram, in the entrance boundary, the gas velocity is relatively small, and the speed is basically the same size in the opening position and cutting velocity is relatively large, and at the edge

of the hole and cutting edge gas flow changes obviously, above and below the right boundary of the gas flow velocity is relatively small, more conducive to gas drainage.

4.2. Symmetrical Slit, Width of 10 Mesh

The center is opened with a hole of 40 meshes, and the width of the width of 10 meshes is at 20-30 and 50-60.
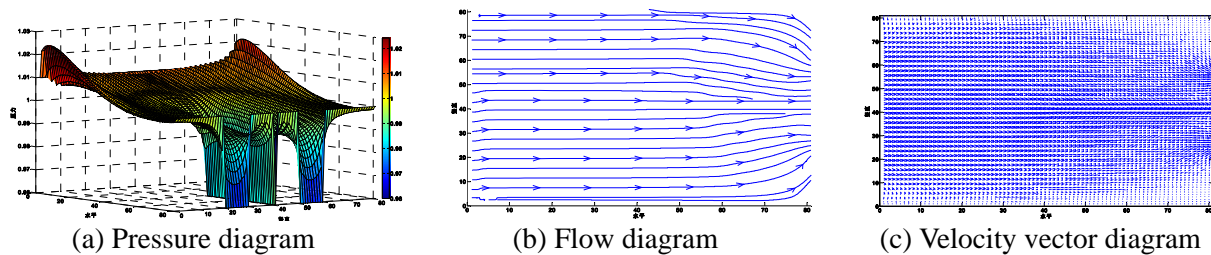

| (a) Pressure diagram | (b) Flow diagram | (c) Velocity vector diagram |

Figure 4. The gas seepage diagram of the symmetric slit width is 10

Figure 4(a) shows that gas pressure cloud diagram. The horizontal and vertical coordinates represent the grid number, the vertical coordinate represents the pressure, and the different colors indicate different pressures. According to the comparison between figure 8 and figure 5, after the gas enters the flow field, there is pressure bulge at the top and bottom of the left boundary and the pressure gradient is large, which can easily cause the vortex of gas generation in this position. And when symmetric slot width of 10, near the hole position and cutting position, when compared to the gas flow streamline symmetric slotted width is 5 when the flow of gas flow is more sparse, the gas flow is relatively small; in the opening position and cutting position of the gas flow speed is relatively slow.

Figure 4(b) and figure 4(c) respectively the trace gas flow chart and the gas flow velocity vector diagram and contrast analysis of figure 3(b) and figure 3(c), when symmetric slot width of 10, near the hole and slot position, compared with when the gas flow streamline symmetric slot width is 5, gas flow streamline is sparse, the gas flow is relatively less; The gas flow velocity is relatively slow at the opening position and slot position.

4.3. Asymmetric Slit, with a Gap of 5 Meshes

Hole opening at center position, hole deeply 40 meshes, in 25 to 30 and 55 to 60 asymmetric take place when the width is 5 grid slot, fractured coal gas drainage pressure distribution as the figure 5(a), the gas flow in the flow field in streamline figure 5(b), gas flow velocity in the flow field vector figure 5(c).
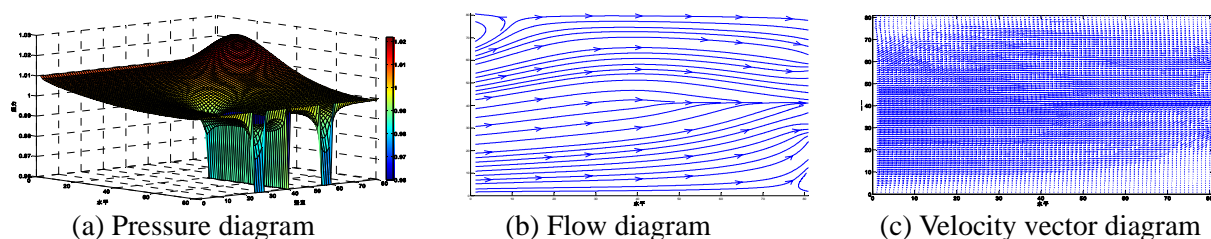

| (a) Pressure diagram | (b) Flow diagram | (c) Velocity vector diagram |

Figure 5. The gas seepage diagram of the asymmetrical slit width is 5

After the gas enters the flow field in figure 5(a), there is obvious pressure at the bottom of the left margin, and the pressure gradient is relatively large. It is easy to cause the gas to generate vortex, which affects the free seepage of the gas. According to the analysis of figure 5(b) and 5(c), the flow of gas flow in the edge of the opening position and the edge of the slit edge is relatively sparse, and the gas flow is relatively small, and the flow velocity of gas is relatively small. It is not obvious that the

laminar flow of the gas in the distance from the hole position and the slot position is not obvious, and the gas flow in the lower left margin is vortex, which affects the gas drainage.

5. Conclusion

The paper is based on the LB method to establish the fissure of coal gas drainage seepage model, and it mainly uses hole opening at center position, the hole position on both sides of the slot of the combination of numerical simulation of gas drainage, based on the different seam width and slot for symmetric and asymmetric distribution under the condition of two kinds of simulation. The above simulation results can be summarized as follows:

(1) The width of symmetrical slit is taken within a certain range, and the effect of gas drainage is better, which is more conducive to gas seepage.

(2) The gas drainage effect of symmetrical cutting is better than that of asymmetric cutting.

(3) The same hole position, the same open hole depth, center hole and bilateral symmetry take the same width and take a certain width of the slot of the drainage effect than only the hole in the center of the drainage effect is better.

(4) Combined drainage with center hole, hole depth, same right on both sides of the border center slot form, when symmetric slot, slot width and take a certain scope, the faster the gas flow rate, the better drainage effect; The gas drainage in this condition is better than that of a gas drainage that is only open in the center.

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