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THE RESEARCH OF CHARACTERISTIC FOR MINING COAL SEAM DEFORMATION AND SEEPAGE FLOW AFTER THE PROTECTIVE LAYER WAS MINED**

1. Introduction

The low efficiency of underground gas drainage for high-gas coal mine mainly exists in the highland stress low permeability of most coal seams is the important parameters for the gas extraction degree of difficulty. Produce relief antireflection of the surrounding rock by using the coal seam mining, resulting in a substantial increase in the surrounding rock and its coal seam permeability coefficient in the exploitation of high gas seam group, which creates the preconditions for the high efficiency of relief gas drainage[1–4]. Therefore, in order to increase the coal seam permeability coefficient, the protective layer should be exploited first in the high gas outburst mine to make the coal body stress-state and the gas dynamic state change after the danger seam with highlight affected by mining, and make the large number of absorbed gas in coal or rock parse out, which contributes to the relief gas drainage after producing the relief effect. This article based on the geological conditions of Huainan Gu-qiao mine analyzes the overburden failure, flaw distribution and pressure relief coal seam horizontal and vertical displacement variation after the protective lager mining through RFPA2D-Gasflow soft ware, and comes to characteristics of pressure relief range and permeability variation for the protective layer. The research results provided a theoretical basis for the pressure relief gas drainage and drainage drilling design.

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2. The numerical analysis for the characteristic of the discharging pressure coal seam deformation and seepage flow

The RFPA2D-Gasflow simulation software mainly used for containing gas coal rock failure process of numerical simulation experimental research [5–6], can calculate the results which can intuitively display the image of the evolution characteristics of the rock stress field and the gas flow field during the containing gas coal rock failure process.

2.1. Calculation model

According to the occurrence of coal seam conditions of Huainan Guqiao mine, rock columnar, mechanical parameters, see Table 1.

By using the plane strain model, *length* × *width* = 200 × 150, divided into 30000 meshes. Both level sides of the model are simply-supported. The bottom of the model is a constraint reinforcement. According to the occurrence of coal seam conditions, the initial gas pressure of the by cover is set to 5 MPa, and 9 MPa equivalent vertical pressure is set on the surface of model. The protective layer is mined from left to right, leaving 60 m pillar on each side, 10 m for the excavation step and 80 m as the total length. In order to research the extraction effect of the discharged pressure of the coal seam, the gas extraction hole is put in model every 20 m layout, calculation model as shown in Figure 1 the gray rock strate in the figure represent the mechanical parameters (such as elastic modulus, compressive strength) size, the brighter the gray is, the bigger the value is.

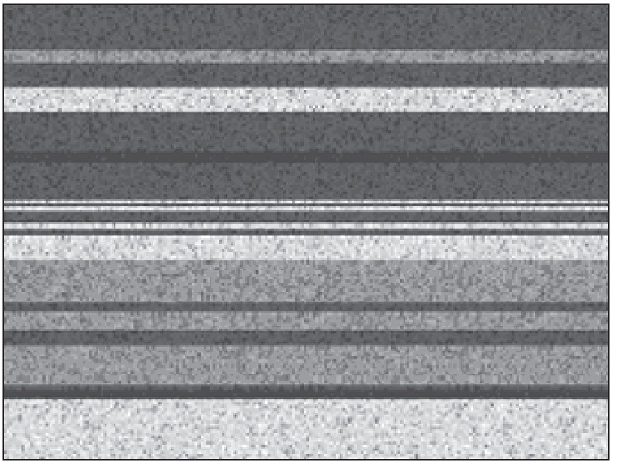


Fig. 1. Numerical Model

TABLE 1

The mechanical parameters of rock seams in numerical model

Rock	Layer thickness h, m	Modulus of elasticity E, GPa	Compressive strength σ_c, MPa	Gas content coefficient	Permeability coefficient λ, $m^2/(MPa^2 \cdot d)$	Weight γ, $10^{-5} Nmm^{-3}$
Mudstone	16	10	15	0.01	0.01	1.6
Sandstone	4	35	35	0.01	0.1	2.5
Sandy shale	8	26	26	0.01	0.01	2.4
Fine sandstone	8	22	20	0.01	0.1	2.6
Sandy shale	13	25	27	0.01	0.01	1.9
Be unloading coal seam	5	15	15	10	1	1.4
Sandy shale	13	26	26	0.01	0.01	1.9
Fine sandstone	2	22	22	0.01	0.1	2.5
Mudstone	4	15	17	0.01	0.01	1.4
Sandy shale	4	26	26	0.01	0.01	1.8
Siltstone	8	24	23	0.01	0.1	2.4
Sandstone	14	35	35	0.01	0.1	2.4
Sandy shale	3	26	26	0.01	0.01	1.8
Sandstone	6	35	35	0.01	0.1	2.5
Sand mud interbed	5	32	32	0.01	0.01	2.1
Sandstone	10	35	35	0.01	0.1	2.5
Coarse sandstone	3	30	30	0.01	0.1	2.4
Mudstone	1	10	56	0.01	0.01	1.6
Protective layer	3.2	20	20	1	1	1.4
Bottom plate	20	40	40	0.01	0.1	2.5

2.2. Analysis of calculation results

1) Overlaying strata collapse process and cracks distribution characteristic in mining

Evolution rule of overlaying strata collapse process and cracks distribution characteristic in mining is in Figure 2. Along with the protective layer mining, fracture overlaying strata development gradually from the bottom, and rock gradually fall down continuously, caving zone is expandding. When the protective layer promotes to 40 m, caving zone over the coal seam reached to 7 m; when to 60 m, caving zone over the coal seam reached to 10 m; but to 80 m, caving zone over the coal seam reached to 20 m. The numerical results show that the protected coal seam is located at the release of pressure mining bending subsidence zone, no fracture damage.

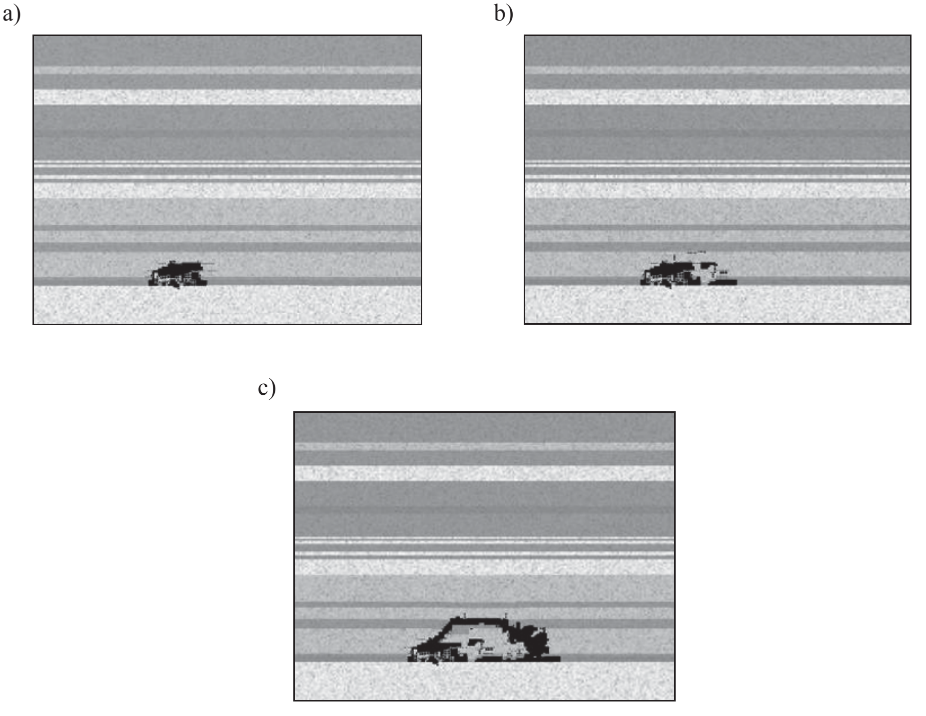
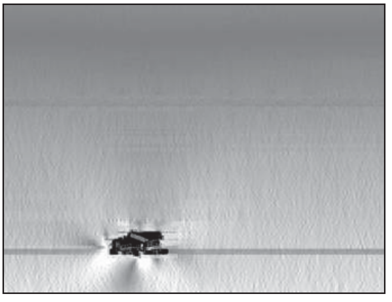


Fig. 2. Overlaying strata collapse process and cracks distribution characteristic in mining: a) Mining distance 40 m; b) Mining distance 60 m; c) Mining distance 80 m

2) Shear stress distribution of overlaying strata

The overlying rock shear stress distribution is in Figure 3. The brighter the gray is, the greater the stress value is. The protective layer is mining that let the protected layer redistribute the stress, leading to the protective layer stress concentration area and the pressure relief area, impeling to generate pressure relief effect in some regions of the pressure releasing seam, and result in unloaded coal seam permeability changing, gas analytical happening, provid the possibility of pressure relief gas drainage.

a)



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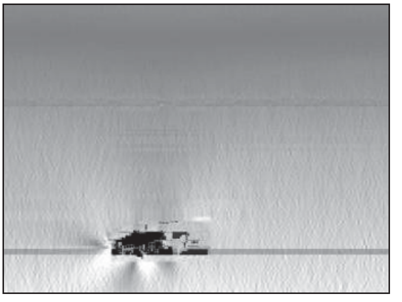

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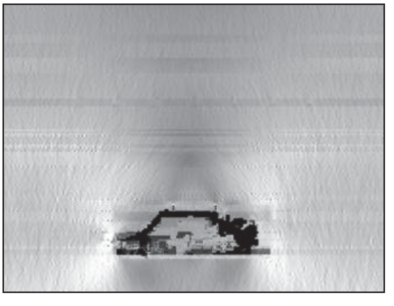
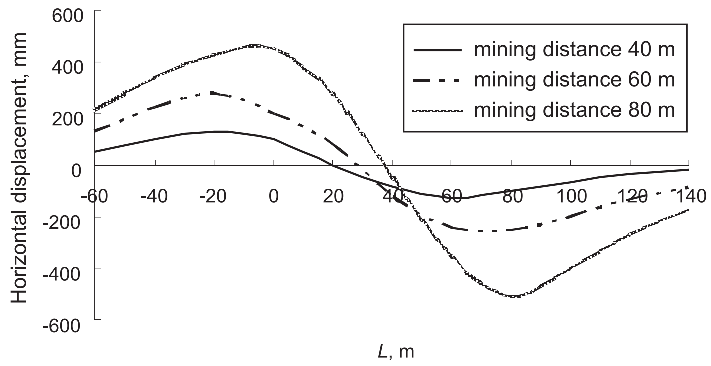


Fig. 3. Shear stress distribution of overlaying strata in mining:
a) Mining distance 40 m; b) Mining distance 60 m; c) Mining distance 80 m

3) Displacement field characteristics seam with pressure relief

Figure 4 shows the displacement curve of seam with pressure relief. From Figure 4a we can see that, the mining of protective layer made upper overburden strata bend and subside. The rock both sides moved to goaf. Horizontal displacement caused tension crack and compaction of rock and caused fracture. The situation was especially obvious in the area nearby open-off cut and stopping line, and it is anastomotic with the characteristics of fracture distribution. From Figure 4b we can see that, with stope promoting, the vertical displacement increased gradually, and rock mass continuously upward developed and the influenced range increased.

a)



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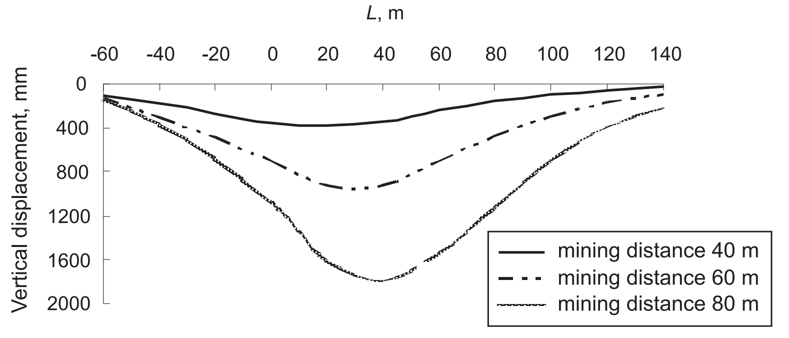


Fig. 4. Horizontal and vertical displacement of protected coal seam:
a) Horizontal displacement; b) Vertical displacement

4) Evolution characteristics of gas pressure and permeability of pressure relief coal

Figure 5 shows the gas pressure change around gas drainage hole in pressure relief coal seams. When the stope promotes 40 m, the average level of gas pressure decreased from 5 MPa before gas drainage down to 2.5 MPa, and it decreased to 0.4 MPa nearby gas drainage hole. When the stope promotes 80m, the gas pressure of protective layer decreased to 1 MPa, and it decreased to 0.1 MPa nearby gas drainage hole. Because the gas drainage holes are in different positions, their stress state and permeability are different. These caused the speed of drainage different, and the gas pressure reduction velocity of gas drainage holes nearby fracture development zone was higher than the other holes'.

Figure 6 shows the permeability change in protected coal seam. Because of the effect of mining, the permeability coefficient of protected coal seam influenced by mining changed greatly. When the working face promotes 40 m, the permeability coefficient of upper overburden protected coal increased about 30 times. With the stope promoting, the permeability coefficient increased gradually. When the protective layer promotes 80 m, the permeability coefficient of coal increased to two hundred times of the initial. And along with the mining areas further enlargement, the permeability of protected coal seam will be dramatically improved.

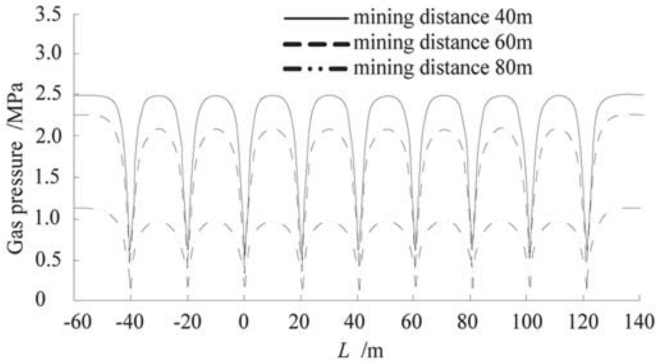


Fig. 5. Changing curve of gas pressure surrounding the drainage hole in protected coal seam

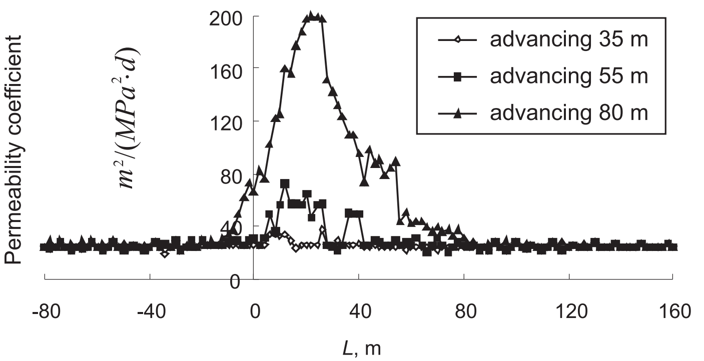


Fig. 6. Curve of gas permeability in protected coal seam

3. Engineering Application

3.1. Test conditions

The length of the test face is 220 m, the length of the stoping is 2596 m, the thickness of the pressure relief coal and the protective coal seam are 5 m and 3.2 m. The interlayer distance is 73 m, the angle of coal seam is 9°, the average buried depth of coal seam is 800 m, the estimated relative amount of gas emission in toping is 5.4 m^3/t, and the absolute amount of gas emission is 37.4 m^3/min. the designed air volume of working face is 2730 m^3/min. The gas amount through wind is 14.6 m^3/min, the surplus 22.8 m^3/min of gas must be drainaged.

3.2. Drilling arrangement for gas drainage in roadway retained

Adopting the method of roof oblique-upward crossing drilling hole for gas drainage in goaf and upper overburden protected coal in retained roadway [2, 8].

1) Crossing drilling of pressure relief gas in retained roadway oblique-upward fracture zone

   When drilling in retained roadway, angle of drilling hole should be less than mining pressure relief angle. The dip angle should ensure that the drilling hole will not disconnect and be on the fracture after the roof falling. considering that the angle between the two coal seams is 9°, the dip angle of drilling were 20°and 25° respectively, every 20 m was a group, every group had two holes, and the drilling hole diameter was 94 mm. The distance between the final hole and the protective layer roof was 50–60 m. 1 and 2 in Figure 7 show the drilling arrangement.

2) Crossing drilling of gas in retained roadway oblique-upward pressure relief coal seam

   When drilling in retained roadway, angle of drilling hole should be less than mining pressure relief angle. The dip angle should ensure that the drilling hole pass through the upper part of roof fracture, and pass through the 13-1 coal seam 10 m or more. Every 20 m was a group, every group had two holes, the dip angle of drilling were 65° and 70° respectively, and the drilling hole diameter was 94 mm. The distance between the final hole and the protective layer roof was 10 m. 3 and 4 in Figure 7 show the drilling arrangement.

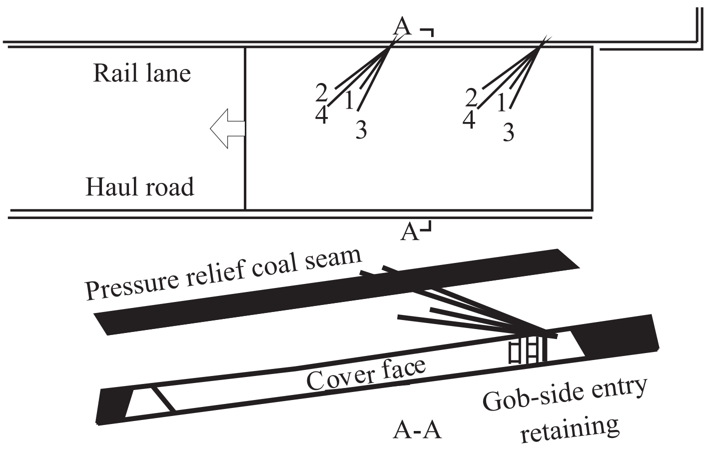


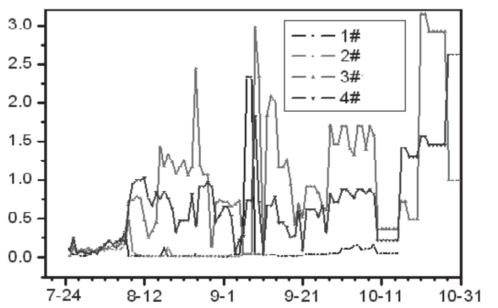
Fig. 7. The drilling arrangement method in gob-side entry retaining drainage of coal bed methane

3.3. Analysis of pressure relief gas drainage effect

The working face promoted 870 m during the test, and the filling length of gob-side entry retaining with the face mining was 860 m. Figure 8 shows the effect using long and short drilling gas drainage relieved and crossing drilling of gas in retained roadway oblique-upward pressure relief coal seam respectively.

1) The effect using roof oblique-upward crossing drilling hole for gas drainage was better, the measured gas drainage concentration was more than 20%, there was not basically high concentration gas accumulation area. The gas concentration and the gas amount with buried pipe drainage were less. And the gas concentration in upper corner and in retained roadway was controlled under 0.5%. The daily output of the raw coal reached million tons. It put an end to the phenomenon of gas exceeding the limit in working face.
2) By adopting the method of he drainage relieved coal bed methane, suction of relieved methane every day was 30 946 m^3, and the extraction rate reached 50–70%. It ensured the safety and efficiency of stoping.

a)



b)

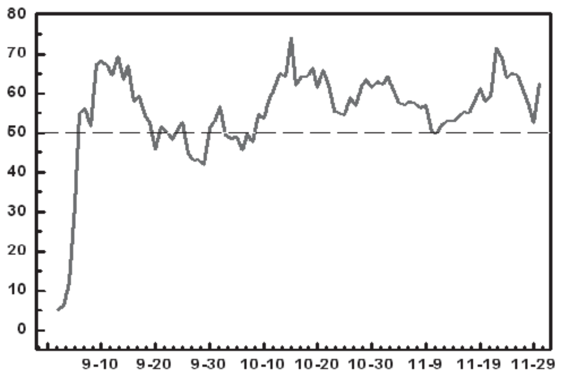


Fig. 8. The relationship of the drainage relieved coal bed methane and time: a) Gas extraction scalar; b) Gas drainage efficiency

4. Conclusion

1) The results of the study show that, due to pressure relief mining of protective layer, pressure relief coal seams were in bending subsidence zone, the whole coal occurred deformation and subsided, and the interlayer bed separation fracture completely developed. It made the stress in the pressure relief coal redistributed that applied the way of pressure relief mining of protective layer, and appeared stress concentration regions and distressed zone, meanwhile the increasing transmission effect of pressure relief coal in distressed zone was very obvious, and it could provide the possibility for gas drainage in pressure releasing area.
2) When protective layer promotes 80 m, gas pressure of pressure relief coal decreased significantly, from five MPa down to 1 MPa. Meanwhile, the permeability coefficient of coal increased to two hundred times of the initial, so the effect of pressure relief and increasing transmission were significant. And along with the mining areas further enlargement, gas pressure further decreased and the permeability of coal seam will be dramatically improved.
3) Application results show that, the effect of suction of relieved methane was good with arranging a group oblique upward long and short crossing hole in roadway retained. Suction of relieved methane every day was 30946 m^3, and the extraction rate reached 50–70%. In this way, both the vitiated air and the gas concentration in upper corner and in retained roadway were controlled under 0.5% during stoping. It solved the problem of gas exceeding the limit in upper corner, and realized the safety and efficiency of co-mining of coal and gas.

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