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***Journal of Scientific and Engineering Research*, 2023, 10(5):159-166**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Investigation and study of gas extraction effect of bottom extraction lane borehole based on COMSOL

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Abstract Coal is an important energy source, mining efficiency will affect economic development, gas content and concentration increase is an important factor affecting coal mining efficiency, so gas extraction is an important prerequisite to prevent gas accidents and improve mining efficiency. Taking 15121 bottom extraction lane of Xinjing mine as the engineering background, in order to investigate the effect of gas extraction from the cavity-making borehole of the bottom extraction lane, this paper investigates the amount of gas extraction from the borehole and the effective extraction radius before and after the borehole extraction through field tests and COMSOL numerical simulation analysis. The results of the study show that the effective extraction radius of the drill hole can reach 1.2m after 40d of continuous pumping, 1.9m after 70d of continuous pumping, and 3.8m after 130d of continuous pumping.After 100 d of continuous pumping, the effective extraction radius of the drill hole can reach 2.6m, and after 130 d of continuous pumping, the effective extraction radius of the drill hole can reach about 3.8m. The validity of the numerical simulation results was tested through field tests, and the two were corroborated with each other to examine the extraction effect of the 15121 bottom extraction lane in the Xinjing Mine.

Keywords Gas, Extraction radius, COMSOL numerical simulation, Effectiveness Inspection

1. Introduction

Coal and gas protrusion has been one of the major problems faced during coal mine safety production [1-3]. Coal seam gas extraction, as one of the ways to effectively manage coal seam gas problems, can effectively reduce the coal seam gas content, reduce the risk of coal seam protrusion, and guarantee the safe, efficient and orderly production at the working face [4-7]. However, in the current coal and gas management process, affected by the geological conditions in which the working face is located, burial depth conditions, construction technology, coal rock own permeability, gas endowment and other factors, in the process of coal seam gas extraction, there is a certain variability of extraction effect in different areas [8-10]. Gong Xuanping [11] et al. constructed numerical models based on field data in order to investigate the influence of different factors on the effect of gas extraction from boreholes and to study the change law of effective extraction radius under different extraction conditions; Jin Xin [12] applied COMSOL software to simulate the gas extraction pressure distribution of single-sided and double-sided extraction methods of extra-long directional boreholes in coal seams, and the results showed that the extraction effect of double-sided extraction method of extra-long directional boreholes was better than that of single-sided extraction method; Zou Shichao [13] et al. used COMSOL numerical simulation to obtain the cloud map of radial gas pressure distribution along the borehole at different extraction times, and the effective extraction radius was linearly correlated with the extraction time, which provided a reference for the management of downhole gas drilling gas extraction; Yanwei Hu [14] et al.

numerically simulated the gas distribution pattern in the mining area by COMSOL finite element analysis software, and derived the distribution pattern of gas in the mining area after it reached stability.

Therefore, this paper takes 15121 bottom extraction lane penetration borehole of Xinjing Mine as the research object, combines numerical simulation and field test to investigate the extraction effect of penetration borehole and analyze the extraction effect of borehole, so as to improve the efficiency of gas management and guarantee the safe and efficient production of working face.

2. Project overview

The 15121 working face of Xinjing Mine belongs to the No.15 coal seam, which is located in the middle of the south flank of +420 level in Fowu mining area of Xinjing Company. The upper part of No. 15 coal seam is overlaid with No. 3, No. 6, No. 8, No. 9, No. 12 and No. 13 coal seams, and all of them are not mined. The depth of No.15 coal seam at 15121 working face is between 600~800m, the dip angle of coal seam is between 2~9°, the distribution is relatively stable, the degree of coal quality is high quality anthracite with medium ash and medium sulfur, mainly mirror coal and bright coal, the top and bottom plate is gray-black mudstone, the permeability of the top and bottom plate is relatively poor, which is conducive to the gas endowment and the gas content is relatively high. The gas content within the mining area of 15121 working face is between $8m^3/t$~$15m^3/t$. Before the working face is retrieved, extraction boreholes need to be constructed to control the coal seam gas and examine the effect of the borehole extraction.

3. Mathematical modeling of gas extraction

3.1 Numerical simulation parameter selection

COMSOL software was selected to analyze the gas pressure variation around the borehole during the drilling and extraction process. In the process of establishing the numerical model using COMSOL, the coal body was assumed to be an isotropic homogeneous medium, and the influencing factors affecting the gas flow were considered for the study of the borehole section of the coal seam [15-17]. Since the top and bottom slabs of coal seams are poorly permeable mudstone, it can be assumed that no free state gas exists in the rock seams, while the gas gas in the coal seams, which is uniformly distributed in the coal seams, is ideal gas in the process of adsorption and desorption, which is in accordance with Langmuir gas equation of state, and the gas flow in the coal seams is in accordance with Darcy's law, and there is no significant change in temperature during the gas transport.

By establishing the coal rock gas seepage field equation and coal skeleton deformation equation, the change of gas pressure distribution around the borehole in the same time under the action of the two fields of flow-solid coupling is studied, and the model parameters are shown in Table 1 below:

Table 1: Main technical parameters of each development project

Initial Symbol	Representative Symbols	Numerical value	Remarks
ρ_0	rho0	0.717[kg/m^3]	Methane density in the standard state
μ	mu	1.84e-5[Pa*s]	Methane viscosity factor
φ_0	phi0	0.414	Initial porosity
k_0	k0	1.7106e-16[m^2]	Initial Penetration Rate
P_0	p0	1[MPa]	Initial gas pressure of coal seam
p_n	pn	101.325[kPa]	Standard atmospheric pressure
a	a	0.0402[m^3/kg]	Amount of gas adsorbed per unit mass of coal
b	b	1.158[MPa^{-1}]	Adsorption constants of coal
klikenberg	klikenberg	13[kPa]	klikenberg coefficient
E	E	2880[MPa]	Young's modulus
v	v	0.23	Poisson's ratio

3.2 Model parameter setting

The coal seam gas flows only in the coal seam, and the coal seam flow boundary conditions are:

$$\begin{cases} \frac{\partial p}{\partial x} = 0, x = 0, x = 20 \\ \frac{\partial p}{\partial y} = 0, y = 0, y = 4 \end{cases} \quad (1)$$

Around the extraction hole, the borehole gas pressure conforms to the DiriChlet boundary condition, i.e:

$$P(x, y, z, t)|_x = H(x, y, z, t)_{(x,y,z)\in x} \quad (2)$$

The initial value of the coal seam gas pressure is:

$$p = p_0 \quad (3)$$

Based on the theoretical derivation model, according to the above basic assumptions and related parameters, a two-dimensional plane model is adopted for the numerical simulation calculation of the extraction radius. The model height (coal thickness) is 4m, the coal seam length is set to 20m, the bottom boundary is fixed, and the left and right sides are free boundaries without reinforcement. The top stress is 8.09MP, the radius of the borehole is 55mm, the negative extraction pressure is -13kpa, the initial gas pressure size is 1.03MPa, and the borehole is arranged at the center of the model, taking the h direction as the y-axis direction and the L direction as the x-axis direction. The model grid is shown in Figure 1 below.

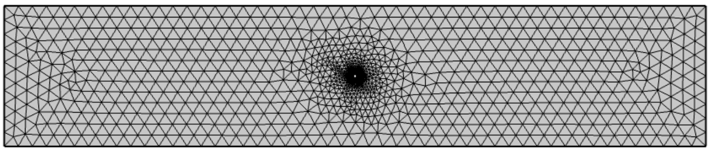
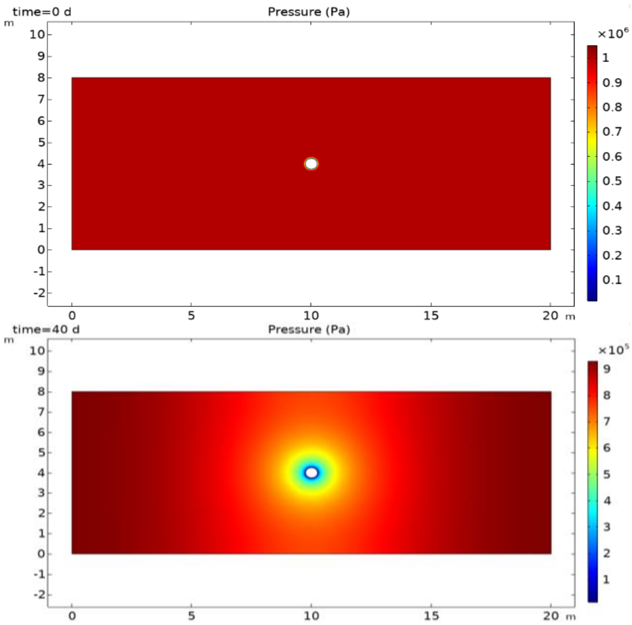


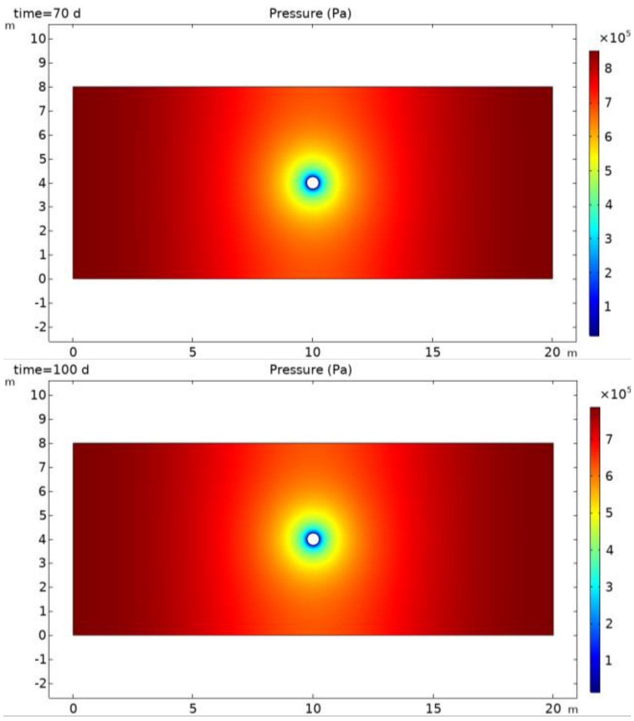
Figure 1: Model meshing

3.3 Numerical simulation results and analysis

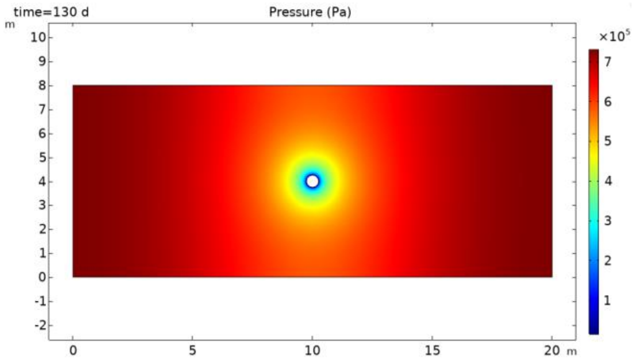
When the negative pressure of the drill hole is -13kPa, the hole diameter is 110mm, and the extraction time is 0d, 40d, 70d, 100d and 130d, the cloud chart of coal seam gas pressure distribution is shown in the following figure.



(a) Stress distribution cloud when not pumped (b) Stress distribution cloud at 40d of extraction



(c) Stress distribution cloud at 70d of extraction (d) Stress distribution cloud at 100d of extraction



(e) Stress distribution cloud at 130d of extraction

Figure 2. Cloud map of gas pressure distribution in coal seam at different times

Radial profiles of extraction boreholes were selected for the study, and the gas pressure distribution curves in the horizontal direction of the boreholes at different times are shown in Figure 3:

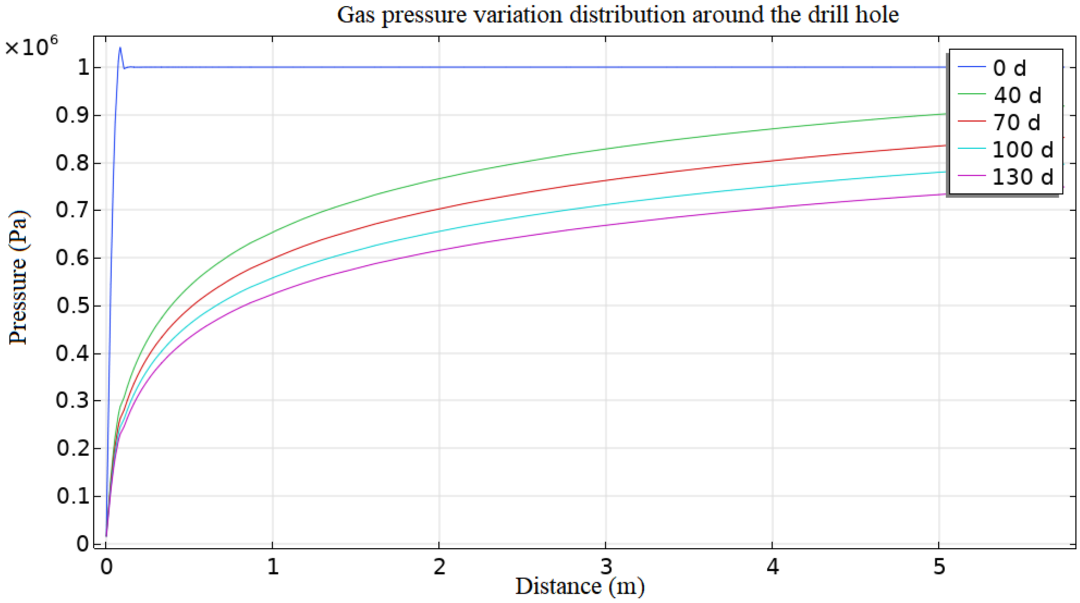


Figure 3. Gas pressure distribution curve around the borehole at different times

According to Article 58 of the Rules for Prevention of Coal and Gas Protrusion, the coal seam gas pressure ≤ 0.74MPa can be considered to have reached the anti-protrusion effect index. Therefore, it is determined here that when P≤0.7MPa, the coal seam gas extraction effect can be considered to be within the effective influence radius around the standard drill hole. From Fig. 3, it can be seen that the effective extraction radius of the borehole becomes larger gradually with the increase of extraction time. When the extraction time is 40d, the effective extraction radius is about 1.2m, when the extraction time reaches 70d, the effective extraction radius of the borehole can reach about 1.9m, when the extraction time is 100d, the effective extraction radius of the borehole can reach about 2.6m, and it is expected that when the extraction time is 130d, the effective extraction radius of the borehole can reach about 3.8m.

4. Field gas extraction effect test

4.1 Borehole Layout method

On the basis of the numerical simulation results, the gas extraction effect test is now carried out in 15121 bottom extraction lane. A total of 2 pressure test boreholes and 1 extraction hole were constructed on site, all with a diameter of 110mm, an inclination of 30° and an angle of 90° between the borehole and the roadway. During construction, pressure test holes were constructed first, and the distance between observation holes 1#, 2# and 3# and extraction holes were 1.2m, 1.9m and 2.6m respectively, as shown in Figure 4. After the completion of the drilling construction, the pressure gauge was installed, and the hole was sealed by the "two plugging and one injection" method to observe the change of the pressure gauge reading, and after the pressure reading was stabilized, the extraction hole was constructed, and the extraction hole was pumped and released, and the pressure gauge readings of the three surrounding investigation holes were observed and recorded every day. A total of 100d pressure gauge readings were observed on site, and the results of pressure changes in the investigation holes with time are shown in Figure 5.

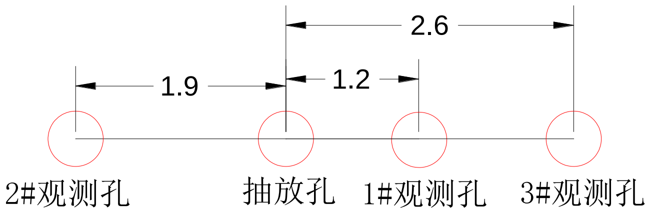


Figure 4: Drill hole layout method

4.2 Analysis of borehole gas pressure decay test results

According to the borehole pressure test results, it can be seen that the borehole gas pressure gradually decreases with the increase of extraction time, and the pressure decay gradually levels off after a certain time. The initial pressure of gas in observation holes 1#, 2# and 3# were 1.02MPa, 1.03MPa and 1.00MPa respectively. After 40d of pumping, the pressure in observation hole 1# dropped to 0.69MPa, observation hole 2# dropped to 0.78Mpa and observation hole 3# dropped to 0.85Mpa; after 70d of pumping, the pressure in inspection hole 1# dropped to 0.59MPa, 2 # inspection hole pressure drops to 0.70Mpa, 3# inspection hole pressure drops to 0.74Mpa; after 100d of pumping 1# inspection hole pressure drops to 0.55MPa, 2# inspection hole pressure drops to 0.66Mpa, 3# inspection hole pressure drops to 0.69Mpa; that is, after 40d of pumping, the effective extraction radius of the borehole is about 1.2m, after 70d of pumping, the effective extraction radius of the borehole The effective extraction radius of the borehole is about 1.9m after 40 d of pumping, about 1.6m after 70 d of pumping, and about 2.6m after 100 d of pumping.

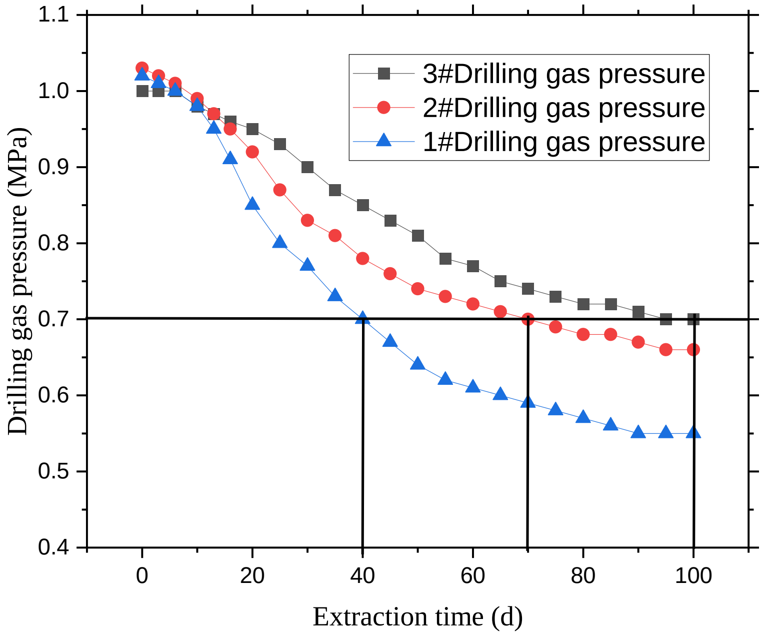


Figure 5: Observation hole gas pressure decay changes

5. Conclusion

(1) In this paper, we take the investigation of the extraction effect of the bottom extraction road 15121 through the seam as the research object, combined with the coal seam itself coal rock physical parameters, by establishing the gas extraction model of the bottom extraction road through the seam, using COMSOL software to simulate the change of the gas effect of the bottom extraction road through the seam with time, that is, after

40d of extraction, the effective extraction radius of the drill hole is about 1.2m, after 70d of extraction, the effective extraction radius of the drill hole is about The effective extraction radius of the borehole is about 1.9m after 70 d of extraction, and about 2.6m after 100 d of extraction.

(2) Observe the change of pressure gauge reading, after the pressure reading is stable, construct extraction boreholes, pump and release the extraction boreholes, observe and record the pressure gauge reading of the three surrounding inspection boreholes every day, combined with the numerical simulation results, it can be seen that with the increase of extraction time, the gas pressure of the boreholes gradually decreases, and after a certain time, the pressure decay gradually leveled off. The validity of the numerical simulation results was tested through field tests, and the two confirmed each other. The field test shows that the measured results are basically consistent with the numerical simulation results, and the research results show that the gas extraction by drilling through the seam in the bottom extraction lane can effectively reduce the coal seam gas content, reduce the risk of coal seam protrusion, and ensure the safe and efficient production of the working face in an orderly manner.

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