

Research of Mining Depth Influence on Floor Coupled Stree-seepage Characteristics

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Abstract

In order to obtain the influence law of mining depth on floor coupled stress-seepage characteristics, the coupled stress-seepage characteristics were studied by numerical simulation. The results showed that when the mining depth increases, the floor failure range progressively increase with expansion of confined water guide rise. As the guide rise of confined water, the permeation velocity became slower. Finally, through the comparative analysis of floor failure process at 800m and 1000m mining depths, the reasonable width of fault waterproof pillar was determined. it was safe to reserve 30m and 40m fault waterproof pillar respectively at 800m and 1000m mining depth.

Keywords: mining depth; plastic area; coupled fluid-solid; fault

1. Introduction

Coal is the basic energy in China, accounting for 70% natural energy, and there is about 2950 billion tons coal occurred at least 1000m of mining depth which is about 53% coal total resource^[1]. As the mining depth increased, the water pressure of aquifer was increasingly great, and the invasion range and height of confined water in aquifuge also increased, which aggravated the potential threat to coal safety production. Field measurements indicated that more than 80% floor water inrush was due to fault

structure. So far, some scholars have studied and gained plentiful research achievements of stress distribution and failure law of floor rock mass by the method of similar material simulation, theoretical analysis, numerical calculation and field measurement^[2-7]. However, the research of floor coupled stress-seepage characteristics with fault was less. The floor failure feature with fault was studied by FLAC^{3D}, revealing the floor coupled stree-seepage characteristics at different mining depths, which provided the theoretical guidance for coal safety production above high confined water of deep mining.

2. Fluid-solid coupling model

The original ground stress changed induced by mining, resulting in the occurrence and migration change of underground water, which influenced the underground seepage field distribution; the seepage field had certain effect of stress state of coal and rock mass by hydrostatic and hydrodynamic pressure, and permeation. Then, the failure of coal and rock mass in turn influenced the seepage characteristics of underground water. Therefore, before studying the floor failure characteristics under coupled stress-seepage, some basic hypotheses were put forward according to floor rock mass and fluid-solid coupling model of confined water was established^[8-13]. There were four basic hypotheses as follows.

(1)The matrix rock mass could be simplified to elastic medium with isotropy and continuity, whose stress and strain obeyed to generalized hook's law.

$$\sigma_{ij} = \lambda \delta_{ij} e + 2\mu \varepsilon_{ij} \quad (1)$$

In the formula, σ_{ij} stands for total stress tensor; δ_{ij} is kronecker's sign; λ , μ represents lame constants; ε_{ij} is total strain; e stands for volumetric strain.

(2)The surrounding rock was saturated and the water was compressible fluid.

(3)The permeability coefficient k of rock mass was not a constant, which is related to plastic area. The permeability coefficient in plastic area was bigger than that of the other area. In a micro-segment pressure gradient, seepage obeyed to darcy's law, that is:

$$q = k \frac{\partial p}{\partial x} \quad (2)$$

In the formula, q is flow; k stands for permeability coefficient; p represents water pressure.

(4) The effective stress of surrounding deformation obeyed to Biot's law, that is:

$$\sigma_{ij} = \overline{\sigma}_{ij} + \alpha p \delta_{ij} \quad (3)$$

In the formula, α stands for Biot's coefficient; $\overline{\sigma}_{ij}$ is effective stress tensor; σ_{ij} is total stress tensor; δ_{ij} represents kronecker's sign.

Based on the basic hypotheses above, the fluid-solid coupling model of confined water was established.

seepage formula

$$k_x \frac{\partial^2 p}{\partial x^2} + k_y \frac{\partial^2 p}{\partial y^2} + k_z \frac{\partial^2 p}{\partial z^2} = S \frac{\partial p}{\partial t} + \frac{\partial e}{\partial t} + W \quad (4)$$

balance equation

$$(\lambda + \mu) U_{j,ji} + \mu U_{i,ij} + F_i + (\alpha p)_{,i} = 0 \quad (5)$$

In the formula, S represents for water storage coefficient; W is source and sink; e is volumetric deformation; p is water pressure; α stands for Biot's coefficient.

Stress boundary condition: $\sigma_D = \sigma_0$;

displacement boundary condition: $\delta_D = \delta_0$;

constant water head: $h_D = h_0$;

constant flow condition: $\frac{\partial h}{\partial n} = g$.

3. Numerical model establishment

Based on some data of fluid-solid coupling material at home and abroad^[14-15], the numerical model was established shown in Fig. 1. The simulation range was 180m long(X axis), 300m wide(Y axis) and 90m high(Z axis). The distance of excavated coal was 100m and the fault was 3m wide. The bottom of model was limestone of ordovician. There was 173910 nodes and 164700 units.

The model boundary conditions were: the boundary of X and Y were constrained in its axis direction, and the bottom side was constrained along Z axis. The weight of overlying strata was loaded above the model by surface force. The floor coupled stress-seepage characteristics was simulated at 800m and 1000m depths. The rock parameters for numerical simulation were chosen from Tangkou coal mine in Shandong Energy Zibo Mining Group Co.,LTD, which were shown in Table1.

Table. 1: Rock parameters for numerical simulation

rock name	rock thickness /m	bulk modulus /10 ⁹ Pa	shear modulus /10 ⁹ Pa	friction angle /°	tension strength /10 ⁶ Pa	bulk density /10 ³ kg /m ³	cohesion /10 ⁶ Pa
fine sandstone	60	12.4	10.4	42	2.9	2.4	3.1
siltstone	18	14.3	12.5	53	3.8	2.1	4.5
medium particle sandstone	10	17	12.5	42	7.8	2.3	6.6
medium particle sandstone	4	12.5	8	46	4.5	2.5	4.5
the above 3 coal	4	4.2	2.4	28	1.0	1.4	1.8
siltstone	4	9	5	40	3.0	2.4	4.0
fine sandstone	14	10	8	48	5.8	2.6	5.0
medium particle sandstone	16	16	10	54	6.4	2.4	6.2
interbedded siltstone . and finestone	8	10	8.5	48	3.9	2.5	4.8
siltstone	12	14.5	13.2	45	3.1	2.7	2.4

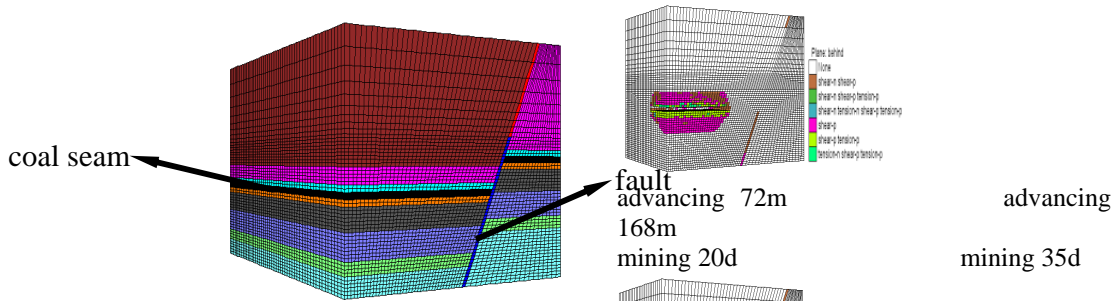
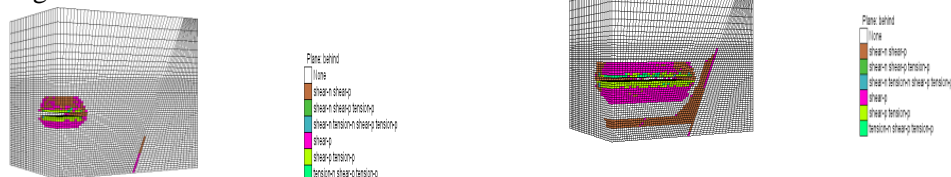


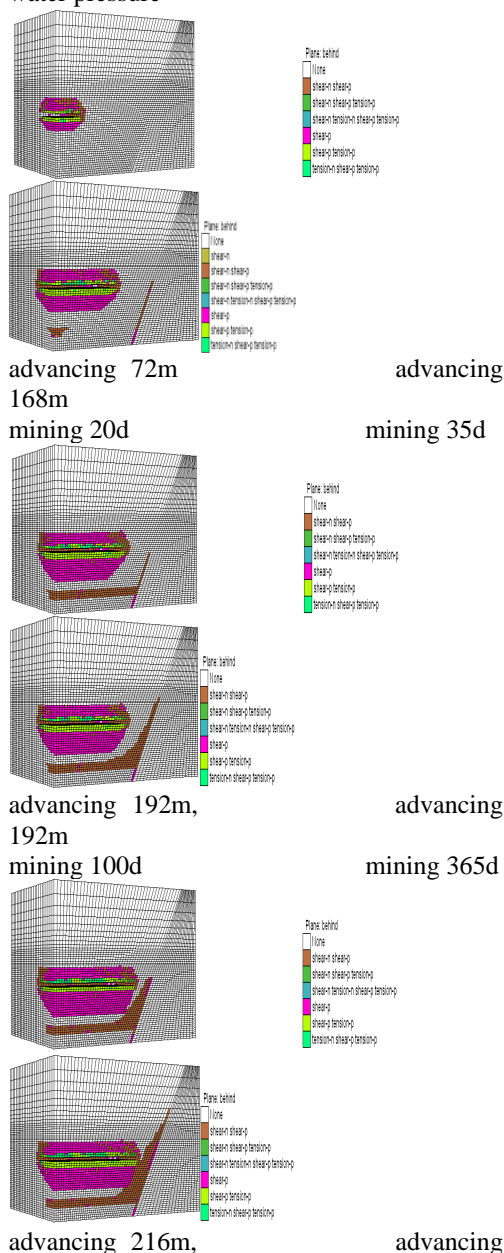
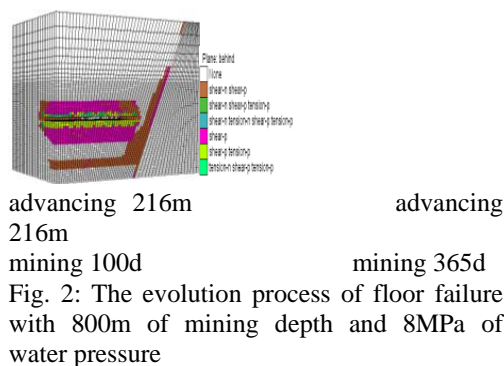
Fig. 1: Floor model with fault of deep mining

4. Simulation result and analysis

4.1 Characteristics of floor coupled stress-seepage

The floor mining failure under coupled stress-seepage was represented by plastic area. The evolution process of floor failure with 800 m of mining depth and 8MPa of water pressure was shown in Fig2, and the evolution process of floor failure with 1000m of mining depth and 10MPa of water pressure was shown in Fig3





216m
mining 100d
mining 365d

Fig. 3: The evolution process of floor failure with 1000m of mining depth and 10MPa of water pressure

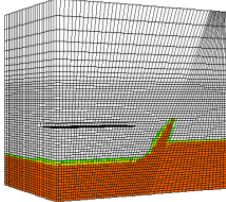
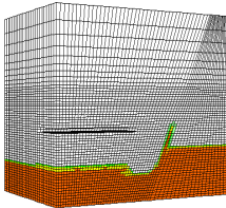
The influence law of mining depth on floor failure under coupled stress-seepage was obtained by comparison study of evolution process of floor failure in Fig2 and Fig3.

(1)The confined water had not risen when the working face was advanced 168m with 800m of mining depth and 8MPa of water pressure, however as the same advancing distance, the floor confined water appeared rise in small range with 1000m of mining depth and 10MPa of water pressure; the range of plastic area also progressively expanded along strike direction not being connected with fault when the mining working face was 192m after 100d with 800m of mining depth, however, the plastic failure area was connected with fault and the conductor was formed which would result in mine water inrush with 1000m of mining depth above strong water pressure; the plastic failure area and guide rise height of confined water with 1000m mining depth were larger than that of 800m mining depth when the working face was mined 365d. These phenomena showed that the deeper of mining depth, the bigger of floor stress, and the high stress promoted the seepage guide rise of confined water, accelerating the floor plastic failure; (2)As the mining depth increased, the coupled stress-seepage had greater effect on floor rock mass, and the floor failure depth and range also increased. The guide rise range and height of confined water were raised. However, as the guide rise of confined water, the permeation velocity of confined water became slower;

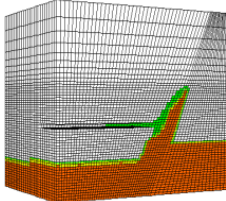
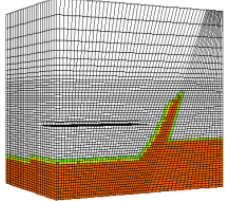
(3)The fault water inrush of deep mining had the obvious lag characteristics. Because as the working face advancement,

the strength of fault substance progressively decreased due to mining stress and high confinde water, and the weaken range developed upward along the fault. At last, the guide rise was higher enough to connect with the mining failure zone.

4.2 Change law of floor water pressure

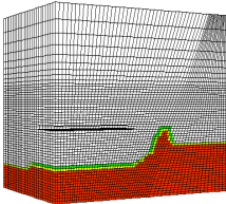
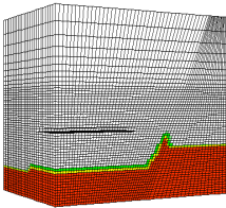


advancing 192m,
192m
mining100d
365d

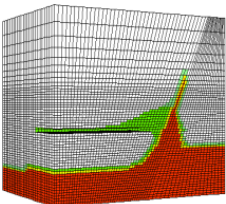
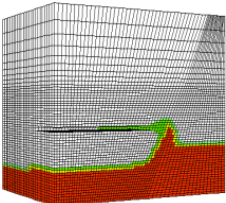


advancing 216m
216m
mining 100d
365d

Fig. 4: Change process of water pressure with 800m of mining depth and 8MPa of water pressure



advancing 192m,
192m
mining 100d
365d



advancing 216m
216m
mining 100d
365d

Fig. 5: Change process of water pressure with 1000m of mining depth and 10MPa of water pressure

The change process of floor water pressure with 800m of mining depth and 8MPa of water pressure was shown in Fig4, and the change process of floor water pressure with 800m of mining depth and 8MPa of water pressure was shown in Fig5.

The change law of water pressure under coupled stress-seepage condition at different depths was obtained by

comparison study of evolution process of floor failure in Fig4 and Fig5.

(1) As the time went on, the confined water developed upward along fault due to water pressure and the water pressure changed small when the working face was mined 100d, however, the guide rise height of confined water was up to 75m next year.

(2) The guide rise velocity of water pressure along fault was initially fast and became progressively slower. At the same mining time, the deeper of mining depth, the bigger of water pressure. For example, the guide rise range of confined water had not connected with goaf when the working face was advanced 216m at 800m mining depth, however, the conductor connected with goaf and guide rise range of confined water had already been formed at 1000m mining depth with the same advancing distance.

5. Fault pillar reservation

From the simulation results above, the floor confined water was connected with mining failure zone, and the fault pillar had lose the ability to obstruct water when the fault waterproof pillar was 19m of width and the working face was mined 365d (the mining distance was 216m) at 800m and 1000m mining depth. The fault waterproof pillar was well, leaving 15m intact obstructing width when the fault waterproof pillar was 31m of width and the working face was mined 365d (the mining distance was 192m) at 800m mining depth, as the same mining condition at 1000 mining depth, there was still 6m of elastic nuclear zone between guide rise zone of confined water and mining failure zone, so the working face had the potential to water inrush. Therefore, the reasonable fault waterproof pillar above high confined water could be determined by numerical simulation, and it was safe to reserve 30m and 40m respectively at 800m and 1000 mining depths.

6. Conclusions

(1) As the mining depth increased, the coupled stress-seepage had more effect on floor rock mass, and the floor failure depth and range increased. The guide rise range and height of confined water were raised. However, as the guide rise of confined water, the permeation velocity of confined water became slower;

(2) The fault water inrush of deep mining had the obvious lag characteristics. The guide rise velocity of water pressure along fault was initially fast and became progressively slower. At the same mining time, the deeper of mining depth, the bigger of water pressure;

(3) Based on the numerical simulation results of floor failure, the reasonable fault waterproof pillar above high confined water were determined by studying the floor coupled stress-seepage characteristics at 800m and 1000m mining depths, and it was safe to reserve 30m and 40m respectively at 800m and 1000 mining depths. The simulation research provided the theoretical guidance for coal safety production above high confined water in field deep mining.

7. References

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