Study on stress and strain of underlying coal rock in protective layer of "Three Soft" coal seam

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Abstract

Mine gas disasters can cause casualties and property losses, which seriously affect the production of coal mining enterprises. In order to study the variation law of stress and strain of the underlying coal seam during the mining process of the upper protective layer and reduce the occurrence of gas outburst accident in the high stress area, this paper uses COMSOL to simulate the distance of different coal and rock. The results show that within a certain range, the protective layer mining can effectively reduce the pressure of the coal seam in the protected layer.

Keywords

Protective layer, Numerical simulation, Stress distribution, Plastic deformation, Creep.

1. Introduction

Nowadays, many coal mines have entered deep mining, coal seam stress has increased, mining conditions have become increasingly complex and deteriorated, and coal and gas outburst have become major factors threatening the safe and efficient mining of mines[1-2]. For coal seams with coal and gas outburst danger, upper protective layer mining is the preferred regional defense prevention measure [3]. The protective layer mining can change the ground stress and gas pressure state of the upper and lower adjacent dangerous coal seams, and the pressure of the protected layer is relieved[4], Release the elastic potential of the coal seam and increase the permeability of the coal seam [5]. At present, considering the creep damage of coal body, there are few studies on the combination of the creep failure stress of coal rock mass. Based on this, the creep dynamics model of coal mining coal seam is established, and the stress and strain characteristics of the underlying coal rock mass during the upper protective layer mining process are studied by numerical simulation.

2. Model building

2.1 Mathematical model construction

The coal body deformation control equation is described by the Poyting-Tomoson model. The Poyting-Tomoson model (hereinafter referred to as the P-T model) is a creep mechanics model. The establishment of the following four basic assumptions is required.

(1) The coal body is a homogeneous elastic medium.

(2) The entire system is isothermal.

(3) The lateral restraint of the coal body remains unchanged, that is $\Delta\varepsilon_{xx}=\Delta\varepsilon_{yy}=0$, the total overburden pressure remains unchanged, that is $\Delta\tau_z=0$.

(4) The shrinkage and expansion of the matrix are similar to the thermodynamic shrinkage and expansion. The expansion and contraction strain caused by adsorption are isotropic.

The mathematical model used in this paper is:

$$\Delta\varepsilon_i=\frac{\sigma_i}{E_{Hi}}-\frac{E_{Mi}\sigma_i}{(E_{Mi}+E_{Hi})\ E_{Hi}}\exp[-\frac{E_{Mi}E_{Hi}}{(E_{Mi}+E_{Hi})\ \eta_i}t]-\sum_{j=x,j\neq i}^{z}\left[\mu_{ji}\left[\frac{\sigma_j}{E_{Hj}}-\frac{E_{Mj}\sigma_{ij}}{(E_{Mj}+E_{Hj})\ E_{Hj}}-\exp\left[-\frac{E_{Mj}E_{Hj}}{(E_{Mj}+E_{Hj})\ \eta_j}t\right]\right]\right]+\Delta\varepsilon_i^s+\alpha_i\Delta T \quad (1)$$

among them, $\Delta\varepsilon_i$ - Total strain; σ - stress, Pa; M-Body of Maxwell; H- Body of Hooke; E_M- Elastic Modulus of M body; E_H- Elastic Modulus of H body; η- Viscosity coefficient of Newtonian body, Pa·S; t-time, S; μ_{ji} - Poisson's ratio; ε^s - Volumetric strain; α - Temperature correction factor; T- Kelvin temperature, K.

2.2 Physical model construction

The geometrical dimensions of the model constructed in this paper are length × width = 300m × 50m. The model diagram is shown in Figure 1. The physical and mechanical parameters of the layers from top to bottom are shown in Table 1. In this paper, the stress-strain changes of the underlying coal seams with the protective layer mining to 20m, 40m and 60m are studied separately, and the mining distance of the protective layer is 40 m. The stress-strain changes of the protective layer with the coal seam spacing of 6m, 9m and 12m are studied respectively.

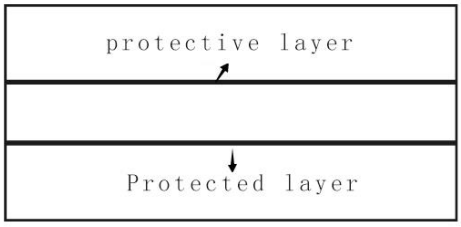

Fig.1 Physical model diagram

Table1 Physical and mechanical parameters of coal and rock layers

Lithology	Thickness /m	density /kg.m3	Elastic Modulus /MPa	Viscoelastic modulus /MPa	Poisson's ratio	Cohesion /MPa	Internal friction angle /°
Middle sandstone	16	2600	10000	--	0.2	3.00	31
Sandy mudstone	4	2500	4000	--	0.23	0.80	28
The protective layer	3	1500	1800	10000	0.25	0.10	26
Sandy mudstone	8	2500	2000	--	0.23	0.50	28
Protected layer	4	1800	1800	10000	0.25	0.10	26
Mudstone	3	2500	2000	--	0.22	0.13	26
Sandy mudstone	12	2500	4000	--	0.23	0.50	0.50

2.3 Restrictions

In this paper, the bottom of the model is set as a fixed constraint, the left and right sides are respectively roller support, and the upper part is applied with a uniform load of 20Mpa.

2.4 Simulation result

2.4.1 Different mining distance simulation results

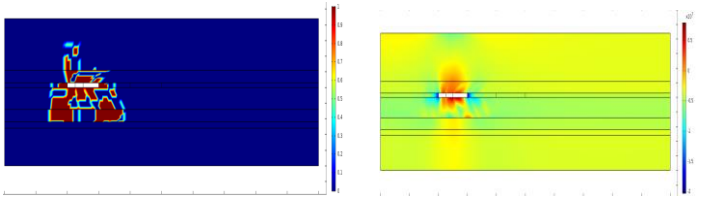

Fig.2 20m stress strain cloud map of protective layer mining

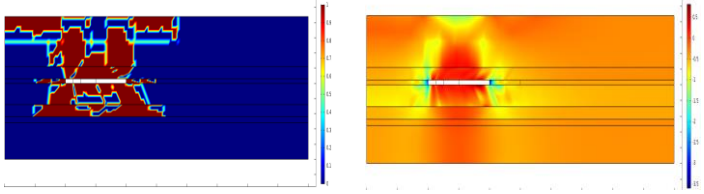

Fig.3 40m stress strain cloud map of protective layer mining

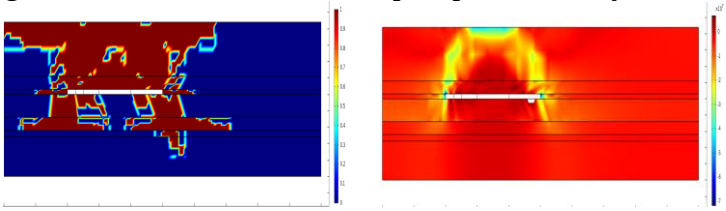

Fig.4 60m stress strain cloud map of protective layer mining

(1) Analysis of strain variation characteristics of underlying coal rock in protective layer mining

It can be seen from Fig. 2 to Fig. 4 that with the advancement of the working face, the plastic strain of the underlying coal seam of the protective layer shows a large increase trend. When the working surface is advanced to 60m, the area where the plastic strain occurs in the lower coal seam about 16.7m returns to the initial state, but the plastic deformation region still shows an increasing trend. It shows that when the protective layer is within a certain mining range, the underlying coal seam will generally undergo expansion deformation, because the exploitation of the protective layer causes the stress above the underlying coal seam to re-distribute, but because the underlying coal rock is still subject to The effect of lateral pressure, so it will produce a sharp expansion and deformation characteristics. When the length of the protective layer exceeds a certain value, the plastic strain will recover in the vertical direction of the protective layer.

(2) Analysis of stress variation characteristics of underlying coal rock in protective layer mining

When the protective layer is mined, it will have a strong pressure relief effect on the underlying coal seam, and the underlying coal seam stress will undergo a process of increasing, decreasing, and increasing. When the protective layer is mined to 40 m, a relatively stable unloading will be formed. The pressure angle, with the advancement of the mining face (to 60m), the pressure relief angle did not change significantly.

2.4.2 Simulation results of different coal seam spacing

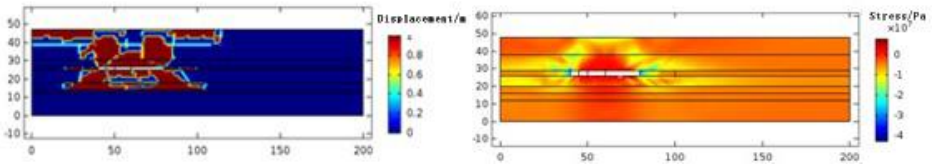

Fig.5 6m layer spacing stress strain cloud map

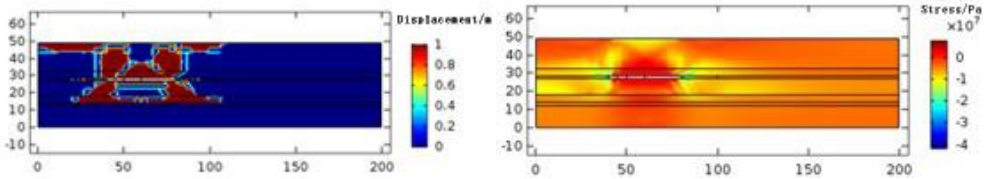

Fig.6 9m layer spacing stress strain cloud map

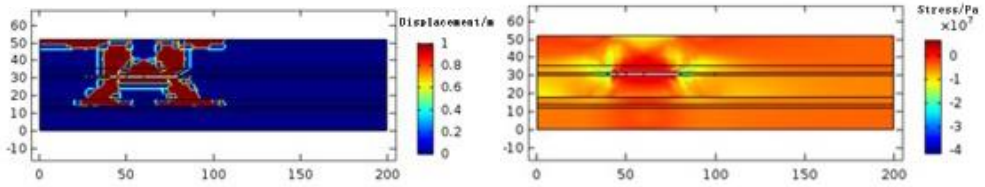

Fig.7 12m layer spacing stress strain cloud map

In the 40m range of protective layer mining, when the coal bed interval is 6m, the continuous deformation zone formed by the protected coal seam, the maximum influence distance is 87.5m, the protected coal seam has obvious pressure relief, and the maximum pressure relief pressure is about 1MPa.When the coal seam spacing is 9m, the part of the protected coal seam is deformed, the maximum displacement deformation distance is 78m, the pressure relief area is reduced compared with the layer spacing of 6m, and the maximum pressure relief pressure is 0.9MPa. When the coal seam spacing is 12m, the continuous deformation zone of the protected coal seam is obviously destroyed. The maximum displacement is 68m and the maximum pressure relief is about 0.7MPa. When the coal seam is 20m, the maximum displacement is 52m and the maximum pressure is about 0.2 MPa.

3. Conclusion

(1) The exploitation of the upper protective layer will cause the underlying coal seam to undergo plastic deformation - two stages of deformation recovery;

(2) The mining of the upper protective layer has a strong pressure relief effect on the underlying coal seam, and the pressure relief effect decreases linearly with the increase of the coal seam spacing; the underlying coal seam stress will experience an increase → decrease → increase In the large process, when the mining face of the protective layer is pushed to a certain distance, the underlying coal seam will form a relatively stable pressure relief angle; affected by the creep damage of the coal rock, with the advancement of the working face of the protective layer and the passage of time, under the undulation The coal seam pressure relief angle has increased, but the increase is relatively small;

(3) During the mining process of the protective layer, the stress and strain changes of the underlying coal seam are basically the same; the exploitation of the protective layer contributes to the formation of the gas pressure relief channel of the underlying coal seam, which is conducive to the release of gas in the underlying coal seam.

(4) The mining effect of the protective layer on the mining of the underlying coal seam is characterized by an inverted “V” type distribution. As the spacing of the coal seam increases, the phenomenon becomes more obvious;

(5) Within a certain range of coal seam spacing, the exploitation of the protective layer can effectively release the pressure of coal and gas in the protected coal seam and reduce the occurrence of coal and gas accidents.

Acknoledgments

National Natural Science Foundation Project (51574153, 51804176), (ZR2014EEM043, ZR2018P EE001), Natural Foundation of Shandong Province（J18KA187）,Scientific and Technological Project Funding of Qingdao West Coast New Area (Huangdao District)（2014-1-62）.

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