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Research on the Height of Water Flowing Fractured Zone of Fully Mechanized Caving Mining in Extra-thick Coal Seam

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Abstract

Failure height of overlying rock mass in extra-thick coal seam conditions by fully mechanized caving mining affects the groundwater occurrence condition, which in turn, affects mine safety. Aiming at extra-thick coal seam conditions, this paper numerically stimulates the dynamic process of actual excavation. Results show that failure height increases with excavation volume, thereby increasing the location of abscission layer dropping along with increasing failure height. An abscission layer is formed along the depth, changing the condition of groundwater occurrence and exposing a hidden safety hazard in the field of continuous mining. The simulation results are in line with the fact by verification with drilling survey data.

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1. Introduction

The Fushun coalfield is a fault basin with an axial, which is nearly east-westward of an asymmetric syncline structure. The north limb is steeper than the south limb, with angles of approximately 30° – 60° and 15° – 30°, respectively. Due to the impact of crustal movement, faults F1 and FA were produced

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in the northern coalfield, thereby destroying the syncline integrality. The impact of crustal movement may have also led to some or all of the missing coal rocks in the north limb.

There are three layers of coal occurrence in the Fushun coalfield: the “mining coal bed” and the A and B coal seam layers. The main layer is the “mining coal bed,” which is a rare, single extra-thick coal seam layer. It has maximum, minimum, and average thicknesses of 130, 8 and 50 m, respectively, as well as a maximum burial depth of 1300 m. At present, the Laohutai mine has applied the comprehensive mechanization of the mining top coal caving mining method.

2. Numerical simulation analysis of the height of water flowing fractured zone in fully mechanized caving mining

2.1 Design of the model control range

Figure 1 shows the 5200e section engineering geology and distribution of the mining area. Analyzing the model using elastic-plastic yield criterion of Druck-Prager, the 5200e section emerges as the center and expands 500 m to north and south sides, respectively. It has a length of 3000 m, a height of 1275 m, and a model geometric size of 3000 m × 1000 m × 1275 m along the depth. The numerical model is divided into 12,024 units and 51,165 nodes. Simulation mining is a four-step process. The Fushun Laohutai coalfield has gently inclined thick seam with a mining advance direction of south to north. The south mining area has not been used since the 1950s, and majority of the remaining area employs a long-wall mining method. Due to the approximate continuity of production time, new and old mining areas are now adjacent; thus, the overlying rock equilibrium state of the old mining area is affected by the new mining area, producing a superposition effect. On the other hand, the activation of the old mining area can act on the new mining area, constituting a “chain” system and dynamic change process. Overlying rock mass movement and deformation mechanism are relatively complicated. In order to make the results more realistic, we simulated an actual mining order and process and combined the simulation with data of engineering geological characteristics.

![Fig. 1. Section 5200e stratigraphy and geological structure map](image)
2.2 Results and analysis of the numerical simulation of the 5200e section

From the numerical simulation, results can be drawn by following some laws (see Figs. 2–Fig.5).

① As the mining geometric space increases, the scope of movement and damage also increases. This is basically the same as the results of conventional theory [1, 2].

② Simulation results show that the new excavation affects the mobile basin of the old mine, that is, the second step excavation has a disturbing and destructive effect on the movement and failure zone caused by the first step excavation. This is also reflected in two aspects. One is the destructive effect on the original balance body due to the overlapping of the disturbance region. Follow-up excavation can disturb or destroy the stress state of the previous excavation, thus damaging its balance. The second aspect is the increase in the original failure zone and mobile range, which is mainly due to the disturbance of the previous excavation balance body coming from the follow-up excavation. The previous mobile region continues to move and does not stop until a new equilibrium occurs.

Analyzing the dynamic evolution of the stress field makes it easier to understand, because the following disturbing effects have changed the distribution of the original stress field. Assuming that the original rock stress state is \( \{ \sigma_0 \} \), then the first mining-induced stress changes \( \{ \Delta \sigma_1 \} \). When the rock mass reaches steady-state, the stress state \( \{ \sigma_1 \} = \{ \sigma_0 \} + \{ \Delta \sigma_1 \} \). If the second mining-induced stress changes \( \{ \Delta \sigma_m \} \), the stress field in the rock mass of the overlapping parts of double mining becomes \( \{ \sigma_2 \} = \{ \sigma_1 \} + \{ \Delta \sigma_m \} \), because of the overlapping part of double mining influence domain. If the stress changes are divided by different mining times, then the mining-induced stress changes are \( \{ \Delta \sigma_{d2} \} , \{ \Delta \sigma_{d3} \} , \ldots \{ \Delta \sigma_{d(n-1)} \} \) due to continuous exploitation in the underground mining area. The state of the stress field of rock mass is \( \{ \sigma_3 \} = \{ \sigma_2 \} + \{ \Delta \sigma_{d3} \} , \{ \sigma_4 \} = \{ \sigma_3 \} + \{ \Delta \sigma_{d3} \} , \ldots \{ \sigma_i \} = \{ \sigma_{i-1} \} + \{ \Delta \sigma_{d(n-1)} \} \), thereby constituting a continuous dynamic superposition system. Stress changes generated by the exploitation of every step in \( \{ \Delta \sigma_{di} \} \) affect the previous stress field \( \{ \Delta \sigma_i \} \) and form new stress fields; thus constituting a dynamic process of change.

③ The ratio change between damage height and mining thickness as shown in Table 1 has an average ratio value of 6.2. The comparison of failure height and mining thickness shows that the ratio micro-increased with the increasing mining steps. This is because follow-up mining activities have destructive effects on the previous mining area. This is in accordance with the laws of the actual damage [3, 4].

④ The damage height of the overlying rock mass increases with excavation volume or mining intensity.

⑤ Increase of mining depth has positive and negative contact stress is downward, that is, the location of the abscission layer is gradually downward; however, if the entire excavation process is combined, it can leave several separation zones. Based on two sections, the simulation results in Table 2 show that the abscission layers of the first, second, third, and fourth step excavations are 120–200, 320–515, 520 and 500–580 m away from the surface of the earth, respectively. Detailed locations are shown in Figs. 4 and 5; among them, the shortest distance apart from the surface is 120 m. Through the borehole investigation, we find that the abscission layer is 130 m underground, which is similar to the simulation result.
Fig. 2. Stress distribution contour map of the Y direction in mining step 4.

Fig. 3. Principal stress vector distribution of the X direction in mining step 4.
Fig. 4 Failure height zoning map of overlying rock mass after excavation.

Fig. 5 Stress distribution along the depth of overlying rock mass after excavation.

Table 1. Contrast relation between failure heights and the mining thickness of the 5200e section.

<table>
<thead>
<tr>
<th>Excavation step</th>
<th>The average thickness of caving (m)</th>
<th>Failure height (m)</th>
<th>Failure height / Mining thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>92.1</td>
<td>532.9</td>
<td>5.8</td>
</tr>
<tr>
<td>2</td>
<td>94.5</td>
<td>575.2</td>
<td>6.1</td>
</tr>
<tr>
<td>3</td>
<td>94.7</td>
<td>590.9</td>
<td>6.2</td>
</tr>
<tr>
<td>4</td>
<td>91.6</td>
<td>648.1</td>
<td>6.7</td>
</tr>
</tbody>
</table>
Table 2. Relationship between excavation step and the height of the abscissa layer away from the surface

<table>
<thead>
<tr>
<th>Excavation step</th>
<th>Height of the abscissa layer away from surface (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>120–180</td>
</tr>
<tr>
<td>2</td>
<td>320, 510</td>
</tr>
<tr>
<td>3</td>
<td>500, 720</td>
</tr>
<tr>
<td>4</td>
<td>500–580, 640</td>
</tr>
</tbody>
</table>

3. Conclusions

It is difficult to confirm the height of water flowing fractured zone and the destruction property of overlying rock mass under extra-thick coal seam caving conditions [5–7]. In this paper, we used the example of the Fushun Laohutai Coal Mine and applied numerical simulation methods to study the distribution of water flowing fractured zone induced by stratified caving. Based on the comparative analysis with the actual drilling observational data, the result is in line with the actual findings. Therefore, the numerical simulation method can be used for confirming danger zones and ensuring safe mining activities.

Acknowledgments

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