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The Study on Ground Stress Measurement and the Stress Distribution Rule on E-W both Sides of Fault F₁₇ of Ore Body Ⅱ in Jingchuan Orefield

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Abstract

The comprehensive study results of variation rule of the stress in the orefield following the measurement depth had been done by mainly put forward the ground stress measurement of level 1200m, 1150m and 1000m of ore body Ⅱ in Jingchuan orefield. The dimension and direction of ground stress of 16 points on E-W both sides of fault F₁₇ are attained by these measurements. The study result shows that the average of maximum principal stress of west fault F₁₇ is about 25MPa, whereas that east of this fault is 20MPa. The general direction of maximum principal stress is NE-NNE, with somewhat local variation. The principal level of horizontal stress weakens progressively in the deep mining area. Nevertheless, the situation of different part of each level isn’t the same as one another. The increase of difference between dimensions of maximum and minimum principal stress shows the increase of shear stress in the deep mining area and the increase of intensity of shear damage. Above the buried depth 500—600m, the maximum principal and horizontal stress shows a linear increase following the increase of depth, whereas the tendency of increase becomes gentle beneath the buried depth 500—600m.

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Keywords: Ground stress Measurement; Jingchuan orefield; Stress relieving method; Distribution rule

1. Introduction

Jinchuan orefield is one of the 3 greatest bases of comprehensive utilization of resources in China. Moreover, it is one of the Cu-Ni sulfide deposits of extraordinarily great scale in the world. Because the complicated geological conditions and high ground stress, the serious deformation and damage of channel in the mining process, the construction and development of the mine have been restricted seriously. The orefield 2 is the principal mine of Jinchuan Mining Group(Ltd). And the ore body Ⅱ in Jinchuan orefield
has been mainly mined many years. In 2000, Jinchuan Mining Group(Ltd) decided to name the original opencast mine of Jinchuan Group(Ltd) “the orefield 3 of Jinchuan Mining Group(Ltd)”, which is responsible for the mining of ore body II east of the fault F_17 in Jinchuan orefield. In 2000, the ore yield of orefield 2 was 420 × 10^4 t, that of orefield 3 150 × 10^4 t, more than 70% of the general ore yield of whole mine. Therefore, the safety, high efficiency and continuity in mining process of them are very significant for the whole mine.

Since 1996, the mining process in orefield 2 below the level 1150m has become the contemporaneous production on 2 levels, formed the horizontal and vertical ore pillars. By the mining process in 10 years, the horizontal pillars become more and more thinner, the height of vertical ones increased continuously. And in recent years, because the horizontal ore pillars of level 1150m have become more and more thinner, the agent of ground pressure of mining area become more and more intense, the deformation of channel more and more intensive. Especially in 2000, people paid great attention to the appearance of deformation and fissure on the surface. At the present time, as to the application of continuous mining method of large area without pillar to the deep engineering, which is not only inexperienced in China, but also unexampled in the world. It is a worldwide difficult problem. Among so many influential factors on the stability of underground engineering, the environment of ground stress is the decisive basic factor. The study on the relationship between deep stress state and stability of underground engineering is the key to the settlement of other problems. Therefore, since 1970s, a series of ground stress measurement and study have been continuously carried out in the orefield(Tab 1.).

Tab 1. Ground Stress Measurement in the Orefield

<table>
<thead>
<tr>
<th>No</th>
<th>Undertaking Unit</th>
<th>Measuring Method</th>
<th>Point</th>
<th>Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Changsha Institute of Mining &amp; Metallurgy, etc</td>
<td>Stress Relief Method of Drill Hole Casing Core</td>
<td>3</td>
<td>1973–1974</td>
</tr>
<tr>
<td>2</td>
<td>Geomechanics Institute, etc</td>
<td>Stress Relief Method of Drill Hole Casing Core(Piezomagnetic Inductance Method)</td>
<td>8</td>
<td>1975-1981</td>
</tr>
<tr>
<td>3</td>
<td>Lithomechanics Group</td>
<td>Stress Relief Method of Drill Hole Casing Core(Hollow Inclusion Method)</td>
<td>3</td>
<td>1986-1988</td>
</tr>
<tr>
<td>4</td>
<td>Beijing University of Science &amp; Technology</td>
<td>Stress Relief Method of Drill Hole Casing Core</td>
<td>11</td>
<td>1994-1997</td>
</tr>
<tr>
<td>5</td>
<td>Lanzhou University</td>
<td>Sound Emission(Kaiser)</td>
<td>9</td>
<td>2001</td>
</tr>
<tr>
<td>6</td>
<td>Geomechanics Institute</td>
<td>Stress Relief Method of Drill Hole Casing Core(Hollow Inclusion Method)</td>
<td>16</td>
<td>2004-2007</td>
</tr>
</tbody>
</table>

In 2004—2007, the key project of stress field and lithomechanics study was undertaken unitedly by Geomechanics Institute of China Academy of Geosciences, Longshou Orefield of Jingchuan Group(Ltd), Orefield 2 of Jingchuan Group(Ltd), Northeast University, Jingchuan Institute of Ni-Co Study & Design, Geophysics Department of Beijing University and Orefield 3 of Jingchuan Group(Ltd). According to the comprehensive consideration of the structural characteristics and rock completion, etc, the ground stress measurement was carried out in the important places, such as the deep part of Orefield 2 and its neighboring deep part of Orefield 3, which have provided the important data for the study of stress characteristics and distribution rule in deep part of Jingchuan Orefield.

2. Measuring Method and Spot Measurement

The measurement precision of hollow inclusion stress relief method is higher than others. And its installation and operation are simple, efficient and this method can measure the 3-dimension stress state of rock body in a single drill hole, which has been applied widely in the ground stress measurement of underground engineering. So we apply the hollow inclusion stress relief method to the measurement this
2.1. Structure of Stress Detector

The stress detector is mainly composed of 12 resistance strain flakes set in the epoxy resin tube. The 3 sets of gage rosette are stamped around the epoxy resin tube at interval 120° one another(Fig 1.) The surface of stress detector is poured with epoxy resin in order to fix the resistance strain flakes in the tube wall. The thickness of outer epoxy resin crust is about 0.5mm.

In the epoxy resin tube, there is an internal cavity, which is specially utilized for filling the bonding agent, and outfitted with a tube plug. During the measurement, the internal cavity is fully filled with bonding agent first, and then the plug is put into the internal cavity about 40mm, and fixed with aluminum wire. In order to install the stress detector in the requisite place. A guide location stick is outfitted on the another plug end. After the stress detector is put into the predetermined position, to push the outfit pole strenuously, cut the aluminum wire, successively push the pole until the bonding agent flows out of the plug pore and fills the interval between the stress detector and the wall of drill hole. The casing core relieving can be carried out after the bonding agent is completely solidified.

2.2. Manufacture of Stress Detector

The epoxy resin round tube is made with the casting mold. At first, add suitable filling material in the epoxy resin, stir evenly, get rid of the air bubble, add the solidified agent, stir evenly, pour into the mold, next put it into the incubator for heating, solidification of epoxy resin, and then knockout until it has a certain mechanical ability, so that the qualified epoxy resin round tube is completed. In order to cause the stress detector to have good insulation, the outer surface must be cast after the gage rosette flakes are stamped on the surface of round tube. The manufacture of other spare parts plug, etc is as same as the mentioned above.

2.3. Spot Ground Stress Measurement
On the measurement point, make a horizontal drill hole, diameter Ф130mm, to the predetermined depth. The drill hole is upward slightly, with elevation angle 2--5°, for the dust and water flowing out easily. Then, make a belled inlet for the convenience of correction guide. Next, make a small measurement hole Ф36mm. After completion, it is washed first with water, then wiped with alcohol or acetone, finally the stress detector is installed. Before installation, the necessary preparation must be taken. Afterwards, fill the bonding agent into the internal cavity of bonding agent, fix the plug, put the stress detector to the requisite place, cut the aluminum wire, fill fully the bonding agent into the interval between stress detector and wall of drill hole. After the solidification of bonding agent, record the set A of gage rosette and the perpendicular included angle(installation angle) of stress detector with the direction finder, read the original data of various strain flakes with the collector, then relieve with Ф130mm concentric drilling. Before the casing core relief, washing with water first. In the meantime, the readings of strain flakes will change. The relief must be carried out after the readings stabilize then. In order to discriminate the state of stress detector and the reliability of measurement, the detection must be carried out in the casing core process. Stop casing core until the readings don’t change following the change of drilling footage. After the casing core finishing, take out the rock core with stress detector, then put into the confining pressure rate tester for demarcation, determine the elasticity modulus and Poisson ratio, and detect the working state of stress detector. By the end of the measurement, determine the direction and dip angle of the drill hole.

2.4. Arrangement of Measurement Point

Basing upon the spot investigation, select the spot measurement point of stress in combination with the spot construction conditions. The spot measurement of 16 points is completed separately on the level 1000m, 1150m of Orefield 2 and level 1200m of Orefield 3 east of F17. The specific arrangement of measurement point is as follows: there are 7 points on the level 1000m, ie, line 6 marble(wall rock) measurement point 1; line 12 rich ore body measurement point 1; line 14 rich ore body measurement point 1; line 20 rich ore body measurement point 2; line 22 rich ore body measurement point 1 and line 25 contact between rich and poor ore body measurement point 1, 2 points on the level 1150m, ie, granite body of Xinfen ore channel points 2(wall rock), 7 points on the level 1200m of Orefield 3 east of F17, ie, line 47.5 poor ore measurement point 1; line 52 poor ore measurement point 1; line 47 poor ore measurement point 1; line 45 poor ore measurement point 1; line 44 poor ore measurement point 1; line 43 poor ore measurement point 1 and line 40.5 poor ore measurement point 1(Fig 2, 3, 4).

![Fig 2. Distribution of Stress Measurement Point on Level 1000m of Orefield 2](image-url)
3. Measurement Result

In the measurement, the stress relief curve and rating curve of 16 measurement points mostly show the evident change rule, which indicate that the stress measurement is normal. Because there are a lot of measurement data, only the stress relief curve and rating curve of line 47 measurement point on level 1200m are put forward in this paper. (Fig 5.) In the meantime, for the sake of convenient analysis, the stress ellipse of various section of different normal direction of line 47 measurement point on level 1200m are also put forward. (Fig 6.) The known original data are dealt with by the least squares method in order to take the most confident data.
Fig 5. Stress Relief Curve and Rating Curve of Line 47 Measurement Point on Level 1200m

Fig 6. Stress Ellipse of Various Section of Different Normal Direction of Line 47 Measurement Point

Tab 2. Ground Stress Measurement Results of Various Orefield

<table>
<thead>
<tr>
<th>Point Position</th>
<th>Object</th>
<th>Major Main Stress</th>
<th></th>
<th>Minor Main Stress</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Value (Mpa)</td>
<td>Direction</td>
<td>Dip Angle</td>
<td>Value (Mpa)</td>
</tr>
<tr>
<td>Orefield 2、1000m Line 20, No.1</td>
<td>Rich Ore</td>
<td>25.8</td>
<td>195°</td>
<td>48°</td>
<td>16.2</td>
</tr>
<tr>
<td>Orefield 2、1000m Line 20, No.2</td>
<td>Rich Ore</td>
<td>17.1</td>
<td>217°</td>
<td>-50°</td>
<td>13.2</td>
</tr>
<tr>
<td>Orefield 2、1000m Line 22</td>
<td>Poor ore</td>
<td>22.3</td>
<td>195°</td>
<td>45°</td>
<td>14.7</td>
</tr>
<tr>
<td>Orefield 2、1000m Line 25</td>
<td>Poor ore</td>
<td>27.6</td>
<td>246°</td>
<td>7°</td>
<td>12.3</td>
</tr>
<tr>
<td>Orefield 2、1000m Line 6</td>
<td>Marble</td>
<td>21.8</td>
<td>197°</td>
<td>40°</td>
<td>15.5</td>
</tr>
<tr>
<td>Orefield 2、1000m Line 12</td>
<td>Rich Ore</td>
<td>23.2</td>
<td>242°</td>
<td>-18°</td>
<td>15.5</td>
</tr>
<tr>
<td>Orefield 2、1000m Line 14</td>
<td>Rich Ore</td>
<td>28.7</td>
<td>131°</td>
<td>-11°</td>
<td>17.8</td>
</tr>
<tr>
<td>Orefield 2、1150m Xinfen Channel</td>
<td>Granite</td>
<td>23.5</td>
<td>112°</td>
<td>-57°</td>
<td>11.5</td>
</tr>
<tr>
<td>Orefield 2、1150m~1100m Sub-Level</td>
<td>Granite</td>
<td>30.9</td>
<td>237°</td>
<td>20°</td>
<td>14.5</td>
</tr>
<tr>
<td>Orefield 3、1200m Line 47.5</td>
<td>Poor ore</td>
<td>19.4</td>
<td>228°</td>
<td>11°</td>
<td>11.8</td>
</tr>
<tr>
<td>Orefield 3、1200m Line 52</td>
<td>Poor ore</td>
<td>21.1</td>
<td>151°</td>
<td>-37°</td>
<td>15.2</td>
</tr>
<tr>
<td>Orefield 3、1200m Line 47</td>
<td>Poor ore</td>
<td>20.6</td>
<td>250°</td>
<td>39°</td>
<td>14.6</td>
</tr>
<tr>
<td>Orefield 3、1200m Line 45</td>
<td>Poor ore</td>
<td>17.3</td>
<td>208°</td>
<td>-6°</td>
<td>9.4</td>
</tr>
<tr>
<td>Orefield 31200m Line 44</td>
<td>Poor ore</td>
<td>18.1</td>
<td>109°</td>
<td>20°</td>
<td>11.4</td>
</tr>
</tbody>
</table>
4. Distribution Rule of Ground Stress in Orefield

4.1. Distribution Feature of Ground Stress on Both Sides of Fault F₁₇

(1) As to the value of major main stress, the stress value of measurement point on level 1200m of Orefield 3 close by Orefield 3, but east of fault F₁₇, about 20Mpa (17—21Mpa), is less than those of level 1150m and level 1000m of Orefield 2 west of fault F₁₇, about 25Mpa (17—31Mpa).

(2) The direction of major main stress is NE-NNE in general, but not complete consistency. The direction change of local major main stress maybe related to the deep intense mining disturb and the complicated engineering structure.

(3) The change of dip angle of major main stress is also evident, the clear increase of included angle with horizontal, indicates that the principal status of horizontal stress decreases progressively in the deep mining, whereas the appearance is not exactly same in different part of various level.

(4) The increase of difference between major and minor main stress shows the increase of shear stress in the deep mining area, the increase of shear damage intensity, which is very disadvantageous to the engineering stability.

4.2. Change Rule of Ground Stress Following the Depth

The analysis of our 16 measurement points and a large amount of previous measurement data indicate that the major, minor horizontal main stress and vertical main stress all show nonlinear change following the depth. The analysis result with polynomial simulation method is very good.

The major main stress doesn’t change linearly following the depth, but cubically in general. The simulation formula of major main stress change following the depth is as follows:

\[
\sigma_1 = 0.656 + 0.086H - (1.11E-4)H^2 + (5.9E-8)H^3
\]

where \( \sigma_1 \) (Mpa)—Major Main Stress

\( H \) (m)—Depth of Measurement Point

The linear correlation coefficient \( R^2 \) of major main stress is 0.995.

The simulation formulas of major horizontal and vertical stress change following the depth are as follows:

\[
\begin{align*}
\sigma_{h_{max}} &= 1.002 + 0.069H - (6.13E-5)H^2 + (1.82E-8)H^3 \\
\sigma_{h_{min}} &= 2.925 + 0.015H \\
\sigma_v &= 0.508 + 0.025H
\end{align*}
\]

where \( \sigma_{h_{max}} \) (Mpa)—Major Horizontal Stress

\( \sigma_{h_{min}} \) (Mpa)—Minor Horizontal Stress

\( \sigma_v \) (Mpa)—Vertical Stress

\( H \) (m)—Depth of Measurement Point

The linear correlation coefficients \( R^2 \) of \( \sigma_{h_{max}}, \sigma_{h_{min}}, \sigma_v \) are separately 0.99, 0.865, 0.976, 0.899.

The curve simulation shows that the major main stress and the major horizontal stress increase linearly and evidently following the depth increase on the buried level about 500—600m. Below this buried level, the linear increase of major main stress and major horizontal stress following the depth increase becomes gentle.
5. Conclusion

Through study of the stress characteristics and distribution rule of Orebody II, had a comparison with the previous ground stress measurement on the shallower level (2-6, 11-13) and analyzed the similarity and new variety. The study results indicate that although the value of major main stress doesn’t clear increase, the difference between major and minor main stress increases evidently, i.e the shear stress increases. Moreover, the dip angle of major main stress increases, the mechanical asymmetry around the channel or mining area appears abruptly. Owing to the influence of mining disturbance in the deep, the stress state of various place is different. The utilization range of measurement result of each measurement point shrinks. The stress function becomes complicated. According to the measurement of deep part of the mine this time, we have had a rather complete knowledge of general ground stress environment of Orefield II, which is very significant in the guidance of mine construction and production.

References