Application of Rock Kaiser Effect in Deep In-situ Stress Test

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Abstract. In order to solve the serious roadway failure in Yaoqiao coal mine, Kaiser effect was used to measure the in-situ stress in level-800m roadway. Through making samples 6 special directions on the beamed rock cores and doing acoustic experiment, the unilateral plus stress values on each direction are obtained. Through coordinate transformation, the magnitude and direction of the primary stress of the original rock were calculated. The result shows that level -800m belongs to high stress area, and there exists certain tectonic stress. The relative position of horizontal maximum and minimum ground stress is determined, which provides reference for the roadway layout and support in Yaoqiao mine.

1. Introduction

In-situ stress is the natural internal stress formed in the long geologic history of the crustal rock mass. It's the fundamental force to cause the deformation and destruction of the underground engineering, and the important factor of determining the regional stability [1].In recent years, with the increasing depth of coal mining, the stability and support of surrounding rock in high stress area under complex geo-mechanical environment have become a major problem to be solved urgently. The ground stress measurement is a necessary prerequisite for determining the mechanical properties of engineering rock mass, analyzing the stability of surrounding rock and realizing the scientific design of underground engineering excavation [2-3].Therefore, how to test the stress field of mining area scientifically, quickly and economically is very important for mine construction and roadway safety construction.

At present, hydraulic fracturing method [4]and stress relieving method [5]are used to determine the three-dimensional stress state of the measured point in the field of rock mechanics and engineering.

Identifying the key points of fracturing test curve accurately is the premise for determining the main strength value of hydraulic fracturing method, which will affect the reliability of the measurement results to a certain extent. The stress relieving method can determine the total stress tensor of the measuring point in a single borehole without any assumption, but when the drilling depth is deep, the casing is easy to cause the broken core, which results in the measurement failure [6].The Kaiser effect refers to the obvious AE phenomenon only when the stress reaches the maximum initial stress in the process of loading.

After a large number of scholars found that the rock material also has the Kaiser effect, and strictly exists in the elastic stage of rock deformation, the maximum stress of memory does not exceed 50% of the damage stress, and the Kaiser effect of rock material has directional independence [7]. Further studies have shown that the Kaiser effect depends on stress relief before the rock-like strain, and the measured stress value is the current stress that should be lifted before [8].On this basis, the method of rock Kaiser effect can be applied to the measurement of ground stress.

Yaoqiao coal mine is located at the northern margin of the he Feng-Pei coalfield, and the structural pattern is controlled by regional geological structure. Affected by the N-S compressive and torsional stress, a north-trending anticline was formed. After the strong tectonic action of Yanshan movement, the faults in different directions were produced, and the original folds were cut. Finally, a northwestward inclined structure was formed.

In this paper, the method of rock Kaiser effect is used to measure the ground stress of the level -800 m West nine mining area.

2. Test Process

2.1Specimens fabricating

The coring drilling is arranged in the fine sandstone of 7# coal roof, the absolute depth of the surface is about 800m, and the lithology is stable and complete. Using TXU-75A type hydraulic drilling rig, φ130mm Diamond bit , Borehole elevation α=14°, Borehole Azimuth angle β=219°09′16″.

The borehole hits the original rock stress area outside the influence circle of the roadway, and takes out the φ110mm core without disturbing. Core bearing accuracy, core rate of up to 90%.

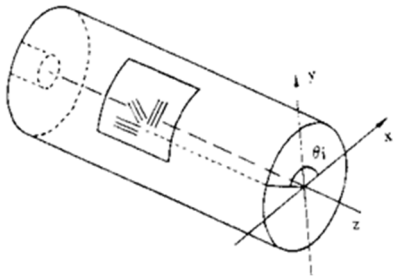


Figure 1. Directional coring space coordinate system

Figure 2. Acoustic emission testing of rock core objects

Coring cores are drilled in 6 directions, respectively along the x axis, y axis, Z axis and X axis angle 45 ° direction on the *xoy* plane, X axis angle 60 ° direction on the *xoz* plane and Y axis angle 60 ° direction on the *yoz* plane to drill cores. The cores are taken as Figure 2, their specifications are φ25mmx60mm.

2.2Test Equipment

The testing system of rock Kaiser Effect consists of loading system, acoustic emission parameter, load analogue measurement system and microcomputer control and processing system. Loading equipment using the MTS815.02-type electro-hydraulic servo rock Mechanics Experiment System . The loading rate is strictly controlled and the consistency of the test process is ensured. Acoustic emission measurement using AE-04 acoustic emission detection system, acoustic emission resonant probe center sampling frequency of 140kHz.

2.3Test design

Before the test starts, in order to achieve the ideal detection effect, the acoustic emission sensor is coupled with the specimen by Vaseline coupling, and the tape is fixed on the side of the specimen, while minimizing the effect of the end surface, the sensor should be as far away from the upper and lower end of the specimen as possible.

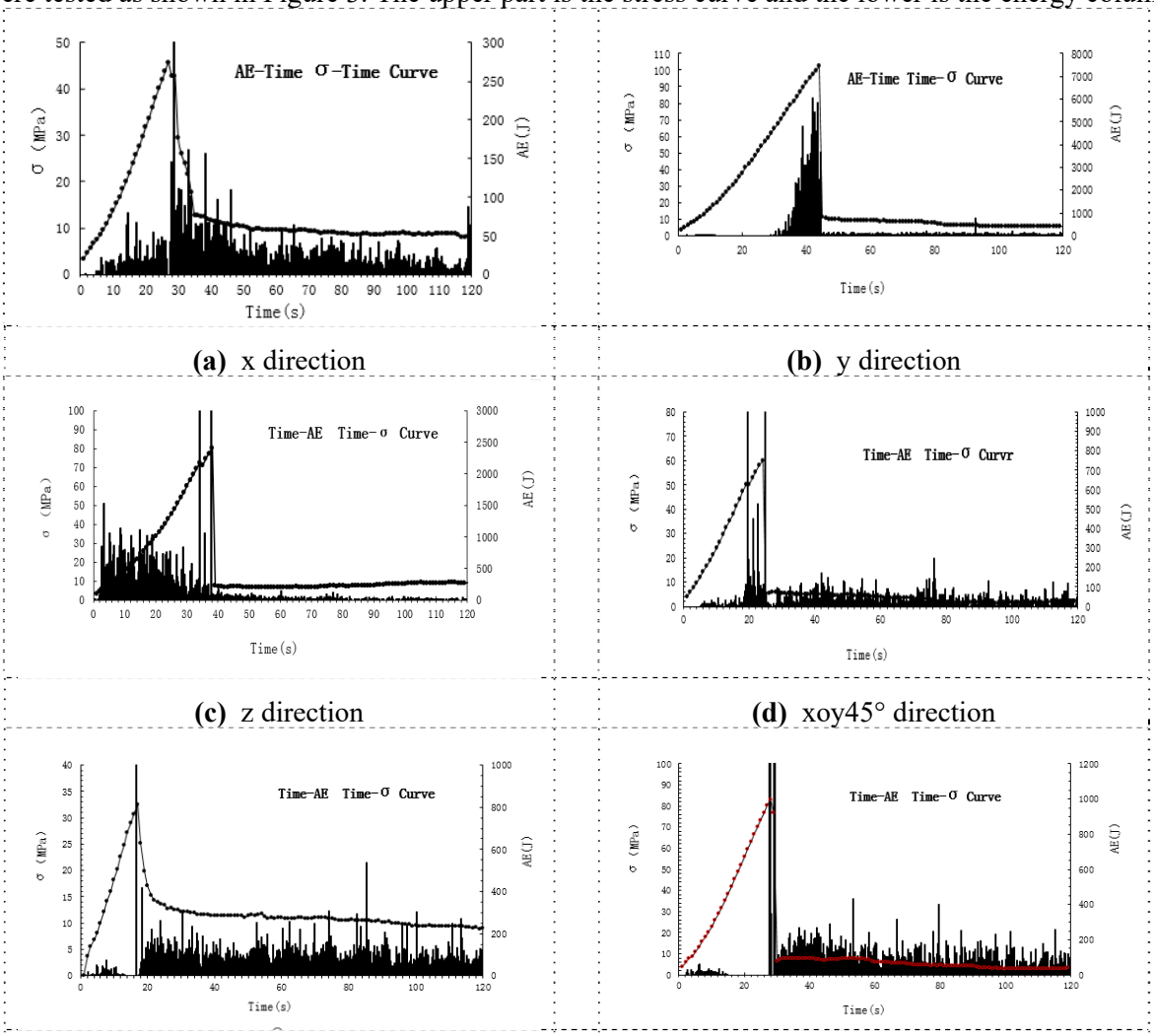
In the course of test, in order to avoid the friction of the end of the specimen and the ambient noise, the test result has a great influence, the threshold voltage is 3.1V, the main amplifier gain is 40dB, the

data acquisition time interval is 0.2s, the loading mode adopts the displacement control mode to 0.002mm/s and 0.003mm/s. The test process is controlled by computer and automatically collects data.

3. Results and Evaluation

3.1Test results

Ground stress tests were carried out on 12 specimens in 2 groups of 6 directions, of which 1 groups were tested as shown in Figure 3. The upper part is the stress curve and the lower is the energy column.



(a) x direction **(b)** y direction

(c) z direction **(d)** xoy45° direction

(e) xoz60° direction **(f)** yoz60° direction

Figure 3. Stress – time and AE -time curve

3.2In-situ stress calculation

According to the analysis of the characteristic points of the AE Kaiser effect, the stress component values in 6 directions are determined in table 1.

A point of stress state is expressed by three-dimensional stress tensor, if you want to show the in-situ stress clearly, the appropriate coordinate system (as Figure 4)must be determined. The calculation of in-situ stress requires three coordinate systems, oxyz is A local coordinate system that varies with the direction of the borehole, OXYZ is geodetic coordinate system, ox′y′z′ is transitional coordinate system. First, obtain each direction stress component value in oxyz coordinate system, as listed below,

normal stress $\sigma_X = 3.303$ MPa, $\sigma_Y = 12.050$ MPa, $\sigma_Z = 17.997$ MPa), shear stress $\tau_{XY} = 7.136$ MPa , $\tau_{XZ} = -1.064$ MPa , $\tau_{YX} = 7.136$ MPa , $\tau_{YZ} = 2.347$ MPa , $\tau_{ZX} = -1.064$ MPa , $\tau_{ZY} = 2.347$ MPa. than In-situ stress of geodetic coordinate system which in table 2 can be obtained by coordinate transformation. The principal stress three-dimensional vector as Figure 5.

Table 1. Stress component value in each direction.

Drilling direction	Stress components at characteristic points *(MPa)*	Drilling direction	Stress components at characteristic points *(MPa)*
x direction	14.00	x axis angle 45 ° direction on the *xoy* plane	15.25
y direction	13.50	x axis angle 60 ° direction on the *xoz* plane	13.00
z direction	5.85	y axis angle 60 ° direction on the *yoz* plane	14.14

3.3Distribution characteristic analysis of In-situ stress field

3.3.1 The above measurements show that the maximum principal stress in the Yaoqiao mining area-800 horizontal skew in plumb direction, the convolution crankshaft which is formed with the field structure is approximately perpendicular to the relationship, which conforms to the mechanics principle of the convolution formation, that is, the convolution formed under the maximum principal stress compression, the axial direction of the convolution is bound perpendicular to the maximum principal stress[10].

3.3.2 If the average gravity density of overlying strata is 1000 and the weight stress is estimated by the formula ABC, the measured plumb stress component 12.050MPa is smaller than the 2000 calculated by the weight stress formula, which indicates that the tectonic stress near the horizontal direction exists in the mining strata.

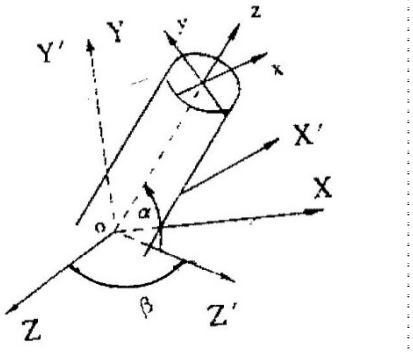


Figure 4. Directional coring space coordinate system

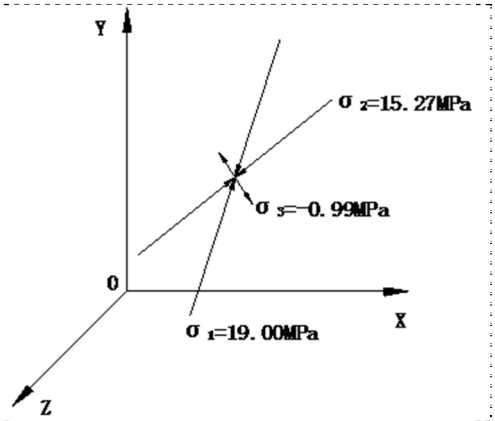


Figure 5. Acoustic emission testing of rock core objects

3.3.3 Zhou Gang [11] have tested in-situ stress on level-650m and level-850m of the Yaoqiao mine, comprehensive analysis of the test results of three points in Yaoqiao coal mine (see table 3) shows that:-650 horizontal geological structure anomaly, horizontal stress is greater, the region has a relatively significant tectonic stress;-850 horizontal geologic structure is simple. The main stress of self weight is the type of self stress field, and the 800 horizontal maximum principal stresses are

inclined to the vertical direction, the minimum principal stress differs from the middle principal stress and tensile stress, which indicates that there is a certain tectonic stress in the region.
The distribution characteristics of the in-situ stress field in the mine area are as follows: With the increase of the stress level in the mining depth, the -800m is the boundary, the sedimentary structure of the upper strata is complex, the tectonic stress is the main, and the -800m is gradually formed under the vertical stress field.

4. Sections

4.1 level -800m belongs to medium-high stress field, and there is some tectonic stress.

4.2 The stress increases with the increase of mining depth. With the -800m as the boundary, the upper strata are mainly controlled by tectonic stress. The direction of the maximum principal stress is north to East, and the angle between the East and West is larger. The North-South compressive stress is produced by geological tectonics, which is not conducive to the roadway support in the East and West. The gravity stress below - 800m is the main stress, and the principal stress near vertical direction is basically consistent with the gravity stress of overlying strata.

4.3 The results are in agreement with the general variation of regional tectonic and in-situ stress field in east China, and the accuracy of the measurement results is indicated.

4.4 Deep well, high ground stress and soft rock are important problems to be solved in deep mining at present. The measurement of in-situ stress provides reliable basis and parameters for prevention and control of deep roadway support and impact area in mining area.

References

[1] WANG L.G, LU Y.L, YAN X.H, et al. (2010) Study of distribution characteristics of in-situ stresses for huozhou mining area. Chinese Journal of Rock Mechanics and Engineering, 29(1): 2768-2773.
[2] KANG H.P, LIN J, ZHANG X. (2007) Research and application of in-situ stress measurement in deep mines. Chinese Journal of Rock Mechanics and Engineering, 26(5): 929-933.
[3] Cai M.F, Guo Q.Y, Li Y, et al. (2013) In-situ stress measurement and its application in the 10th Mine of Pingdingshan Coal Group. Journal of University of Science and Technology Beijing，35(11) : 1399 -1406.
[4] CAI M.F, CHEN C.Z, PENG H, et al. (2006) In-situ stress measurement by hydraulic fracturing technique in deep position of Wanfu coal mine. Chinese Journal of Rock Mechanics and Engineering, 25(5): 1069–1074.
[5] CAI M.F, LIU W.D, LI Y. (2010) In-situ stress measurement at deep position of Linglong gold mine and distribution law of in-situ stress field in mine area. Chinese Journal of Rock Mechanics and Engineering, 29(2): 227–233.
[6] HOU M.X, GEI X.R. (2007) Study on a calculation model for 3D in-situ rock stress tensor. Rock and Soil Mechanics, 28(10):2017-2021.
[7] Zhang G.Q, Jin Y, Chen M. (2002) Measurement of in-situ stress by Kaiser effect under confining pressures. Chinese Journal of Rock Mechanics and Engineering, 21(3): 360-363.
[8] JIANG Y.D, XIAN X.F, XU J. (2005) Research on application of Kaiser effect of acoustic emission to measuring initial stress in rock mass. Rock and Soil Mechanics, 26(6): 946-950.
[9] ZHAO K, YAN D.Q, ZHONG C.H, et al. (2012) Comprehension analysis method and experimental verification for in-situ stress measurement by acoustic emission tests[J]. Chinese Journal of Geotechnical Engineering, 34(8): 1403–1410.
[10] MA X.J, ZHANG C.F, LI L. (2010) Deep hole measurement of stress in Kongzhuang mining of Datun. Coal Mining Engineering, 1: 66-68.

[11] ZHOU G, LI Y.S, WU Z.Y. (2005) Measurement of crustal stress and analysis of characteristics in Datun mining area. Journal of China Coal Society, 35(7):1065-1070.