ISSN: 1813-4890

Research and Application of Trajectory Offset Law for Drilling Through Layers

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Abstract

In view of the problems of large blind area and difficult to reach the standard due to the deviation of borehole through strata extraction borehole, theoretical analysis and field test methods are adopted to study the variation law of borehole pitch Angle and azimuth Angle deviation with borehole depth based on the borehole track data measured by borehole tracker. The borehole deviation law is obtained through linear fitting, and the borehole Angle compensation and correction technology is proposed. The application practice of 4 boreholes through layers was carried out in the subordinate mine of Guxu Coal Field Company. The results show that the calculation of borehole deviation rule is simple and fast, and the field operation of Angle compensation and correction technology is simple and feasible, which meets the requirements of engineering practice accuracy, and can provide guidance for the accurate construction of subsequent boreholes or supplementary boreholes.

Keywords

Borehole migration rule; Angle compensation method; Drilling correction technology; Pre-pumping through zone drilled.

1. Introduction

In the actual production process of coal mine, the construction of gas extraction, water exploration and drainage holes will be offset, which is mainly affected by rock properties, gas treatment equipment and many other factors, drilling can not reach the designed position, which brings difficulties to the analysis of later data, prone to occur in the construction of more holes, more difficult to accurately analyze the occurrence of coal strata and structures [1-3]. The more difficult it is to accurately grasp whether there is a pumping blank area in the control range of drilling, the more difficult it is to effectively play the role of coal seam pressure relief and coal seam gas extraction, which will leave a major safety hazard for the coal seam mining in the later period. At present, the acceptance method of underground water exploration and release borehole, gas extraction borehole and all kinds of other engineering borehole is manual on-site inspection or rod by rod extraction. There is no video monitoring system installed at the drilling site [4,5]. This method of borehole acceptance is time-consuming and can only accept the opening azimuth, dip Angle and depth of the borehole, but can not master the track of the borehole and the spatial position of the final hole. It is impossible to determine whether the borehole has reached the designed position, which will cause potential safety hazards for mine water damage and gas control [6-8]. According to Article 47 of the Rules for the Prevention and Control of Coal and Gas Outburst, the trajectory of at least 2 boreholes shall be measured for every 10 boreholes with a depth of more than 120m. The trajectory of at least one borehole for

ISSN: 1813-4890

every 10 boreholes with a depth of 60 to 120m shall be measured. The trajectory of the borehole shall be measured if the length of the borehole is more than 1/3 different from that of the borehole designed for pre-pumping gas through the strata.

Therefore, studying the deviation rule of borehole and putting forward targeted rectification measures can not only improve the fine management of gas extraction borehole, but also provide reference and guidance for coal mine to solve the problem of gas management, which has targeted practical guiding significance for underground coal mine gas management.

2. Drilling deviation rule and Angle compensation and correction technology

In the construction process of drilling through strata, in order to obtain the best pumping effect, the final coal point of drilling through strata should be as consistent as possible with the design coal point, so as to ensure that there is no pumping blind area in the pre-pumped coal seam. Because the drilling track is easily affected by many factors such as geological conditions of drilling site, coal seam dip Angle, dead weight of drill pipe and drilling parameters, the actual drilling track always deviates from the designed track. It is difficult to determine the quantitative relationship between real drilling trajectory and these influencing factors, so it is necessary to find the overall law of drilling deviation in this drilling field according to the existing real drilling trajectory and design trajectory, and redesign drilling Angle according to the deviation law in subsequent drilling construction. The actual track of the borehole in the coal seam is as close as possible to the designed track, or the landing point of the actual track is as close as possible to the blind area of borehole gas extraction, so as to achieve the purpose of controlling and eliminating the blind area of gas extraction [9-11].

According to the borehole track and the distribution of borehole track in coal seam, the characteristics of borehole migration in the drilling field are counted and the rules of borehole migration are summarized. Considering the difference of borehole trajectory deviation with different azimuth and inclination angles, firstly, boreholes are classified into several dip Angle intervals according to the designed dip Angle. Then, the dip deviation of boreholes within different dip Angle intervals is statistically analyzed according to equations (1) and (2).

$$\bar{\theta}_i = \theta_i - \theta_1, \quad i=1,\ldots, \quad n \tag{1}$$

$$\hat{\theta}_i = \frac{1}{m}\sum_{j=1}^{m} \bar{\theta}_{ij} \tag{2}$$

Where, θ_i in formula (1) is the dip Angle measured at the i th measuring point, $\bar{\theta}_i$ reflects the deviation of the dip Angle of each measuring point in the borehole relative to the dip Angle of the opening hole, $\hat{\theta}_i$ in formula (2) reflects the mean value of the maximum deviation of each borehole in each dip Angle interval, and then the approximate relation of the change of dip Angle with depth is fitted according to the curve of $\hat{\theta}_i$ changing with the depth of the borehole. Then, the boreholes are classified into several azimuth intervals according to the azimuth Angle of the designed boreholes, and then the azimuth deviation in different intervals is analyzed statistically according to formula (1) and formula (2). At this time, the inclination Angle θ in formula (1) and formula (2) should be replaced with azimuth Angle a. Finally, the approximate relation of azimuth variation with depth is obtained by fitting $\hat{a}_i$ curve with borehole depth.

According to borehole migration characteristics, modify the design track of subsequent boreholes or design the track of supplementary boreholes, determine the opening dip Angle and azimuth Angle of subsequent boreholes or supplementary boreholes, so that the position of boreholes at the entry and exit points of coal seams is as consistent as possible with the

ISSN: 1813-4890

design position under the condition that the geological conditions of rock strata, coal seam distribution, drill pipe dead weight, drilling parameters and other factors remain unchanged. So as to achieve the purpose of controlling and eliminating the blind area of gas extraction. The principle of designing the track of the supplementary drilling is to set the offset of the supplementary drilling in the opposite direction in advance according to the offset direction and value of the drilling, so as to ensure that the position of the drilling at the inlet and outlet point of the coal seam is consistent with the designed position under the condition that other factors remain unchanged. Its schematic diagram is shown in Figure 1.

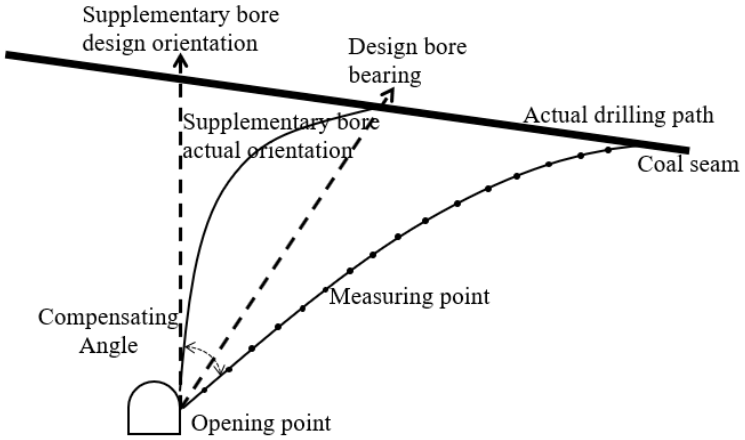


Figure.1 Track design principle of subsequent drilling or supplementary drilling

According to the track design principle of subsequent drilling or supplementary drilling, the length value of construction drilling is substituted into Table 2 borehole migration rule, and the pitch Angle and azimuth deviation Angle at this depth are calculated. When drilling holes, the calculated deviation Angle is increased in reverse to ensure that the final hole point falls to the design point.

3. Field application cases

3.1. Test drilling construction and drilling track determination

The test boreholes were selected in four strata of gas bottom drainage roadway of Guxu Coal Field Company, and the target pre-pumped coal seam hardness coefficient f was 1~2. ZDY-2300 or ZDY-3200L drilling machine, supporting φ63mm×800mm drill pipe, diameter φ94mm drill bit for construction, finally coal seam roof 0.5m, after the completion of construction, the use of water or (pressure air) to wash the hole, reduce many drilling cuttings left in the hole. The drilling design and construction parameters are shown in Table 1.

Table 1 Test drilling design and construction parameters

Bore number	Design azimuth /(°)	Design pitch /(°)	Bore length /m	Actual azimuth /(°)	Actual pitch /(°)	Actual bore length /m	Maximum offset
11#	244	52	67.6	245.50	49.49	61.3	4m (left) 20m (bottom)
12#	243	56	63.7	230.91	53.88	58.4	1.4m (above) 1.4m(right)
13#	233	80	53.7	203.13	80.48	51.5	31.3m(bottom)
14#	203	86	53	186.77	79.70	50.5	8.4m(above) 0.6m(right)

The YZG360-Z mine borehole track measuring instrument is used to test the borehole track, which can measure the pitch Angle, azimuth Angle and depth of borehole for borehole

ISSN: 1813-4890

engineering at any time, so that the working state of borehole drilling tool can be understood in time, and the accurate borehole track and depth can be reproduced. The drill pipe can be connected to the drill pipe for measurement while drilling, or the drill pipe can be sent to the bottom of the hole after drilling. (The standard length of the drill pipe is 100m. If the drilling depth exceeds 100m, the drill pipe can only be pushed.) In this test, a specially equipped push rod was used to send the probe rod to the bottom of the hole [12]. The implementation steps of drilling trajectory measurement are as follows:

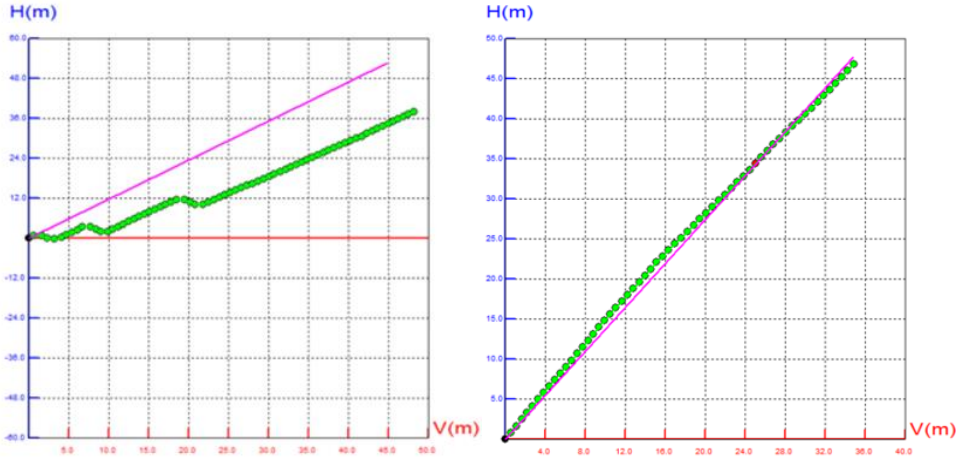
(1) Before drilling, connect the probe pipe to the YZG360-Z mining display controller with communication cables, connect the power supply of the display controller, and start the measuring software to synchronize the probe pipe and display controller.

(2) During drilling, data measurement is carried out according to the set interval, and the measured data is automatically saved to the probe pipe.

(3) After the completion of drilling construction, retrieve the probe pipe, connect the handheld computer to the computer after exiting the well. After further processing by the trajectory analysis system of the ground computer, the 3D trajectory diagram of the drilling and the deviation between the actual trajectory and the design trajectory can be displayed, and the data can be imported to fill in the drilling and design information. The computer directly generates vertical profile map, horizontal projection map, vertical projection map, front view map and rotatable three-dimensional trajectory map, and automatically calculates the spatial relative coordinate values of each measurement point, and can automatically generate reports, as shown in Figure 2.

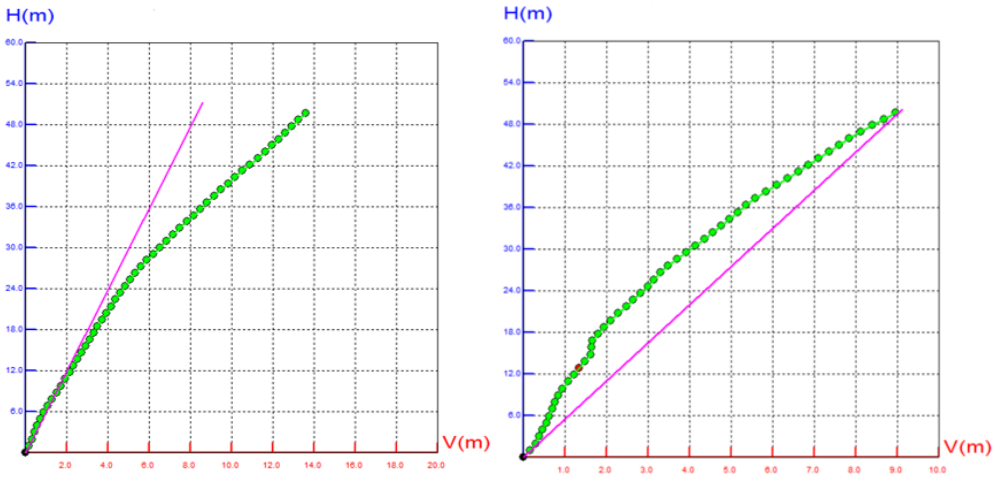
Figure.2 Borehole track measuring instrument of intrinsic safety type used in mine

The software can not get the borehole migration rule, so based on the measurement data, the relationship between the deviation value of borehole azimuth and pitch Angle and the change of hole depth is found. Data anomalies were removed from the 4 boreholes (11#, 12#, 13#, 14#) measured on site, and the track data of boreholes were sorted out, as shown in Figure 3.



(a)11# (b)12#

ISSN: 1813-4890



(c)13# (d)14#

Figure 3. Projection of design hole surface

3.2. Analysis of drilling deviation rule and correction measures

According to the measured data of borehole track and the theoretical calculation method in Section 1, the variation law of pitch Angle and azimuth Angle with depth is obtained through analysis and research, namely the borehole migration law, as shown in Table 2.

Table 2 Pitch and azimuth of test boreholes as a function of depth

Drill hole number	Design opening angle /(°)	Opening azimuth /(°)	Approximate relationship between azimuthal deviation Q (°) and drilling depth L (m)	Deviation angle/(°) at 50m drilling depth
11#	244	245.5	Q=-0.2812*L+1.959 R^2=0.8368	12.101
12#	243	231	Q=-0.289*L+9.0793 R^2=0.8781	5.3707
13#	233	203	Q=-0.4845*L+15.283 R^2=0.836	8.942
14#	203	187	Q=-0.2046*L+10.91 R^2=0.3565	0.68
Drill hole number	Design opening angle /(°)	Pitch angle of opening /(°)	Approximate relationship between pitch angle deviation P (°) and drilling depth L (m)	Deviation angle/(°) at 50m drilling depth
11#	52	49.5	P=0.1236*L-8.7388 R^2=0.4615	2.5588
12#	56	54	P=-0.1164*L+2.4495 R^2=0.5868	3.3705
13#	80	80.5	P=-0.265*L+0.6778 R^2=0.8614	12.5722
14#	86	80	P=-0.2519*L+6.0075 R^2=0.9072	6.5875

As shown in Table 2, drilling migration rule:

(1) The pitch Angle and azimuth Angle of the borehole change linearly with the depth, and the deeper the borehole, the greater the Angle deviation;

(2) The larger the opening azimuth and pitch Angle, the larger the deviation Angle at the same depth;

(3) The actual hole positioning of drilling is not accurate, and the deviation of azimuth Angle and pitch Angle from the design value is large. In the only four test holes, the maximum deviation of azimuth Angle is 30° (13#), the maximum deviation of pitch Angle is 6° (14#), and

the difference of azimuth Angle is even much larger than the deviation Angle 12.1° at 50m of drilling;

(4) According to the deviation rule of borehole, it can guide subsequent boreholes of different lengths or supplementary boreholes to carry out deviation correction processing under similar drilling conditions, so that the final hole position falls at the design position, to achieve the purpose of controlling and eliminating the blind area of gas extraction.

4. Conclusion

(1) The theory puts forward the borehole migration rule, that is, to find the linear calculation formula of the borehole azimuth deviation value and the pitch deviation value and the borehole depth respectively. It is obtained that the deeper the borehole, the greater the Angle deviation; The larger the opening azimuth and pitch Angle, the larger the deviation Angle at the same depth.

(2) Applying the Angle compensation method, a deviation correction method for subsequent drilling or supplementary drilling is proposed. That is, the length value of the designed drilling hole is substituted into the formula of the variation of the pitch Angle and the azimuth Angle with the depth of the drilling hole to calculate the pitch Angle and the azimuth Angle of the final coal hole point. When the drilling hole is opened, the calculated deviation Angle can be increased in reverse to ensure that the final hole point falls to the design point.

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