Original Research Article

Analysis on data processing of a three-component magnetic survey in a well

Feng Li[1*], Guo Wenjian[2]

[1.]Department of Resources and Civil Engineering, Shandong University, Taian, Shandong, China
[2.]The Fifth Exploration Institute of Geology and Mineral Resources in Shandong Province, Taian, Shandong, China

***Abstract*:** The three-component magnetic survey in a well is an important method in geological prospecting; it plays an important complementary role in geological magnetic survey data. During data processing of a three-component magnetic survey, the drilling technology, instruments of three-component magnetic survey in a well as well as performance and precision of the gyroscope inclinometer should be considered. The appropriate data processing method should be selected according to the different trajectory feature of the borehole, in order to improve the accuracy of data interpretation.

***Keywords*:** three-component magnetic survey in a well; azimuth; data interpolation; precision

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*Correspondence to: Feng Li, Department of Resources and Civil Engineering, Shandong University, Taian, Shandong, China, 389992652@qq.com.

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Introduction

The three-component magnetic survey in a well can detect the target's magnetic body's effective vector information to the greatest extent, playing an important complementary role in geological magnetic survey. At present, with dwindling shallow resources, borehole measurements will play a leading role in deep prospecting[1,2]. In order to improve the precision interpretation of geological data during geological explorations, comprehensive analyses are made on the factors which affect data processing accuracy of a three-component magnetic survey in a well. Through the corresponding treatment measures, more accurate parameters of magnetic survey can be obtained[3].

Principle of three-component magnetic survey in a well

A three-component magnetic survey in a well measures the three components (x, y, and z) of the geomagnetic field at different drilling depths, calculating the abnormity of the three-components, judging whether there are magnetic ores around or under the well, or analyzing the position and attitude of the magnetic ores. Generally, there are three mutually independent and vertical magnetically-sensitive measuring elements in the test tubes of logging tools. With the aid of gravity, automatic orientation can be performed with a certain borehole inclination (generally more than 3°–5°), making the x point the borehole tilt direction and y the vertical direction. The plane composed of the x and y directions are horizontal; thus, the z direction is a vertical downward, conforming to the right-hand rule. The directional azimuth β should be obtained by the gyro survey method without magnetic interference.

During data processing, the data of x, y, and z mea- sured at each data points is subtracted from the normal vector of the background field, namely the measuring point exception vector. The measured vector anomaly at the point may be drawn into different angle projections via a drawing tool. The specific formula is as follows:

$$Z_0 = T\sin\alpha$$

$$H_0 = T\cos\alpha$$

$$\Delta Z = Z - Z_0$$

$$X_0 = -H_0\sin\beta$$

$$Y_0 = H_0\cos\beta$$

$$\Delta X = X - X_0$$

$$\Delta Y = Y - Y_0$$

Equation 1 Formulas used during data processing

Equation 1 ΔX are the exception vectors; x, y, and z are measurement point data; t is the local background field; Z_0, H_0, X_0, and Y_0 are the vertical magnetic field vector background value, horizontal magnetic field vector background value, x component background value of the horizontal vector, and y component background value of the horizontal vector. α is the inclination. β is the drilling azimuth.

Analysis on the influence of data processing accuracy

According to the principle of calculation, the parameters affecting the processing results are the measured data x, y, and z, the background field t, magnetic inclination α, drilling azimuth β, *etc*. Among them, background field t is the total magnetic field modulus value of the ground or no abnormal drilling period, and has a directional effect on the final data results. The inclination α is the included angle between horizontal magnetic field vector H_0 and vertical magnetic field vector Z_0 of the ground, or no abnormal drilling period, deciding the value of the final vector ΔH and ΔZ. It may change the final direction of the magnetic anomaly total vector ΔT mildly.

A full three-component magnetic measurement in a well needs the three-component magnetic logging out pipe and borehole gyroscopic inclinometer. The three- component elements in the three-component logging tube have high sensitivity, can be affected by its relative position, hole orientation and obliquity, leading to diversionary error and other disruptive errors. The commonly used borehole directional device is the optical fiber independent north finder. The static measurement function is recommended (general spot measurement)—one spot requires about 2 to 3 minutes to measure. During drilling work, the coring equipment needs to be removed in the hole, and then the test tube is lowered for measurement. Therefore, the hole trajectory data is a single point interval data, 50 m per point, which cannot meet the requirements of the three-component small spacing vector calculation. Hole azimuth data interpolation calculation should be made. According to the characteristics of the drilling process, there are different methods to process the hole trajectory interpolation[4].

Horizontal x and y measurements are within the one circle scope of a magnetic sensor. Measured values show changes of sine and cosine curves. A difference between maximum and minimum data is about 80000 nT. When the measured magnetic components are consistent with the horizontal magnetic vector, the maximum is obtained, and the reverse is the minimum. When there is a slight change of the angle of the measuring element, the values of x and y will

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have thousands of nT changes. Generally, when the measuring element of x or y is consistent with the horizontal vector, the error is smaller. The error increases with the increase in angle. When the angle of the measuring element of x or y and horizontal vector is 90 °, the error change is prevalent. Because x and y components are orthogonal vertical, when the angle of x and y components and horizontal direction vector is 45 °, the degree effects are the same. Therefore, the accurate position of x and y components in the well during actual measurements is based on the gyroscope azimuth. When the azimuth measured by the gyroscope has a smaller error, the effect on the final data will be much more than the error of the three-component logging pipe, becoming the most important factor that affects the precision processing of the data.

Treatment measures for increasing data accuracy and examples

1) Background values of magnetic field, magnetic inclination, magnetic declination of the three-component logging position can be obtained from the information query. In order to get a more accurate data, we suggest collecting the local background value by magnetic three-component logging instruments used in the field. Magnetic inclination can be obtained by conversion. Magnetic declination data also need to compare the data obtained under the field, in order to eliminate system error from the instruments so that the azimuth β obtained from the gyroscope and three-component magnetic logging instrument are consistent in the background area.

2) During the three-component data processing, the angle data should consider the hole inclination data in continuous measurement of the three-component magnetic measurement equipment as far as possible, in order to accurately map the borehole trajectory. Azimuth β is obtained from the gyro interpolation survey. During the process of hole azimuth β interpolation, the simulation degree of hole azimuth β and the true state is mainly in order to get a more accurate position curve, so as to draw more accurate magnetic vector line projection.

3) In theory, under the condition of real-time positioning by magnetic survey of the three-component element, the hole azimuth at this point and hole azimuth β obtained via gyroscope are considered to be equal. In fact, due to the difference in measuring conditions, such as a naked hole casing, the two are not completely consistent. The measuring pipe should be lengthened as far as possible in order to improve the consistency.

The measurement data of a mining area, with magnetic survey three-component data interval of 2 meters and the gyroscope azimuth β data interval of 50 meters is presented in *Figure 1*. From the azimuth data interpolation processing graph, it can be seen that the curve shape of the hole position becomes smooth and more in line with the actual state after dealing with the azimuth interpolation. The initial treatment results, magnetic vector line projection without the azimuth interpolation processing is presented in *Figure 2a*. It can be seen that since the measure spacing of the original azimuth is 50 m, plume staggered phenomenon appeared along the borehole trajectory at every 50 m, leading to a discontinuity of the magnetic vector line state and vector information distortion. The ordinate is the vertical depth of space, as it is an inclined hole, the gyro and space depth did not overlap. *Figure 2b* demonstrated the optimization results after dealing with the azimuth interpolation. After azimuth interpolation treatment, the magnetic vector line status of magnetic vector lines projection is continuous, showing the complete space form, and a more accurate vector direction.

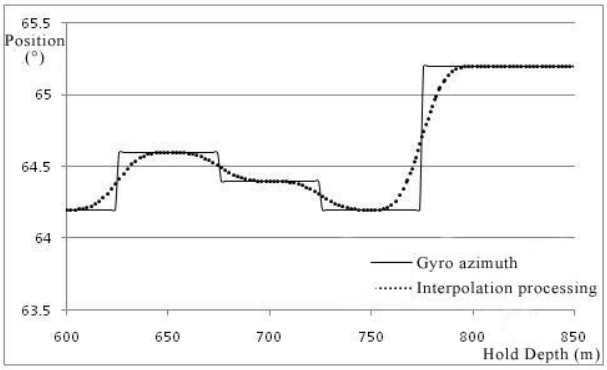

Figure 1. Azimuth data interpolation process diagram

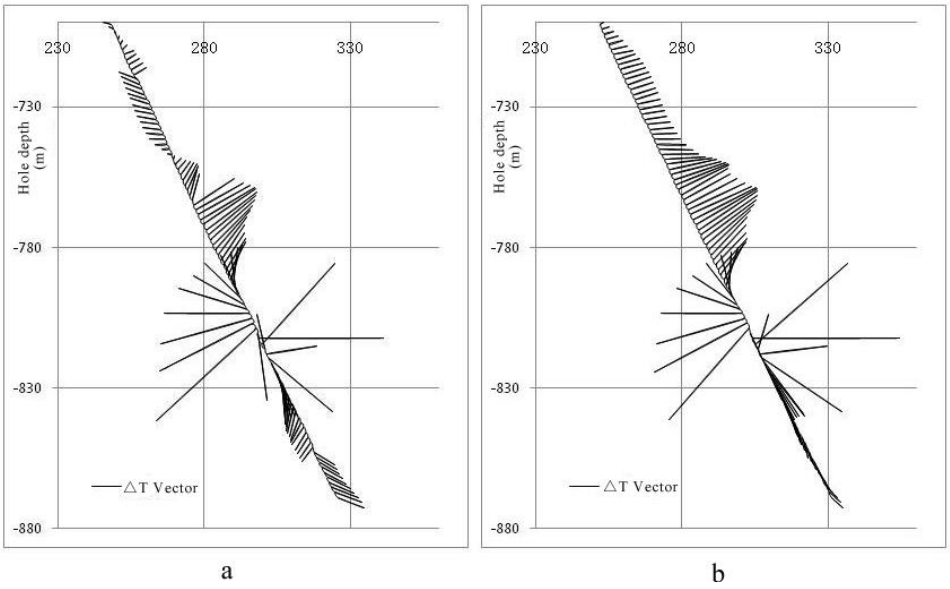

Figure 2. (a) Initial data; (b) Optimization results;

Conclusion

The characteristics of the magnetic anomaly should be considered during a borehole three-component magnetic measurement. The appropriate instrument with high precision should be selected, corresponding to requirements for hole integrity and oblique holes. During the drilling process, we should minimize sudden changes to the hole inclination and azimuth in order to obtain the mathematical model of data processing in accordance with the actual drilling condition as far as possible.

The azimuth measured via borehole gyroscope is the most important factor which affects the accuracy of data processing. Due to the functional characteristics of spot measurement of the present gyroscope, the measurement data are used as late interpolation basis points, so we must ensure the measured data are accurate and reliable.

During magnetic three-component data processing, data interpolation processing should be made selectively according to the different characteristics of borehole trajectory, giving attention to both efficiency and prudence.

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