Research of Dynamic Azimuth Gamma Instrument while Drilling for Mine

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Abstract. In view of the problems that the existing gamma logging instruments in coal mines can only carry out static fixed-point measurement and are not suitable for rotary drilling, this paper, based on the analysis of the characteristics of measurement while drilling in coal mines and the principle of gamma logging, designs and realizes the dynamic gamma azimuth instruments for mines by means of power line carrier, rotation positioning and gamma measurement technology, which can measure the intensity of natural gamma ray in two directions around the borehole in real time, effectively reflect the changes of different radioactive strata, and guide the geosteering while drilling in coal mine.

1 Introduction

At present, the most direct and effective method of gas control is to drill and extract along the coal seam. How to improve the rate of hole formation and the efficiency of gas extraction has become the key to reduce gas accidents in coal mines. Natural gamma is a common judging basis for identification of coal-bearing strata. Different coal-bearing strata have different changing ranges of natural gamma. During drilling construction, the characteristics of natural gamma difference of different coal-bearing strata can be fully utilized to identify lithology in combination with the situation of slag returning from the orifice, so as to guide the directional drilling construction, realize the identification of drilling strata and improve the control efficiency of drilling trajectory [1-3].

Some researchers have developed measurement instruments while drilling based on natural gamma in coal mine, which can realize all-round natural gamma measurement and multi-directional static azimuth gamma measurement while drilling, and provide some reference for directional drilling trajectory control. However, because the instrument can only conduct static fixed-point measurement, which is not suitable for rotary drilling and cannot achieve azimuth imaging, with low working efficiency. With the change of directional drilling technology from sliding directional drilling technology to complex rotary directional drilling technology, the instrument cannot meet the requirements of natural gamma dynamic measurement while drilling in complex rotary directional drilling [4-6].

2 Principle of azimuth gamma while drilling

The principle of azimuth natural gamma while drilling is basically the same as that of traditional natural gamma logging, which is to measure the natural gamma radiation intensity of the stratum. Gamma rays emitted by radioactive elements in the stratum transmit the energy to the natural gamma measurement detector to generate flash. The flash is detected by the photomultiplier tube (PMT) and converted into an electronic pulse. The electronic signal and other directional parameter signals are encoded into serial signals, which are transmitted to the orifice equipment through wire or wireless transmission, and the real-time gamma curve of the stratum corresponding to the well depth data is obtained, so as to determine the roof and floor of the coal seam, guide the adjustment of drilling trajectory, and control the drilling tool to pass through the best position of the coal seam effectively.

The traditional natural gamma logging tool uses a gamma detector to detect the total radioactivity of natural gamma in the stratum, while azimuth gamma logging while drilling uses one or more detectors to detect in the process of drilling. During data acquisition, the azimuth measurement is realized by recording the total gamma quantity of different detectors in different sectors.

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3 Instrument design

3.1 Overall instrument design

The electrical connection block diagram of the instrument is shown in Figure 1. The orifice computer superimposes the control command on the DC signal through the carrier transformation. After receiving the carrier signal, the probe tube carries out the rectification

and filtering transformation to convert the DC carrier into the power supply part and the signal part. After boosting and stabilizing the voltage, the power module supplies power for the main control board and gamma sensor. The main control board collects the control instructions issued by the orifice computer to complete the corresponding operation, and transmits the collected information to the orifice computer through carrier transformation.

Fig. 1. Electrical block diagram of instrument

3.2 Design of carrier module

DC carrier coupling mode includes capacitance coupling, inductance coupling and direct coupling. Considering the safety requirements of coal mine, it is impossible to use capacitance and inductance with large capacity, so direct coupling mode is adopted. In this paper, the special modulation and demodulation chips for PWBS752 and PWBS331 DC power carrier are used to realize the design of low-voltage DC carrier module with the peripheral coupling circuit.

3.3 Design of Power module

The power supply is the basis of the whole work. The DC power supply transformed by the carrier module of the probe will gradually decrease with the increase of the communication distance, so the DC voltage will be stabilized at 20V through the DC-DC chip to supply power for the gamma sensor; and then the DC-DC chip will convert the voltage to 12V to improve the power conversion efficiency. Finally, 12V DC is converted into 5V and 3.3V through LDO chip, which supplies power to the peripheral circuit and core devices of the main control board.

3.4 Design of main control board

The main control board collects the pulse signal of gamma sensor and measures the attitude information of probe tube under dynamic conditions. The schematic diagram is shown in Figure 2.

Fig. 2. Schematic diagram of main control board

The azimuth gamma instrument while drilling is a rotating measurement mode. Compared with static measurement, the effect of centrifugal acceleration caused by rotation and vibration acceleration caused by drilling should be considered. The inertial measurement unit used in this paper is MTI-3-8A7G6T, which includes three single axis accelerometers, three single axis gyroscopes and three single axis magnetometers. It is mainly used to measure the three-axis attitude angle (or angular rate) and acceleration of the object.

For the solution of inclination angle and tool face angle, the direction cosine matrix is selected as the attitude updating algorithm. Only the elements of the last row and the first two elements of the first column of the cosine matrix are taken as state variables to update, which greatly reduces the calculation amount of the direction cosine matrix. The zero-bias value of three-axis gyro is also added to the state variable, and the dynamic estimation is carried out to ensure the long-term data stability of the instrument.

The rotation speed of the downhole drilling tool in coal mine is usually 60-200r/min, and the high-frequency interference caused by vibration and impact can be eliminated through a low-pass filter using the corresponding low-frequency characteristics of MEMS accelerometer itself [7-10].

3.5 Gamma detector

The gamma sensor is composed of NaI scintillator, photomultiplier tube (PMT) and pulse shaping circuit. The crystal senses the rays and converts them into optical signals. The photomultiplier tube collects these optical signals and transforms them into electrical signals. By collecting these electrical signals, the natural radiation intensity of the stratum of the instrument is obtained.

The output signal of PMT in gamma detector is weak and negative current signal, which usually needs to be transformed into voltage signal with certain amplitude. The operational amplifier selected for the amplifier should have high open-loop gain and high input impedance, so as to effectively pick up the weak current signal output by the photomultiplier; the output impedance of the operational amplifier should be as small as possible to reduce the impact of the voltage drop on the output voltage caused by the output impedance. Through amplitude identification and reshaping to the pulse signal, as well as suppression of interfering noise, purified and standard pulse signal can be gained.

Fig. 3. Schematic diagram of gamma detector

3.6 Instrument structure design

Based on the purpose of distinguishing the coal rock interface in the borehole and the actual working conditions of the coal mine, the structure of azimuth gamma logging tool while drilling with detection capability in four directions is designed. The gamma detector is installed on the framework of the azimuth gamma logging tool while drilling, and the scintillation crystal and photomultiplier tube are shielded by tungsten-copper-nickel alloy. The density of tungsten-nickel alloy is higher than that of lead, and its ability of absorbing rays is 30% - 40% higher than that of lead. A 75° window is hollowed out on the tungsten-nickel alloy, so that the gamma detector can receive the gamma ray from the window direction, but not from other directions. In this way, the azimuth gamma logging tool while drilling can be used to detect and identify the roof and floor interface of coal seam when drilling along the coal seam.

Fig. 4. Instrument structure and the opening window when shielded

4 Experiment

In order to verify the accuracy of the instrument, a rotating test platform is built in the laboratory. Use the decelerating motor to drive the probe tube to rotate, simulate different radioactive strata with the transmitted radiation, and carry out the simulation experiment.

Two sets of strata with different radioactivity are simulated. The API value of the roof and floor of one stratum is 150, and the API value of the roof and floor of the other stratum is 250. The simulation instrument gets close to the first radioactive stratum from the middle extended floor of the coal seam; the whole instrument

enters the stratum and then returns to the coal seam; then the instrument gets close to the first radioactive stratum from the middle extended roof of the coal seam and enters and returns. In the same order, the simulation instrument enters and returns in the second stratum.

Figure 5 shows the measurement results. The red curve is the upper gamma data collected by the instrument, and the blue curve is the lower gamma data. The results of physical simulation show that the communication of instrument is normal and the data measurement is stable. The upper and lower gamma measured can correctly reflect the change rule of stratum radioactivity.

Fig. 5. Test results of two sets of simulated strata

5 Conclusion

In this paper, a set of dynamic azimuth gamma instrument while drilling in coal mine is developed. The instrument can measure the intensity of natural gamma ray in two directions around the borehole in real time. Through the ground test, it is verified that the instrument is superior in performance and easy to operate. The instrument can meet the requirements of natural gamma dynamic measurement while drilling in complex rotary directional drilling, and provides a new equipment of drilling construction for gas control in coal mine. The next step is to carry out the industrial test under the coal mine to make the instrument meet the requirements of the field use.

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