Design and Realization of E-MWD Instrument in Coal Mine

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Abstract: In order to ensure safe and efficient coal mining, it is usually necessary to construct a large number of gas drainage holes and water exploring and drainage holes in the coal mine. Directional construction drilling can improve the quality of such drilling construction, measure the main parameters such as drilling inclination angle, azimuth angle and tool orientation angle in real time, draw the drilling trajectory and adjust the drilling attitude according to the needs, realize the efficient utilization of gas drainage, and advance, regional, precise prevention and control of disasters. The measurement while drilling (MWD) system is the necessary support for drilling directional construction, which is applied to various directional drilling rigs in coal mines to measure the drilling trajectory in real time to guide the design and construction of drilling.

1. Introduction
At present, most of MWD in the coal mine use a wired method to transmit the measured attitude data to the hole, and a special cable drill pipe is used to form the transmission channel. The processing technology of the cable drill pipe is complicated and expensive, and its transmission quality is seriously affected by the sealing condition at the joint. The existing electromagnetic measurement while drilling (E-MWD) technology generally uses mud pulses to form a transmission channel, while the mud pulse E-MWD technique is not suitable for air, foam and unbalanced drilling, and has a low transmission rate and can only communicate in one direction. In view of these problems, China Coal Science and Technology Group Xi’an Research Institute Co., Ltd. has researched and implemented an E-MWD device, the data is transmitted by electromagnetic wave, which has certain advantages in directional drilling of coal mines.

2. System Components
As shown in Figure 1, the system consists of a computer for coal mine and an in-hole device. The computer for coal mine is placed beside the drilling rig. Its transmitting and receiving antennas are two electrodes, one of which is connected to the drill pipe and the other is a copper rod that is reliably connected to the coal seam at a certain distance from the rig. The insulated short joint end of the in-hole device is screwed with the upper non-magnetic drill pipe and the drill pipe in turn, and the outer pipe
end of the instrument is screwed with the lower non-magnetic drill pipe, the screw motor and the drill bit in sequence, and the drill bit is in contact with the ground layer in the hole, thereby forming stratum/drill pipe transmission channel.

3. Computer for coal mine
The computer for coal mine is powered by an external explosion-proof power supply of 127V/AC. The upper computer data processing and mapping unit realize the human-computer interaction, draw drilling trajectory graphics to guide drilling construction, store and record data. The lower computer intelligent data transmission system transmit and receive signals, and communicate with the in-hole device through the stratum/drill pipe transmission channel.

The intelligent data transmission system generates a transmission signal from a DDS circuit, which is composed of a low-power FPGA chip Intel® Cyclone® 10CX085 and a D/A module AD7111. The signal is amplified and output by multistage amplifiers such as variable gain amplifier, and the communication frequency can be adjusted through the DDS circuit, the communication power can be adjusted by a variable gain amplifier. The receiving circuit of the signal is mainly composed of a switched capacitor bandpass filter MAX267, as shown in Figure 2, and the center frequency of the bandpass filter can be adjusted by programming.

![Figure 2 Intelligent data transmission system](image)

4. In-hole device

![Figure 3 The relationship between insulation distance and communication efficiency](image)
other. In order to satisfy the communication requirements, the insulation resistance should not be smaller than 500 M$\Omega$ at DC500V. As shown in Fig. 3, the longer the length of the insulating segment in the middle of the insulating stub, the smaller the transmission loss, but the more difficult the processing. At the same time, in order to meet the drilling requirements, the diameter must be the same as the outer diameter of the drill pipe, and the torque resistance is not less than 10000 N·m.

The probe pipe includes a rechargeable battery pack, an intelligent power management unit, an attitude measuring unit, and a multi-mode data transmission system. The battery pack of the probe pipe can be used separately to power the probe pipe or external turbine generator to satisfy the needs of continuous operation (longer than 100 hours). The intelligent power management unit uses the techniques of attitude detection, pressure detection and comprehensive decision-making to intelligently manage the system power supply, automatically supply and disconnect power to the measurement module in the hole based on the needs, control the working state of the equipment in the hole, and sleep during the drilling process, wake up when the drilling stop to reduce system power consumption. The attitude measuring unit transmits the measured attitude data to the multi-mode digital transmission system, and the multi-mode digital transmission system modulates the data in a set modulation mode, and completes two-way communication with the computer for coal mine through the stratum/drill pipe transmission channel.

5. System implementation
After years of research and development, China Coal Science and Technology Group Xi’an Research Institute Co., Ltd. has developed the YSDC electromagnetic wave E-MWD instrument with independent intellectual property rights for the first time, and developed supporting software. As shown in Figure 4, the instrument is mainly composed of KDY127/24 (B) mine explosion-proof intrinsically safe DC power supply, KXH24 (B) mine intrinsically safe controller, YSDC-T mine intrinsically safe electromagnetic wave MWD instrument probe pipe and supporting drilling tools.

![Figure 4 YSDC E-MWD](image)

The electromagnetic wave E-MWD instrument complies with the mining standards such as MT/T677-1997, MT 209-1990, MT 210-1990, etc. It can be used in coal mines with an ambient temperature of 0 °C ~ +40 °C. The attitude measurement range and the error of the probe pipe are shown in Table 1. The maximum communication distance between the computer for coal mine and the probe pipe in the hole is 500m, and the transmission speed can reach 50bit/s.

| Measurement index | measuring range | measurement error  |
|-------------------|-----------------|--------------------|
| pitch             | -60° ~ 60°      | ±0.2°              |
| Azimuth           | 0° ~ 360°       | ±1.5°              |
| roll              | 0° ~ 360°       | ±1.5°              |
6. Conclusion
The YSDC mining electromagnetic wave E-MWD instrument forms a potential loop between the drill string and the grounding wire, and is received after being transmitted to the ground through the stratum, which has the characteristics of high signal transmission rate and short measuring time.

This instrument is used for monitoring the main parameters such as MWD drilling inclination angle, azimuth angle and tool orientation angle in the near horizontal directional drilling construction process, and at the same time, real-time display of the drilling parameters and drilling trajectory of the hole can be realized. The drilling personnel can keep track of the drilling construction situation and adjust the drilling process parameters in time so that the drilling holes can extend as much as possible according to the design trajectory. This measuring instrument is suitable for hole drilling construction such as coal mine gas drainage drilling, water exploring and drainage hole, advanced exploration hole, etc., and can be applied to drilling construction such as underground exploration drilling, horizontal branch well of coalbed methane mining.

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