Hole Depth Measuring Device based on Mechanical Wave Reflection

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Abstract. In view of the problems of low efficiency and large human factors in the current quality acceptance of underground drilling construction in coal mine, which mainly depends on the manual counting of drill pipes during drilling withdrawal, a portable drilling depth measurement device is designed based on the principle of mechanical wave reflection in drill pipe string, using the propagation speed of mechanical wave in the drill string and the time of one cycle of mechanical wave back and forth in the drill string, the length of drill string in the drill hole is calculated and the drilling depth is determined. The designed mine drilling depth measuring device is mainly composed of three parts: exciter, probe and host. The key functions of data processing and human-computer interaction are realized by the software and hardware of the host. The field tests in Dafosi Coal Mine and Sihe Coal Mine verify that the measuring depth of the device is greater than 200m and the maximum error is no more than 10m, which can meet the urgent needs of underground hole depth measurement in coal mine.

1. Introduction
Underground tunnel drilling in coal mine is the most direct and effective technical means to prevent accidents and ensure safe and efficient coal mining. It plays a great role in the fields of coal mine gas drainage, water disaster prevention and hidden disaster causing factor exploration. Large-scale drilling construction is carried out in coal mine every year in China.

In order to strengthen the management of drilling construction, standardize the completion acceptance of drilling construction and ensure the quality of underground on-site construction, all coal mining enterprises have formulated the management measures for drilling construction acceptance, of which the most important acceptance index is the actual drilling depth [1-3].

At present, due to the lack of effective and convenient means to detect the drilling depth [4-5], the acceptance personnel can only verify the drilling depth by counting the number of drill pipes when returning the final drilling hole, which is time-consuming and laborious, and can not accept each drilling hole. Therefore, workers falsely report the footage, resulting in the emergence of "artificial" exploration and governance blind areas, it forms a huge potential safety hazard for coal mine safety production.

2. Method for measuring borehole depth by mechanical wave reflection
The measurement method of borehole depth in coal mine is shown in figure 1 and calculated according to the following formula:
\[
L = S - L_1
\]

where:
\(L\) - drilling depth, unit: m;
\(S\) - total length of drill string in borehole, unit: m;
\(L_1\) - length of drill string in exposed section of orifice, unit: m.

During normal operation, the connection mode between the hole depth measuring device and the drill string is shown in figure 2. The host maintains the acquisition mode. When the probe collects the trigger signal of the exciter, the host starts to record the acoustic wave waveform, and the acoustic wave propagates longitudinally from the orifice to the hole bottom until the bit end is reflected by different media. The host collects the complete reflected waveform, and then the drilling depth can be calculated.

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\[
S = \frac{V \times (t_2 - t_1)}{2}
\]

where:
\(S\) - total length of drill string in drilling before lifting drill pipe in final hole, unit: m;
\(V\) - propagation speed of mechanical wave in drill string, unit: m/s;
\(t_1\) - recorded peak time of first wave, unit: s;
\(t_2\) - recorded peak time of reflected wave, unit: s.

In field application, before measuring the drilling depth, it is necessary to calibrate the propagation speed of mechanical wave in the drill string. The calibration steps are as follows:
(1) Connect the test drill string, and the actual length is $S_0$;
(2) Measure the time difference between the first wave and the echo of the standard drill string with an oscilloscope connected to the probe $\Delta t = t_2 - t_1$;
(3) Calculate the wave velocity $V$ in the drill string according to formula 2.

3. Hardware design of hole depth measuring device

Based on the method of measuring drilling depth by mechanical wave reflection, the hardware block diagram of mining drilling depth measuring device is determined, as shown in figure 4. On this basis, the circuit design and hardware selection are carried out. As can be seen from the figure, the device is composed of power module, core board module, trigger circuit, A/D module, differential amplification circuit and probe. The power supply is composed of 6 section 12AH lithium battery pack. When the battery is full, the instrument can work for more than 8 hours; the core board is the core unit of the device, which can realize the functions of data calculation, waveform processing and host computer communication; touch screen and LCD module can conduct human-computer interaction conveniently and quickly; the trigger circuit is triggered by the acoustic signal received by the probe to start the host to record the waveform; A/D module and differential amplifier circuit can realize the functions of data conversion, amplification and filtering, and improve the discrimination of waveform; the probe is responsible for collecting the acoustic signal at the end of the drill pipe, converting it into voltage signal and transmitting it to the differential amplification circuit.

![Hardware block diagram of measuring device](image)

Figure 4 Hardware block diagram of measuring device.

When measuring the drilling depth, the probe relies on the magnet to adsorb at the tail end of the drill pipe until it receives the mechanical wave generated by the longitudinal percussion of the drill pipe by the exciter, triggers the circuit and starts to record the waveform. After amplification and filtering, the waveform is sent to the core board for processing and calculation. The obtained waveform and measurement results can be displayed on the LCD screen.

4. Field Test

In order to verify the application effect of mining drilling depth measuring device, field tests were carried out under different working conditions, such as Dafosi Coal Mine of Shaanxi Binchang Mining Group Co., Ltd. and Sihe Coal Mine of Shanxi Jincheng coal industry group.

In Dafosi Coal Mine of Shaanxi Binchang Mining Group Co., Ltd., there are 15 survey holes in total, 8 follow-up survey holes in the whole process, and the maximum hole depth is 180m. It is mainly carried out in two drilling yards: the belt centralized roadway 22# drilling yard in the west of Dafosi Coal Mine 4 and the No. 2 roadway 33# drilling yard in the west of Dafosi Coal Mine 4. The design hole depth is mostly between 100~180m. In the test, the mechanical wave velocity is all 5150m/s, including 1#, 2# The measurement curve suitable for the drill pipe of the mine is fitted with the detection data of 3# holes, as shown in figure 5 (a), and then the correction value of the drill pipe length is inversely calculated according to the measurement data of 4#, 5#, 6#, 7#, 8# holes. Compared with the actual length of the drill pipe, as shown in figure 5 (b), the final error curve is obtained, as shown in figure 6, 78% of the measurement errors in the figure are within 5m and 22% are between 5m and 9m, the instability of the test results is attributed to the mixed use of drill pipes and the serious
aging of drill pipes in the mine.

After directional drilling in 53022 Lane 8# across the drill yard in Sihe mine, Jincheng coal industry group, Shanxi Province, the field test was carried out. The drill pipe length in the drill hole was detected, the maximum hole depth was 222 m, and one hole was measured in the whole process. There were 8 measuring points in the process of tracking the hole. The wave velocity was set at a constant 5150 m/s in the first 7 tests, and the detection error increased with the increase of the drill pipe length. According to the first 7 groups of detection data, get the fitting curve and fitting formula, as shown in figure 9. Input the fitting formula coefficient into the instrument for the eighth detection. The detection waveform is shown in figure 7.

The field test shows that all functions and technical indexes of the instrument are normal, and the conditions for industrial promotion have been basically met, meeting the basic requirements of the target application field.
5. Conclusion
The method of measuring the drilling depth through the parameter monitoring device of mining drilling rig still has great room for improvement in the reliability and accuracy of measurement. In the field application, it is also necessary to continuously accumulate data and experience in all aspects to improve the technical details, such as the elastic deformation of drill pipe, the setting of various parameters of drilling rig and misoperation, will affect the final measurement results.

The drilling rig parameter monitoring system is a method to measure the drilling depth. It can monitor the changes of drilling rig parameters in real time during drilling construction and record the drilling depth. It can not only be applied to the quality inspection of drilling construction, but also be applied to the construction of intelligent drilling systems such as drilling rig fault monitoring and drilling construction condition monitoring.

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