Research on application of mine transient electromagnetic method in detecting collapse column

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Abstract. The transient electromagnetic detection has been widely applied to mine roadway excavation engineering. In order to figure out the front geological conditions of roadway excavation, the application of mine transient electromagnetic method (TEM) in detecting collapse column was conducted in this paper by taking the TEM-based advanced detection of 53152 working face in a mine located in Jincheng, Shanxi Province as an example. The results showed that if TEM is applied, geological structures like water-free collapse column could be largely delineated. Besides, by combining the interference source of detection environment and related geological data nearby the detection site, ‘false abnormalities’ could be effectively eliminated, thus providing the reference basis for the water prevention and control work of mines.

1. Introduction
The frequency occurrence of water disaster accidents in coal mines have posed enormous loss to miners’ lives and state properties. The water prevention & control work of mines is especially important to prevent water disasters. Mine transient electromagnetic method (TEM) is a detection method for the surrounding geological conditions based on transient electromagnetics and serves an important means of water prevention and control work in mines, which achieves favorable application effects in the water prevention and control work of coal mines. Featured by rapidness, high efficiency and high accuracy, TEM can rapidly and accurately prospect the front geological conditions of roadway excavation in cooperation with advanced drilling, with a definite object in view, so as to reduce the drilling workload and provide the reference basis for the water prevention and control work of mines.

However, as this method is susceptible to the ironware, ponding and electricity in roadway, the detection results can be diversified, which leads to misreporting. Hence, some measures should be taken to reduce the “false abnormalities” caused by the interference.
2. Principles of TEM

TEM prospecting is achieved by utilize unearthed loop or magnetic dipole to emit the electromagnetic pulse as the exciting field source (“primary field”) into ground. Under the excitation of primary field, the induced vortex current is generated inside the underground good conductor and then it generates an induced electric field. Next, the received induced electric field is observed to explore its relationship with observation time, so as to determine the spatial form of underground conductor. TEM was initially applied on the ground to seek for various objects such as underground mineral products, underground water-rich area and underground space. With the continuous development, this technology has been gradually applied to underground engineering, such as tunnels and mines [1]-[4].

Mine TEM was evolved from the ground half-space TEM. This detection method, characterized by simple construction layout, short construction time and high detection accuracy, is capable of prospecting the water condition and development status of geological structures within a certain range in the front, and effectively preventing and reducing the water disaster accidents.

Given the characteristics of TEM principle, the transient electromagnetic detection is extremely susceptible to factors like ironware, ponding and electricity, which will aggravate the difficulty in the data processing and result interpretation. Hence, before the detection, the interference sources nearby the detection site like ironware and ponding should be cleared away as far as possible, and the power supply of nearby circuit should be cut off. The interference sources that really cannot be eliminated should be recorded on the construction list in detail and avoided as much as possible during the data collection, in an effort to ensure the quality of data collected [5]-[8].

3. Case Analysis of Collapse Column Detection via Mine TEM

The detection was implemented at the place 727m from the opening of 53152 roadway in a coal mine in Jincheng, Shanxi Province. This roadway was located at 3# coal seam, containing anthracite, the average seam thickness was 6.7 m, and the immediate roof in the roadway was mudstone with average thickness of 4.4 m; the upper roof consisted of sandy mudstone with average thickness of 8.30 m; both immediate floor and lower roof were mudstone with average thickness of 20.6 m. This roadway, which was supported by anchor bolts and anchor network, was horizontally excavated. During this detection process, a large quantity of float coal existed on the head-on floor. In order to identify the water conditions and development status of geological structures within 100 m range in front of roadway excavation, the mine TEM was used to perform the advanced detection of this roadway, providing the reference basis for the water prevention and control work of this roadway[9].

Intrinsic safety type transient electromagnetic instrument along with 2×2 m overlapped loop device dedicated for mines was used in this detection. Four detection directions were designed, including three transverse detection directions (forward detection at an included angle of 30° with the roadway roof, forward detection along the direction of rock strata, and forward detection at an included angle of 30° with the roadway floor) and a longitudinal detection direction[8][9].

Fourteen transverse detection angles (as shown in Figure 1 (a)) were arranged in each transverse detection direction; fourteen detection angles (Figure 1 (b)) were arranged in the longitudinal detection direction; the data were collected from totally 56 measuring points in the four detection directions.

Following the steps like filtering, time-depth conversion and depth correction, the collected data were processed by selecting a proper algorithm via professional computer mapping software. In the end, the pseudo-section diagram of apparent resistivity in each detection direction was finally obtained. The false abnormalities interpreted by the interference results were eliminated by comprehensively analyzing the detection results, so as to improve the accuracy of result interpretation.
Figure 1. Schematic Diagram of TEM Detection Angles.

The TEM detection depth was 100 m, where 0-30 m was the blind zone of detection. The origin of coordinates of detection results corresponded to the position of the heading end, and the horizontal and vertical coordinates represented the detection depths in different directions. Different color codes represent different apparent resistivity values, and the apparent resistivity increased continuously from the cold tone to warm tone.

The pseudo-section diagrams of apparent resistivity values in the directions of roof 30°, along rock strata (0°) and floor 30° are displayed in Figures 2, 3 and 4, respectively.

Figure 2. Pseudo-section diagram of apparent resistivity in advanced detection in roof 30° Direction.

The high resistivity abnormality area in the roof 30° direction was largely located at 45°-90° of detection direction, and the range of apparent resistivity was roughly 70-120 Ω·m.
Figure 3. Pseudo-section diagram of apparent resistivity in advanced detection along rock strata (0°).

The high-resistivity abnormality area in the direction along rock strata (0°) largely fell within 30°-75° of detection direction, and the apparent resistivity was roughly within 70-120 Ω·m.

Figure 4. Pseudo-section diagram of apparent resistivity in advanced detection in the direction of floor 30°.

The high-resistivity abnormality area in the direction of floor 30° was largely within 30°-90° of detection direction, and the range of apparent resistivity was roughly within 70-120 Ω·m.

It could be seen that obvious high-resistivity area (the area delineated by the white dotted lines) existed in the partial right direction of roadway head-on, and the high-resistivity areas in the three transverse detection directions showed a very high corresponding degree. By combining the field detection environment and related geological data, it was speculated that the high-resistivity area was water-free collapse column or fault.

The pseudo-section diagram of apparent resistivity in the direction of longitudinal section is as shown in Figure 5. It could be seen that the high-resistivity area (the area delineated by the white dotted lines) basically penetrated through the roadway roof and floor. Based on a comprehensive analysis of
combining the pseudo-section diagrams of apparent resistivity values in the three transverse directions, it could be basically judged that this high-resistivity area was collapse column.

Through the subsequent ore drilling and excavation verification, this high-resistivity abnormality area was water-free collapse column, with the major axis of 100 m and minor axis of 88 m, and the cross section was approximately round. The pseudo-section diagram of apparent resistivity along rock strata was superposed with the planar graph of excavation engineering. It could be seen that the results inferred by the TEM coincide with the actually disclosed results to a great extent.

4. Conclusions
The advanced detection based on mine TEM show that high-resistivity abnormality areas are discovered by combining the detection results in three transverse directions and a longitudinal direction, and these areas are deduced as collapse columns, which accords with the actually disclosed result.

When the water-free collapse columns developed in a larger scale or show evident differences from the surrounding rocks in the aspect of resistivity, their electrical response will be characterized by higher resistivity, easier recognition and higher detection accuracy.

By eliminating the inference source on the detection field and combining the regional geological data, the ‘false abnormalities’ that affect the inference can be effectively excluded, thus enhancing the accuracy of result interpretation.

Acknowledgements
The author gratefully acknowledges the funding by the National Natural Science Foundation of China (51704162, 51804162).
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