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Preliminary Study on Detection and Application of Transient Electromagnetic Method in Coal Mine

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Abstract This paper introduces the principle, device and method of commonly used down-hole transient electromagnetic detection, makes conclusions and innovations of the application effects of down-hole advanced detection and detection of sidewalls in combination with examples, describes the existing problems in the down-hole transient electromagnetic detection and puts forward some opinions.
Keywords TEM, mine water detection, down-hole measurement

Along with the development of coal mining in recent years, the underground flood has become the main factor to restrain the safe production of the coal mine. The transient electromagnetic method has been characterized by the easy and flexible detection mode and outstanding application effect ever since it was introduced from the ground down in the hole. This paper describes the down-hole transient electromagnetic method frequently adopted, makes conclusions and improvements of the application effects in combination with examples and gives some extraordinary opinions on how to use the transient electromagnetic detection technology in a better way based on the current status of transient electromagnetic detection and existing problems in the coal mine.

Principle and device of transient electromagnetic detection

Principle

The transient electromagnetic method (or time domain electromagnetic method), also called TEM for short. Its operating principle is to emit the primary pulse electromagnetic field into the ground through the earth-free coils or earth wire and observe the secondary vortex field by making use of the earth-free coils or grounding electrode during the off - period of the primary pulse electromagnetic field.

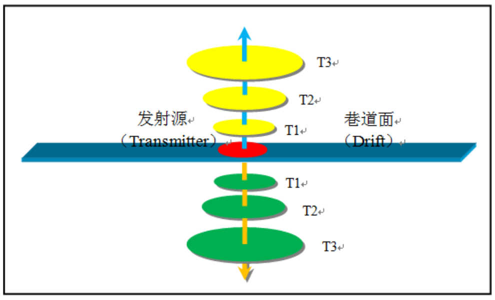

Fig. 1 *Schematic Diagram of Underground Whole-Space Transient Electromagnetic Detection*

The emission current produces a stable electromagnetic field in the space around the return before it is turned off (fig. 1). When t=0, the current is suddenly turned off and the electromagnetic field produced disappears immediately. The dramatic change of the primary electromagnetic field is transmitted back to the ground around the coils through the air and underground conducting medium and inspires induced current in the ground to maintain the electromagnetic field before the emission current is turned off, so that the electromagnetic field in the space will not disappear before the energy of electromagnetic field completely consumes due to the thermal loss of the medium.

The change rule of electromagnetic property of the medium around the heading face of roadway can be identified so as to determine the size, shape and distance of the anomalous body of electromagnetic property from the heading face of roadway according to the features of induced electromotive force changing with the time measured through the receiving coil in the vicinity of the heading face of roadway.

Device

Owing to the fact that the transient electromagnetic instrument currently used in the roadway under the shaft is restricted by the space of the heading face of roadway, the physical dimension of the transmitting and receiving coil for transient electromagnetic method is limited to a certain extent and only the transmitting and receiving devices with multiples turns of small coils (i.e., with the length of side of 1.5-2 m) could be used. The detecting method is to divide the operating devices into dipole and overlapping returns. What is described below is the overlapping coils.

Current application and innovation of transient electromagnetic method under the coal mine

Transient electromagnetic method is often adopted for the advanced detection of dummy roadway and the detection of the sidewall of working face in the coal mine, it is mainly applied to detect the anomalous body of hidden water-bearing structure in front of the roadway and inside the working face as well as the water-bearing condition of the goaf in order to identify the exact goals for further drilling, thus, the economic benefits of the coal mine may be guaranteed to the maximum extent.

Advanced detection

At present, overlapping return device is frequently applied to prevent the iron in the roadway from interfering with the electromagnetic wave. The transient electromagnetic instrument used for advanced detection is YCS160 transient electromagnetic instrument manufactured by Hunan Feiyi Corporation and its main performance parameters are as follows: maximum supply current ≤3.2 A; transmitting frequency: 25 Hz; transmitting voltage: 8.4 V; overlapping times:32; sampling interval: 2μs; transmitting coil: 2 m×2 m×32 and receiving coil: 2 m×2 m×64.

(1)Conventional sector detection mode

Currently, the sector detection mode is widely adopted for the heading end, as shown in fig. 2, the detection starts from the left of the heading face of roadway and ends at the right sidewall, with the normal of the transmitting and receiving antenna vertical to the left sidewall of roadway. During actual data acquisition, the included angle between the normal of antenna and the roof and floor of roadway may be adjusted for each transmitting point to detect the change of surrounding rocks at the roof, bedding and floor of roadway and collect data from multiple perspectives in order to obtain information of the front space as much as possible. The detecting direction is as shown in fig. 3.

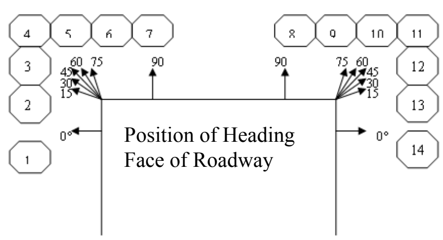

Fig. 2 *Schematic diagram of sector layout of advanced detection points*

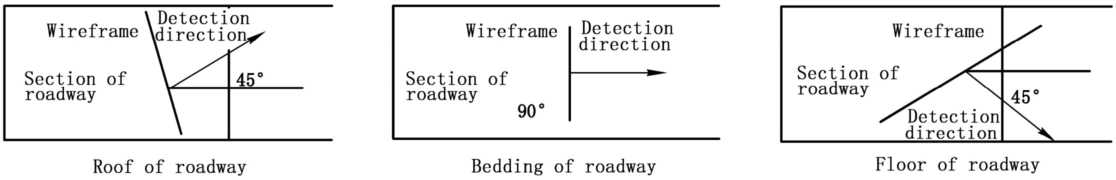

Fig. 3 *Schematic diagram for the layout of forward looking detection*

(2) Improvement of sector detection mode

The sector detection mode is improved based on our several sector detections, Sector detection combines the detection of transverse bedding with that of vertical section. Detection of transverse bedding is to provide 13 advanced detection points for the heading face according to the detection directing which is clockwise and each point is subject to one direction. Detection of vertical section is to provide advanced detection points in three directions (namely 45° at left sidewall, central roadway and 45° at right sidewall) from an elevation of 60° to a depression of 60°, with 13 detection points arranged at interval of 10° (as shown in fig. 4).

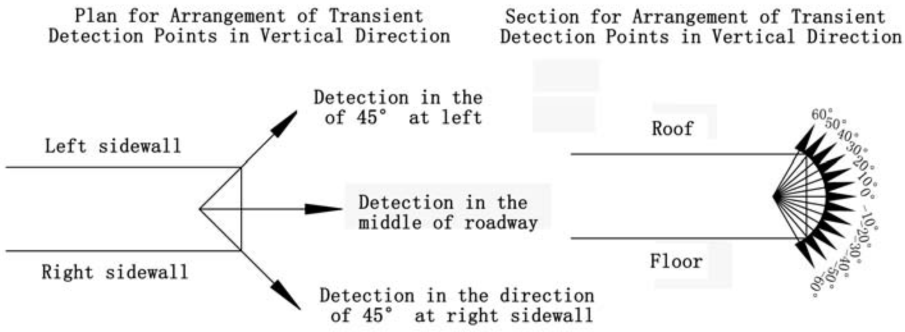

Fig. 4 *Layout of detection points for in heading face*

(3) Comparison of examples of two advanced detection methods

To make further comparison of the advantages and disadvantages of the two detection methods, an forward looking detecting test on the goaf water of II7322 goaf is conducted at the heading face of II8222 external machine roadway of Renlou Coal Mine based on the fact that the transient electromagnetism is sensitive to the water-bearing body. Please see Fig. 5 for the Based on the actual location of the old goaf and the site environment, both regular sector detection methods and the improved advanced vertical detecting methods are adopted, the comparison of plots are as shown below.

① Fig. 6 shows the apparent resistivity contour map obtained through sector detection in the direction of of 15°. The on-site detection environment is not significantly affected by iron, so it is provided with good conditions. According to the figure, the center and roof of the roadway is free from any relatively low apparent resistivity area and barely responds to the goaf water.

② Fig. 7 shows the apparent resistivity contour map obtained by improved vertical detection (The contour map obtained by left and right 45° detection is omitted), with detection conducted in the middle of roadway from an elevation of 60° to a depression of 60°. The detection environment on the site is as same as that described above. According to the figure, there is an obvious relatively low apparent resistivity area in the direction of an elevation of 10°-50°, with the value of 8 Ω·m. The analysis shows that the area is produced due to the occurrence of goaf water.

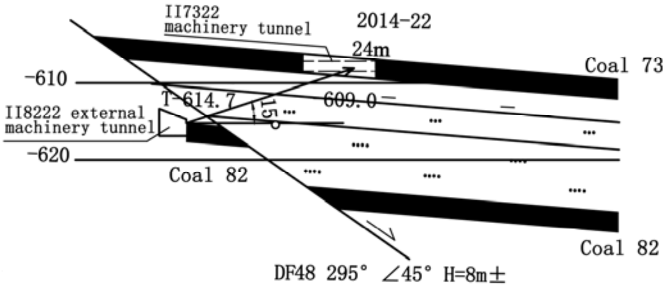

Fig. 5 *Diagrammatic section of goaf water of II7322 belt entry*

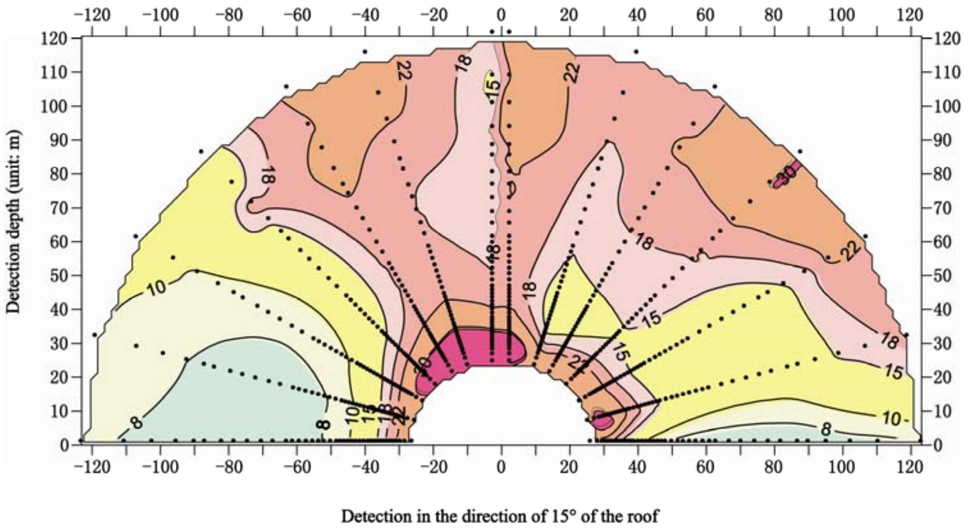

Fig.6 *Schematic diagram for transient electromagnetic detection at the heading face of II8222 external machine roadway*

About 650 m^3 of goaf water is released as verified by sequential drilling, which conforms to the detection result as shown in fig. 7.

③ Analysis and comparison

The analysis and comparison of two detection methods indicate that the original sector detection method could only be adopted in three directions on the section (fig. 3) and it could be adopted for several times as appropriate at the roof and floor for abnormal position. However, it could not be adopted for too many times.

Based on the original detection points, the improved method is to control the change rule of the electrical property of the medium of the roof and follow in front of the heading roadway, with the number of detection points and data size increased and the detection efficiency taken into consideration, having good effects during actual production. Therefore, it is worth of being popularized.

Sidewall Detection

At present, the transient electromagnetic detection for sidewall is mainly conducted before recovery of the working face to detect the water-bearing condition of the working face and bottom board. For the abnormal area, drilling will be carried out for verification in advance in order to ensure the safe recovery of the working face. Of course, sidewall detection may also be conducted to identify the scope of down-hole goaf.

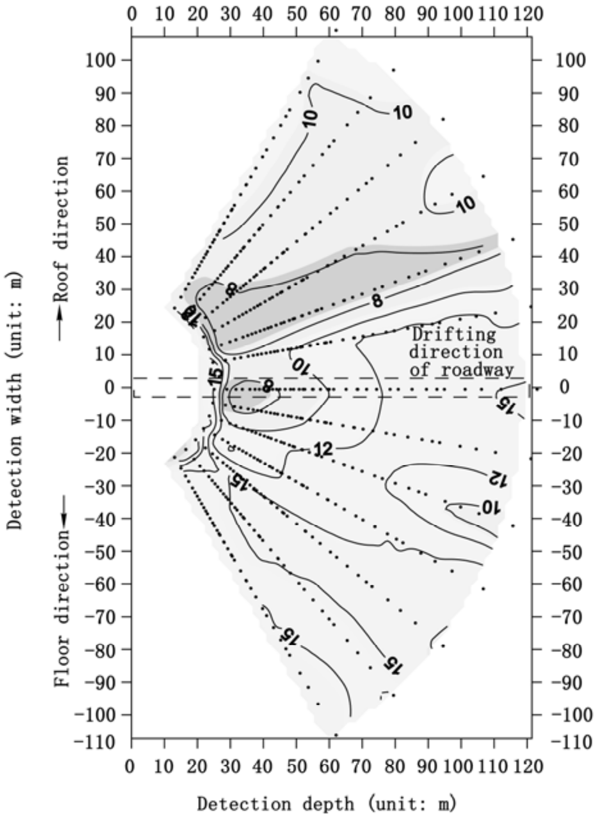

Fig. 7 *Section of vertical detection at the heading face of II8222 belt entry*

For the sidewall detection, the aforesaid YCS160 transient electromagnetic instrument and YCS50 high-power transient electromagnetic instrument developed by China Coal Technology & Engineering Group Chongqing Research Institute are used for comparison test. The detection starts from Point L1 of -520 main north-wing haulage roadway and the measuring lines are arranged as follows: The detection line stretches out from Point L1 and then 10° obliquely upward, along which 30 detection points are provided, with an interval of 10m. The purpose of detection is to identify the water-bearing condition of the goaf of 7227 working face (For details, please see Fig. 8). The detection line is provided with the water pipeline above and the track and drain below, affecting the detection results to a certain extent.

(1)Detection result of YCS160 transient electromagnetic instrument

Fig. 9 shows the apparent resistivity contour map obtained through detection with YCS160 transient electromagnetic instrument, with the detection conducted from an elevation of 10°. According to the figure, there is an obvious abnormal low-resistivity area at 130m-160m in the horizontal coordinate and 60-120 m in the vertical coordinate (The another abnormal area is disturbed by the iron and it could be excluded), and no obvious relatively low apparent resistivity area in other districts which barely respond to the goaf water is discovered.

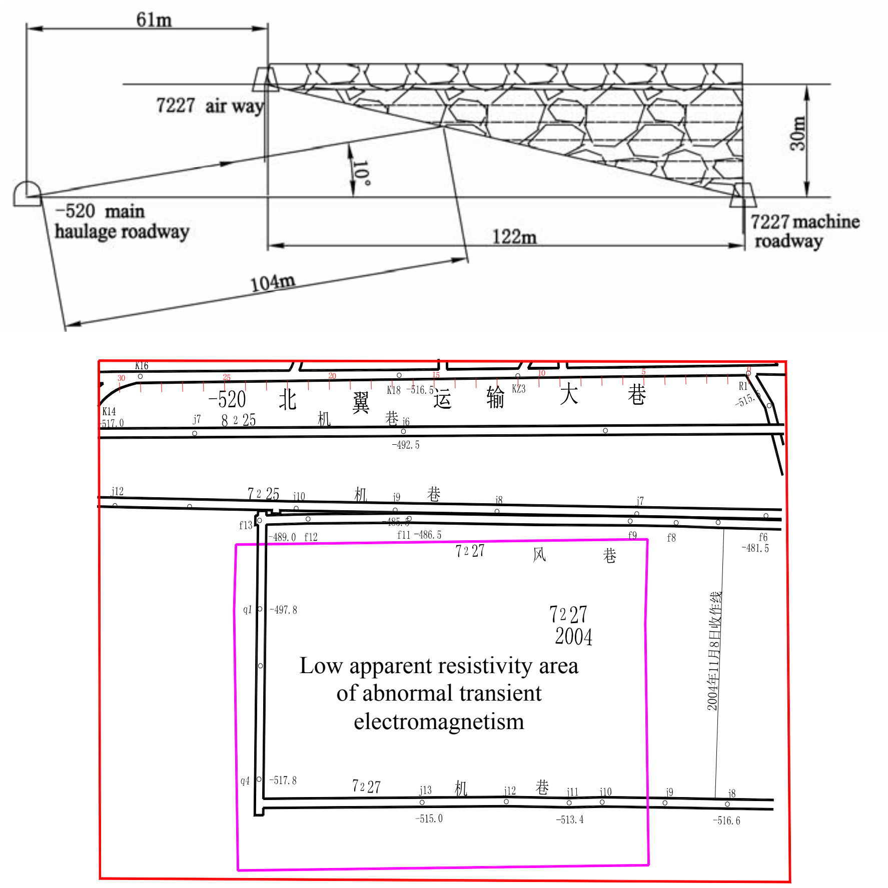

Fig. 8 *Schematic diagram of abnormity in the section and plane during detection of goaf water in -520 main north-wing haulage roadways*

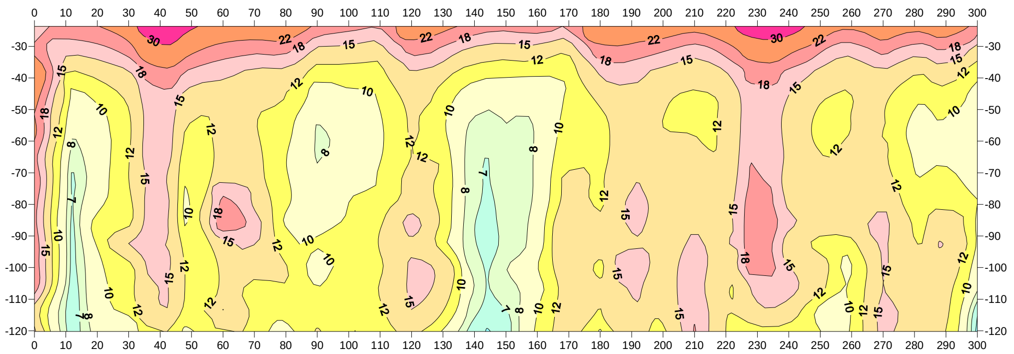

Fig. 9 *Apparent resistivity contour map obtained by detection from an elevation of 10° of sidewall of -520 main north-wing haulage roadway*

(2)Detection result of YCS50 transient electromagnetic instrument

YCS50 transient electromagnetic instrument is the high-power instrument developed by China Coal Technology & Engineering Group Chongqing Research Institute, with the main performance parameters as follows: maximum supply current ≤50 A; transmitting frequency: 25 Hz; overlapping time: 1024; receiving coil: 1.5 m×1.5 m.

Fig.10 shows the apparent resistivity contour map obtained through detection with YCS50 transient electromagnetic instrument, with the detection conducted from an elevation of 10°.

According to the figure, there is an obvious abnormal low-resistivity area at 50m-245m in the horizontal coordinate and 70m-210m in the vertical coordinate. The analysis based on the geological data indicates that the abnormal area is formed because the goaf in front of it is filled with water (This area is identified with purple lines in Fig. 8).

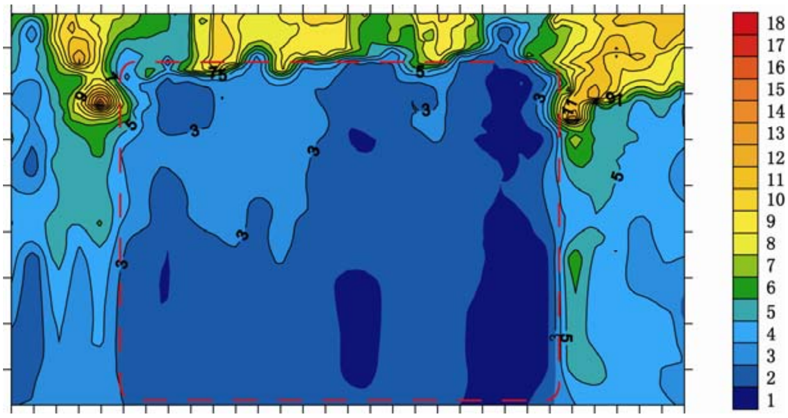

Fig. 10 *Apparent resistivity contour map obtained through detection from an elevation of 10°of sidewall of -520 main north-wing haulage roadway*

(3)Analysis and comparison

The current during detecting with YCS160 transient electromagnetic instrument is 3.0A and that of YCS50 transient electromagnetic instrument is 48A±. Based on the analysis and comparison, we think that remote detection is impossible with a small-current transient electromagnetic instrument because the external interference could not be suppressed appropriately in case of poor roadway conditions and a large detection distance. During actual data acquisition, it is found that the tail data of voltage signal obtained with a small-current transient electromagnetic instrument are of poor quality and low reliability, while those obtained with a large-current transient electromagnetic instrument are of good quality and high reliability. Besides, the large-current transient electromagnetic instrument is characterized by the advantages in suppression of the external interference and remote detection and its effects have been verified. However, it is so heavy not easy to be transported down the hole.

According to the comparison above, transient electromagnetic method servers well for identification of the abnormal area in the goaf, providing the accurate target region for drilling. It is of great significance in guiding the production.

Existing problems

Although good results have been achieved in downhole coal detection through transient electromagnetic method, improvements are needed in many aspects as follows according to our practical application experience:

Great interference from roadway conditions during detection. At present, anchor buoy and U-type shed are usually used for supporting roadway, it is urgent to solve the problem of how to minimize or eliminate such interference; for the time being, maintaining a proper distance to the ion work during detection is an effective method to ensure the homogeneous detection environment; electric current increasing is also effective in ensuring the quality of data acquisition in tail.

Superior detection in coal roadway is superior to that in rock roadway under the same support condition; because the detection data of coal roadway is better than in rock roadway, which is caused by the electrical property contrast between the coal seam and rock stratum.

Presently, domestic transient electromagnetic instrument could reach to approximately 100m and can be used to guide the production; however, if intending to catch up with modern mining machines, the manufacturers are suggested to improve transient electromagnetic instrument; it is extremely urgent to produce heavy duty electromagnetic instrument while enlarging the distance for downhole coal detection.

Conclusion

This paper generally describes the application of transient electromagnetic method in downhole mine detection and improves this method in practices, while analyzing problems of such method in detection and proposing points of view on how to solve the problems. In a word, the transient electromagnetic method is of a precise and effective downhole water detection method. It is worth of further study and improvement for better service in modern mine production and also for positive contribution to safe coal production and economic effect.

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