MINE TRANSIENT ELECTROMAGNETIC METHOD AND ITS APPLICATION IN CHINA

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ABSTRACT

Mine transient electromagnetic method (MTEM) applied to the prediction of the water-bearing structure in the mine has been developed recently, the small multi-turn loop is adopted and it has many advantages compared with other technology, which are low in cost, and high in accuracy and efficient. The data received is easily interrupted by the metallic body when the transmitter with magnetic bipolar source is used, so the transmitter with electric dipolar source is put forward. Finally, problems needing to be solved in further researches are pointed out.

Key words: Mine transient electromagnetic method; water-bearing structure; small multi-turn loop; magnetic bipolar; electric dipolar.

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INTRODUCTION

The coal output and consumption of china is maximal in the world, and it wouldn't be changed in a long time that the coal dominates the energy structure in china. Water burst is a geological disaster often seen in coal mines, which not only influences on the normal mining activity but also brings about substantive economic loss[1]. With the increase of mining depth and the application of fully mechanized mining as well as the sublevel caving, the influence of water burst on working face become more and more obvious. So finding out the buried water-bearing structure and preventing advanced have been the key for the safety in the coal mine production. Now, some geophysical techniques have been applied in the prediction of the buried water-bearing structure, such as the channel wave seismic method mine direct electric method, mine transient electromagnetic method[2]. The channel wave seismic method is very good in detecting geological structures exactly, but not good in detecting the water-bearing loads of such structures. Based on the difference in rock conductivity, the mine direct electric detection technology has many advantages. It is quick, simple and convenient to operate, it is effective over long distances and sensitive to water. It has been successfully applied in the detection of water conducting and water bearing loads of structures in mine [3]. However, it also has some limitations. For example, the roadway must be longer than the detection distance and cannot have water and metal in its sight. A mine transient electromagnetic method (MTEM) with a small multi-turn loop used in coal mines has recently been developed in china[4, 5]. Compared with the direct current method, this technology is not limited by the size of the construction site and has no problem of electrode grounding. With its many advantages, such as rapid and convenient operation, the small effect exerted by the volumes involved and its long detection distance, the effect of the MTEM applications have been satisfactory in detecting and predicting the conduct of water conduits of faults, collapsed columns and hydrologic boreholes [6, 7], and the result shows a good prospect.

PRINCIPLE

The mine transient electromagnetic method (MTEM) is a geophysical method used in roadways of mines for observing the secondary eddy current field in time domain. The principle of it is essentially the same as the ground transient electromagnetic method. Two loops are adopted, one is the transimitter loop *(Tx)* and the other is the receiver loop *(Rx)*. The *Tx* loop and the *Rx* loop have various sizes, depending on available access in the roadway. Normally the loop is square and the side length is 2~3m. A stepped pulse current is supplied to the *Tx* loop. At the moment t=0, the current is turned off abruptly and the primary magnetic field will disappear at once. According to Faraday's law of induction, the eddy currents flowing near the *Tx* loop is generated so as to maintain the magnetic field at the value that existed just before cut-off. The eddy currents diffuse to greater depths with the passage of time and decay as a result of the finite conductivity of the rock around the roadway. An electromotive force, proportional to the time rate of change of secondary magnetic field, is measured at various time intervals at each receiver location and yields information about the geoelectrical structures with depth. Because of the small loop configuration adopted this technology makes the detection possess directionality the loop can be laid out at will according to different target orientations. The normal direction of the loop is just the detection direction and the loop can be laid out to make the normal direction aim at the roof (Fig. 1a), the floor (Fig. 1b) and the bedding (Fig. 1c). It must be pointed out that the full space effect has been an inherent problem of MTEM because this technology is constructed in a roadway and the field is distributed over the entire space.

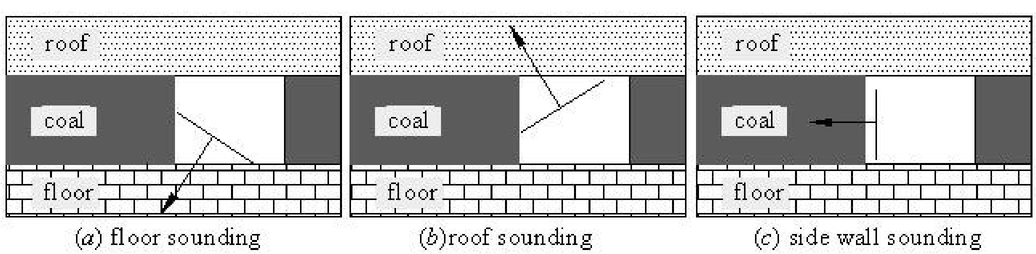
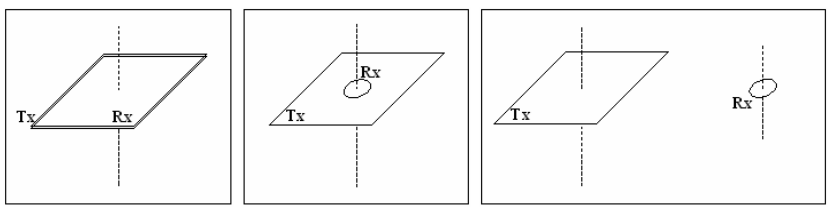


Figure 1.: Sketch map of detecting direction.

CONFIGURATION

Because of the roadway space restriction a small multi-turn loop is adopted in MTEM. The loop side length is not longer than 3m. Some configurations can usually be used, such as a coincident loop, an in- loop or a displaced loop (dipole-dipole). The transmitter loop of the coincident configuration overlaps the receiver loop (Figure 2a), its advantages are: 1) high signal levels, 2) sensitivity to abnormity and 3) convenient in operation. However, there is a detection blind zone from 0 to 20 m because the early data is disturbed by the mutual inductance between Tx and Rx (See Figure 2.). In the in-loop configuration, the small receiver loop with hundreds of turns is located in the center of the transmitter loop (Fig. 2b). In the displaced loop configuration, the receiver loop is separated from the transmitter loop, so the mutual inductance is small, but the signal received is weak and the operation is not convenient (See Figure 2c).



(a) Coincident loop (b) In loop (c) Displaced loop

Figure 2.: Sketch map of configurations.

ELECTRIC DIPOLAR

There are some metallic bodies in the roadway, such as the railway, pipes for draining, machines. When the magnetic bipolar adopted a strong second electromagnetic field is induced in them, of which the amplitude is higher than that of the geological abnormal body, so the observed data is interrupted greatly. At the same time, because the induced electromagnetic field diffused in the whole space around the roadway, the observed signal includes the geoelectric information from the whole space and confirming the place of the abnormal body is difficult. In order to avoid the interruption and the whole space effect it is suggested that the electric bipolar should be adopted in the coal mine. Once the electric bipolar was used as the excitated source, the induced field would diffused in the rock around the roadway and there was no longer interruption from the metallic bodies because they would be not excitated, besides it would make for confirming the place of the abnormal body because the observed signal mainly reflected the geoelectric information coming from the side at which the source lied.

CASE

Prospecting for roof water[8]

The 34223 working face in Xuzhou Quantai coal mine is 140m in width, 730m in length, with a roadway width of 4m and a height of 2.5m. The coal to be mined is seam No.3 with a thickness of 4.58m, an overlying formation of argillaceous sandstone. In order to prevent the roof water from bursting in the mining production, the water abundant zone must be made clear and the borehole position to discharge water must be determined.

The instrument SIROTEM-III was used and the small multi-circle coincident loop was adopted with the transmission loop being 2m×3m×34 circles and the receiving loop being 2m×3m×60circles. 22 measuring points were laid with an interval of 30m. Noise removal and time-depth conversion as well as resistivity calculation are carried out, resulting in an apparent resistivity sectional view of the conveyer belt roadway (Figure 3.).

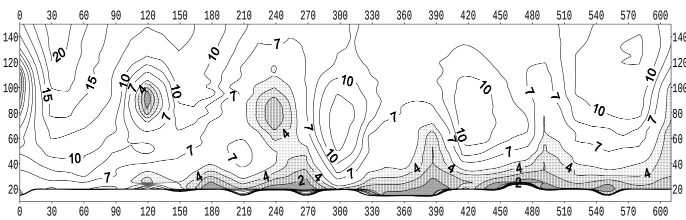


Figure 3.: Apparent resistivity sectional view of the conveyer belt roadway.

Prospecting for goaf water

It is 150m long between No.1 driving head and No.2 driving head of 2# main return airway in one coal mine of Shanxi (Figure 4.). According to the geological report there may be a disused roadway, but the place and the water bearing are not known. In order to avoid the water burst, the water abundant must be made clear. The instrument Terratem was used. 11 measuring points were laid at the No.1 driving head and 10 measuring points at the No.2 driving head (Figure 5.). The two apparent resistivity isolines views (Figure 6) shows there is an abnormal area between 80-100m in front of No.1 driving head. The result of boring proved that the abnormal area was just the goaf filled with water.

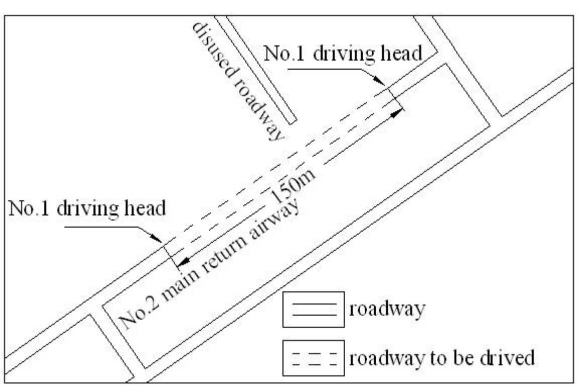


Figure 4.: Sketch map of the driving.

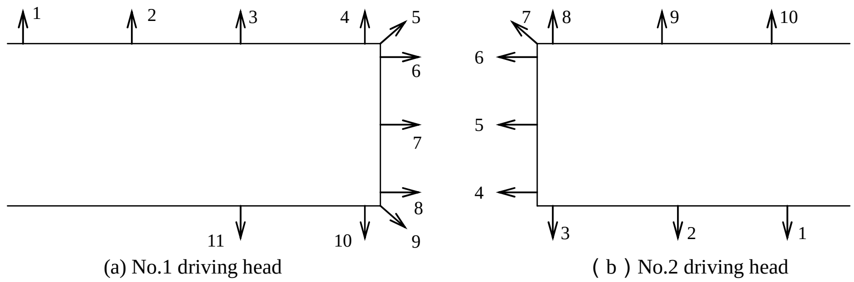


Figure 5.: Sketch map of the observation station.

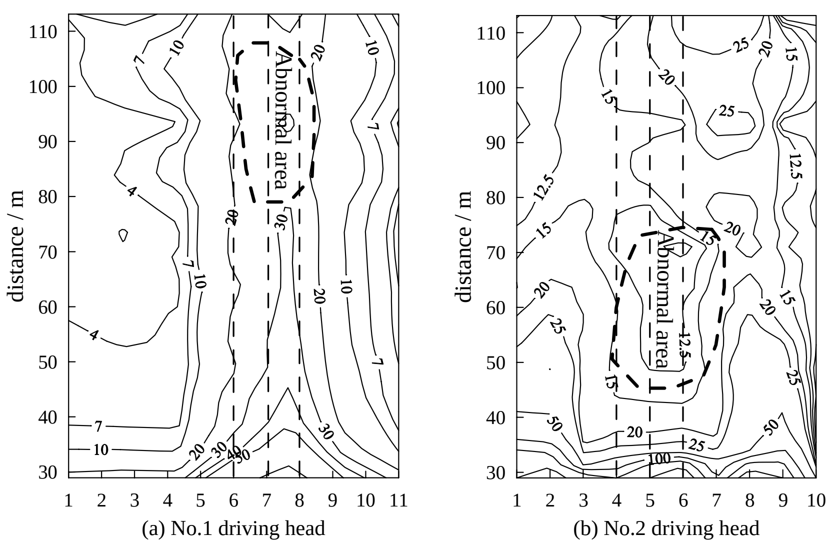


Figure 6.: Isolines of the apparent resistivity.

DISCUSSION

The detection technology of the mine transient electromagnetic method has a number of merits. These include a rapid and convenient operation, a small effect independent of the volume involved a long detection distance, which avoids the difficulty of grounding the electrodes and the space limitation in the construction site. It has been shown that the application of this technology has been satisfactory in detecting a water conducting and water bearing structure.

As a new technology, developed recently, MTEM is still incomplete. The conditions under which it can be applied and its effects has not been completely investigated, while the data processing is still at the 1D level without any development in 2D and 3D. To ascertain the geological unique location of the abnormality in space, it is essential to distinguish the geoelectric abnormality from the effects of the roadway and the entire effect of space. At the same time, the effective detection depth in the bedding and its perpendicular layer must be known. MTEM research on the response regularity of the 3D geoelectric abnormality under different roadway conditions and different observation methods must be developed by numerical simulation and physical modeling. It is believed that MTEM must become gradually more important in the roadway driving of coal mines, in tunnel engineering and underground engineering of cities.

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