Research on Multi-components Characters of Mining Transient Electromagnetic Advanced Prospecting method

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***Abstract*—In order to grasp the rule of mining transient electromagnetic multi-components characters, numerical modeling methods are employed to simulate the advanced prospecting multi-components response characteristics of gob water with measuring-point arrangement of fanned shape. Results of numerical modeling indicate that there really exist anomaly response in the profiles of induced electrical potential for the case of gob water in front of roadway head. Where the amplitude is highest in the direction of 90 degree for the vertical component, however the results of horizontal component exhibit double peaks abnormality and the amplitude is zero in the direction of 90 degree. Besides for the case that gob water being in front-right of roadway head, the highest amplitude of vertical response component appear in the direction of 45 degree in the right, however the zero amplitude points of horizontal response component appear in the direction of 45 degree in both sides of left and right of tunnel. Nonetheless, the ghost can be removed by contrast between the vertical response components. Based on numerical simulation, application of miming indicates that integrated interpretation using horizontal and vertical component can obtain reliable results. Therefore, it is feasible that using multi-components transient electromagnetic response to prospect gob water, and it provides a new idea for using miming transient electromagnetic method.**

Keywords*—mining transient electromagnetic; roadway head; advanced prospecting; multi-components; numerical simulation

I. INTRODUCTION

For the research of transient electromagnetic multi-components, McNeill et al calculated the vertical response components and horizontal response components of conducted plate in the half space, however he did not further analyze the rules of three components [1]. Wang et al did the numerical simulation by computing the vertical response components and horizontal response components of 3D conducted body in faults contact zones using finite difference method [2]. Besides, Xi et al calculated the three response components in x, y and z directions for sheet with different dip angles using intrinsic current instead of swirl current [3]. Nevertheless, all the above research only consider the ground half space to be background field. On the contrary, both of transmit and receive of mining transient electromagnetic method are in the narrow tunnel, hence only small TEM central loops can be employed. However, small loop is easy to measure the multi-components data in different directions by rotating with different angles. In this paper, we did the numerical simulation of multi-components responses for the gob water located in the front of roadway head and conclude the rules of multi-components responses. Based on above jobs, we propose the interpret method of mining transient electromagnetic multi-components. Finally, actual mining application indicates that multi-components transient electromagnetic response is feasible to prospect gob water. Hence it provides a new idea of process and interpret of miming transient electromagnetic data.

II. TIME DOMAIN FINITE DIFFERENCE METHOD

3-D time domain finite difference method was firstly proposed by Yee who adopted the mesh technique which meet the continuous condition of field components at the sudden surface change [4]. However, Yee employed the explicit difference scheme which is very time-consuming. Fortunately, Wang et al proposed a method using virtual displacement current instead of displacement current to deal with Maxwell equations makes time step longer so as to save time-consuming [5]. The proposed Maxwell equation are described using the Eq. (1) and Eq. (2):

$$\nabla \times E = -\frac{\partial B}{\partial t}, \tag{1}$$

$$\nabla \times H = \sigma E + \gamma \frac{\partial E}{\partial t}, \tag{2}$$

Here, E is strength of the electric field, B is magnetic induction intensity, H is strength of the magnetic field, σ is conductivity, γ indicates virtual dielectric constant and t express propagating time of electromagnetic wave. Difference scheme of electric field and magnetic field can be obtained by differentiating equation (1) and equation (2). Besides, based on the job of Wang et al Sun et al introduced the electric current density of rectangular loop into Maxwell equation and realize computation of transient electromagnetic field with the source of rectangular loop [6].

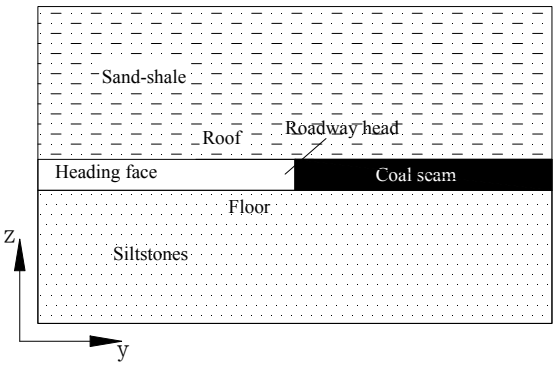
Based on above methodology, we make the forward modeling code and simulate the multi-components characters in the whole space. Finally we conclude the rules of multi-components response for different anomalous bodies in different directions.

III. Simulation of Multi-components Response Characters

A. Horizontal Components Response Characters of Gob Water in the Front of Roadway Head

In the research, gob water is chosen to be as an example to do the modeling to simulate the mining transient electromagnetic multi-components characters. According to coal mine geology, we design coal geological model with resistivity of 100 ohm-m roof and 150 ohm-m floor as well as 400 ohm-m. Besides the thickness of coal seam is 10m, as shown in Fig.1 (a). An anomalous body of low resistivity as gob filled with water is located in front of roadway head. The length of the side is 30m and its resistivity is 0.5 ohm-m, as shown in Fig.1 (b). Meanwhile fanned shape of measuring arrangement is employed to detect anomalous body in different directions in the front of roadway head, as shown in Fig.1 (b). Here, normal direction of transmitting loop is defined to be vertical.

Fig.2 is the results of forward modeling. Furthermore, coordinate of measurement points and normalized induced electrical potential serve as horizontal coordinate axis and vertical coordinate axis respectively. As shown in Fig.2 (a), time profile exhibit peak value which correspond to NO.7 measurement point in the direction of right ahead of roadway head. However, negative peak of NO.4 measurement point and positive peak of NO.10 measurement point appear in Fig.2 (b). Due to symmetry of transmit loop, cancellation of horizontal responses of two sides make measurement value of NO.7 point to be zero. Compared with vertical component and horizontal component, horizontal component are much sensitive to the position of anomalous body than vertical component, hence horizontal component much more accurately locate the direction of anomalous body than that of vertical component.



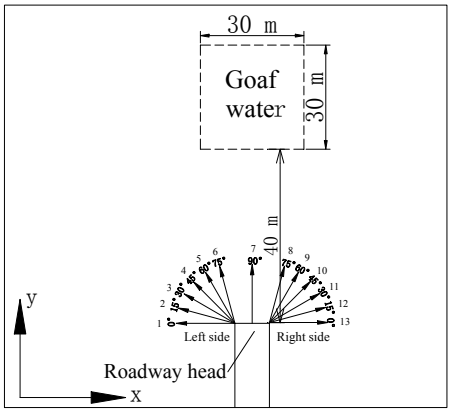


Fig. 1. (a) Geological model of coal seam formation. (b) Geological model with gob water in front of roadway head

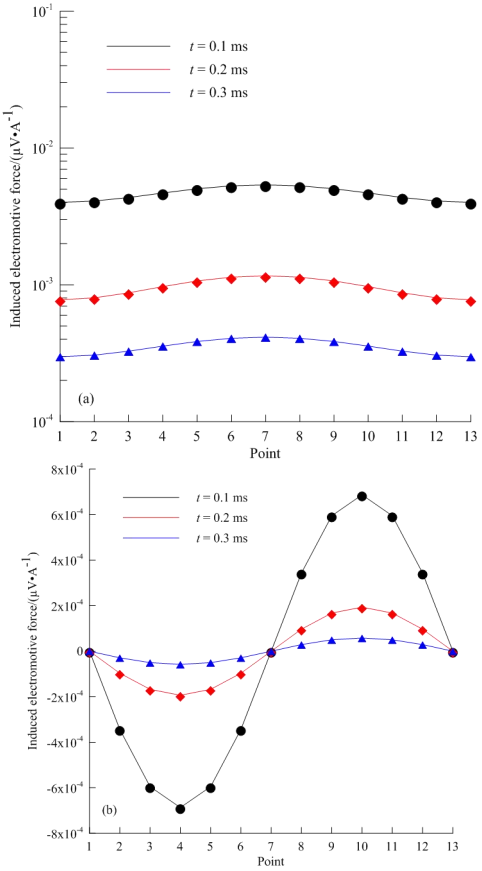


Fig. 2. The profile of multiply test channels with the model that gob water is in front of roadway head.(a) the results of vertical components; (b) the results of horizontal components

B. Horizontal Components Response Characters of Gob Water in The Sides of Roadway Head

In fact, anomalous body of bearing water can be located in anywhere in front roadway head. Here, we design the model with the gob water in the front-right of the roadway head, as shown in Fig. 3. In addition, the value of resistivity of roof and floor as well as gob water are the same as the model described in Fig.1. The

modeling results are shown in Fig. 4. Hereinto, (a) is vertical component and (b) is horizontal component. The location of peak value of vertical component appears in NO.10 measurement point which corresponds to the position of gob water, hence the peak value of vertical component can effectively indicate the information of gob water.

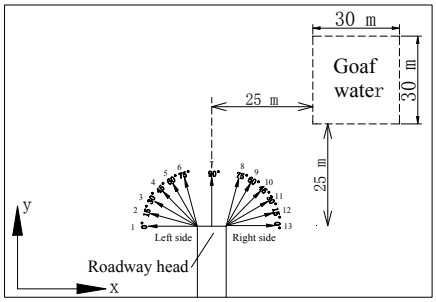


Fig. 3. Geological model that the gob water in the right side of tunnel.

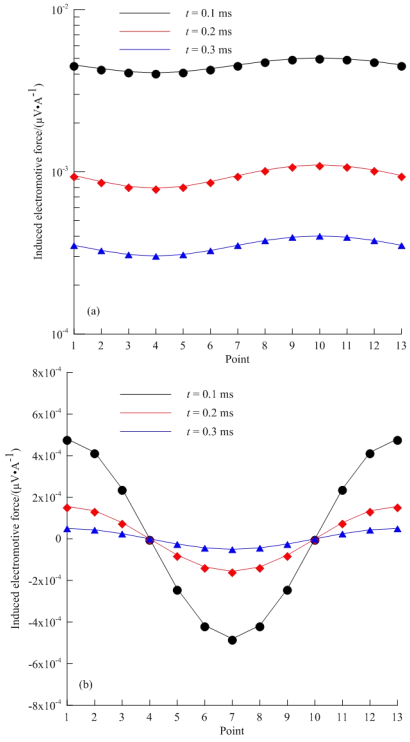


Fig. 4. The profile of multiply test channels with the model that gob water is in front-right of roadway head.(a) the results of vertical components; (b) the results of horizontal components.

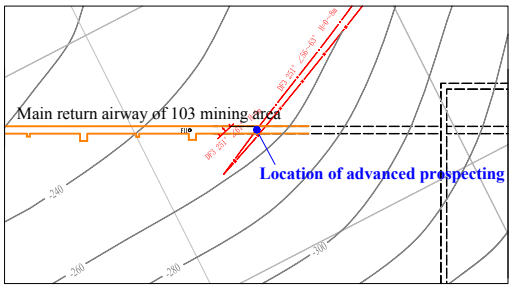


Fig. 5. The plan of main return airway in 103 mining area in a mine.

IV. Production Practice

The formation of coal mine geology include Pleistocene, Growing new and Shanxi formation of Permian. Limestone with water bearing is located at the bottom of wellbore. The plan of main return airway in 103 mining area in a mine, as shown in Fig. 5. The TerraTEM is employed for advanced prospecting with small multi-turn loop of 2 m×2 m.

The prospecting results of mining transient electromagnetic multi-components are shown in Fig.6. Here, coordinate of measurement points and normalized induced electrical potential serve as horizontal coordinate axis and vertical coordinate axis respectively. Fig. 6(a) is induced electrical voltage of vertical component and there are three maximum values who are 441 μV/A of the NO.3 measurement point, 965 μV/A of the NO.6 measurement point and 2491 μV/A of the NO.8 measurement point. Obviously, NO.8 measurement point with the highest peak which is the response of anomalous body. However, there exist three zero points which are NO.2 measurement point, NO.8 measurement point and NO.11 measurement point, respectively. Combining the results and data of hydrogeology, the area of water bearing is concluded in the direction of 15 degree at the mid-right. And the conclusions have been verified by the drilling.

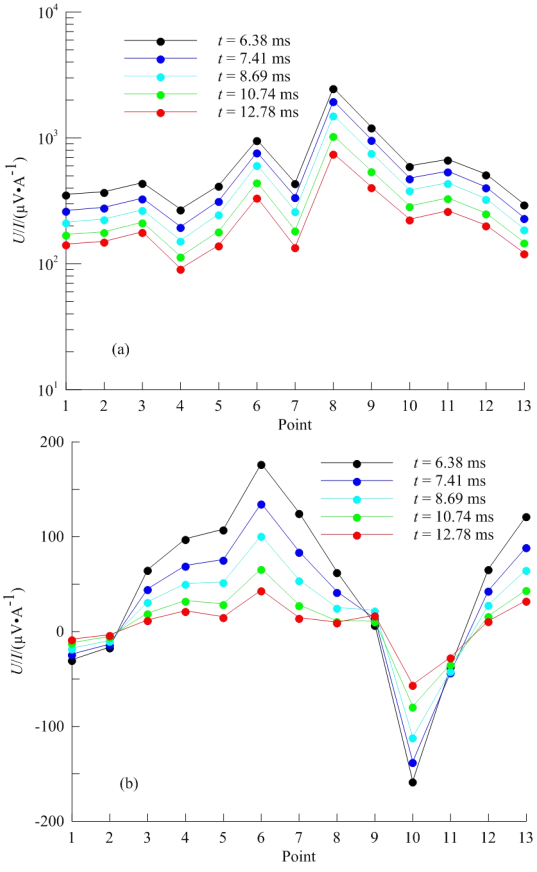


Fig. 6. Induced electrical potential profile of mining test data.(a) Vertical component; (b) horizontal component.

V. CONCLUSIONS

The numerical simulation of multi-components characters of mining transient electromagnetic in the whole space have been done by time domain finite difference and the response rules have been obtained, as following. (1) When the anomalous body is in the front of roadway head, the horizontal component response is relative weaker, oppositely, vertical component is relative stronger. And the resolution of horizontal component is higher than that of vertical component. (2) Several zero points of horizontal components will appear in the case of anomalous body in the side of tunnel, we can locate the direction of anomalous body using the information of horizontal component by removing false abnormity via comparing with vertical component. (3) Applications in the mining indicate that comprehensive analysis of horizontal component and vertical component can locate the area of anomalous body. Hence the multi-components of mining transient electromagnetic provide a new way of data process and interpretation.

ACKNOWLEDGMENT

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