Numerical Simulation of 3D Borehole-to-Surface Electrical Method

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ABSTRACT

The anomaly response characteristics of the vertical line-source 3D borehole-to-surface model are simulated by an adaptive finite element method. The calculation shows that the anomaly in the radial direction is pressed and the closer to the source, the more pronounced, the anomaly is stretched in the direction perpendicular to the radius. Adding a B pole in the Y direction can offset the effect of stretching to some extent. The anomaly that is closer to the source of the profile is clearer than the anomaly that is far from the source. The research results are of great significance for guiding the practical application of the borehole-to-surface electrical method.

Key words: Borehole-to-surface electrical method, adaptive finite element, line-source

INTRODUCTION

The borehole-to-surface electrical method was first proposed by Former Soviet Union scientists in 1958, and is now widely applied in oil fields, coal fields, engineering, etc. (Tang et al., 2007). In terms of 3D numerical simulation, Xu Kaijun and Li Tonglin (2006) completed 3D forward modeling of the vertical line-source borehole-to-surface electrical method using finite difference. Wang Zhi and Pan Heping (2014) realized the 3D numerical simulation of the borehole-to-surface electrical method by the finite element method. Most of these calculations were based on structured grids, and the unstructured adaptive grids are used in this paper, which can effectively simulate complex models with multi-scale and arbitrary shapes.

THEORY AND METHOD

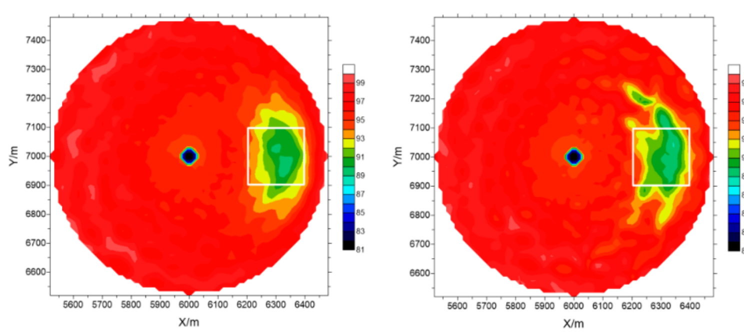
The formula of the boundary value problem of borehole-to-surface electrical method is

$$\nabla\cdot(\sigma\nabla\Phi)=f(\sigma\frac{\partial\Phi}{\partial n}=0,\frac{\partial\Phi}{\partial n}-\lambda\Phi=0 \quad (1)$$

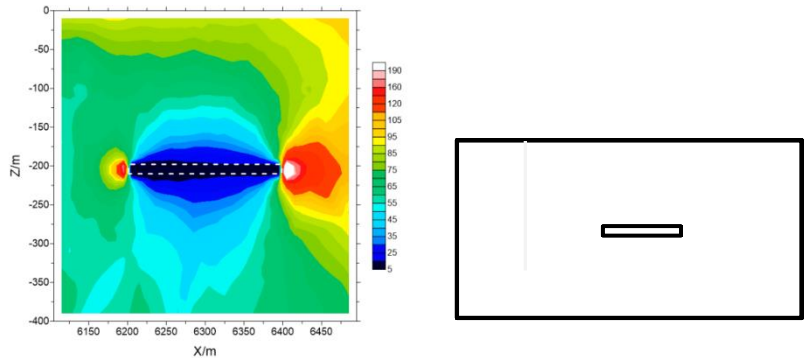
Where, Φ is the potential; f is the line-source; σ is the conductivity.

MODEL CALCULATION

The model is set up as follows: casing well length –300 m, diameter --0.1 m, resistivity --0.1 $\Omega\cdot m$, resistivity of model background --100 $\Omega\cdot m$, resistivity of low resistance anomaly--1 $\Omega\cdot m$, scale (in x, y, z order) --200*200*10 (m), top surface depth—200 m, and 200 m from the left side. And the white or white dashed line frame is the boundary of the anomaly.



(a) (b)



(c) (d)

Figure 1. Apparent resistivity response results and model diagram. (a) Apparent resistivity plane diagram of Y direction with B pole. (b) Apparent resistivity plane diagram without B pole in Y direction. (c) Apparent resistivity profile. (d) Model diagram.

From figure 1b, the low resistivity anomaly is suppressed and narrowed in a radial direction, and the suppression on the side near the source is more serious. This is mainly due to the influence of the source, which produces a false high resistivity anomaly on the left and right sides of the low resistivity anomaly. And the anomaly is stretched in the direction perpendicular to the radius, which is mainly due to the compression of the source in the radial direction and the processing of data along the radial direction. Figure 1a is the result of adding a B pole in the Y direction. It can be seen that the stretching problem of direction perpendicular to the radius can be solved to some extent by adding a B pole in the Y direction. From the map in Figure 1c, we can see that the boundary description of the anomaly on the profile is accurate, and the closer to the source, the more sensitive is the reaction.

CONCLUSION

The anomaly response characteristics of a 3D borehole-to-surface model are simulated by an adaptive finite element method with unstructured grid. Through the analysis of the calculation results of different models, the following understandings are obtained:

(1) The apparent resistivity response of anomaly is suppressed in the radial direction and stretched in the direction perpendicular to the radius, and the stretching problem can be offset to some extent by adding a B pole in the Y direction.

(2) The closer the anomaly to the source, the more sensitive the detection.

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