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Geotechnical Control of the Borehole Drilling by Phasometric Method

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ABSTRACT

To optimize the rotation parameters of the drill and reduce the load on it during the drilling process, it is necessary to have information about the composition of the layers of the geological environment through which it passes. This information will reduce the wear of technical equipment and tools, as well as allow to plot optimal drilling trajectories and track the penetration of the drill into the target layer of the geological environment. This issue is especially relevant for the mining industry, where work is carried out at great depths with a complex structure of soil and rocks. Effective extraction of this information can be obtained by monitoring the phase changes of the recorded electrical signals from the receiving lines of the electrodes of the geoelectric monitoring system. The paper considers the general mechanism of implementation of the phasometric method in relation to the tasks of monitoring the drilling process, describes the equipment, as well as laboratory and field experiments to study the effectiveness of monitoring the drilling process by the phasometric method. The study of the dynamics of changes in the phase signals of the receiving lines of the electrodes during passage through the layers of soil with different electrical characteristics, which affects the change in the parameters of the recorded geoelectric signals. The research results are accompanied by graphic material confirming the possibilities of the proposed method and the prospects of its application in the extractive industry to optimize the parameters of drilling wells in real time.

Keywords: well drilling, shallow geophysics, geotechnical monitoring, geoelectrics, phasometric method

INTRODUCTION

In the process of well drilling, it is necessary to monitor the soil layers surrounding the well, since well drilling can be highly efficient only with a certain combination of drilling mode parameters. At the same time, even on adjacent and nearby land plots, the composition of the soil can be different, which is due to the heterogeneity of its composition. For this reason, one should not be guided by the conclusions and conclusions made during geological studies from neighboring areas, since they may be inaccurate [1, 2].

The main information that needs to be obtained is the following: soil granulometric characteristics, porosity, moisture level, degree of plasticity and deformation of layers, depth of groundwater [3, 4].

Control of the geological environment in the drilling area by direct geophysical methods of control is technically and economically inexpedient. In this case, to obtain information about the main elements of the geological environment, as well as about its physical and mechanical properties, it is advisable to use monitoring methods of engineering shallow geophysics [5-7].

Thus, the aim of the work is to develop a method for obtaining information about the soil layers through which the drill passes during drilling. This information can be obtained through geophysical methods of control. This will increase the efficiency of the drilling process by reducing the cost and time of searching for target layers.

DESCRIPTION OF LABORATORY EXPERIMENT

In [7,8], the application of the phase-measuring method of geoelectric control is explained, namely, the use of several sources of probing signals located in close proximity to the object under study and the required number of vector sensors for measuring the electric field. The most promising in the organization of automated control is the use of geoelectric methods of sounding media, which provide an effective organization of observations of geological objects, assessment of the state and forecast of development, which is determined by their high manufacturability [8, 9]. To increase the efficiency of studies of the geological environment by reducing the ambiguity of the assessment of geophysical data will allow the use of vector measurement systems with registration of the phase characteristics of the electromagnetic field. These systems underlie the phase-metric method of geoelectric control using the phase characteristics of the field for subsequent detection and localization of geodynamic processes [10, 11]. Laboratory and field studies were carried out on the possibility of determining the location of the drill using the phase-metric method of control. The same method allows you to determine the characteristics of the soil layers through which the drill passes. Mountain layers can differ in moisture saturation and particle size distribution, which affects the change in electrical characteristics [12, 13]. In this case, the objects of control are the technological equipment, the well and the soil surrounding it.

The works [12, 14, 15] explain the application of the phase-metric method of geoelectric control, namely the use of several sources of probing signals located in the immediate vicinity of the object under study and the required number of vector sensors for measuring the electric field. In this case, the electrodes can be located along a line or on a plane. In the latter case, we get the opportunity to track the immersion of the drill in three-dimensional space, and also increases the accuracy of determining the characteristics of soil layers.

To assess the prospects of using the phase-metric method in the tasks of obtaining information about the properties of the soil, laboratory modeling of the natural-technical system "soil-well-drill" was carried out. For this, a laboratory setup was created, the scheme of which is shown in Figure 1. It includes a generating subsystem for quadrature probing signals supplied to point sources of alternating electric field A and B, as well as a receiving subsystem for recording and isolating its phase characteristics, information about which is contained in input signals coming from receiving pairs of point electrodes M1N1…M3N3 located in a particular spatial configuration on a controlled territories of the geological environment. In general, the principle of measurements in the receiving subsystem of phase monitoring for an arbitrary line of the monitoring system can be represented as a sequential passage of recorded geoelectric signals through a device for comparing them (differential amplifier), an information component isolation device (low-pass filter) and a device for direct phase isolation. The mock-up model of the control object is a reservoir with soil (wet sand), on the surface of which the phase control system is directly placed, near which a metal pin is installed to a certain depth from the ground surface to simulate the drilling process with its help.

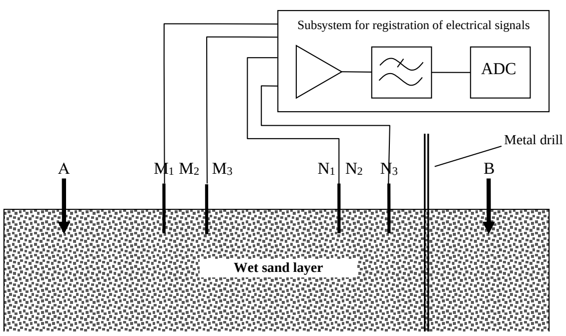

Fig.1. Scheme of the organization of the laboratory experiment

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Each of the point sources generates an electric field signal of the following form:

$$\vec{E}_{AX} = \vec{E}^{0}_{AX} + \Delta\overline{E}_{AX}\,,\quad \vec{E}_{BX} = \vec{E}^{0}_{BX} + \Delta\overline{E}_{BX}\,,$$

where $\vec{E}^{0}$ - electrical signal recorded before the drill plunged into the ground; $\Delta\overline{E}$ - anomalous component of the electric field caused by the presence of a drill in the soil, causing a change in the electrical characteristics of the soil.

During the experiment, the drill was immersed in various parts of the soil. In all cases, the dive was carried out starting from the 80th second in stages, every 50 seconds. The immersion step of the drill was 10 cm. A pair of harmonic signals with a phase shift of 90 degrees relative to each other, frequencies of 166 Hz and amplitudes of 5 V. The registration of preprocessed analog geoelectric signals in an analog-to-digital converter was carried out with a sampling frequency of 1001 Hz. Then, the change in the phase of the output signals was recorded (Fig. 2, 3) during the immersion of the drill. When the drill passed through layers with different electrical characteristics, the phase of the digitized electrical signals changed.

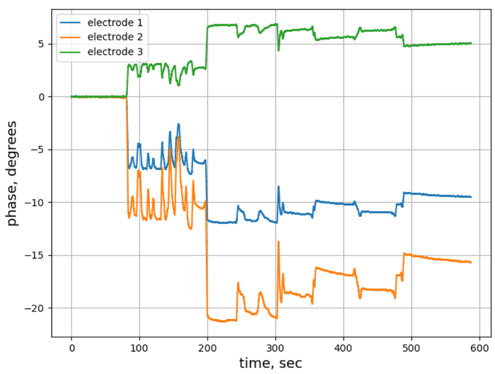

Fig. 2.

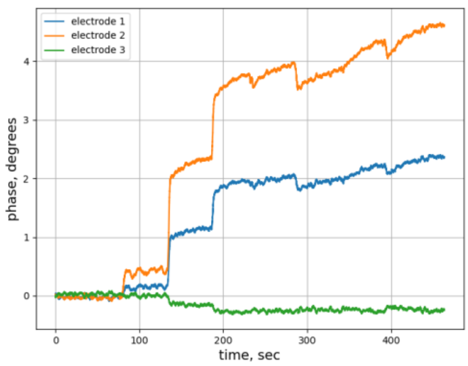

Fig. 3.

Studies have shown that the degree of change in the phase of the probing signal depends both on the depth and on the electrical characteristics of the soil. Thus, by the degree of change in the phase of the signal from different receiving lines, one can judge the process of immersing the drill into the ground or the characteristics of the ground. Thus, it is necessary to have information about the depth of immersion of the drill.

The figures show that the drill progressively plunged into the ground and, as it exited from one layer to another layer with different characteristics, the phase signal angle changed. Thus, Figure 3 shows that starting from the 410-th second, the drill hit the less wet ground, and in the case of Figure 4, the drill hit the less wet ground, starting from the 290-th second.

Similar results were obtained as a result of field tests using a layout of an experimental phase control system, which is a geotechnical monitoring system based on a software and hardware complex with a receiving part consisting of a variety of highly sensitive spatially spaced recording devices in the form of grounding electrodes, analog and digital signal processing paths, storage, transmission and display devices. the received geodynamic information, as well as the software necessary for their joint work. The layout of the emitting and receiving electrodes of the control system is shown in Fig. 4. The following designations are adopted in the diagram: A and B - radiating grounding electrodes, M1…M4 and N1…N4 - receiving grounding electrodes forming pairs. The distance between the emitting electrodes is

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110 m, between the receiving M1N1 - 45 m. For this group of experiments, the system parameters are assumed to be the same as for laboratory studies, except for the level of probing signals (30 V).

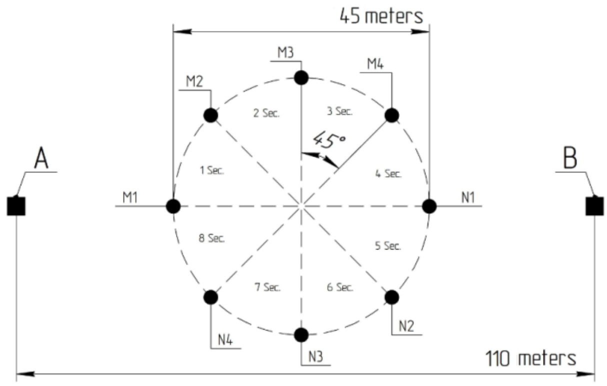
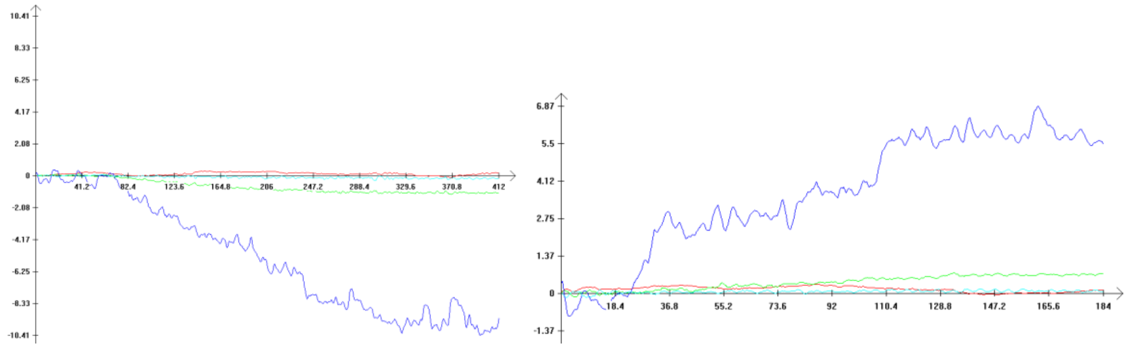


Figure 4 - Layout of the emitting and receiving electrodes of the phase control system

Figure 5 shows examples of phase signals for four receiving lines of the phase control system obtained during drilling of a well with a depth of 10 m (a) (at a distance of 20 m from the center of the geoelectric installation) and extraction of the drill from the geological environment (b). In this case, the immersion was carried out uniformly, starting from the 60th second in stages, and extraction, starting from the 20th, is stepwise with variable time steps.



a) b)

Figure 5 – Phase signals for four receiving lines of the control system obtained during drilling of a well with a depth of 10 m (a) (at a distance of 20 m from the center of the geoelectric installation) and extraction of the drill from the geological environment (b).

From the obtained family of curves (Fig. 5a) it can be seen that in this case the geological medium is close to homogeneous and is not layered, since the change in phase signals during the drill immersion occurs quasi-linearly for all receiving lines. In addition, it has been established that the processes of drilling into the geological environment and subsequent extraction are accompanied by opposite geodynamic processes and corresponding antiphase signals, on the basis of which their effective control can be carried out.

CONCLUSION

The conducted studies have shown that the degree of phase change of the recorded geoelectric signals of phase control systems depends both on the drilling depth and on the electrical characteristics of the soil and the degree of its uniformity. As a result, according to the level of these signals, it is possible to effectively control the process and depth of immersion of the drill into the ground, as well as changes in its characteristics. Thus, the paper proposes a method for qualitative determination of the characteristics of soil layers in the process of drilling wells, a distinctive feature of which is the use of the phase of the resulting signal as an informative parameter. A laboratory installation has been developed and a number of experiments have been carried out, which have confirmed the possibility of monitoring, which will increase the accuracy of drilling and reduce the time and economic costs of oil industry enterprises.

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