Upgrading of deviation measurement system for more exact determination of sub-horizontal hole profile

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Abstract. Tests of a developed system for measuring deviation of drill holes reveal its shortcomings. Regarding subhorizontal holes, the key problem is measurement of inclinations and deviations from vertical line at a huge number of points (up to 200) by the measuring device moving inside a casing string to 100 m long. The authors analyze influence of different-type data channels on reliability, accuracy and stability of the data recording in the system based on analog and digital signal converters. Applicability of liquid and solid-state integral deviation sensors for pointing of the down-the-hole measuring device is discussed. The paper proposes to use digital microprocessor methods for measuring and converting signals with software support at the upper and lower levels of the deviation determination system.

1. Introduction

Safety of mining can be provided using various methods, including integrated geomechanical assessment of properties and behavior of rock mass. Protection from water inrushes in mines under water bodies on the ground surface, or under aquifers involves creation of safety pillars, and the only reliable tool to maintain mining safety and prevent risk of flooding is instrumental monitoring of deformation of such pillars.

One of the main characteristics of movement in undermined rock strata is vertical displacements (subsidence).

In top-downward cut-and-fill, the cemented backfill is a support for the protective pillar. Safety of the pillar essentially depends on sagging of the underlying backfill. Sag of a check layer in the backfill is determined based on the difference between final and initial profile of a measurement hole drilled in the backfill. These profiles are determined by deviation measurements. Applicability of directional survey in backfill control is discussed in [1, 2]. The deviation survey consists is sequential measurement of inclinations at equal spacing along a hole [3]. Reconstruction of the hole profile uses available standards and guidelines [4, 5] by averaging the measured inclinations:

\[
\alpha_i = \frac{\alpha_i + \alpha_{i-1}}{2},
\]

where \(\alpha_i\) is the inclination of casing at a point \(i\).

In a general case, a hole profile can be represented by a smooth curve.
Deviation devices have different channels to receive and measure signals proportional to inclinations of the device. Currently, international manufacturers offer a wide selection of inclination sensors differing in principles of inclination measurement and intended for solving various problems connected with human activities [6].

As a rule, deviation devices use sensors in the form of spherical gyroscopes (accelerators with magnetic rotor suspensions), one-axis gyro, magnetoresistive inclination sensors, angular accelerometers, liquid-type pickups, etc. Inclination sensors made on the basis of liquid-type pickups are less sensitive to vibrations as against solid-state accelerometers, and are immune to magnetic masses nearby (drill tubes, casings, reinforcement, etc.) as compared to inclination meters with magnetic elements.

2. Development of downhole measurement system

For measuring inclinations at preset points, a system comprised of a downhole deviation device, signal converter and a personal computer is designed. The downhole deviation device consists of a sealed housing with two liquid sensors of inclination in vertical and horizontal planes. The tests of the device have revealed a number of its blind sides such as:

1. Insufficient measurement reliability due to considerable noise in outputs of deviation devices manufactured in Russia. The upgraded system is equipped with the deviation devices produced by Seiko, Germany (Figure 1). German devices have housing of protection class IPG65, which ensures reliable operation in wide temperature range from –40 to +85°C, at humidity up to 100%, inclination range of ±30° for the main sensor and ±45° for the ancillary sensor, with resolution of 0.005° and linearity of ±0.06° for readings within the whole range of measurement [5].

2. In case of elongation of data channel, application of deviation devices with weak analog output results increases capacitive load and diminishes signal amplitude, which degrades dynamic characteristics of the measurement circuit and, as a consequence, adds stabilization time of the deviation device readings. In the upgraded system, wire interface connection with PC (RS-232) is replaced by Bluetooth, which ensures operator’s comfort. The upgraded deviation device has larger spacing (distance between lower supports) from 25 to 50 cm. The outer diameter of the devices is diminished from 70 to 55 cm.

![Figure 1. Seika deviation device and dimensions.](image)

The flow chart of the upgraded downhole tool in Figure 2 comprises of two deviation devices, p-c board with AD converter chips, sensor reference processor and chip of connection with RS-485 channel.
Signal conversion device is arranged in an individual housing and connected to tablet computer via Bluetooth.

Receiving and processing of signals from deviation devices, as well as their conversion to standard protocol RS-232 for wireless transfer via Bluetooth is implemented by a signal conversion device equipped with (Figure 3):

- RS-232–RS-485 interface converter (module ADAM-4520, Advantech);
- Bluetooth wireless communication modul (BT-0240 RS232 Adapter [7];
- Li–Ion accumulator battery, capacity 12 A·h.

The interface converter ADAM-4520 and wireless adaptor Bluetooth provide wireless communication in standard Bluetooth V2.0. The accumulator battery maintains operation of the downhole tool and recording station for not less than 24 h.

The engineering problem to be solved is improvement of efficiency and accuracy of the downhole tool—two-coordinate deviation system—by means of more accurate orientation of the tool and recording of inclinations at control points in the hole relative to horizontal and vertical planes.

The electronic devices in the flow charts in Figure 3 are placed in a sealed housing of the downhole tool. The communication and electric connection are implemented by a coupler with four-wire cable channel RS-485 and supply.

The described upgrading enables more efficient monitoring of subhorizontal hile profile in rocks and backfill owing to higher accuracy, operational efficiency and reliability of data assessment directly at the measurement point and in real time. These assessments are the basis on decision-making on the experimentation control. Furthermore, the efficiency of automated data recording and processing system for operational control of drill hole profile is increased due to more exact measurement of inclinations in the check hole relative to horizontal plane and, thus, better precision of stress state determination in rocks.
Program support is greatly amended. The new version is composed of two parts with regard to the block structure of the software system [8]. First, software of the microprocessor, the flow chart of which is demonstrated in Figure 4, performs cyclic and sequential interrogation of signals from deviation devices and supply voltages via a commutation system, actuation of AD conversion, expectation of interruption upon data availability from each channel, interrogation of digital data on inclinations from two deviation devices and supply voltages, formation of data blocks from each analog channel and data transmission on demand to tablet computer. Second, software of the tablet computer allows a researcher to monitor and control the process of experimental determination of subhorizontal hole profile (Figure 5).

**Figure 4.** Flow chart of software support for microprocessor system of downhole tool.

**Figure 5.** Software support modules for experimentation on determination of profile of subhorizontal holes.

### 3. Conclusions

Upgrading of the downhole tool, electronics and software makes it possible to:

- improve accuracy of inclination measurements at check points owing to introduction of high-precision deviation devices Seiko;
- reduce amount of sampling for averaging (4 samplings as against 20 samplings before the system modernization) and to speed up the hole survey owing to higher accuracy and shorter time of measurement at a single point to 1–2 s;
- eliminate influence of connection cable of data transfer reliability from deviation devices due to discrete data transmission between the downhole tool and signal converter;
- greatly simplify the process of measurement, especially in mines, and to accelerate the experimentation, for instance, to 1.5–2 h in a hole 100 m long, as the deviation system uses a tablet computer and Bluetooth wireless channel for the measured data transfer between the computer and signal converter;
- implement on-the-fly control over the experiment;
—use express-analysis and compare the earlier and current measurement of the check hole profile, promptly detect jumps in the profile and locate zones of possible dog-legs;
—real-time assess experimental results on-site and to compare them with the earlier obtained data.

References

[1] Baryshnikov VD, Baryshnikov DV and Kachalsky VG 2012 Displacement control in undermined backfill Nonlinear Geomechanics and Geodynamics in Deep Level Ming: II Sino–Russian Conference Proceedings Novosibirsk 2012ing: International Conference Proceedings Novosibirsk: Nauka pp 385–388

[2] Baryshnikov VD, Baryshnikov DV and Kachalsky VG 2010 Displacement control in undermined backfill Proceedings of IV International Conference on Geomechanics Bulgaria pp 127–135

[3] http://doidpo.rusoil.net/pluginfile.php/14563/mod_resource/content/2BD.pdf Basic principles of inclino-metry

[4] RD 153-39.0-072-01 Guidelines on Geophysical Survey and Cabled Instrumentation Operation in Oil and Gas Wells Approved by the Ministry of Energy of Russian Federation, Order No. 134 Dated 7 May 2001 (in Russian)

[5] Register of EAGO Standards. Systems for Certification of Geophysical Products Available at: http://eago.1gb.ru/en/uploads/files/Cert_EAGO_Standards.pdf www.eago.ru

[6] https://ru.wikipedia.org/wiki/Inklinometer

[7] http://www.seika.de/english/pdf_e/NA_e.pdf

[8] Leontiev AV and Petrov VE 1997 Block-modular principle of construction of geomechanical measuring and computing systems Journal of Mining Science No 1 pp 110–119