Upgrading the multi-component borehole strainmeter for the accuracy improvement of stress measurement in rocks

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Abstract. The trials of the automated stress measurement equipment have revealed the necessity to upgrade its component represented by the borehole strainmeter. Application of the digital microprocessing methods for signal measurement and conversion has allowed elimination of negative impacts and enhanced efficiency and reliability of stress–strain control in rocks.

Assessment of geomechanical behavior of rocks to substantiate safe mining flowsheets is supported by various techniques, including integrated geomechanical researches of stress state and mechanical properties of rocks. A systemic approach is required to obtaining reliable information on:

—initial stress field and its variation with depth;
—structural features and mechanical properties of ore body and enclosing rock mass;
—displacement of rocks and concentration zones of stresses;
—structural elements of mine, mining sequence and support of development entries.

As one of the method of stress state assessment in rock mass, the method of parallel drilling consists in measuring small deformations in walls of a measurement hole in the course of parallel drilling of a disturbing hole further subjected to loading by uniform pressure [1, 2]. For the implementation of this method, the Institute of Mining has developed the theoretical framework [3] and a prototype model of the automated measurement equipment set composed of the downhole strainmeter, communication unit, manual hydraulic jack and a loading device [4]. The downhole strainmeter meant for measuring radial displacements of hole walls consists of sensitive strain sensors attached or glued to steal beams; deformation of the beams is sent tot the sensors and converted into signals by a measurement channel. The full-scale trial of the equipment has shown that it needs upgrading to ensure better accuracy and reliability of measurement in case of very small radial displacements.

Aimed to increase measurement accuracy, the analysis of measurement circuits of strainmeters with different channels of amplification of signals has revealed a number of shortcomings:

—half-bridge connections in the resistive strain sensors needs that temperature stabilizes, which takes much more time for the experimentation;
—half-bridge connection of the sensors and beams incompletely uses capacities of transformation of deformation to electrical signal;
—when deformation of the beams is small, weak signals and their wire transfer to a recording station adds extra error to measurement because of the influence of deformation of wires and ambient temperature;

—stress measurement errors due to inaccurate orientation of measurement directions (diametrical beams) can be high.

These limitations of strainmeters result in considerable interference in measurement channels. The only way to handling this problem successfully is the use of well-balanced full-bridge measurement circuits on each beam and reduction in spacing of sensors and signal amplifiers. The block-diagram of the modified experimental facility (Figure 1) involves the strainmeter to be installed and advanced in a hole, communication unit and a tablet computer with Bluetooth pairing.

The engineering problem is improvement of stress measurement reliability in rocks by means of more precise orientation of measurement directions of strainmeter in a measurement hole relative vertical and horizontal planes, and through more accurate determination of radial displacements along the measurement directions of strainmeter, control of measurement of displacements in the measuring hole and increased accuracy of stress state determination later on. The real-time information allows prompt and reliable estimation of the test quality on-spot. The design includes full-bridge connection circuits of strain sensors pair-wise arranged on two elastic beams and balanced during assembling. Balancing adjustment of bridges is carried of pre-deformed beams with the strainmeter installed in a calibration cylinder with the diameter conformable with the diameter of drill bit intended for the measurement hole drilling. This approach enables preserving balance of bridge circuits during measurement and allows maximum compensation of temperature drift. The measurement circuit of the multicomponent strainmeter includes bridges of resistive strain sensors, multichannel signal amplifiers, 8-channel commutator, 24 bit AD converter and a microprocessor (Figure 2).

![Figure 1. Block-diagram of upgraded experimental equipment for stress measurement in rocks by the method of parallel drilling.](image)

![Figure 2. Microprocessor circuit to take signals from strain sensors and driftmeters: V—vertical driftmeter (incline of the hole); H—horizontal driftmeter (orientation of measurement directions relative to horizontal plane).](image)

The position of the strainmeter is controlled by two solid driftmeters connected, similarly to the commutator and DC converter, via the intra-circuit digital 12 C channel, to the microprocessor. All
electronic devices in Figure 2 are arranged in the sealed housing of the strainmeter. The data and power connections are ensured by the communication unit (refer to Figure 1) and connected to the strainmeter by information channel RS-485 and supply.

The implemented upgrading enhances reliability of stress state control in rock mass owing to promptness and accuracy of data obtained in real time and directly at the measurement site and serving the basis for the decision-making on experimentation adjustment. Moreover, the modifications enhance efficiency of the automate data recording and processing system in terms of stress state determination in rock mass owing to the improved accuracy of measuring radial displacements of the measuring hole wall and considerably shortened time of the experimentation.

The updated software consists of two parts. The microprocessor software (Figure 3) enables serial polling of bridge circuits of the resistive strain sensor via the commutator, actuation of transformation by AD converter, waiting for interrupt by availability of data from each channel, taking of digital data on angles of position from two driftmeters, formation of data base on deformation per each of 8 strain bridges and two driftmeter and RS-485 channel transfer of the data on demand of tablet computer software.

**Figure 3.** Block-diagram of software modules to support operation of microprocessor system of strainmeter.

**Conclusion**

The implemented upgrading of electronics and software allows:

— considerable reduction in temperature drift in measurement circuits of strain sensors;
— increase in strain measurement sensitivity and, thus, two times higher signal intensity owing to full-bridge connections of strain sensors and beams;
— elimination of influence exerted by cables on signals from strain sensors due to digital data communication between strainmeter and communication unit;
— improved precision of orientation of strainmeter in measurement hole by two driftmeters;
— real-time and prompt control over experimentation;
— express-analysis and comparison with the earlier data on radial displacement measurements in hole walls;
— operation decision-making on expediency of the continuing stress measurement deeper in the hole based on on-spot estimation of test data and comparison with the earlier experimental results.

**References**

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