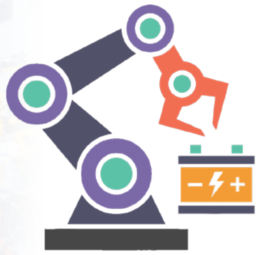

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The Use of G-652 Fiber-Optic Fibers for Identification Control

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Abstract. *The relevance of the use of fiber-optic sensors for monitoring the technical condition of mining machines in the coal mines of the Karaganda coal basin is extremely high, because they are extremely categorical and dangerous for a sudden explosion of coal dust and methane gas during mining operations in dangerous conditions of mines. The author describe the idea of using an optical fiber of the ITU-T G. 652.D standard for monitoring the mountain range of coal mines, which is very promising, since the fiber-optic sensors developed on its basis have a sufficiently high accuracy, measurement speed and have good linearity of characteristics. To test the methods of monitoring and measuring the geotechnical parameters of the workings, a simulation laboratory stand based on fiber-optic sensors was developed. The author used a quartz single-mode optical fiber 9/125 microns (OS2) Corning SMF-28e+®. The article offers systems in two versions, depending on the tasks and functionality. In the first variant, the well-known optical reflectometry method OTDR (Optical time domain reflectometer) is used. In the second variant, the values of additional losses caused by mechanical action on the optical fiber are controlled. When the optical fiber is mechanically affected, micro- and macrobends occur, leading to additional losses of the optical signal in the fiber. These losses can be measured and the pressure values on the optical fiber can be set, and the displacement value can also be determined.*

Keywords: *attenuation, losses, information and measurement system, optical fiber, safety, mining operations, array defects, fiber-optic sensor.*

Introduction

The design and planning of an underground mine is aimed at creating an integrated system in which the extraction and processing of useful minerals is carried out for a certain market with minimal operating costs and high safety requirements. The mining system requires an interdisciplinary engineering structure and coordination of its work [1-9]. One of the important aspects of the functioning of a complex mine system is the safety of mining operations. Undoubtedly, underground mines are one of the most difficult and tough environments for people to work in.

Problem statement

Taking into account the analysis, a thorough study is necessary to better understand the geomechanical behavior of rocks and to ensure higher productivity together with a safe working environment for workers and mechanisms. One of the important points is the control of the rock pressure on the walls of the workings and the prediction of their sudden collapse. As an object of research, the model of mining of the mine of the Karaganda coal basin is considered. The relevance of the use of fiber-optic sensors (FOS) for monitoring the technical condition of mining machines in the coal mines of the Karaganda coal basin is extremely high, because when mining operations are carried out in dangerous conditions of mines belonging to super-categorical, dangerous for a sudden explosion of coal dust and methane gas. Therefore, reliable systems for measuring, monitoring and monitoring the condition of mine workings and equipment with increased requirements for spark and explosion hazard are required. Neglecting these factors, it is possible to create conditions for the occurrence of serious accidents with significant human casualties. Information and measurement systems based on fiber-optic sensors meet all safety rules and can be used in the mines of the Karagandy coal basin [10].

Laboratory research

The first stage of the development of an information and measurement system based on fiber-optic sensors (IMS FOS) is to conduct an analytical study of the existing achievements in this field, based on a systematic approach and solving the problem as a whole. The results of the literature analysis made it possible to use the accumulated experience to develop an information and measurement system based on fiber-optic sensors that can work effectively in mines that are dangerous for sudden release of meth and dust. To develop methods for monitoring and measuring geotechnical parameters of workings, a laboratory model for conducting research was developed, shown in figure 1.

In real conditions, it is desirable to have an intensive monitoring program for support pressure using modern continuous monitoring systems on an electronic gadget in order to evaluate and store data at the required time intervals.

A modern communication system for underground mines can be wired or wireless. Both types of systems can fail when faced with fires, a falling roof, an explosion and a power failure.

The implementation of miniature integrated circuits, a suitable design of secure power supply systems and microelectronics for data storage and transmission can be useful in the development of cost-effective continuous monitoring systems.

An optical fiber is intrinsically safe if the light energy transmitted through the fiber is at or below a certain power level. They are not affected by noise, lightning, interference from RF, EMF, electromagnetic interference, common in the mining industry [11-15]. The use of fiber optics for reliable communication during monitoring, analysis and management of equipment and objects during the mining process will increase the safety and efficiency of production. Fiber-optic communication is uniquely suited for connecting real-time data from environmental sensors

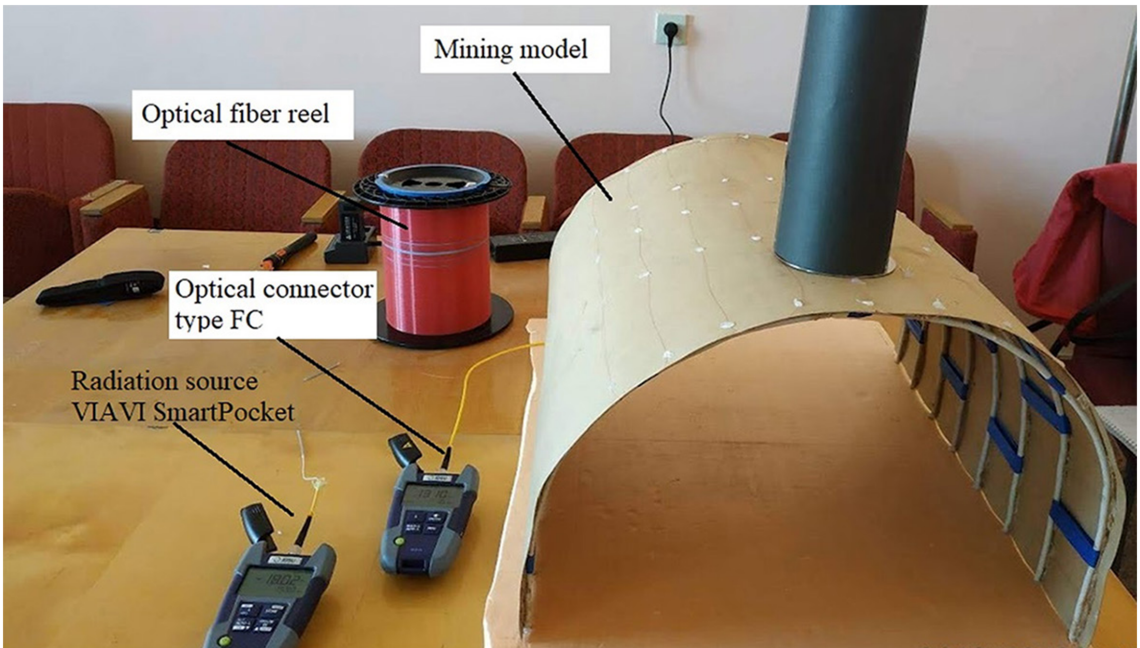


Figure 1 – The appearance of a laboratory stand for practical testing of theoretical research results

and equipment to ensure maximum performance while meeting the highest safety standards. Fiber-optic cables must be properly designed so that they remain operational under the following conditions: the movement of underground vehicles, the collapse of an underground roof, flooding of underground water, the impact of a pressure wave resulting from underground explosions.

A simulation laboratory stand was developed for testing the design of an information and measurement system based on fiber-optic sensors (figure 1). Corning SMF-28e+® quartz single-mode optical fiber 9/125 microns (OS2) with a low «water level» (ITU-T G. 652.D standard) was used. It is not advisable to use a fiber with the Ultra series, since it has a lower sensitivity to bending. The opto-fiber has a primary coating of 245 microns (with an outer shell). To determine the values of optical radiation power and losses, the VIAVI optical power meter (JDSU) SmartPocket OLP-38 was used, operating in the dynamic range from –50 to +26 dBm, with a wavelength range of 780-1650 nm. The SmartPocket OLS-34/35/36 with built-in Auto-λ and Multi-λ options was used as a radiation source, the SmartPocket OLP-38 can automatically measure the power level and insertion losses in a single-mode and multimode optical cable. The connection to the optical fiber was made through a universal UPP 2.5 mm adapter and optical connectors of the FC type.

The length of the compensation coil is 2 km of optical fiber (ITU-T G. 652.D standard).

The second experiment was carried out using the Yokogawa AQ1200E optical reflectometer (figure 2, b).

Results of numerical simulation

With the help of the developed laboratory stand, a number of experiments were carried out to determine the losses of an optical fiber at different pressure values.

The numerical study of the FOS model was carried out using the Wolframalpha program, which is an interactive system for processing experimental results and is focused on working with data arrays.

Boundary condition: the pressure energy on the fiber is from 0 to 15 Nm, the step interval is 2.4 Nm, only 7 steps, the temperature in the laboratory room is 25°C. Movement along the axes until the pressure is applied OX=0m; OY=0m; OZ=0m. As a result of automated data approximation, one-dimensional mathematical models were obtained. Each measurement was performed 10 times.

Optical fibers with a wavelength of 1310 and 1550 nm were studied. The graph of the dependence of the loss value of an optical fiber with a wavelength of 1310 nm with a step-by-step increase in pressure is shown in Figure 3.

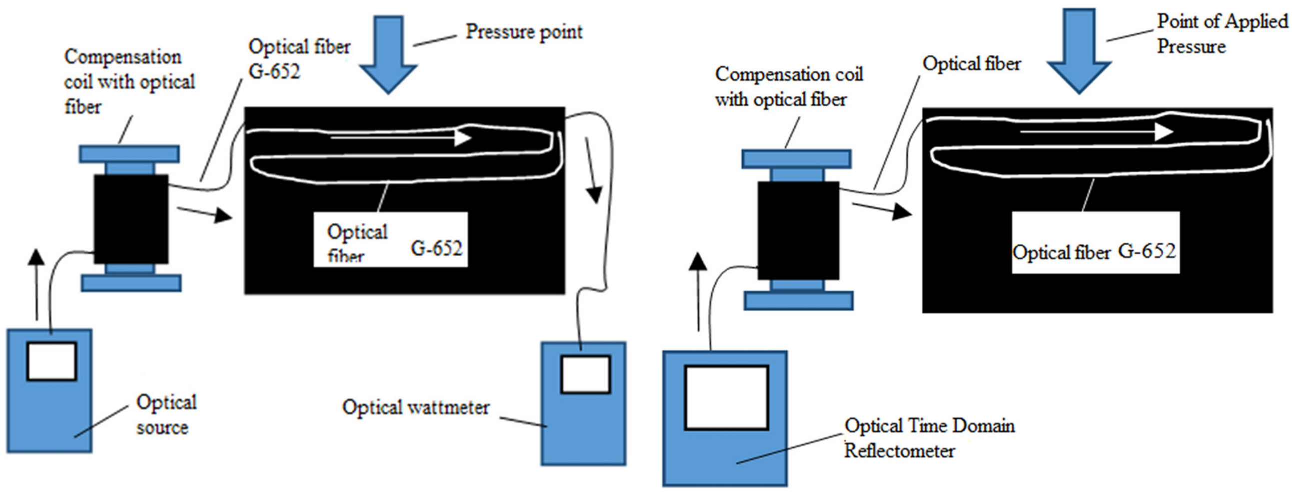
During the automatic approximation, the following results were obtained:

1. $0,0718438P+25,2616=\varepsilon$ the approximation is linear;
2. $0,000022611P^3–0,000522694P^2+0,0749118P+25,2589 =\varepsilon$ approximation of the third degree (cubic);
3. $+0,0000237653P^2+0,0721934P+25,2609=\varepsilon$ approximation of the second degree (quadratic).

Since the best mathematical model is considered to be the model with the lowest value of the AIC criterion (Akaike Information Criterion), the dependence of the loss values in the optical fiber is better represented by a quadratic approximation, in which the Akaike information criterion is –53.6639.

To determine the distance to the place of violation of perimeter security, a YOKOGAWA AQ1200 OTDR reflectometer was used. The reflectogram (figure 4) clearly shows on which part of the optical fiber the loss change occurs.

The reflectogram shows that in the range of 1,989-2,03079 km, the return loss of the optical fiber was 0.066 dB, which indicates that the pressure on the optical fiber is higher than normal at this interval.



а б

Figure 2 – Block diagram of the laboratory stand of an information and measurement system based on fiber-optic sensors: a – with an optical wattmeter; b – with an optical reflectometer

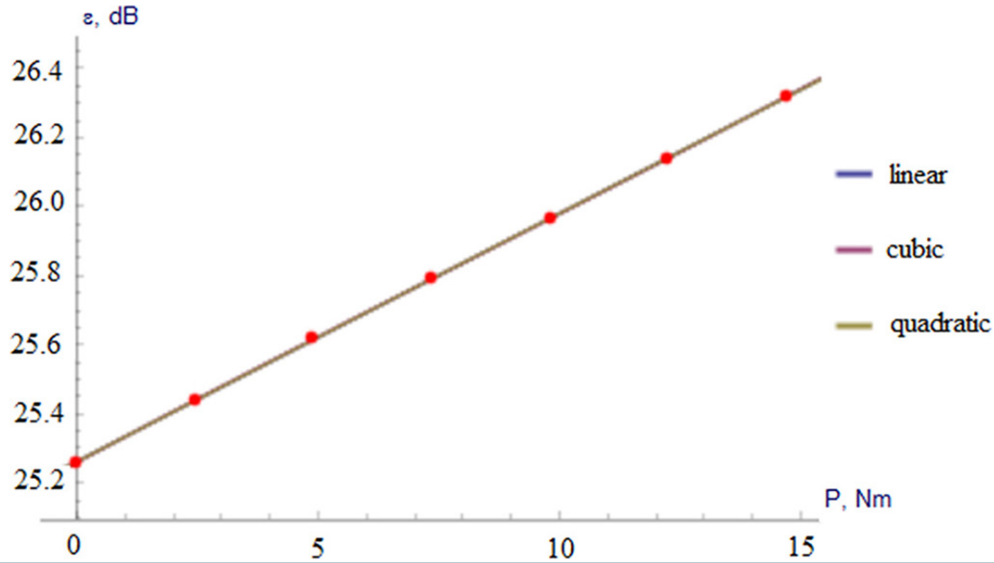


Figure 3 – The value of losses of an optical fiber with a wavelength of 1310 nm with a step-by-step increase in pressure

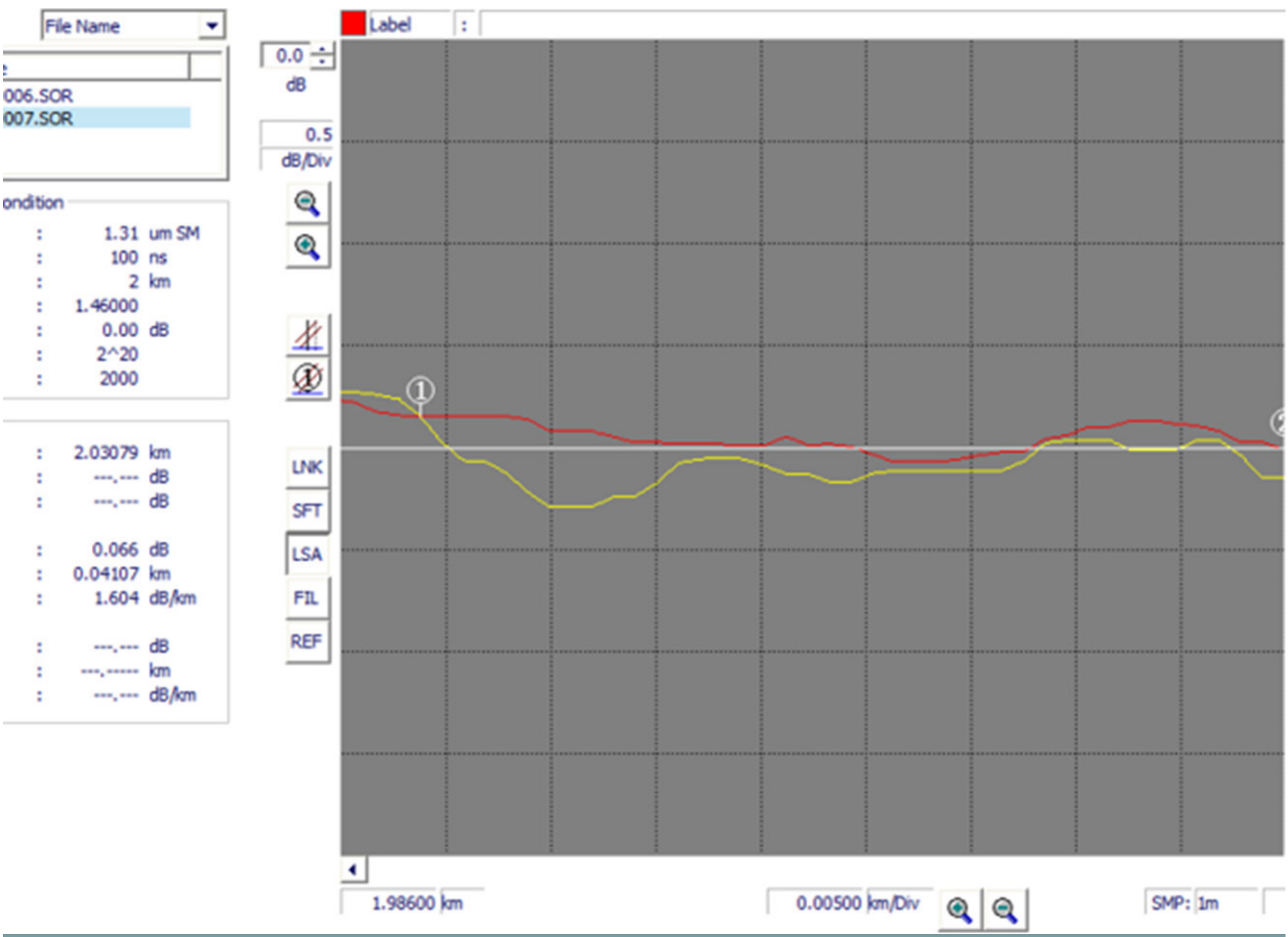


Figure 4 – Reflectogram

Development of an information and measurement system based on fiber-optic sensors

When the optical fiber is mechanically affected, micro and macro bends occur, leading to additional losses of the optical signal in the fiber. These losses can be measured and the pressure values on the optical fiber can be set, and the amount of displacement can also be determined. An important advantage of this measurement system will be its complete spark and fire safety. The energy passivity of the sensors allows you to switch off power sources directly located in the coal mining zone. The water management System is capable of monitoring the mining workings around the clock. The system can be presented in two versions, depending on the tasks and functionality. In the first variant, the well-known optical reflectometry method OTDR (Optical time domain reflectometer) is used. In the second variant, the values of additional losses caused by mechanical action on the optical fiber are controlled.

The area of operation of the IMS FOS is about 50 km, which is quite enough for transmitting signals within the mine workings and feeding them to the surface. The WATER AIS can have more than a hundred channels and measurement points. The waters are located directly in the mine workings. The connection is carried out through optical connectors to the main optical cable, and the photo receivers, laser and analyzer are located in the safe zone of the near-trunk yard or on the surface. The IIS shown works as follows: a light source (a semiconductor laser) generates short probing pulses of the required duration (from 5 ns to 20 microseconds), with wavelengths of 1310 nm and 1550 nm. The pulse passes through the splitter via an optical cable to the FOS located in the mine workings. When the sensor's optical fiber is mechanically affected, additional losses occur, and part of the signal is reflected and enters the photodetector through the same conductor. The splitter provides the passage of light reflected in the window to the optical radiation receiver for its registration and measurement. The sensitive photodetector has a device for primary signal processing and accurately measures the levels and time delays of all reflections that appear as the probing light pulse passes along the fiber. Measuring all the reflections from a single probing light pulse will not allow you to get a reliable picture of the pressures and movements of the rocks of the mine, since the laser creates a low-power pulse and a large amount of random noise is created when it is reflected, so it is necessary to perform measurements within 10-30 seconds and send thousands of probing light pulses to the fiber and measure the reflection of each of them. After that, it performs averaging, analysis and display of the results with the help of an analyzer and a computer, on which all information about the measurement of pressure and displacements that occurred in the mine during the specified time (days, months) will be stored. An important point is the operation of the analyzer, which reads the time of passage of the forward and reverse (reflected) light pulses through the optical fiber, calculates the distance to the pressure application point at a known speed of light. The level of the reflected signal amplitude determines the additional losses and, accordingly, the values of the applied pressure to the water. The IMS FOS is shown, it is more simplified in terms of the equipment used (photodetector, optical splitter) and has a lower cost, since the analyzer is made simpler with less processing power of the processor. The laser beam passes through the direct optical fiber to the FOS and returns along the reverse to the photodetector. With a mechanical effect on the FOS, for example, an increase in the pressure on the support or the displacement of the plates, additional losses increase, which are recorded by the analyzer.

The measurement of rock pressure and rock movements are two important parameters that can be used to quantify the effectiveness of supporting the roof of a mining operation in a given state of geoengineering.

Discussion and conclusion

The use of optical fiber of the ITU-T G. 652.D standard for monitoring the mountain range of coal mines is very promising, since the systems developed on its basis have a sufficiently high accuracy, measurement speed and have good linearity of characteristics. It is undesirable to use the fiber of the ITU-T G. 652.D Ultra series, since it has a lower sensitivity to bending. The water IIS allows us to ensure high safety requirements when conducting mining operations in hazardous conditions of mines that are classified as ultra-categorical for a sudden explosion of coal dust and methane gas, reliable systems for measuring, monitoring and monitoring the condition of mine workings and equipment with increased requirements for spark and explosion safety are required.

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Ұқсастырғышты бақылау үшін G-652 талшықты оптикалық талшықтарын пайдалану

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Аңдатпа. *Қарағанды көмір бассейнінің көмір шахталарының тау-кен машиналарының техникалық жай-күйін бақылау үшін талшықты-оптикалық датчиктерді қолданудың өзектілігі өте жоғары, өйткені олар шахталардың қауіпті жағдайларында тау-кен жұмыстарын жүргізу кезінде көмір шаңы мен метан газының кенеттен жарылуы бойынша аса таулы және қауіпті болып табылады. Автор ITU-T G. 652.D стандартының оптикалық талшығын пайдалану идеясын негіздейді, көмір шахталарының тау-кен массивін бақылау үшін өте перспективалы, өйткені оның негізінде жасалған талшықты-оптикалық сенсорлар өте жоғары дәлдікпен, өлшеу жылдамдығымен үйлеседі және сипаттамалардың жақсы сызықтығына ие. Қазбалардың геотехникалық параметрлерін бақылау және өлшеу әдістерін пысықтау үшін талшықты-оптикалық бергіштер негізінде имитациялық зертханалық стенд әзірленді. Автор 9/125 мкм (OS2) Corning SMF-28E+® кварцты бір режимді оптикалық талшықты қолданды. Мақалада қойылған міндеттер мен функционалдылыққа байланысты екі нұсқада жүйелер ұсынылған. Бірінші нұсқада OTDR (Optical time domain reflectometer) оптикалық рефлектометрияның белгілі әдісі қолданылады. Екінші нұсқада оптикалық талшыққа механикалық әсерден туындаған қосымша шығындардың мәндері бақыланады. Оптикалық талшыққа механикалық әсер ету кезінде микро- және макроиілістер пайда болады, бұл талшықта оптикалық сигналдың қосымша жоғалуына әкеледі. Бұл шығындарды оптикалық талшыққа қысым мәндерін өлшеуге және орнатуға болады, сонымен қатар ығысу мәнін анықтауға болады.*

Кілт сөздер: *сөну, жоғалу, ақпараттық-өлшеу жүйесі, оптикалық талшық, қауіпсіздік, тау-кен жұмыстары, массивтің ақаулары, талшықты-оптикалық датчик*

Использование волоконно-оптических волокон G-652 для контроля идентификации

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Аннотация. *Актуальность использования волоконно-оптических датчиков для контроля технического состояния горных машин угольных шахт Карагандинского угольного бассейна крайне высока, потому как они относятся к сверхкатегоричным и опасным по внезапному взрыву угольной пыли и газа метана при проведении горных работ в опасных условиях шахт. Автором обосновывается идея использования оптического волокна стандарта ITU-T G. 652.D для контроля горного массива угольных шахт, что является весьма перспективным, так как разработанные на его основе волоконно-оптические датчики обладают достаточно высокой точностью, скоростью измерения и имеют хорошую линейность характеристик. Для отработки методов контроля и измерения геотехнических параметров выработок был разработан имитационный лабораторный стенд на основе волоконно-оптических датчиков. Автором использовалось кварцевое одномодовое оптическое волокно 9/125 мкм (OS2) Corning SMF-28e+®. В статье предложены системы в двух вариантах исполнения в зависимости от поставленных задач и функциональности. В первом варианте используется известный метод оптической рефлектометрии OTDR (Optical time domain reflectometer). Во втором варианте контролируются значения дополнительных потерь, вызванные механическим воздействием на оптическое волокно. При механическом воздействии на оптическое волокно возникают микро- и макроизгибы, приводящие к дополнительным потерям оптического сигнала в волокне. Указанные потери можно измерить и установить значения давления на оптическое волокно, также можно определить величину смещения.*

Ключевые слова: *затухание, потери, информационно-измерительная система, оптическое волокно, безопасность, горные работы, дефекты массива, волоконно-оптический датчик.*

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