Technical requirements to laboratory facility for stressed state rock massive spectral-acoustic control method sensitivity depth research if front of a development heading

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Annotation. The article presents the basic requirements for a laboratory facility creation that allows one to investigate the spectral-acoustic monitoring method sensitivity depth when testing the face area stressed state in front of a development heading. These data are necessary for establishing the scope of the spectral-acoustic method use for forecasting the dynamic phenomena in the process of various technological operations performance when mining: forecasting the outburst danger, controlling the anti-outburst measures effectiveness, assessing the anchor support quality and the hard-to-collapse roof directed hydraulic fracturing efficiency and so on. The reported study was funded by Russian Scientific Foundation grant (project No. 17-17-01143).

1. Introduction
Mining operations intensification and the coal deposits development depth increasing are complicated by the dynamic and gas-dynamic phenomena manifestation. Beginning from 500 m depth, intensive and dangerous sudden extrusions of coal with increased gas emission and other types of dynamic and gas-dynamic phenomena (hereinafter – DPh) occur at the extraction faces with thick hard-to-collapse roof, as a result of which face equipment is damaged and serious danger for mining workers occurs [1,2]. In addition, the hanging roof causes the of rock pressure concentration on the coal massif in the area of the extraction face and on its junction with the mine workings, which provokes a rock shock. In some cases, a local rock shock can develop into a sudden coal and gas outburst. Due to the significant area hanging roof influence, the abandoned pillars and protected development workings are subject to the action of high support pressure. This leads to the mine workings’ destruction and, accordingly, to the mining transport normal operating mode and face ventilation failure.

2. Research objective
In Kuzbass gas dynamic phenomena (sudden outbursts of coal and gas and similar phenomena - in fact, underdeveloped outbursts) mainly occur in development headings [3, 4]. To exclude them at depths below the critical by the factor of outburst danger, it is necessary to carry out the current forecast of the indicated phenomena [5].

The stressed condition control at the walls of the opening is also necessary for other technological operations of mining: for assessing the state of the anchor support [6], at directed hydraulic fracturing
of a hard-to-collapse roof [7], for performing anti-outburst and anti-shock hydraulic treatment of coal seams [5] and in a number of other technological operations [8].

Since for these purposes the spectral-acoustic method is now increasingly used, it was decided to justify the field of its application, since the method has a feature that raises the question of the radius of its sensitivity. This feature is due to the fact that when using this method, the face area is probed by acoustic vibrations generated by the cutting device of the combine (or other operating mechanisms). In this case, the receiver of acoustic vibrations (geophone) is installed in the wall of the development heading at a certain distance from the face behind the controlled area. It has been experimentally established that, in spite of that, this method allows to fix an approach to a dangerous DPh manifestation area ahead of the face [9, 10]. And the revealed danger, as shown by theoretical and experimental studies [11], when using this method is due primarily to the growth of stresses. At the same time, currently there is no scientific basis characterizing the method sensitivity depth ahead of the development heading. Therefore, the authors set the task to develop and to make a laboratory facility for modeling the stressed condition of the face area ahead of the development heading, probing it with acoustic oscillations and receiving them with the sensors installed behind the face.

The list of basic requirements to laboratory facility was compiled based on the laws of wave acoustic processes, on the similarity theory elements when scaling the design of a mining opening for the creation of a laboratory facility and proceeding from the spectral-acoustic control method.

3. Requirements for design, parameters and functionality

- Dimensions of the simulated and the real development heading width have the ratio 1:20.
- Small-grained sand is used as a material for coal seam modeling.
- The stress field in the face area in front of the simulated development heading should be smoothly changed within 0-5 MPa with the possibility of adjusting the ratio between the maximum and minimum stress values within the range of 1-1.5.
- The installation should ensure that the position of the maximum created stress zone moves relatively to the opening face front at a distance of 0.2 to 1.4 times of the opening width discretely with a step equal to 0.2 of the opening width. Thus, the total number of bands for the stressed state creation is seven. They are located perpendicular to the opening axis and parallel to the floor and the roof and are arranged sequentially from the face front to the depth of the massif.
- The width of the modeled part of the rock mass at the walls of the opening to the beginning of the acoustic traps should be two widths of the opening model (0.4 m).
- The width of acoustic traps at the walls of the opening, in front of the modeled face area and behind the massif at the walls of the opening is 0.5 m.
- The thickness of the modeled part of the floor and roof above the walls of the opening is equal to the opening width (0.2 m for floor and roof); to provide access to equipment at the face of the opening, the space above the opening is not filled with anything.
- Measurement of the stress field in front of the opening must be carried out by sensors located in the middle (to the width of the opening) of at least nine sectional planes parallel to the face in their lower part and separated from each other by a distance equal to 0.2 part of the opening width, when the first plane is removed from the face at a distance equal to the model metal wall thickness.
- The model should provide continuous emission of acoustic vibrations and their registration with sensors installed on the wall of the opening model. The range of simulated frequencies should correspond to the operating range of the spectral-acoustic method equipment for monitoring the stressed state of a rock massif lying in the range of 20-3500 Hz. The simulated frequencies should be evenly distributed in this range. Their number should be around 10. The approximate values of the simulated frequencies are 50, 400, 750, 1100, 1500, 1850, 2300, 2650, 3000 and 3500 Hz.
• If it is not possible to create continuous radiation at these frequencies, pulsed radiation can be applied, followed by the determination of the signal spectrum by means of a Fourier fast transform.
• The acoustic vibrations emitter should not touch the body of the model, but be isolated from it by a sound-absorbing gasket. It must be installed in one of three possible locations on a straight line running along the middle of the height of the development heading, parallel to the floor, and the centers of the two of them being removed from the walls of the opening at a distance equal to 0.1 part of its width, and the third – to be in the middle.
• The model should measure the amplitude of the acoustic signal by three-coordinate receiving sensors installed at the wall of the modeled opening at distances equal to one, two, three and four values of the opening width (i.e., the centers of the receiving sensors are removed from the face front at distances of 0.2, 0.4, 0.6, and 0.8 m).
• In order to suppress the reflected acoustic oscillations from the model walls, it must have acoustic plugs on the two side, one front and one back surfaces of the model.
• Operating conditions of the laboratory facility – average room conditions (temperature: 20º-25ºС, relative humidity: 40-50%).
• Laboratory facility storage conditions – heated and ventilated rooms located in any macroclimatic regions.
• Conditions of laboratory equipment transportation:
  - The laboratory facility can be transported by a covered motor vehicle in accordance with the rules and conditions for cargoes loading and fastening that act on motor vehicles;
  - Transportation of the laboratory facility is carried out in wooden boxes specially made to the sizes, determined by the installation dimensions.

4. Requirements for the emitter and receiver of acoustic oscillations and to the measuring equipment for monitoring the stresses and the acoustic signal amplitude-frequency characteristics

4.1. Requirements for the emitter (or set of emitters) of acoustic oscillations
• Frequency range: 20-20000 Hz.
• Dimensions of the emitter surface – no more than 20 mm.

4.2. Requirements for the receiver of acoustic oscillations (converter of acoustic oscillations into electrical ones)
• Type – three-coordinate (three-component) – for recording longitudinal and transverse acoustic waves.
• Frequency range: 20-20000 Hz.
• Uneven frequency response – up to 10%.
• Dimensions: any linear dimension – no more than 20 mm.

4.3. Pressure sensor requirements
• Measured pressure range 0-5 MPa.
• Overall dimensions:
  length, width – no more than 30 mm; thickness – no more than 15 mm.

5. Control requirements for laboratory facility
Control of the creation of a laboratory facility is carried out in two stages:
• At the first stage, the mechanical strength of the installation is monitored by creating a limiting planned stressed state at 5 MPa throughout the whole simulation area of the stressed condition zone.
At the second stage, the control consists in checking its operability. For this, the following is done:
- An initial stressed condition is created in the modeled face area. When the stresses increase, they are convinced of the pressure sensors operability.
- The source of acoustic vibrations is connected to one of the transitional devices, through which sound is introduced into the simulated coal-rock environment.
- The outputs of the acoustic receivers via the appropriate terminal block are connected to the recorder (oscilloscope or voltmeter).
- By switching on/off the source of acoustic oscillations, on the appearance of signals from the outputs of piezoelectric accelerometers they are confirmed of the laboratory facility operability.

Subsequent work on the laboratory facility to investigate the sensitivity depth of the spectral-acoustic method for monitoring the stressed state of the face area in front of the development heading is carried out following the research procedure methodology.

6. Conclusion
The specified list of requirements in the opinion of the authors should provide an opportunity of stressed state rock massive spectral-acoustic control method sensitivity depth research if front of a development heading.

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