Energy-efficient mine ventilation control system

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Annotation. The paper considers the principle of constructing a control system of energy-efficient mine ventilation by using new dust detectors that can function in difficult operating conditions. One of such automatic dust meter sensors is described, which contains two sources of radiation in the measuring and reference channels operating at wavelengths in the region of maximum and minimum dust absorption, the radiation which are transmitted sequentially using prisms and mirrors directed through the measuring and reference channels into a single light stream and then to the input of a broadband photodetector. To give the system the possibility to function in difficult operating conditions, the sensor comprises a blower device that contains a protective windows and a heating viewing windows that maintains the temperature of the measuring channel within specified limits. The use of such sensors makes it possible to quickly make decisions about the redistribution of air in mine controlled by the mine ventilation control system.

Currently, in all existing national and international systems for automatic control of mine ventilation, operational air redistribution is carried out according to data on the speed and temperature of air flows on outgoing streams and in working lavas, and dust concentration is usually taken into account indirectly using static characteristics. This fact does not allow you to quickly and correctly make decisions on the redistribution of air in mines. In this regard, the creation of a dust meter for a mine ventilation control system is an urgent task. The purpose of this work is to provide energy-efficient control system of the mine ventilation by using a dust meter with increased accuracy and continuity of operation in the sensor control system.

In most of the existing automated control systems (ATMOS, AKMD, (Russia,) KPAU (Ukraine), MAJHOS (England), MCO–060 (Czechoslovakia), BMTA–BMJK (Hungary), A1, K11, K12 (China), CTT 63/40, CTT2, CGA/1 (France) [1, 3, 4], mine ventilation control is carried out not by the dust factor, but by the results of measuring other parameters such as:

- Temperature;
- Speed of the air stream;
- Methane concentration;
- Oxygen concentration.
Dust control is not carried out in most of the known automatic mine ventilation systems [1, 4]. However, the ventilation control of the mines is necessary to solve the problem of delivering a clean stream of air to the working area and ejecting the dusty stream from it. Therefore, it is advisable to control the ventilation of the mines, taking into account the dust.

Figure 1. Functional diagram of the mine ventilation control system: 1 – methane concentration control equipment; 2 – air velocity (flow) control equipment; D – dust meter; N – other sensors; 3 – control equipment of a local air flow regulator with an indicator of the position of the regulatory body; 4 – executive device of the local air flow regulator; 5 – control equipment for a group air flow regulator with an indicator of the position of the regulatory body; 6 – actuator for group air flow regulator; 7 – underground telemechanics; 8 – surface telemechanics; 9 – teleinformation reception devices with recording devices; 10 – air distribution control apparatus; 11 – apparatus for main ventilation fan controller; 12 – actuator for main ventilation fan controller; 13 – matching device; 14 – controlling computer.

Thus, the most important elements of the proposed mine ventilation control system are the sensors that measure the concentration of coal dust. As was shown in a number of works, the operation of such sensors is usually based on optical principles — scattering and attenuation. Dust gauges [5–12] are installed at a distance of 10–15 meters from dust sources (lavas, conveyor lines, etc.) in cleaning drift of coal mine at the incoming and outgoing streams, 10 meters from the pumping and ventilation drifts. The sensors must be fixed at a height corresponding to the miners breathing zone.
Figure 2. Block diagram of the implemented sensor – dust meter: 1 – 4 – radiation sources, 6, 9, 20 – separation prism, 5, 7, 8, 10, 19, 21 – mirror, 17 – the first protective window, 18 – the second protective window, 15 – measuring channel, 16 – reference channel, 11 – inspection window heating device, 12 – inspection window dust control device, optically connected to the inspection window 17, 13 – airflow control device, 14 – protective airflow device windows, 25 temperature control device, 22 – broadband photodetector, 23 – amplifier, 24 – microcontroller.

Figure 2 shows a block diagram of an implemented sensor – dust meter system. Optical sensor - dust meter works as follows [5]. The microcontroller 24 sequentially supplies a pulse voltage to the radiation sources 1.3 and 2.4, while the radiation sources 1.3 have a wavelength in the region of maximum dust absorption, and the radiation sources 2.4 have a wavelength in the region of minimum dust absorption. In this case, the microcontroller sequentially supplies identical bursts of pulses to the emitters 1, 3, 2 and 4. The radiation source 1 sends the generated pack of pulses through the separation prism 6, the radiation enters the measurement channel 15, by the time that the second pack of pulses supplied to the radiation source 3, the radiation arrives at the reference channel 16, then by the time that the third pack of pulses supplied to the radiation source 2 the radiation is transmitted through mirrors 7, 5 and the separation prism 6 is received in the metering channel 15, then by the time that the fourth pack of pulses supplied to the radiation source 4 the radiation is transmitted through the mirror 10, 8 and the separation prism 9 is supplied to the reference channel 16. Next, the process of formation of bursts of pulses to radiation sources of 1.3, 2.4 is repeated. Thus, at the output of the second viewing window 18 of the measuring channel 15, there is a sequence of bursts of light pulses generated by sources 1,2, and at the output of the second viewing window of the reference channel 16 there is a sequence of bursts of light pulses formed by sources 3,4. Next, the light pulses from the radiation sources 1,2 of the measuring channel 15 pass through the separation prism 20 to the input of the photodetector 22. In this case, the pulsed light radiation passing through the measuring channel 15 is attenuated by dust according to the Beer–Lambert law.
Light pulses from the radiation sources of the 3,4 reference channel are transmitted through mirrors 21, 19 and the dividing prism 20 as well as to the input of the photodetector 22. In this case, the light pulses are arranged in the sequence 1, 3, 2, 4. the sequence of electric current pulses Formed by the photodetector is transmitted through the amplifier 23 to the microcontroller 24, where the received sequences are processed. First, the pack formed by the radiation source 1 is subtracted from the pack formed by the radiation source 3 and the pack formed by the radiation source 2 is subtracted from the pack formed by the radiation source 4, then the logarithm of the ratio of the obtained values is determined, which characterizes the level of the measured dust. All operations are performed synchronously.

The device for heating the viewing Windows 11 maintains the temperature of the measuring channel viewing Windows in the range of 210-250°C. The mode of operation of this device is set by the microcontroller 24.

The dust control device for the inspection windows 12 controls the blower 14 with specially cleaned brushes fixed on the fan blades, automatically approaching the inspection windows when the fan is operating. When a certain dust concentration threshold is reached, a light beam reflected at an angle of 135 degrees to the axis of radiation enters the device 12, which is a photodiode, the voltage from which is supplied to the fan control device 13, the operation mode of which is set by the microcontroller 24.

The temperature control device 25, made in the form of a semiconductor temperature sensor and an amplifier, continuously measures the air temperature of the working area and is connected to the microcontroller 24 to correct the fluctuations in ambient temperature.

Thus, the proposed optical sensor - dust meter operates in automatic mode and has design features that allow it to be used for energy-efficient control of the ventilation as part of automatic ventilation control systems. Due to the use of two wavelengths in the region of maximum and minimum dust absorption, the sensor dust meter can improve the accuracy of determining the total dust concentration and eliminate errors that occur when changing uncontrolled parameters: humidity, concentration of carbon dioxide, methane, etc., which makes it possible to quickly and correctly make decisions about air redistribution in mines by the mine ventilation control system.

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