Analysis of security parameters specific to coal mines

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Abstract. Coal continues to remain a basic energy source for industry, but the impact on the environment and underground security resulting from its extraction and use must be given ever-increasing attention. Ecological impact analysis is currently the most powerful tool for preventing pollution and environmental degradation, respectively for underground security, in any project related to coal mining. The current trend of restricting mining activity in more productive perimeters, but far from the main connections with the surface, implies a substantial increase in the demand for ventilation systems due to underground pollutants and implicitly the continuously increasing risk factors. The particularly complex conditions and with major implications in the security levels of mining operations require the objectification of control by monitoring security parameters, through systems, installations, devices and modern automatic programs in parallel with the manual control system with modern portable devices. The paper analyzes the possibility of monitoring security parameters related to the environment, mine fires and degassing installations specific to mining operations in the Valea Jiului coal basin, in order to remove several risk factors that endanger underground mining. The main safety parameters analyzed refer to the underground environment, endogenous fires and degassing of coal seams. The parameters that are followed in order to assess the efficiency of the degassing networks are: the depression in the degassing network, the methane concentration of the captured gas and the methane flow from the network.

Keywords: environment, security, parameter, analysis.

1. Introduction

The concentration of several mines on a relatively small area, such as the case of the Valea Jiului coal basin, influences the environment and the state of security, with different intensity on each component, because a mine is a dynamic entity that changes continuously both as a result of the change in structure of the network, as well as of the values related to the aerodynamic resistance of the ramifications in their composition.[1]

Any underground opening is unique from the point of view of geometry, geology, location, pollutants, security and its formation, which can be natural or artificial. Air currents through underground openings are variable. An underground aeration system can be thought of as a large heat engine where air enters the system through the extraction shaft where it is compressed and heated due to the heat given off by the rocks and equipment used in the mine.

In all mines, the energy of the natural draft is supplemented by the energy of the fans. The changes that can intervene in the gas-dynamic regime in the expansion of mining works and implicitly in the modern work technologies amplify difficulties regarding the realization and supervision of general ventilation, ensuring the safety and comfort of underground work.

The technical development of the automatic control of the security parameters represents a solution. The question that must be considered is to determine the appropriateness of applying this solution. Is the automatic control of security parameters an alternative? These questions need to be researched, because the development of such a system is expensive and this must be analyzed in relation to the potential advantages that such a system would have.

Since dangerous situations underground can be generated by the cumulative effect of several risk factors, the paper analyzes the possibility and methods of monitoring the security parameters related to the specific environment of coal mines.

The work is structured on several stages:
• Identification of security parameters specific to coal mines;
• The risk factors determined by the underground environment and their characteristic sizes;
• The conclusions resulting from the analysis of the security parameters.

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2. Identification of security parameters specific to coal mines.

The main characteristics of an automatic control system consist of:

- Monitoring of security parameters;
- Telemetry of these parameters;
- Decision-making system and the ability to change the state of control devices remotely and automatically.

For the monitoring of security parameters, two aspects must be taken into account:[6]

- The introduction of measuring and control equipment underground must ensure the identification of risk factors caused by the environment or work technologies and not produce the appearance of new risk factors determined by their construction, respectively due to false information or operation without positive safety that allows quick identification of fault states.
- The construction of equipment for measurement and control of security parameters must present a different high level of protection for equipment intended to operate in potentially explosive atmospheres because gas concentrations can be high in coal mines.

These elements involve the identification of risk factors and their location in space with the characterization of their manifestation from a quantitative and qualitative point of view. In this sense, the following more important aspects must be clarified:

- The physical size characteristic of the risk factor whose evolution can be characterized by its continuous or intermittent measurement.
- The range and law of variation of the physical quantity that determines the evolution between the dangerous and non-dangerous state.

The dynamics of the change in time of the physical size in order to establish the static or dynamic principles of control. The main hazard factors analyzed in this paper refer to the underground environment, endogenous fires and degassing of coal seams.

3. The risk factors determined by the underground environment and their characteristic sizes.

Mining activity is characterized by a certain degree of knowledge of the underground environment, and the risk factors determined by it can only be influenced if they are known before reaching a certain stage and mode of manifestation.

The characteristics of the environment in which the mining activity is carried out are determined both by the geological-mining conditions and the physical, mechanical and chemical dimensions of the deposit, as well as the applied work technology.[2]

In order to control the evolution of the determined risk factors in the environment, it is important to establish the place and manner of manifestation of these factors so that the technical means used for control are effective.

Also, after establishing the controlled parameter, it is useful to determine its evolution speed so that the information provided can be used in a timely manner. In some situations, due to the cumulative effect of several risk factors, it is necessary for the control means to ensure the integration of several monitored parameters at the level at which decisions are made by the specialized staff of the mining unit.

The main gases present in the underground atmosphere are: dry air, oxygen, nitrogen, methane, carbon dioxide, carbon monoxide, sulfur dioxide, nitrogen dioxide, hydrogen sulfide, hydrogen, radon and water vapor.

The physical or chemical principles of measuring devices related to security parameters are: detection devices with sensors, the thermocatalytic combustion principle, the acoustic principle, the diffusion principle, the ionization principle. Regardless of the operating principle applied, the devices used for the permanent control of the underground atmosphere can fulfill the functions of measurement, signaling, control and automatic protection of electrical equipment.

Regarding the quality of measuring devices, the following clarifications are made:

- The rapid and continuous variation of gas concentrations requires permanent measurement or with a short time interval (10-20 s).
- The concentration of the gas to be measured can vary between 0-100% vol. A fact that involves the combination of measurement principles.
- The alarm levels must take into account the dynamics of the variation of gas concentrations and the random evolution respectively.

The precision of the measuring devices should be high; controlling the parameters that define the underground atmosphere means having an image, in absolute values, of the environment in which the technological activity is carried out. Such a concept would involve the control of the following parameters:

1. From the point of view of the danger of explosion:
   - Methane concentration.
   - The concentration of hydrocarbons accompanying methane and hydrogen respectively.
2. Monoxide concentration.
3. From the point of view of the danger of toxicity:
   - The concentration of carbon monoxide and carbon dioxide in correlation with the value of the oxygen content.
   - The concentration of hydrogen sulphide, sulfur dioxide and nitrogen oxides.
A second concept would consist in expressing the quality of the environment through the air flows circulated in the mining networks. The application of this concept would lead, on the one hand, to the dilution of toxic and explosive gases below the permitted limits, and on the other hand, it would lead to air circulation speeds through the mining works inadmissible from the point of view of underground comfort. Any realistic control must combine the two concepts, i.e. the quantities to be controlled are the gas concentrations, but also the air circulation speeds. The values thus controlled must be correlated with each other and compared with values regulated by regulations and orders in force.

Permanently monitoring of the underground environment consists of continuous monitoring of methane, carbon monoxide, oxygen and air circulation velocity. There are three main reasons why methane needs more attention:

- First, natural gas is the one that occurs most frequently in the Valea Jiului coal basin.
- The second reason is methane has caused most of the fires and explosions underground with great loss of human life.
- The third reason is to find and develop drainage technologies to reduce methane emissions;

Methane emission rates in mining operations range from near steady state to dynamic phenomena of the type of large, untimely emissions. In general, the emission rate from one source to another depends on:

- Initial gas content of coal seams.
- Degree of previous degassing through methane drainage through mining operations
- Permeability and natural thickness of the layer.
- Applied exploitation method, etc.

Methane released from coal seams in mining excavations usually has a high concentration. During the dilution of this methane gas will pass through the range of 5-15% (explosive), for this reason it is important that the time and space in which the explosive mixture is formed be reduced as much as possible, until the methane is diluted right at the emission points. [4]

The monitoring of slow methane emissions from coal mines is ensured by telemetric centers that have 40 measurement points. When placing the methane transducers, the following aspects will be taken into account:

- Methane concentrations in the working fronts are dependent on the size of the relative methane flows (m3/t) specific to the coal layer exploitation.
- Methane concentrations are not uniform.
- In the meeting area of the abattoirs with the head galleries, methane concentrations are higher than those measured in the abattoir, due to the migration of methane from the exploited space through air losses.
- Air velocities along the abattoirs both in the working area and towards the exploited space, have a pronounced non-uniformity due to the complex process of air flow in the free space of the front work.

Knowing that an aeration network represents a non-linear system of multiple variables with a significant number of interconnections, it follows that any change in the work system can lead to major disturbances in the distribution of air flow throughout the mine.

In grit mines, the ventilation system of a working front, respectively the dilution and removal of gases, has a complex character, namely the presence of gas emissions and air flow. The efficiency of the aeration system in relation to gas releases is demonstrated by the gas content in the exhaust stream from the working front. In this context, the transition from manual measurements of average air velocities in the cross-section of the mining work, to point specific velocities of automatic measurements with the help of stationary transducers, requires the establishment of requirements to ensure the correspondence between the two types of measurements at the same degree of precision.

Ventsim Visual Advanced is a specialized program that was created to meet the requirements for monitoring, analyzing, and simulating the safety parameters of underground environmental conditions to ensure the proper conditions for miners and equipment. Primarily, it was designed as a ventilation tool, which can work independently of other mine planning software, but ensures a high level of compatibility. [3]

Ventsim Visual Advanced provides additional tools on:

- Conducting thermodynamic analysis regarding heat, humidity and cooling in underground mines;
- Consideration of air compressibility for deep mines;
- Providing tools to analyze several options for dimensioning the ventilation ways, both financially and for establishing the ventilation capacity;
- Analysis based on the dispersion and concentrations of gases in an underground mine;
- Providing tools for checking aspects related to air recirculation;
- Simulation of the dispersion of dust in suspension from diesel engines. The VENTSIM Visual Advanced software, used for monitoring, analysis, and simulation of security parameters, has the following features: graphics – 3D solid or monofilar, hardware acceleration, animation of flows & fans, units – SI metric, DXF import; DXF solid import, undo function, job network – 30,000 branches, simulation method – multipass HC mass flow, reverse flow direction, compressibility of air flow, color data display, air data types, alternate fan start, variable fan speed, changing fan flow direction, heating and cooling, input of rock temperature, natural ventilation - automatic, distribution prediction, source generation assistance, source concentration generation, diesel particle simulation, recirculation detector, analysis predictor network economy, auto simulation, types of files used – SIM, VSM, TXT, importable data – text, DXF, VNE, TPC.

As an example, I present the solution of the ventilation network of the Vulcan Mine, the analysis of the security parameters at the level of gas dispersion and air circulation in the ventilation network. Figure 1 shows the ventilation network.
Figura 1. – The ventilation network of the Vulcan Mine
Figures 2, 3 and 4 show details from the monitoring of gas dispersion and air circulation at the front work level (methane, carbon dioxide, carbon monoxide).

Fig. 2. CH4 dispersion and air circulation at the level of an front work

Fig. 3. CO2 dispersion and air circulation at the level of an front work

Fig. 4. CO dispersion and air circulation at the level of an front work

With the help of the Ventsim Visual Advanced program, it is possible to establish the dynamics of gas dispersion both in normal conditions and in virtual simulation conditions regarding changes in the ventilation network at the level of the ventilation network related to a coal mining operation.

The mine fire is the result of a spontaneous combustion produced as a result of the heating of the coal material through slow oxidation, under the conditions of the existence of an air current that passes through the network of small cracks in the massif. The dangers that accompany mine fires are:

• Intoxication, asphyxiation.
• Inversion of ventilation.
• Producing explosions;

Endogenous fires give off carbon monoxide, a colorless, odorless, tasteless gas whose density is 0.967. This gas exerts a special action on the human body by transforming blood hemoglobin into carboxyhemoglobin. Through this, carbon monoxide reduces the property of hemoglobin to fix oxygen, causing anoxemia, respectively death by progressive asphyxiation.

The danger of carbon monoxide poisoning depends on its concentration in the breathed air, the duration of exposure, the intensity of the activity carried out and the physical constitution of the individual. Figure 5 shows to what extent and under what conditions it is possible to work in an atmosphere containing carbon monoxide.

Fig. 5. CO dispersion and working conditions

Endogenous fires are generally accompanied by the appearance of carbon dioxide. This is a toxic gas much heavier than air, accumulating at the bottom of the mine workings. The level of toxicity of air polluted with carbon dioxide depends on the content of this gas, respectively on the time it stays in the respective atmosphere. Figure 6 shows to what extent and under what conditions it is possible to work in an atmosphere containing carbon monoxide.
Fig. 1. – The ventilation network of the Vulcan Mine

Figures 2, 3 and 4 show details from the monitoring of gas dispersion and air circulation at the front work level (methane, carbon dioxide, carbon monoxide).

Fig. 2. CH₄ dispersion and air circulation at the level of an front work

Fig. 3. CO₂ dispersion and air circulation at the level of an front work

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Study of the dynamics of formation of potentially explosive / toxic / asphyxiating atmospheres, PROGPAM

The main security parameters analyzed refer to the underground environment, endogenous fires and the technical substantiation of decisions in the event of an accident.

The concentration of carbon monoxide is much higher than the other gases, being detected already at the beginning of the ventilation of the underground environment, which is why this gas was chosen as a spontaneous combustion trigger.

The slow oxidation reaction of coal leads to the appearance of carbon monoxide, carbon dioxide and water. The permanent reduction of personnel with underground atmosphere concentration network of the Vulcan Mine using the 3D Canvent and Ventsim.

Establishing the dynamics of gases at the level of underground mining operations, Bucharest Technical University, 2000.

The parameters that are followed in order to assess the efficiency of degassing networks are:

- The depression in the drainage network in relation to the underground pressure at the measurement point;
- The methane concentration of the captured gas;
- Methane flow rate.

The central analysis and control facilities allow the collection, centralization and surface processing of the assembly of measurements performed at various points of a degassing network. A central control and analysis facility can perform numerous functions, the most important of which are:

- It allows the evolution of the degassing process continuously and at numerous points;
- Facilitates and directs the activity of the staff in charge of degassing supervision;
- It allows comparing the records from the central station with the values of methane concentrations and air flows from the exhaust streams;
- It is an effective means of study, especially for determining the optimal depression.

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4. Conclusions
The analysis and research carried out in this work allowed the following conclusions to be highlighted:

The monitoring of security parameters is one of the main elements of the automatic control system of these parameters

- Analysis, monitoring of security parameters mainly ensures:
- the objectification of underground atmosphere control;
- detection in the early phase of mine fires;
- operative alarming of the staff and validation of the recovery of electricity in the accident area;
- reduction of personnel with underground atmosphere control tasks;
- technical substantiation of decisions in the event of an accident.

- The main security parameters analyzed refer to the underground environment, endogenous fires and the degassing of coal seams.
- The characteristics of the environment in which the mining activity is carried out are determined both by the geological-mining conditions and the physical, mechanical and chemical dimensions of the deposit, as well as by the applied technology.
- Ventsim Visual Advanced is a specialized program that was created to respond to the requirements regarding the monitoring, analysis, and simulation of safety parameters in underground environmental conditions, to ensure the proper conditions for miners and equipment.
- The quality of the underground environment can be expressed either by the quantities that define the underground atmosphere (parameters that express the danger of explosion and that of toxicity) or by the specific sizes of the quantities of air circulated through the mining works.
- The permanent monitoring of the environment adopted by all mining operations consists in the continuous measurement of methane, carbon monoxide, oxygen and air circulation speed.
- The slow oxidation reaction of coal leads to the appearance of carbon monoxide, carbon dioxide and water. Additionally, by increasing the temperature and by the partial pressure changes due to the formation of oxidation gases, phenomena of desorption or chemical transformation of the gases contained in the coal appear.
- The concentration of carbon monoxide is much higher than the other gases, being detected already at the temperature environment, which is why this gas was chosen as a spontaneous combustion detector
- The parameters that are followed in order to assess the efficiency of degassing networks are: the depression in the network of degassing, the methane concentration of the captured gas and the methane flow from the network.

References