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Improvement of safety management system at the mining enterprises of Ukraine

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Abstract

Purpose. Search for ways and their analysis to improve the safety of mining operations at coal mines in case of inadequate perception of risks or deliberate violation of occupational safety.

Methods. An integrated approach is used in the work, which involves: analysis and generalization of previously performed research into the miners' injuries during underground mining of minerals; analysis of the occupational safety management system; mathematical statistics methods; experiments planning in the questionnaires and expert groups development; expert assessment method.

Findings. After analysis of the modern methods for the occupational safety system management, three main groups of factors leading to injury have been revealed. The ways to impact on injury factors are outlined. The objective of research has been formulated – identify the distinguishing features of the safety system at coal enterprises in case of inadequate perception of risks or deliberate violation of occupational safety, as well as development of the conceptual solutions to improve the safety system. A conceptual management graph has been created after summarizing the existing approaches to safety management. The actions have been analysed according to the developed graph through substitution into it of factors from the "staff-machine-environment" system during their pairwise interactions. The analysis of actions according to the safety management graph, performed by the reconstruction method indicates that the existing safety management system can be improved for specified conditions. It is proposed to improve the safety system by introducing a "smart-protection" system, which is triggered at the stage of hazards identification, increasing the decision-making adequacy.

Originality. Improving the safety system in case of inadequate perception of risks or deliberate violation of occupational safety is achieved by introducing new sensors into the system, increasing the systems response speed, changing the principle of their operation, as well as improving installation schemes through analysis of devices, principles of processing information and making decisions.

Practical implications. The developed aerogas method of controlling the coal mines atmosphere can be used in case of inadequate perception of risks or deliberate violation of occupational safety. It complies with the proposed principles of "smart protection" and includes continuous monitoring for the mine atmosphere parameters.

Keywords: *rate of injuries, fatality, labour conditions safety, human factor, smart protection*

1. Introduction

The rate of accidents in mining sector connected with fatalities, serious injuries and long-term disability is still the highest in the industry. At the same time, the state of the labour protection level remains unsatisfactory and does not comply with accepted social standards, despite the continuous improvement and implementation of ever new measures and requirements of safety [1]-[4].

Despite the regular increase in the occupational safety costs, more than a thousand fatal injuries are recorded annually in the world mining sector. The main causes in mining casualty investigation reports or similar documents of other countries, are gas or dust explosions, gas poisoning, careless handling of explosives, electrocution, collapse of underground structures, roof fall and collapse, flooding, people fall, mechanical injury by working equipment [5]-[9].

The world mining industry employs more than 40 million miners. The largest number of miners, about five million people, are employed in the Chinese mining industry. Over the past 60 years, 250 thousand miners have died in China. For the recent years, the level of injuries there has gradually decreased from inadequately high to medium in relation to the global trend. For example, from 2002 to 2012 the number of fatal accidents decreased from 6995 to 1384. This is mainly conditioned by an increase in the level of works mechanization. The main causes of fatal accidents in China are as follows: explosions and fires – 43%; roof fall – 33%; mine workings flooding – 8%; and coal transportation – 9% [10]-[13].

The mines of Ukraine are among the most dangerous in the world, due to difficult mining-and-geological and temperature conditions. Two-thirds of Ukrainian mines are of "excess-category" in methane content, a third – in coal dust content. In addition, their operation is affected by the domestic coal industry technical backwardness [14]-[16].

As a result of the Ukrainian territory occupation in 2014 that led to the armed conflict in the Donbass, the number of coal mines in Ukraine has decreased significantly. Since the beginning of 2019, the total number was 69 mines. Forty-two are state-owned mines. Of these, 31 mines are operating for extraction, 1 mine is at the stage of construction, 7 mines are being dissolved and 3 mines are operating in the mode of hydraulic protection. Twenty-seven mines are non-state mines. Therewith, the Donbass includes 33 mines operating in Donetsk region, 12 mines – in Lugansk region and 10 mines – in Dnepropetrovsk region. The coal enterprises which are in the field of state supervision of labour protection and industrial safety of the State Labour Committee of Ukraine as of 01.01.2018, employ 100160 people.

The mining industry is still one of the most dangerous in terms of fatal injury rate. To increase occupational safety performance, researchers and industry experts all over the world make a lot of efforts to identify the causes of accidents and improve the occupational safety control system [17]-[21].

2. Literature review

Today, there is a common approach to safety research, which is based on the "staff-machine-environment" system analysis. Each industry is characterized by its own set of technological processes, which leads to various types of interactions in the specified system. The great hazardous factors variability, the specifics of labour conditions, production management, the systems of control and punishment have led to the need for these factor types assignment. Though this simplifies the analysis of the accidents causes, in many cases it does not reveal the nature of the causes leading to them. The "typical definition" often hides the real cause of the accident or emergency case. Therefore, to develop systematic measures of injuries reduce, it is necessary to get a truthful pattern that has led to the accident. For this purpose, according to the author, it is necessary to discretize the causes, based on the pair interactions study in the "staff-machine-environment" system. Each interaction type requires discretization and development of appropriate measures.

Recently, the greatest attention has been paid to the research into the so-called "human factor". Thus, it is proved in the Hinze [22], Haslam [23] studies that more than 70% of injuries are caused by workers' hazardous activity, and prof. Rasmussen [24] believes that this parameter is 70-80%. An analysis of investigation reports in the domestic coal mining industry indicates that in the vast majority of them, the employee is guilty, who has got an injury [25].

According to the author, the "human factor" can be differentiated into four groups:

– safety violation reasoned by poor emotional and physical condition;

– violation of safety rules or work technology due to lack of awareness of safe working methods;

– deliberate violation of safety or work technology;

– safety violation caused by non-recognition or delayed response to hazard and underestimation of possible consequences.

The injuries, according to the first group of factors, are reduced by introducing psychological methods, compliance with the requirements of industrial sanitation in the workplace (lighting, noise, vibration), compliance with temporary labour standards and the like. Constant scientific research is carried out all over the world in this direction. In many countries, there are common standards and requirements for the maintenance of working places and labour conditions. The practice of analysing and accounting of the emotional condition when conducting instructions and making out work order is widespread in the world. Thus, the negative influence of the first factors group can be reduced by improving organizational and psychological measures.

The activities against safety violations caused by a lack of employees awareness are constantly carried out at the mining enterprises. The regular training activities, retraining, instructions on labour protection, inspections, safety days, proving the accidents cases, as well as explaining the reasons, and the like have been established by legislation. Various methods of training in occupational safety are provided in the world, using both traditional and non-traditional approaches. The domestic mining industry constitutes no exception to this. In our country, there are high standards and legislative acts of an international level. The negative influence of the second factors group can be reduced by improving at the enterprise of the labour protection services responsibility.

Deliberate violation of safety or work technology is hardly possible to predict or anticipate. It is extremely difficult to prevent such phenomena, since the motivational component of the personnel that allows for deliberate safety rules violation is uncertain, and it is difficult to determine the number and characteristics of such employees. Thus, the third group of factors is of heterogeneous and random nature. The reduction of these factors influence at the enterprises is performed mainly by increasing the personal responsibility of employees. The author does not diminish this approach importance and proposes the introduction of a "smart protection" system to reduce deliberate violations to nothing. This system should take into account the risks of deliberate violation of safety requirements and prevent them.

The third factor of influence, unfortunately typical of the domestic industry, is not consistent with an international experience. For example, research conducted by prof. Tixier [26] proves that the vast share of employees' hazardous activity is not a deliberate safety violation, but is a result of poor hazard recognition and inadequate risk perception. Similar statistic data are presented by prof. Fang [27], according to which the main reason for the majority of observed hazardous behaviours is an inadequate understanding of hazards and risk perception among employees.

It is hardly possible to draw such an unambiguous conclusion in view of the domestic mining industry, given the results of the mining casualty investigation [25]. Labour protection inspections annually record hundreds of violations at coal mines related to artificial deliberate shutdown, damage, or breakdown of sensors and systems for monitoring the state of atmospheric air, electrical protection, and the like. Such violations are not specific to the European countries.

It should be noted that a deliberate violation of safety requirements occurs when the offender underestimates the danger, therefore, an emergency or an accident seems unlikely to him.

The safety violations caused by non-recognition or delayed recognition of hazards can inherently be divided into two groups. The first group is related to insufficient employee experience, lack of skills to analyze the state of the working environment. Improving the skills and gaining the experience can be practiced through safety classes, instructing classes and surveys.

There are several methods available to improve hazards recognition. These methods can usually be classified as:

– predictive or retrospective in nature [28]-[30], which are based on a generalization of knowledge acquired as a result of incidents and injuries that have already occured, and their subsequent comparison with working situations in the workplace;

– methods for predicting hazards, requiring from employees to mentally visualize tasks that will be completed in the near future and predicting expected hazards [31];

– other methods (safety instructions before performing the task, control of the knowledge level, etc.) [32].

The second group is related to the inadequacy of means for monitoring the technological processes state. Safety decisions in certain situations are made by a rapid response to the registration results of work processes indicators, for example, the state of a mine atmosphere. The existing safety system should be improved in this regard.

The purpose of this work is searching for ways and their analysis to improve the safety of mining operations at coal mines in case of inadequate perception of risks or deliberate violation of occupational safety.

3. Methods

Unfortunately, there is no tool today to directly identify the real causes of accidents and group them into pairs of interactions. Therefore, the expert assessment method is used in order to obtain such information. Based on the options of interaction in the "staff-machine-environment" system, the following three groups have been distinguished:

– factors connected with hazards in the "human-environment" system. Everything is done right by a man;

– factors connected with hazards in the "human-machine" system; everything is done right by a man;

– factors connected with the "human factor"; man behaves incorrectly.

Experts are proposed to assess each factor weight by a 10-point scale, thereby characterizing the share of its influence on the accident (indicator "probable cause").

The experts are the scientific and scientific-pedagogical staff members of leading industry research centers and universities of Ukraine with degrees of candidates and doctors of science, whose scientific interests are the issue of safety in mining operations; staff members of the mine technical inspection service, the State Inspectorate for Environmental and Technical Safety, Prosecutor staff members, mine engineering service workers, representatives of supervision, labour protection services with at least 10 years of experience in the industry.

The experts had an experience in the Donetsk region and in investigating the accidents at the coal mines of SE "Selydivvuhillia", SE "Myrnohradugol", LLC "DTEK Dobropilliavugillia", PJSC Mine Management "Pokrovske". The technical and financial state of enterprises was different, therefore, the survey results were different, that only increases the reliability of obtained results and the comprehensiveness of their analysis. About 89.7% of experts had an experience in mining casualty investigation.

Number of factors $n = 3$. Number of experts $m = 49$.

The concordance coefficient was adopted as a measure of consistency in experts' assessments. After calculation, it was $W = 1.77$ which evidences a high degree of expert opinions consistency. In order of importance, the factors are grouped as follows (Table 1).

Table 1. Grouping of factors in order of importance

	Factors	Sum of ranks
x_1	"human-environment"	132.5
x_2	"human-machine"	140.5
x_3	"human factor"	241.5

Among all the injuries, involved by "human factor", by which we mean hazardous actions or inaction of employees under the dangerous factors influence, four groups can be distinguished:

– safety violation caused by poor emotional and physical condition;

– violation of safety or work technology due to a lack of awareness of safe working methods;

– deliberate violation of safety or work technology;

– safety violation caused by non-recognition or delayed response to hazard and underestimation of possible consequences.

Experts were also proposed to assess the weight of each four factors by a 10-point scale, thereby characterizing the share of its influence on the accident (indicator "probable cause"). Grouping of factors in order of importance is presented in Table 2.

Table 2. Grouping of factors in order of importance

	Factors	Sum of ranks
x_1	"poor emotional and physical condition"	150.0
x_2	"lack of awareness of safe working methods"	203.0
x_3	"deliberate violation of safety"	240.5
x_4	"non-recognition or delayed response to hazards"	223.5

4. Results and discussion

Summary graph of expert assessments, grouped by factors, is given in Figure 1.

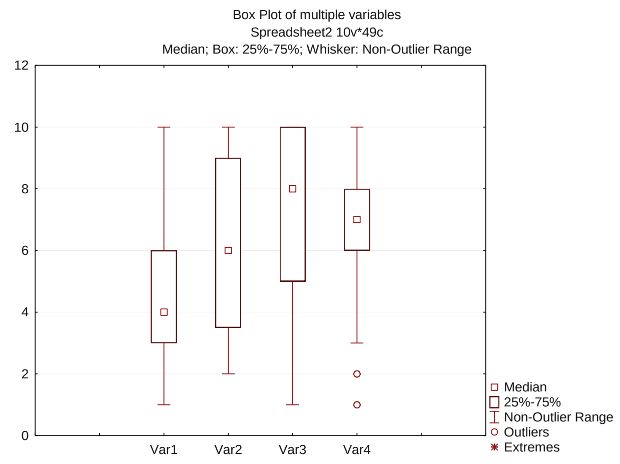

Figure 1. Graph of experts' assessments, grouped by factors

The analysis indicates that the experts' opinions regarding the x_4 factor influence ("non-recognition or delayed response to hazards") were the most consistent. The least consistent assessments were x_2 ("lack of awareness of safe working methods"). The range of assessments for factors x_1 ("poor emotional and physical condition"), x_3 ("deliberate violation of safety") was the widest. It is interesting that a low assessment on the latter factor was given by experts who were not directly involved in the accidents investigation, but only analyzed the investigation results. Personal experience, specific labour conditions, and various professional responsibilities explain such large values in the results difference. Thus, the expert assessments analysis shows that the results can be used in further analysis.

Safety management is one of the most popular research trends of occupational safety area in different countries. There are various approaches to assessing risks, the level of acceptable risks, and the probable or stochastic nature of accidents. After summarizing the existing approaches to safety management, the author has developed a conceptual management graph, shown in Figure 2.

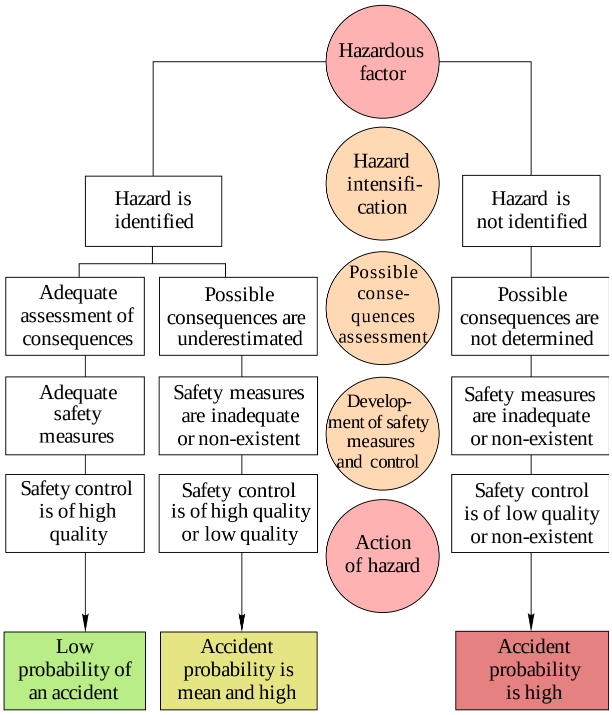

Figure 2. Safety management graph

Factors x_3 and x_4 can be generalized by the block "possible consequences are underestimated" of the safety management graph. An example of such course of events, for the hazard factor "methane gas explosion" as a result of "disorder" in the methane control sensors operation, according to the author, is characterized by the parameter "deliberate violation of safety", which is shown in Figure 3.

The scheme illustrates the reconstruction of the accident at the Novodonetsk mine of 06/12/2017, in the 3rd northern longwall face of the stepline slope No. 1 of the seam l_3. The circumstances of the accident are given in detail in [33].

A methane ignition occurred at 9.05 p.m. in the upper part of the 3rd northern longwall face of the stepline slope No. 1 of the seam l_3, and, as a result of which, workers have received burns of varying severity.

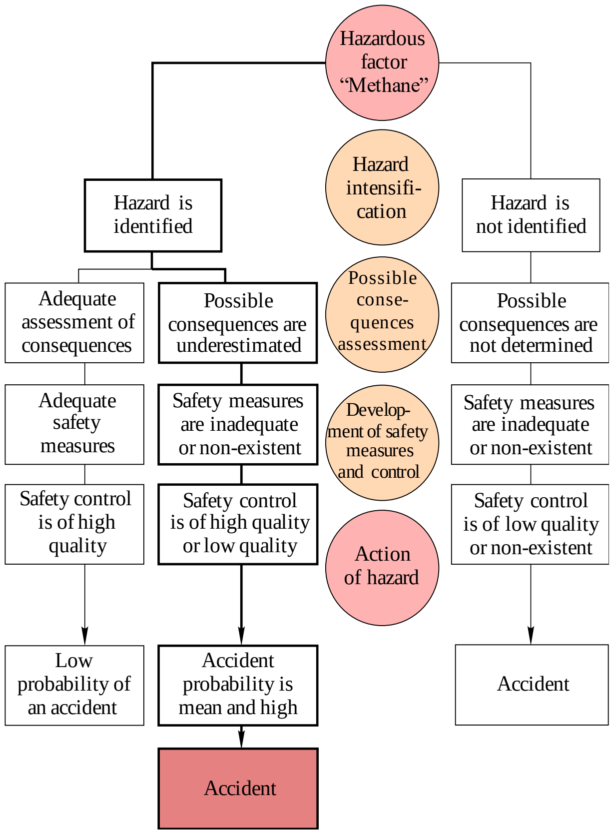

Figure 3. Safety management graph with parameter "deliberate violation of safety" (scheme illustrates the reconstruction of the accident at the Novodonetsk mine of 06/12/2017)

Therefore, the 10th squad of the State Militarized Mine-Rescue Service was called up for the "explosion" type of accident in accordance with the established procedure.

On the day of the accident 06/12/2017, according to the diagram, from 2 to 9 p.m., the indicators of methane content ranged within 0.5% with slight deviations. Later, in the period from 9 to 10 p.m., the methane content increased to 0.75%, and about 10 p.m., there was a sharp increase in methane concentration to 2.5%, and then from 10 to 10.30 p.m., a methane concentration increased up to 3.1%. These data were until 12 a.m. of the next day (06/13/2017).

The methane concentration sensor D2i-1, according to the AGC (automatic gas control) project, should have been placed on the outcoming jet at 10-20 m from the longwall face window in the 3rd north upper entry of the stepline slope No. 1 and adjusted for the actuation setpoint at 1.3%. On the day of the accident 06/12/2017, the sensor readings from 2 to 9 p.m. were stable at the level of 0.6% methane concentration. At 9 p.m., after a slight drop, the readings decreased to 0.4% and up to 10.15 p.m. – to 0.3% methane concentration. At 4 a.m., the readings slightly increased to 0.4% and subsequently remained at the same level.

The methane concentration sensor DZi-1, according to the AGC project, was located at the reclaimed blind corner in the 3rd north upper entry and adjusted for the actuation setpoint at 2%. On the day of the accident 06/12/17, from 2 to 9 p.m., the sensor readings were at the level of 0.75% methane concentration with small deviations. Then, after a slight decrease at 9.45 p.m., there was a sharp increase in concentration up to 10.15 p.m., reaching the level of 2.3%, and at 10.18 p.m. the sensor turned off and its readings were subsequently zero. The actual arrangement of the sensors D2i-1 and DZi-1 methane concentration has not been determined by the commission.

The mine workings at the emergency site were examined by members of the special investigation commission, the expert commission and mine workers from 12.30 to 6.20 p.m. of 06/23/2017.

The squad of the State Militarized Mine-Rescue Service, which examined the emergency longwall face, has taken air samples. The gas situation, identified at 3.10 a.m. by express method in the area of upper connection (section No. 166) was as follows: CH_4 = 1.1%; CO = 0.0%; in the blind corner – CH_4 = 2.2%; CO = 0.0%.

It turns out that at the time of the explosion during the longwall face operation, the methane concentration was lower than during the examination after the longwall face was stopped.

Obviously, a methane explosion could not occur with the concentrations indicated on the sensors. Moreover, the methane sensor D2i-1, located at a distance of 20-30 m from the place of explosion, has not recorded a single increase in methane concentration either during the accident or after that. This can only mean that the sensor was not operating in normal mode. The methane concentration sensor DZi-1 untill 9.45 p.m., that is, for additional 40 minutes after the accident, showed 0.75% methane concentration, and then the readings increased sharply to 2.3%, after which the sensor turned off. This can only mean that at the time of the accident the sensor did not show accurate information, it was either covered, or set in another place. It is evidenced by a sharp increase in the sensor readings at 9.45 p.m., when it was probably set in the appropriate position according to the AGC project.

These two sensors, according to the author, were deliberately made "sluggish". As for the DZi-1 sensor, although it has recorded concentrations that are up to 3 times higher than the permissible Industrial Safety concentrations, but they were obviously delayed by at least 30 minutes, which cannot but cause questions.

In the above example, the fact that the hazard was identified, but underestimated can be asserted based on the fact, that the methane content in the longwall face should have been monitored using the episodic mining device by the mining master of the mining site, as well as using the devices of continuous operation by the miners at the upper connection and by the operator of rock removing machines on the mining combine.

The case given as an example is not an isolated one. Unfortunately, during the investigation, it is extremely rare possible to establish the real facts of unauthorized tampering with the operation of aerogas protection systems. But such suspicions of the investigation commissions and expert groups arise periodically. As an example can be the I category accident that occurred on March 2, 2017 at 12.05 a.m. at the Stepova Mine of the SE "Lvivvuhillia" – methane-air mixture explosion that occurred in the belt entry No. 119 in the area from 0 to 50 m from the longwall face. The authors of work [34], devoted to the details of the accident at the Stepova Mine, point out as the main problems "the main reasons for obtaining data that are not true: a problem with the power supply; incorrect adjustment and arrangement of control sensors; loss of connection with the server; instability of the ventilation system; repair operations with the control system; the absence of air velocity sensors at the locations of methane control sensors, as well as unauthorized tampering with the system and other factors". In the work [35], it is noted that accidents by drilling and blasting works (DBW) at gassy mines can bring about larger tragedies because of the gas-dynamic phenomenon, e.g. gas explosion caused by the local strata congestion at A.F. Zasiadko mine on June 31, 2002.

The main reasons of accidents and injuries caused by explosives at mines are:

– unauthorized conduction of blasting operations or violation of their DBW certificates;

– blasting works in the presence of people in the dangerous zone;

– use of such explosives at coal mines that do not comply with safety grade;

– carrying out DBW by the staff without the appropriate qualifications or the right to conduct such works.

The analysis shows that over 80% of accidents in industry are caused by administrative reasons and only 20% are associated with violation of the DBW certificates.

The indicated 80% may be interpreted as a deliberate violation of safety.

The performed analysis testifies that the existing safety management system can be improved to account for "deliberate violation of safety".

The peculiarity of underestimating the hazard is that there are situational and subjective factors that are difficult to predict. Moreover, the control system, designed for adequacy and constancy of the response, which in fact is not stochastically determined. Improving the safety system for such factors is proposed by introducing a "smart protection" block that is actuated at the stage of hazard detection, increasing the decision-making adequacy. The discretization of the process improves the protection quality. An example of such a safety management scheme implementation is given in Figure 4.

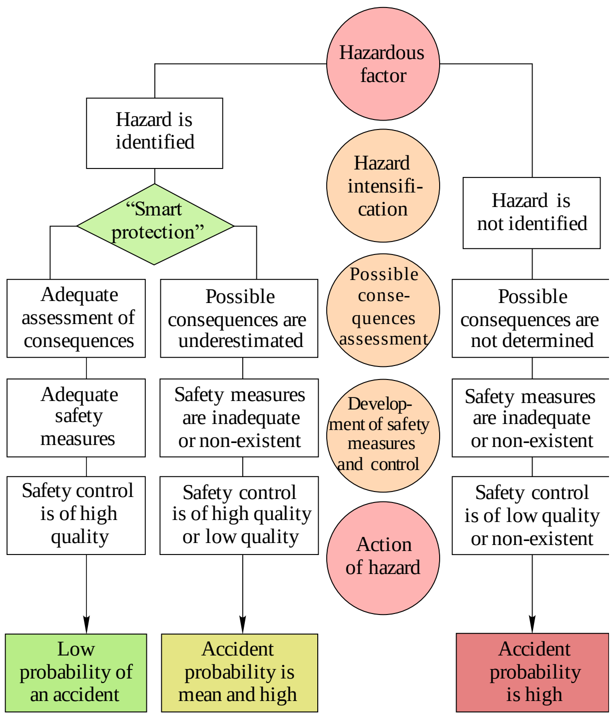

Figure 4. Safety management graph, improved for hazards that can be parameterized as "deliberate violation of safety"

In practice such a system is possible to implement by introducing additional elements, sensors, increasing the systems response speed, changing the principle of their operation, improving installation schemes through analysis of devices, principles of processing information and making decisions.

An example of the practical implementation of the above approach is the aerogas control method of the mine atmosphere developed by the author [36].

The basis for the developed solution is the task of improving the aerogas control method of the mine atmosphere, by means of which it is possible to detect "unauthorized tampering" with the system operation by setting additional control elements. This "unauthorized tampering" is represented by restricting the methane-air mixture penetration into the sensor reaction camera and changing the sensors position in space at any stage of operation. These measures would prevent the occurrence of increased methane concentrations in the mine atmosphere and the threat of methane explosions and ignitions.

The problem is solved in such a way, that in the developed method of aerogas control of the mine atmosphere, which includes continuous monitoring of the composition and parameters of the atmosphere in the mines, hazardous in gas and dust, rock blows and sudden emissions, an increase in the information content in operating the system of aerogas control of the atmosphere, in accordance with the invention of increasing the information content in operating the system of aerogas control of the atmosphere, is performed by fixing the mechanical restriction of methane-air mixture penetration into the reaction camera of the methane control sensors by setting at least one additional optical emitter with beams focused on the methane control sensor camera, in which there is an optical receiver with a recording sensor. Information from the sensor is transmitted to the control and alarm system, which detects an unauthorized change in space of methane control sensors position by setting at least one optical distance sensor with the beams focused on the distance change controller housing, the information from which is transmitted to the control and alarm system.

It is expedient to perform the additional setting of an optical emitter with beams focused on the methane control sensor camera, in which an optical receiver with a recording sensor is installed at a distance of 0.1-1.0 m from the latter. And an optical distance sensor with the beams focused on the distance change controller, from which information is transmitted to the control and alarm system to prevent "unauthorized tampering" with the system operation by fixing the changes in space of methane control sensors position, should be set at a distance of 1.0 – 5.0 m.

It is expedient, when setting an optical emitter with the beams focused on the methane control sensor camera, in which an optical receiver is set with a recording sensor, to provide for kinematic connection with the corresponding methane control sensor.

Increasing the information content in operating the system of aerogas control of the atmosphere by fixing the mechanical restriction of methane-air mixture penetration into the methane control sensors camera with additional setting of at least one optical emitter with beams focused on the methane control sensor camera, in which an optical receiver is set with a recording sensor and information from which is transmitted to the control and alarm system, makes possible to detect an "unauthorized tampering" in the form of restricting the methane-air mixture penetration into the sensor camera at any stage of the system operation. When unauthorized blocking of methane-air mixture access to the methane sensor camera occurs, the optical contact between the emitter and receiver is broken, fixed by the recording sensor and, through the control and alarm system an unauthorized tampering is notified. That way, an "unauthorized tampering" is detected at any stage of the system operation in the form of restricting the methane-air mixture penetration into the methane control sensor camera. This, in turn, prevents the occurrence of increased gas concentrations and the threat of methane explosions and ignitions.

Fixing of an unauthorized change in space of methane control sensors position by additional setting in them at least one optical distance sensor with the beams focused on the distance change controller housing, the information from which is transmitted to the control and alarm system, makes possible to detect an "unauthorized tampering" in the form of changing in space of the sensors position at any stage of the system operation. In case of unauthorized methane control sensor displacement in space, the distance between it and the distance change controller housing is changed, which is recorded by the sensor and notified through the control and alarm system about an unauthorized tampering. That way, an "unauthorized tampering" is detected at any stage of the system operation in the form of changing in space of the methane control sensors position at any stage of the system operation. This, in turn, prevents the occurrence of increased gas concentrations and the threat of gas explosions and ignitions.

Setting of an optical emitter with beams focused on the methane control sensor camera, in which an optical receiver with a recording sensor is set at a distance of 0.1-1.0 m from the latter, allows reliable control of the optical contact. When increasing this distance by more than 1.0 m in a dust mine atmosphere, the contact will be unstable due to dust flow, and this will contribute to a large number of signals with an error. If the distance between the sensors is less than 0.1 m, the recording sensor will obstruct natural movement of air and the methane-air mixture penetration into the reaction camera of the methane control sensor.

Setting of an optical distance sensor with the beams focused on the distance change controller, from which information is transmitted to the control and alarm system at a distance of 1.0-5.0 m allows reliable monitoring of the distance between the sensors and, accordingly, to detect an unauthorized change in space of methane control sensor position. When the distance between the sensor and the controller is less than 1.0 m, there is a technical possibility of synchronous relocation of the sensor and controller within mine dimensions in order to avoid fixing of tampering with the system. When the distance between the sensor and the controller is more than 5.0 m, the distance measurements accuracy decreases, which requires an improvement in the distance fixation quality and may lead to an unreasonable increase in the cost of the system.

Setting of an optical emitter with beams focused on the methane control sensor camera, in which an optical receiver is set with a recording sensor, kinematically connected with the corresponding methane control sensor, enables to increase the system reliability and reduce the number of false alarms. This method is presented in Figure 5.

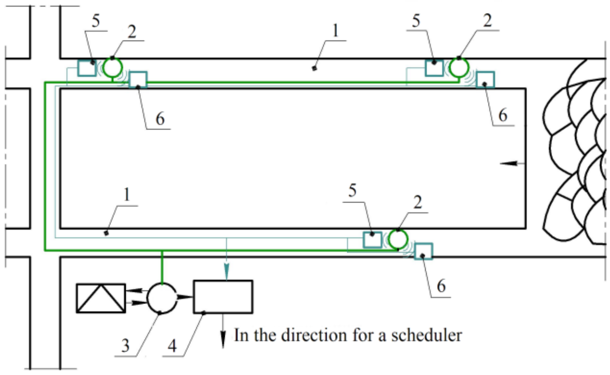

Figure 5. Method for aerogas control of the mine atmosphere: 1 – mine working; 2 – methane control sensor; 3 – stationary equipment of automatic gas control; 4 – telemetry pedestal; 5 – recording sensor with an optical receiver; 6 – distance change controller

The method is implemented as follows. In mine workings *1*, the methane control sensors *2* are being installed. In case of exceeding the maximum permissible gas concentration, the AGZ *3* command is given to turn off the power supply in the longwall face. Control engineers receive telemeasurements through the telemetry pedestal *4*. In the case of "unauthorized tampering" with the system operation by mechanical blocking of the methane-air mixture penetration into the reaction camera of the sensor *2*, the optical contact between the emitter and the optical receiver of the recording sensor *5* is broken. Information about "unauthorized tampering" is transmitted to the control engineer through pedestal *4* and the control and alarm system is triggered. In the case of "unauthorized tampering" with the system operation by changing the position of the methane control sensors *2* in space, the distance between the distance sensor built into the methane sensor *2* and the distance controller *6* is changed. This is recorded by the system and information about "unauthorized tampering" is transmitted to the control engineer through pedestal *4*, and the control and alarm system is triggered. This allows to detect an "unauthorized tampering" at any stage of the system operation and prevent the occurrence of increased methane concentrations in the mine atmosphere, as well as the threat of methane explosions and ignitions.

The implementation of the proposed aerogas control method of the mine atmosphere by setting a "smart protection" system, which includes additional control elements, is achieved by the possibility of fixing "unauthorized tampering" with the system at any stage of its operation, which helps to prevent the formation of explosive concentrations of dust-gas mixture and the possibility of its explosions.

5. Conclusions

An analysis of the existing labour safety management system indicates that in order to improve the miners' operation safety in the domestic mining industry, the labour safety system should be improved in case of inadequate perception of risks or deliberate violation of occupational safety.

Improving the safety system of above conditions is proposed by introducing into the system additional elements, sensors, increasing the systems response speed, changing the principle of their operation, improving installation schemes through analysis of devices, principles of processing information and making decisions.

A method of aerogas control of the mine atmosphere developed by the author is presented, which includes the proposed "smart protection" system and additional control elements. In addition, it is possible to record an "unauthorized tampering" with the system at any stage of its operation. Improving the safety system at coal mining enterprises is an important scientific task, which will be the subject of further research.

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Удосконалення системи управління безпекою гірничих підприємств України

Б. Кобилянський, А. Михальченко

Мета. Пошук і аналіз шляхів удосконалення безпеки робіт на вугільних шахтах при неадекватному сприйнятті ризиків або навмисному порушенні безпеки робіт.

Методика. У роботі використано комплексний підхід, що включає: аналіз і узагальнення раніше виконаних досліджень травматизму гірників при підземному видобуванні корисних копалин; аналіз системи управління безпекою праці; методи математичної статистики; планування експериментів при розробці опросних листів та експертних груп; метод експертних оцінок.

Результати. Проаналізовано сучасні методи управління системою безпеки праці, визначені три основні групи чинників, що призводять до травмування. Намічено шляхи впливу на фактори травматизму. Сформульовано завдання дослідження – виявлення характерних рис системи безпеки вугільних підприємств при неадекватному сприйнятті ризиків або навмисному порушенні безпеки робіт і розробка концептуальних рішень з удосконалення системи безпеки. Створено концептуальний граф управління після узагальнення існуючих підходів до управління безпекою. Проведено аналіз дій по розробленому графу при підстановці в нього факторів з системи "персонал – машина – середовище" при їх парних взаємодіях. Проведений аналіз дій по графу управління безпекою методом реконструкції свідчить, що існуюча система управління безпекою може бути удосконалена для визначених умов. Пропонується удосконалення системи безпеки вести за рахунок введення системи "смарт-захисту", яка спрацьовує на етапі ідентифікації небезпек, підвищуючи адекватність прийняття рішень.

Наукова новизна. Удосконалення системи безпеки при неадекватному сприйнятті ризиків або навмисному порушенні безпеки робіт досягається шляхом введення в систему нових датчиків, підвищення швидкості реагування систем, зміни принципу їх роботи, удосконалення схем встановлення аналізуючих пристроїв та принципів обробки інформації і прийняття рішень.

Практична значимість. Розроблено спосіб аерогазового контролю атмосфери вугільних шахт, що може використовуватись при неадекватному сприйнятті ризиків або навмисному порушенні безпеки робіт, відповідає запропонованим принципам "смарт-захисту" і включає безперервний моніторинг параметрів шахтної атмосфери.

Ключові слова: *травматизм, смертельний травматизм, безпека умов праці, людський фактор, смарт-захист*

Совершенствование системы управления безопасностью горных предприятий Украины

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Цель. Поиск и анализ путей совершенствования безопасности работ на угольных шахтах при неадекватном восприятии рисков или умышленном нарушении безопасности работ.

Методика. В работе использован комплексный подход, включающий: анализ и обобщение ранее выполненных исследований травматизма горняков при подземной добыче полезных ископаемых; анализ системы управления безопасностью труда; методы математической статистики; планирования экспериментов при разработке опросных листов и экспертных групп; метод экспертных оценок.

Результаты. Проанализированы современные методы управления системой безопасности труда, определены три основные группы факторов, приводящих к травме. Намечены пути воздействия на факторы травматизма. Сформулирована задача исследования – выявление характерных особенностей системы безопасности угольных предприятий при неадекватном восприятии рисков или умышленном нарушении безопасности работ и разработка концептуальных решений по совершенствованию системы безопасности. Создан концептуальный граф управления после обобщения существующих подходов к управлению безопасностью. Проведен анализ действий по разработанному графу при подстановке в него факторов из системы “персонал – машина – среда” при их парных взаимодействиях. Проведенный анализ действий по графу управления безопасностью методом реконструкции свидетельствует, что существующая система управления безопасностью может быть усовершенствована для определенных условий. Предложено совершенствование системы безопасности вести за счет введения системы “смарт-защиты”, которая срабатывает на этапе идентификации опасностей, повышая адекватность принятия решений.

Научная новизна. Совершенствование системы безопасности при неадекватном восприятии рисков или умышленном нарушении безопасности работ достигается путем введения в систему новых датчиков, повышения скорости реагирования систем, изменения принципа их работы, совершенствования схем установки анализирующих устройств, принципов обработки информации и принятия решений.

Практическая значимость. Разработан способ аэрогазового контроля атмосферы угольных шахт, который может использоваться при неадекватном восприятии рисков или умышленном нарушении безопасности работ, соответствует предложенным принципам “смарт-защиты” и включает непрерывный мониторинг параметров шахтной атмосферы.

Ключевые слова: *травматизм, смертельный травматизм, безопасность условий труда, человеческий фактор, смарт-защита*

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