Improvement of production control of coal mining enterprises with underground mining method

Tatyana Tyuleneva [1,2*]

[1]T. F. Gorbachev Kuzbass State Technical University, 650000 Kemerovo, 28 Vesennyaya st., Russian Federation
[2]T.F. Gorbachev Kuzbass State Technical University, Branch in Prokopyevsk
653049, Prokopyevsk, 19a Nogradskaya str., Kemerovo Region – Kuzbass, Russian Federation

Abstract. Production safety is one of the problems of competitiveness of underground mining enterprises, one manifestation of which is the reduction and minimization of the number of accidents and incidents of personal injury or even death. To solve this problem, it is necessary to improve the system of production control of coal mines in order to eliminate these factors. Relative indicators of accidents and injuries at underground coal mines of Russia in comparison with the average indicators are considered, and also importance of the human factor in the occurrence of dangerous production situations and the evaluation of their causes and effects are revealed. In addition, the article considers the most common violations of safety requirements for underground coal mining, analyzes the experience of foreign countries in improving the production control system, assesses the possibility of its application for improving production control at Russian coal mines, and determines main areas for implementing a risk-based approach at coal mining enterprises.

1 Introduction

The problem of improving the production control system has always been relevant for coal mining enterprises [1]. It has particular importance for underground coal mining. This circumstance is explained by the complexity of the mining and geological conditions of thmineral deposits, the obsolescence of the production base, the need to conduct preparatory work , and higher production costs then in coal mines.

The practice of underground mining enterprises` activity shows that ensuring the necessary level of safety of the production process is a significant competitive advantage, guaranteeing the reliability of operation when achieving the required economic efficiency [2, 3]. And the importance of safety as a factor of competitiveness is constantly growing,

* Corresponding author: kta.bua@kuzstu.ru

because both Russian and foreign underground coal mines are comparable in conditions of the production process and implemented safety measures [4].

The last 30-40 years of operation of underground coal mines have been marked by an increase in the level of mechanization and automation of the production process. The essence of reforming the production management system is not only to improve its safety and economic efficiency, but also to ensure sustainable development . This requires the formation of a production control system focused on improving the safety and economic efficiency of coal mining [5].

The transformation of the working conditions of Russian coal mines and changes in their organizational and production structure and the applied technologies have improved the efficiency and safety of the production process. But ensuring the safety of production with a constant and large-scale increase in its volumes is caused by the appearance of repeated failures in the security system, the formation of dangerous production situations, and the failure to perform a number of functions in the management system of labor protection and industrial safety [6]. Taking into account tendencies of production development and its national and industrial features, and applied scientific-methodical base in the field of risk management, objective evaluation of the system of labor protection and industrial safety, improvement of production control in the mines of the Russian Federation are promising field.

2 Characteristic of the work

Coal mines of Russian Federation are continuously working to improve the production control system, which allows for a steady trend of reducing accidents and injuries in the industry for 16 years (table. 1).

Table 1. The ratio of production indicators, accidents and deaths at coal mines in Russia [7]

Years	Production, mln t		Number of accidents		Fatally injured, pers.	
	Total	Underground mining	Total	Underground mining	Total	Underground mining
2004	284,5	103,2	33	28	148	132
2005	300,2	108,5	27	15	107	81
2006	294,2	111,1	23	20	68	53
2007	294,1	111,5	21	18	232	216
2008	316,0	105,28	12	9	53	41
2009	319,47	108,41	9	8	48	36
2010	301,79	102,72	22	17	135	122
2011	323,18	100,99	13	9	46	33
2012	337,4	112,91	16	11	36	28
2013	355,2	101,0	11	11	63	57
2014	352,01	105,3	8	7	26	18
2015	373,4	103,7	8	6	20	11
2016	385,7	104,6	8	7	56	53
2017	408,9	104,5	3	3	18	12
2018	439,3	108,3	5	5	17	13
2019	440,07	107,48	1	0	15	11
Total	5525,42	1699,49	220	174	1088	917

Thus, from 2004 to 2019, the number of fatal injuries decreased from 148 to 17. However, underground coal mines accounted for an average of 79 % of accidents during this period (a minimum of 56 % cases in 2005 and 100 % ones in 2013, 2017 and 2018) and 84 % of fatal injuries (a minimum of 55 % was recorded in 2015, and 90 % or more in 2007, 2010, 2013 and 2016). The share of underground coal mining averaged about 31 % of the total coal production in the country during this period. This circumstance indicates the need for increased control of the underground mining method as the most vulnerable to production risks.

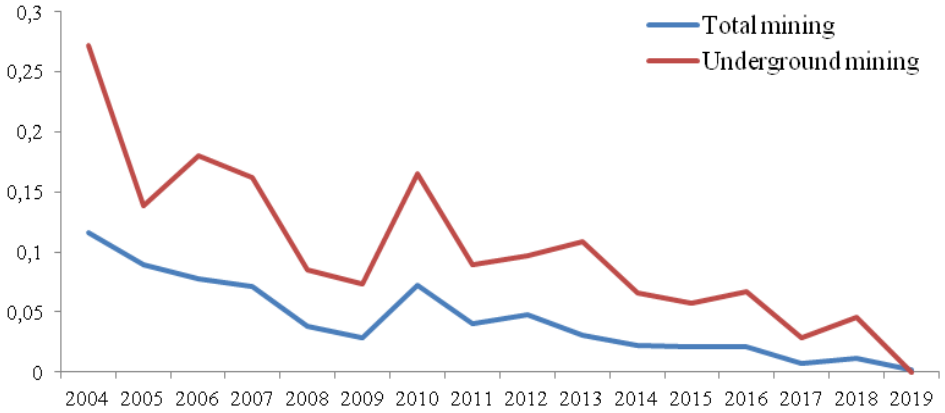

Fig. 1. Dynamics of indicators of specific accident rate of coal mining, the number of cases per 1 million tons

Dynamics of indicators of specific accident rate of coal, presented in Fig.1, demonstrates a two-fourfold excess of their values for the underground mining above to values of similar indicators for total mining in corresponding years. Over the past 16 years, there has been a decrease in the specific accident rate of underground mining by more than 6 times, and in some years (2006, 2010 and 2018) there were sharp increases in values compared to previous years – by 1.4 times, 2.3 times and 2 times, respectively).

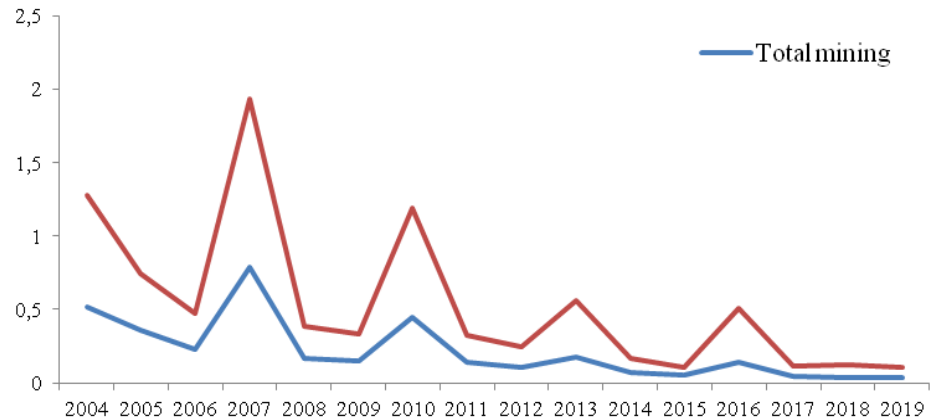

Fig. 2. Dynamics of specific fatally injured rates for coal mining, people per 1 million tons

The Fig.2 shows that for 16 years the number of fatal injuries per 1 million tons of extracted coal increases sharply every three years with a decline in the next two years. Thus, a sharp increasing in this indicator compared to the previous year was observed in 2007 (4 times), in 2010 (3.6 times), in 2013 (2.2 times) and 2016 (5.1 times). In a whole in 2004-2019 values of the specific fatally injured rate for underground coal mining decreased by 10 times, but every year of analyzed period, they exceeded same indicators for total production by 2-4 times.

Assessment of the current state and historical aspects of the development of production management systems indicates that improving the production control system needs improving the organization of production activity. To do this, it is necessary to determine features of modern production systems that have led to the need to improve the technology, management and production control.

Having studied the distribution of accidents and fatally injured accidents at coal mines in Russia by causes and injured factors for 2016-2019 (table 2), we can conclude that in some cases, fatally injuries were not caused by emergency situations (in particular, it can be seen by analyzing the ratio "Cause" / "Injured factor" in indicators "Transport" and "Action of machines and mechanisms". Based on this, we can draw a conclusion about the significant role of the human factor in the occurrence of life-threatening situations.

Table 2. Distribution of accidents and fatally injured accidents at coal mines in Russia by causes and injured factors [7]

Causes and injured factors	**Accidents, units**				**Fatally injured accidents, units**			
	2016	**2017**	**2018**	**2019**	**2016**	**2017**	**2018**	**2019**
1. Explosion, combustion, flare gas and coal dust	4	-	-	-	36	-	-	1
2. Fire	-	-	3	-	-	-	-	-
3. Sudden release of coal, rock, and gas	-	1	-	-	-	1	-	1
4. Transport	-	-	-	-	3	3	3	-
5. Action of machines and mechanisms	-	-	-	-	7	5	5	3
6. Flooding of mine workings	1	-	-	-	-	1	-	-
7. Collapse of workings and supports	1	1	2	-	7	2	4	3
8. Other types of accidents and injuries	1	1	-	-	-	-	1	3
Total	7	3	5	-	53	12	13	11

The results of external control measures show the following reasons of accidents and fatal fatally injured accidents [8]:

- insufficient qualification of personnel : gaps in the organization and conduct of personnel training, training and familiarization with operational documentation;
- low technological and labor discipline: unsatisfactory implementation of production control over compliance with industrial safety requirements ; lack of control over the state of technical devices; non-compliance with the requirements of design and technical and operational documents.

Typical violations of mandatory requirements by legal entities engaged in coal mining identified during control measures are following [8]:

- defaulting on the requirements for passing the industrial safety briefing;

- violation of safety requirements by employees when operating equipment under pressure;
- unsatisfactory organization of loading and unloading operations;
- weak control over compliance with industrial safety requirements when working in the installation chamber;
- failure to comply with the requirements of the order system;
- violation of safety rules when working on transport;
- working in hazardous areas by employees without the necessary professional training;
- violations of labor regulations and labor discipline requirements;
- lack of rules for organizing and carrying out maintenance and repair of equipment (air pipeline) in the design and operational documentation, taking into account the specific conditions of its operation;
- failure to comply with the requirements of the manufacturer's documentation for technical devices during their operation and maintenance;
- malfunction of technical devices;
- timeliness measures for the elimination of coal dust;
- failure to comply with project documentation requirements.

The regulatory framework for improving the production control system is the "Regulations on the production control system of the enterprise", and job descriptions and other local regulations. Therefore, improving the production control system is an integral part, or stage, of improving the management system of labor resources, production process, labor protection and industrial safety, among them [9]:

- transition from authoritarian principles of labor management to management with delegation of authority and responsibility;
- reforming the legal framework for disciplinary actions;
- introduction of a system of individual responsibility based on the principles of unity of command through the formation of job descriptions and professional instructions.

Russian Federation as a member of the International labour organization takes part in improving production control by developing methods for ensuring industrial safety in accordance with global trends[10]:

- implementation of a policy to improve labor safety in order to avoid injuries in order to effectively use labor resources within the framework of managed risk;
- tightening of legal requirements in the field of labor protection in order to avoid injuries;
- improvement of the labor protection system on the part of employers through the implementation of collective and individual responsibility of employees, involvement in the risk management.

Providing protection of employees from the influence of harmful production factors is part of the production strategies of the European Union and the United States , and studying the experience of countries in this field is of interest to Russia [11, 12, 13, 14].

Since 2004, the basis of the UK's industrial safety system has been legislated on the state of the system of labour and health of each employee safety. To achieve this strategic goal, four fields have been identified, such as: strengthening cooperative ties with trade unions and scientific consulting structures; and promoting a culture of labor protection and personal responsibility for one's health. The results of the risks self-assessment are recorded in the employees' registration cards for the subsequent development of an action plan to minimize health threats with an annual repeatability, and it ensures self-control of professional risks and updating of their management system. The employer is responsible for assessing professional risk in the workplace and taking measures to minimize it. The implementation of this approach allowed to develop methods for motivating employers to finance labor safety, which provided a sharp reduction in fatal industrial injuries.

Promoting workplace safety is a strategic goal of the U.S. government in the labor field, for which new innovative approaches to protecting the health and labor rights of employees are being developed at the legislative level. Americans are predicting an increase in demand for coal as one of the main sources of energy security in the country and are developing long-term strategies for labor protection. In this field, the industry's labor protection administrations have round-the-clock hotlines that receive complaints about violations. This is the basis for immediate inspection; it is sufficient that the information contains data about the place and the fact of a threat to human health. Along with strict sanctions for violations of labor laws on labor protection, special federal programs are in place in the country in the field of labor protection and health of employees.

Every workplace in Finland keeps a trade union recording of factors that are potentially dangerous to the employee's health, and a formalized and standardized system has been established for taking into account professional risks, the degree of their threats, and their impact on health. The employee, along with trade unions, takes part in assessing occupational risks and taking measures to minimize them by complying with labor protection requirements. Priority ways are to promote global partnership and strengthen comprehensive cooperation in the field of employee health and safety, establish communications and disseminate information in the field of labor protection, and conduct research on the dangers of new professional risks. Special attention is focused on the younger generation, among which a responsible attitude to their work and health is popularized.

The global experience of applying the new production control system through risk management shows the prospects for its application in Russia. Currently, the American way of improving production control is being implemented in our country. In order to increase the attention of employers to the problems of labor protection, mass violations are divided into many separate cases with the corresponding accrual of penalties. In the United States it provided a focus for employers on labor protection issues.

At the same time, the scientific and methodological basis for ensuring production control in Russian Federation has been significantly improved in terms of principles and methods for minimizing risks. In addition, the established practice of Russian underground coal mines in this field served as the basis for the development of the following principles of the production risk management system [15].

Firstly, improving the reliability of multi-functional safety systems and aerogas control. The main risks in coal mining are the threat of explosive concentrations of methane and suspended explosive coal dust. Measures to improve aerological safety include equipping mines with multi-functional systems for safe mining, monitoring and managing operations in normal and emergency circumstances: aerological safety systems for managing stationary fan installations, local ventilation and gas disposal fans, degassing network, aerogasic monitoring of gas-dynamic phenomena; systems for detecting potential hazards of endogenous and exogenous fires; water supply and drainage systems; communication, notification and location systems for workers in mine workings; search and detection of people in emergency conditions; emergency underground communication and notification system.

Secondly, improvement of coal mine degassing systems by means of complex degassing of workings with a methane content of more than 10 m^3 per ton, accompanied by drilling of degassing wells to remove methane from the extraction site, application of advanced degassing methods and gas- collecting equipment.

Third, improving the effectiveness of measures to eliminating coal dust by establishing increased criteria for shale mining under the influence of inert dust.

Fourthly, strengthening control over compliance with labor protection and industrial safety requirements by preventing violations, reducing the number of injuries and accidents,

maintaining a unified database of violations with the use of disciplinary penalties and administrative and criminal liability measures. Production control in this direction is implemented by specialized services of the mine in the following order: division of the production system into separate objects; on each of them by assessing violations and work injuries are defined jobs and operations with a maximum degree of production risk; in relation to them will be determined by priority for production control requirements, rules and regulations; taking into account their compliance with the specialized service organizes the procedure of the planning and operative production control objects.

3 Conclusion

The increased vulnerability of Russian underground coal mines in terms of production safety in comparison with foreign ones makes it necessary to improve the production control system. It needs taking into account global trends in the development of appropriate methods for ensuring production control, focused on the formation of effective risk management systems.

Currently, two main directions are being implemented in the world practice of industrial control – sanctions control by detecting violations and applying measures of influence to violators and responsible persons - and training in self-control of negative events of industrial activity by assessing and minimizing the risks of professional activity. The use of a particular direction is largely determined by the value of the controlled object in terms of ensuring the safety and efficiency of the production process. This is due to differences in production facilities and production processes in the probability of dangerous production situations occurring in them, and the degree of consequences from their manifestation. It seems appropriate to combine both of these ways, since the parallel implementation of social responsibility measures and economic assessment of the consequences of violations will minimize and even eliminate the role of the human factor in the occurrence of dangerous industrial situations in underground coal mining.

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