50 years University of Mining and Geology "St. Ivan Rilski"
Annual, vol. 46, part III, Mechanization, Electrification and Automation in Mines, Sofia, 2003, pp.227-232

RISK ANALYSIS OF MINE EQUIPMENT

Michael Michaylov
University of Mining and Geology "St. Ivan Rilski"
Sofia 1700, Bulgaria
mihailov@mgu.bg

Nikola Marhov
University of Mining and Geology "St. Ivan Rilski"
Sofia 1700, Bulgaria

Elena Vlaseva
University of Mining and Geology "St. Ivan Rilski"
Sofia 1700, Bulgaria
elena@mgu.bg

Zahari Dinchev
University of Mining and Geology "St. Ivan Rilski"
Sofia 1700, Bulgaria
zdinchev@mgu.bg

ABSTRACT
The issue is discussed of contemporary stringent requirements to ensuring of safe labor conditions for mine workers. Risk assessment of mine equipment breakdowns and failures is reviewed in more detail. Risk assessment of a raise driving complex is presented as an example.

THE ISSUE OF INDUSTRIAL SAFETY

It is well known that in the last decades, in industrial countries, concern about working conditions and safety of industrial personnel has been increasing. The importance of these issues has both human and social and economic aspects. For example, nearly 120 mill labor accidents are reported in the world each year, representing approximately 40 accidents per 1000 workers per year. Those accidents result in the death of approximately 200 000 people per year making, or 8 fatal accidents per 100 000 workers/a. The number of temporarily disabled people as a result of labor accidents is much greater. This is the price the public pays for the continuous strive towards life quality improvement. It is obvious that living standards should not be raised at the expense the health and lives of the people that work to achieve it.

RISK IN THE MINING INDUSTRY

World over, approximately 1% of industrial personnel is working in the mining industry. Specific labor conditions in this branch predetermine a risk of accidents and occupational diseases 8 times higher than average industrial one. The situation in our country is similar to that.

Considering the above-said, it is necessary to answer the radical question, why does modern society accept the high risk for mining industrial personnel? The answer seems simple and obvious, but for considerations of comfort and consumption, modern society is too willing to look away from the truth about prodigal utilization of material resources. And the truth is that only a small portion of materials resources come from the flora and fauna, the rest mining industry extracts from the earth.

The price society is paying for better life quality is the higher risk of mining activity. It is unfair, but still a fact that such higher risk only concerns miners and not the entire society.

The risk (possible danger) is always related to a hazard. Рискът (възможната опасност). In industrial activity, a hazard means every source of potential damage, injury or potentially damaging situation. Substances, materials, energy, methods, work technologies, systems, equipment, etc., all could be hazardous.

The risk has two components: the probability for a certain hazard to become real and the consequences of the hazard that has become real. The probability for one or more people to be injured during exposure to hazard depends on the probability for this hazard to be realized in work environment and on exposure frequency and duration.

The magnitude of consequences depends on thier severity and is defined by the degree of injury (temporary or permanent disability or death) and on the number of affected persons.

Professional risk for miners is defined by the probability of suffering consequences of different severity in respect of their health and safety in mines. This risk differs for each mine and depends on labor conditions in each mine. For example, labor accidents and occupational diseases in opencast mining are two or three times less in number that in underground mining. This means that risks for opencast mine workers are smaller that for underground miners. It should be pointed out that risks associated with opencast mining are still greater than those associated with most industrial activities.

It is known that mining technology is implemented in complex and changing geological and technical conditions, with specific risks for miners, but here only the risk of mining equipment is discussed.

SOME TERMS RELATED TO MINING EQUIPMENT AND ITS SAFETY

Mining equipment– the totality of machines, mechanisms, facilities, devices and apparatuses for various applications used in

the usual implementation of main and independent technological procedures in mining.

Machine – mechanical device, comprising components in coordinated operation and performing specific purposeful movements to covert energy into work.

Facility – a functional combination of one or more machines with the so-called **equipment**. The most characteristic mining equipment includes winding, compressor, ventilation and other facilities.

System – **a network of components (subsystems**), които performing as one whole piece for achieving a certain objective. Generally, the system is defined as a set of objects and events. The mining equipment employed in a mine or section thereof can be presented as a system as well.

Machine serviceability - defined by the status that at any given time corresponds both to the main parameters of machine availability and to secondary parameters relating to safety and other factors.
Fault – defined by the machine condition that at any given time does not comply even with one single requirement of either main or secondary parameters.

Breakdown- event resulting in making the machine non-operable.

Failure - event resulting in making the machine non- operable.
Each failure is a breakdown but not every breakdown is a failure.

RISK FILE OF MINE EQUIPMENT

This file must record the hazards, which the machine creates during performance and inherent machine hazards and also the measures planned to reduce the risk of such hazards happening. The file must also contain all information about realized and potential risks of the equipment and its systems.

The main document introducing the risk accent is the Law on Healthy & Safe Working Conditions, enforced in our country. In this aspect, machine risk files must include two major analyses – of technological risks and of technical risks of equipment. These analyses should contain appropriate measures for avoiding and minimization of technological risks of machine-performed operations and of technical risks of breakdowns and failures of equipment functional and structural subsystems.

Generally, risk assessment should include:

- Work processes;
- Work equipment;
- Work places;
- Labor organization;
- Utilization of raw materials;
- Other factors that could present risk

The two key analyses for the files should systematize hazards (including those created by materials used, extracted and transported by the equipment) of individual operations in their technological sequence, measures to avoid such hazards (including organizational ones) and should assess residual risks.

EXAMPLE RISK ANALYSIS OF KPV-4 RAISE DRIVING COMPLEX

Mechanized raise driving is associated with risks for miners inherent to driving technology and technical condition of complex subsystems (platform and monorail):

- Gas inhaling while miners work in poorly ventilated faces;
- Injuries and traumas of various degree while working in unsafe face;
- Fatalities in case of non-compliance with basting regulations;
- Silicosis disease from blast hole boring with insufficient water flush.

The main technological operations in one driving cycle (raise driving) are:

- Driving of chamber for the complex;
- Complex installation;
- Inspection of platform technical status at shift start:
- Taking of air samples from the face;
- Platform advance to face;
- Making the face safe
- Monorail extension;
- Drilling of blast holes;
- Charging of blast holes;
- Moving platform to chamber;
- Blasting and ventilating of face;
- Technical inspection and maintenance of complex;
- Dismantling of complex.

Example analysis of technological risks associated with certain operations is presented in table 1. Potential mechanical risks are associated with unsatisfactory technical conditions of the complex and the following hazards are possible:

- Injuries of different severity during operations for remedying breakdowns and failures of the complex;
- Fatalities in case of failure of complex undercarriage.

In order to identify potential technical hazards, it is recommended to split the complex into functional systems and subsystems. For example, the complex on fig. 1 comprises the following systems:

- Hose winch;
- Power supply block;
- Pneumatic system;
- Monorails;
- Platform;
- Signaling & communication system.

Complex risk file would analyze all systems but here we only focus on platform – the most important one. For risk assessment of breakdowns (failures) of the system, it would be necessary to analyze all subsystems, starting from the most important (most hazardous) one and ending with the least risky one. For example, the platform system comprises several subsystems, the most closely associated with miners' safety being: driving mechanism, manual brake and automatic arrestor (eccentric safety clutch), all shown on fig. 2.

Breakdown risk analysis should assess technical condition of important structural system elements at any given time, as well as define boundary admissible wear of important working surfaces of system and subsystem components. It is recommended to describe in words particularly responsible actions. .

Here, risk analysis is performed of the drive mechanism subsystem, for the operations "platform hoist" and "platform lowering", as shown in table 2.

The drive mechanism subsystem operates in the following way: reversible pneumatic motor 1, via gear 2, drives shaft 3, which in turn, via cylindrical wheels 4 and 5, drives shaft 6. Screws 7 and 8 are mounted on shaft and drive two parallel units:

- -first: screw 7, via screw wheel 9, shaft 11 and wheel 13, interlocked with monorail 15 and via support rollers 17, the platform moves forward;
- - second (similar to first unit): via the sequence screw 8, screw wheel 101shaft 12 and wheel 14, interlocked with monorail and via alignment rollers 18, the platform moves forward.

This drive system with two parallel power chains was designed solely for safety purposes. For example, in case a monorail component falls out, the system will continue its uninhibited movement in the specified direction.

Similarly, if there is a faulty component in one drive unit, the other unit will implement movement. However, if there is a faulty component from pneumatic motor 1 to shaft 6, the platform is secured against free downward gravitational movement because screws 7 and 8 in this case are self-braking, i.e. these serve as platform brakes.

If compressed air supply is discontinued, the platform could be emergency-lowered through manual operation of flywheels 37

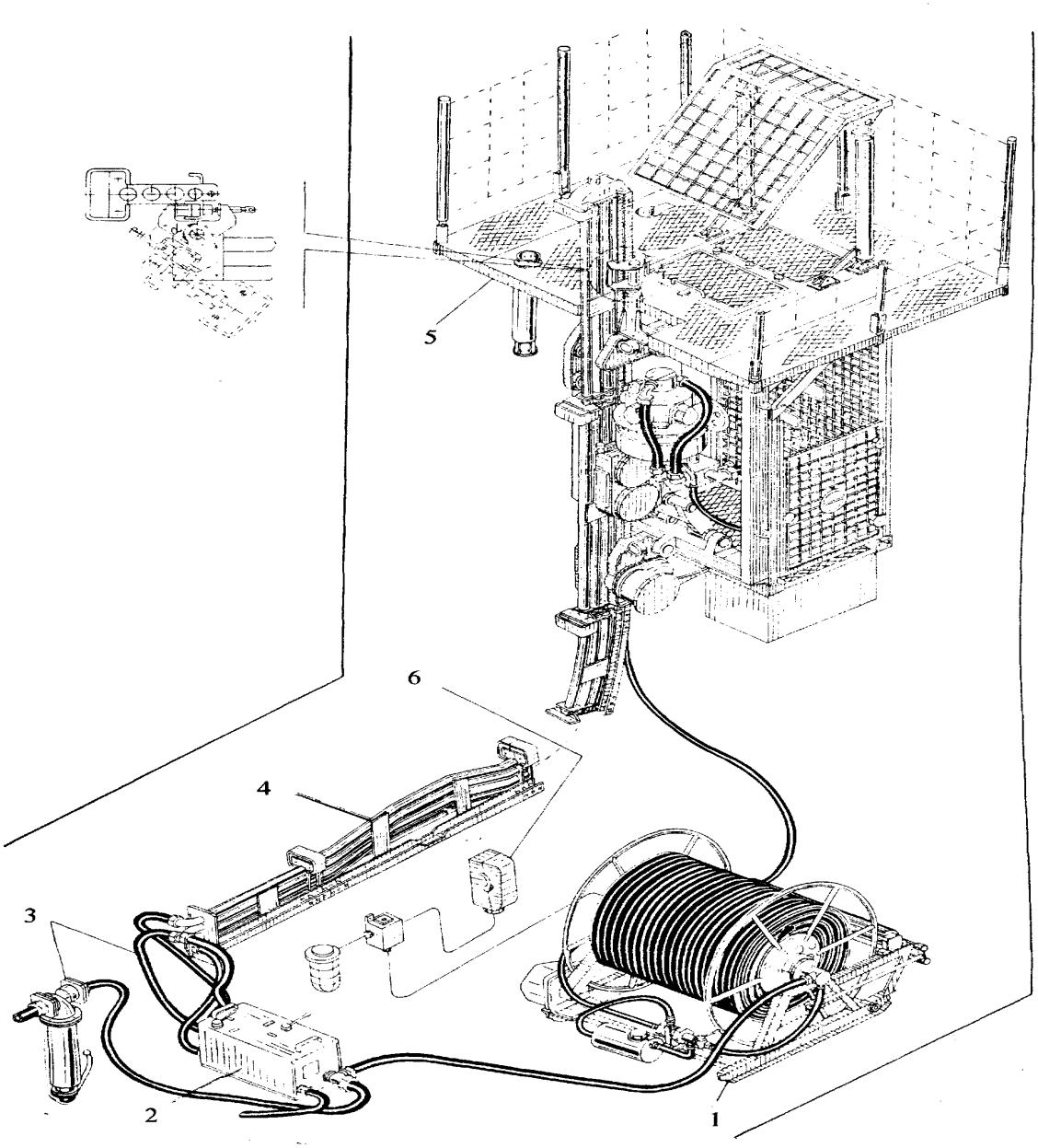

Figure 1. General arrangement of KPV-4 complex

Table 1. ***TECHNOLOGICAL RISK ANALYSIS*** *Raise driving with* ***KPV-4 Complex***

OPERATION	POTENTIAL HAZARD	RECOMMENDED SAFETY MEASURES	SAFETY EQUIPMENT	RESIDUAL RISK		
				F	C	R
7. Monorail extension	7.A.1. Insecure and improper installation of monorail section creates risk of platform failure and hazard for miners.	7.A.1. New monorail section must be installed by two miners in compliance with the following requirements: - Linearity (alignment) of section with monorail track; - Secure section support; - Distance between upper section end and face should be greater than 1 m.	Hard hat			
		7.A.2.For the purpose of ensuring sufficient robustness and stability of vertical monorail section, each 10th section should be reinforced.				
8. Blast hole drilling	8.A. Breach of technology and technical requirements creates hazard of injury and sickness for miners	8.A.1. Drilling in old holes is strictly forbidden.	Hard hat, gloves			
		8.A.2. In the presence of so-called "pixes" the minimal spacing of holes should be observed.	Hard hat, gloves			
		8.A.3. At the beginning of hole drilling, so-called " flushing", the assistant miner must support the drill end to face.	Hard hat, gloves			
		8.A.4. Hole drilling with insufficient water supply is not allowed, i.e. dry drilling mode.				
9. Blast hole charging	9.A. Breach of hole charging requirements creates real hazard for miners' safety. Such hazards almost always have lethal outcome.	9.A.1. On commencement of hole charging, lighting and telephone systems must be switched off.	Hard hat, gloves			
		9.A.2 Blast holes must be loaded in strict compliance with Safety Regulations.				
10. Platform movement to chamber	10.A. Breach of technical requirements for platform downward movement creates hazard for miners.	10.A.1. During platform lowering and occurrence of excessive speed and operation of automatic safety clutch (arrestor), manual brake must be operated immediately.	Hard hat			
		10.A.2. Platform should be lowered only with operating safety clutch.				
		10.A.3. Blocking of safety clutch as strictly forbidden after being operated for the purpose of faster movement of miners in chamber.				
11. Face ventilation	11.A. Insufficient face ventilation after blasting creates hazard for inhaling gases by miners.	11.A.1. Face must be ventilated with water-air mixture for 30 min.	Breathing device – isolating			

Table 2 RISK ANALYSIS OF BREAKDOWNS - Machine: Raise driving complex; System: Platform; Subsystem: Driving

Identification mark	Operation Function	Possible fault	Possible consequences	Severity C_m	Possible reasons for breakdown	Probability P_m	Indication (finding)	Finding probability D_m	Risk R_m	Additional safety measures	Responsible person	Period of implementation day/month/year	Result			
													New severity Cn	New probability Pn	New probability of finding Dn	Residual risk Rn
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Platform hoisting	Irregular and non-smooth platform movement	Increased impact load of wheels (pos.13 и 14) and teeth of 15 of monorail, creating hazard of breaking and disruption of interaction between platform and monorail	7	Wear of wheel teeth (pos. 13 и 14) or enlarged gaps between drive wheels, alignment rollers and monorail components	4	Unusual noise and vibration and characteristic "beat" of wheels 13 and 14 interlocked with monorail	4	112	Inspection and measurement of machine component wear. Instruction on fault warning signs.	Section mechanic	One week	7	3	2	42
	Platform hoisting or lowering	One driving unit not operating	Lower safety level of system and increase of load on the other unit	6	Wheel breaking off conic shaft end 11 or 12 because of damaged fasteners (nuts) or deformation of splint and splint grooves of wheel or shaft. или вала	3	Low vibration and characteristic noise with smaller intensity. Visual inspection of drive wheels.	9	162	Stopping of platform operation until drive unit is restored. звено	Section mechanic	During the shift	6	2	5	60

and 38, conic wheels 39 and 40 , and through brake device 19 driving shaft 3, platform, respectively.

System analysis leads to the conclusions that this mechanism is very secure against platform self-lowering. Theoretically, it could be accepted that system safety is very high. However, several years (15) of experience with the driving complex in our country show certain weak points of the system in real conditions of raise driving. For example, the two parallel driving units create certain difficulties for platform movement. This is due to the circumstance it is hard to drive that raise walls with small plane deviations, which makes alignment of monorail components with strata difficult.

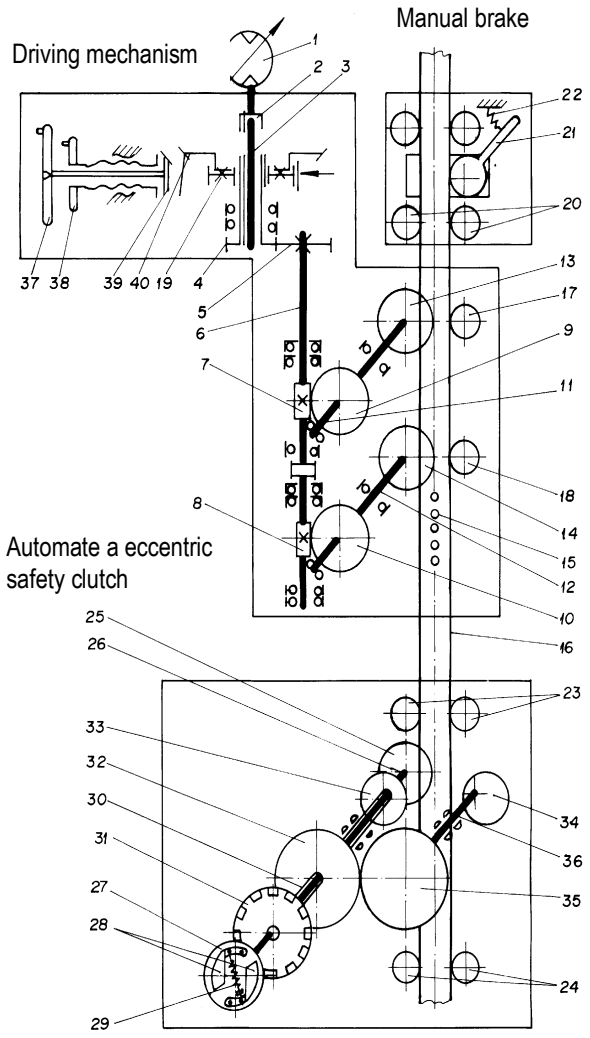

Figure 2 Kinematical charts of driving mechanism, manual brake and eccentric safety clutch subsystems

This circumstance is the reason for inhibited upward movement of the platform when passing from one monorail component to another. Sometimes, poor alignment of monorail components may cause blockage of upward platform movement.

In such cases, platform operators would purposefully dismantle the wheel interlocked with monorail thus resolving the problem at the expense of system safety.

Risk analysis of breakdowns (table 2) includes measures for component safety control as well as quantitative assessment of such measures according to M.Michaylov's methodology (2001).

CONCLUSION

The risk file documents the sequence of logic steps ensuring systematic identification, assessment and management of risks associated with mining equipment operation so that such risks could be reduced to acceptable levels. To this end, the risk files has the following goals:

- To assist employer in adopting adequate program of engineering and administrative solutions for risk management of mine equipment. Measures should be consistent with state of the art of safety and with risk specifics and magnitude, as well as with available resources. The measures included in analyses represent an optimization technical – economic task.
- To create a basis for improvement of safety culture of equipment operators. This would require additional knowledge – knowledge of hazards and measures for risk minimization, application of such knowledge, change in attitude to safety and achieving of quantitatively new safety level in equipment operation.
- To establish the basis of a unified and manageable system of mine equipment safety. Implementation of unified targeted policy of safe equipment operation is only possible on the basis company standards and procedures for safety and specific risk management.

Creation and keeping of up-to-date risk files of mine equipment would require consistent application of general rules in relation to team formation, source document compiling, carrying out of analyses, file storage, use and updating. These general rules should be personified for the experts employed by the company.

REFERENCES

Michaylov M., N.Marhov, E. Vlaseva. 2001.Risk diagnostics of mine equipment. Publishing House of St. Ivan Rilski University of Mining & Geology, Sofia, 284.

Recommended for publication by Department of
Mine ventilation and occupational safety, Faculty of Mining Technology