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Occupational Safety And Risk Assessment In The Mining Industry

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Abstract *Global dynamics of the technological changes creates a need for modern approaches while evaluating and analysing the risk in the mining industry. Analysing and managing technical systems in the mining industry is a key factor concerning the quality of their functioning. Dependability, safety, and maintenance management based on the risk analysis can contribute substantially to the overall effectiveness and efficiency of the mining technological systems. Besides applying adequate technology, organizing and harmonizing the system links among various structures and standardization is of the great importance in achieving business goals. The choice and use of the optimal solutions in the analysis ought to recognize, anticipate, forestall, reduce, and minimize the risk and possible destructive applications. The mining industry production practice recognizes the need for the strategy of organizational and process redesigning as well as raising this issue to the level of the other managing functions of the company. A realistic view of the present state in the risk analysis shows the need for the rapid transformation in the mining industry. The study puts forward a proposal for the possible approaches and improvement relating to the following and implementing modern, standardized world trends, (models and methods) concerning the analysis of the technical and occupational safety risk in some of the basic processes in the mining industry.*

Keywords: *risk analysis, mining industry, coal, technical system, occupational safety.*

1. INTRODUCTION

The completion of the planned production activities in the mining industry means satisfying complex requirements of reliability and safety of both parts of the system and a whole technological process completely. This is of particular importance for big companies and it also places a special responsibility on them. The control and management of the work position risk becomes a central category of the logistic operatibility of the top management. The general context of the problem is the need for coming to wise strategic decisions while doing some long-term planning. While pursuing business excellence the companies' ultimate goal is completing safe, dependable, and profitable work. Within the technological systems of the mining industry there is a real need for the correct positioning of the problem concerning the management of the risk. The analytical and methodological approach to the problem includes: correct and complete risk identification, reduction of the critical potentials to the level of acceptable limits and constant monitoring. A practical problem is to find the way of minimizing typical and atypical states of a failure optimally, as well as detecting accurately the destruction levels with the full critical potentials for technican and technological systems in the mining industry. In the mining industry analytical and methodological approaches to this problem are both partial and different. Concerning that context, production practice recognizes a lot of concrete incompatibility and illogicality. The outcome of such a state is considerable disturbance to the parts of the system or to the whole sytem functioning. Process management, risk management, and risk managers are factors that can acknowledge and establish the need, regularity, and quality of the risk positioning for the focussed technological processes. The realization implies the implementation of the standardized organizational forms, methods, and models. At the same time, overall intergradibility and compatibility of the process at the level of all management functions of the company must be taken into consideration, [1]

2. RISK AND TECHNICAL SYSTEMS

During its life cycle technological systems and processes are under the various destructive influences which can considerably reduce the quality of their performance. The chances of unwanted events and anticipated consequences of the events in the even cycle are considered to be a risk in the system analysis during the established length of time or a certain process (the combination of frequency and chances of appearing) , as well as the result of a specific prejudical event. The identification of the critical points of the technical systems in the mining industry which can generate risks and risky events is a professional problem. This proves the need for a management approach in both analytical and methodological sense. The risk aspects in the mining industry can be various and are mainly connected with all the influences within/and near the system/process itself: design, redesign, technical, technological, maintaining, ecological, technical protection, sociological, economic, and the other.

The risk research carried out on fundamental processes shows that safety, dependability, and security of the systems and processes in the mining industry can be hardly achieved without identifying all the aspects or at least, a large number of them, without expert processing and proposals concerning complete solutions, the ways of following particular suppositions at an expert level and the upper limits of the proffesional plausibility, [2]. The project focuses on the technical aspect of the risk analysis and the aspect of occupational safety and health. The risk can and must be managed. The chances of a risky event occurance can be reduced to the acceptable level by establishing the adequate control. A high-quality analysis, risk assessment, reduction and monitoring are prerequisites for the prevention of the critical potentials destruction planning. The next step is developing the strategy of a reaction to a failure concerning the recovery from the consequences. The aim and need for the research concerning the risk analysis, reduction, and monitoring, the production practice of the mining industry of Serbia recognizes through:

1. Development of methodology for the system analysis of the process and the system.
2. Development of criteria and processes for implementation of standards which is of help to the assessment of technical systems risk.
3. Development of methodology for the assessment of the influences of all identified aspects of the technological complex destructive potentials.
4. Assessment of the system/process current conditions, as well as the assessment of the real needs for the partial or complete redesign and improvement.
5. Defining conditions and choosing modes of management of the technical protection risk and the occupational safety in the mining industry.

We can conclude that formulating the adequate strategy for analysis, monitoring and management of a risk is a very complex issue. It is at the very beginning of the professional interest. It requires considering a large number of aspects and parameters of a technological and non-technological kind. The influence of the external and internal environment, organization, studying previous data, as well as the mandatory forecast in the near and distant future are always present.

The research throughout the world proves the need for rapider development, standardization of both present and new modes and methods for risk analysis, assessment, reduction, and monitoring. Determinative strategies for the risk assessment and reduction in the coal processing can be recognized through the generic powers that form the development of the process by the strategic actions and integration powers created in a organizational and industrial context .

3. PRACTICAL EXPERIENCE CONCERNING RISK ANALYSIS IN THE MINING INDUSTRY

The research done worldwide indicates the need for the rapid development, standardization of both existing and new models and methods for the risk analysis, assessment, reduction and monitoring. The results of the domestic practical experience can be characterised as follows: There are good regulations which create favourable conditions for the change of the existing state concerning positioning, handling, and monitoring the risk for the focused aspects in the mining industry of Serbia. The use of standardized methods and models, together with the good practical experience worldwide, is at it the very beginning of the professional possibilities and interests. There are considerable efforts of the scientific public to create positive trends and broaden the experience of the subject matter. Domestic practical experience is typical of its lack of the experts concerning significant and qualitative changes. There are not licensed risk managers who would join the project teams. There are not any institutions in charge of schooling and licensing this type of personnel. There is either no implementation of modern standardized models and methods for analysis,reduction, monitoring and managing the risk in the production practice of the mining industry of Serbia or it is rare. There is a real problem concerning the competence while analysing the risk. The improvisations and inadequate treatment are frequent in recognizing the risk in the production practice.In companies’ organizational models, units of risk management are not provided for. The risk analysis and assessment are not given enough attention in the strategies of top management of companies. The lack of financial and other logistics for rapid transformations and changes of the existing practice and state of affairs is evident.

4. FORMALIZATION OF THE PROBLEM OF RISK ANALYSIS

Modern multi-aspect approaches to the occupational safety problems impose the requirements for great degrees of reliability and safety of the process on project and engineering teams. Such requirements are justified by the fact that there is the need for reducing occupational injuries, as well as various accidents, occupational diseases, partial or total invalidity and death. This can generate a human approach line in the problem analysis. Mining industry is an area of particular interest concerning the use of scientific knowledge within the sphere of risk. Previous requirements strain the relations in the process of system projecting and the need for redesigning the existing ones which have been functioning for a long time. The question is whether engineering teams are able to recognize new requirements and approaches? Some surveys show that one part of project teams accepts and recognizes new requirements concerning the process/system design and redesign with difficulty or does not accept and recognize them at all. The reasons for this can be: consciousness, culture, educational problem, training for new methods and techniques which are in the function of new approaches. Selecting basic events of technological processes in coal processing is an important and responsible task for the risk analyst or a multi-disciplinary team. Proposed events basically close the continued technological process flow. Being like that,they have to be both representative and respectable enough. The omission of any of the events while selecting, even those that seem to be less important, is basically a major fault of analysts. A fault can influence the final outcome to greater or lesser extent, in a direct or indirect way, while positioning system within the context of risk limits/possibility of risky events occurrence. As a final outcome, it can cause the use of the unplanned financial resources. A safe, secure, and dependable functioning of the system is threatened.Such faults need to be avoided/eliminated completely. The chosen technological process, is fully defined and closed by the following events:

1. Distribution station (1.1. Belt conveyor C-11; 1.2.Distribution bunker; 1.3. Belt conveyor T-240).
2. Run of mine coal bunker (2.1. Run of mine coal bunker; 2.2. Coal shovelling machine A-131 and B-131; Belt conveyor T-132).
3. Crusher plant (3.1. Sieve grate 242 A and 242 B; 3.2. Hammer mill 243 A and 243 B; 3.3. Belt conveyor T-312; 3.4. Belt conveyor T-244).
4. Loading station (4.1. Belt conveyor T-350; 4.2. Re-distribution loading coal bunker).

Further course of work on the problem analysis implies an in-depth analysis of each defined event, together with the positioning the risk limit in two directions: the risk system aspect as the variable that influences the safety and health of the base process. What follows is a presentation of a detailed decomposition for the chosen event. The stem decomposing is accomplished to the third level. Further decomposition is unnecessary because all structure modes are detected. According to them, the characterisation of all critical potential with influences is possible, [3]. During the decomposition process the method FTA (Fault Tree Analysis) is employed. The examined interaction of events and faults in the project gives a rank order/combination of critical elements. A systematic approach is provided and at the same time a considerable flexibility as well, in consideration of the advantages of a muli-variational analysis. Then there is a stem of events production, which is accomplished by using standardized logical symbols. Repeating the steps until the required amount, and according to real limitations, primary and secondary faults are identified, and the stem is completed to the lower level of identification of the fundamental fault/another starting event. The completed stem has enabled the evaluation of the system/process including the cross-sectional cluster (minimum of sequence which has resulted in upper event occurence or critical way). In the analysis FTA has determined probability of events by using logical relations and bonds for calculating a relative risk while redesigning the existing system, [4].

5. THE ADOPTED METHODOLOGICAL APPROACH AND THE STARTING POINTS

Designsafe is a tool for the users who are familiar with modern demands of the designing and redesigning processes. They must be provided with a complete and quality knowledge of technological processes which are the subject of the analysis, [5]. They must be able to take the results of the analysis and expertly develop the engineering solutions to the risk reduction. The analyst of the safety analysis is responsible for solving all the problems emerging within that context. Designsafe is a guide and an engineering tool, where the user’s skills, experience and expertise make a crucial component while creating results. The quality and selection of the data that the analyst enter in the programme is an essential component. Inferior/incomplete data reduce the validity of the output results. With such options, errors are treated as subjective ones. The tools used in the analysis pay a particular attention to the remaining part of the reduced risk while assessing it, before they are focused on the risk levels. The same have been implemented in the subject analysis and assessment (MIL STD 882, ANSI B11, EN 1050, TR3 etc.), [7]. One of the most impressive and progressive models was developed by Prof Fred A. Manuele. At the same time, this is a quantitative model for assessing the most progressive models using the matrix of the dimension 4*4*5 and three factors in developing the general assessment and evaluation of the selected top event as a critical potential for the origin of a failure/incident, /accuracy, exposure and probability/, [3]. In the analysis it is Designsafe tools for which it is necessary to define the sources of information as well as limitations. The sources of information for the subject analysis are the following:

1. The experience of following the process of the coal processing functioning.
2. Interviews with subjects who are either direct or indirect participants within the working process.
3. Testing the collected data.
4. The history of casualties connected with the process of coal processing at

the Dry Separation, /the available database of RB (Coal Mining Basin) Kolubara, Kolubara prerada (Kolubara Processing)/.

5. Management expert meetings, /the available data/.
6. Notes from scientific gatherings and symposiums whose subject was the risks and safety in mining/the process of coal processing.
7. Experts' assessments and suggestions connected with the problems of the risk analysis, [6].

The facts that the analysis of the single decomposed technical units, which are a part of the process of coal processing, are considered to be a limitation. Within that context the analysis may be considered to be partial. There is a resistance of the operative management and the employees to this approach as a result of not recognizing the needs for the analysis. There are no organizational units for the multidisciplinary approach to the risk problems on the platform of the company's managing functions. According to the collected data, the general constitution of the participants in the process /directly or indirectly connected with the hammer mill 243A/ has been presented. The following have been engaged: a locksmith 1, a locksmith 2, an electrician, an electronic engineer, a locksmith spreading lubricants, an auxiliary worker, an operator at the Control Console, a foreman, a fire preventive measure worker and a shift responsible man. The structure of their work/responsibility has been addressed/delegated.

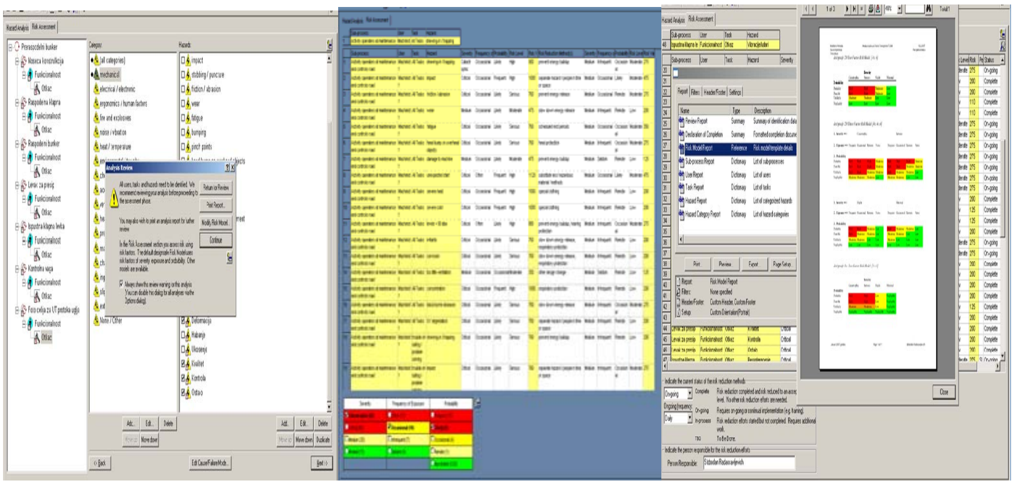

Figure 1. The display of the initial analysis of the risk for all the operators and the detected destructive modes of the identified aspects within the project on the portal of the model interface, [1], [2]

Table 1. The display of all the characteristics of the event, /run of mine coal bunker/, for the reverse step of the analysis of the decomposed trunk FTA, [1].

Chosen Event : Run of Mine Coal Bunker					
R. b.	**Factor name**	**Factor value**	**Index**	**Identified level**	**Note**
1	**Object dependability**	**0.21**	**%**	**Zone of low dependability**	**Calculated value according to collected data and assessment**
2	**Object independability**	**0.79**	**%**	**Zone of high independability.**	**Difference between maximum dependability (1) and calculated system dependability**
3	**Risk exposure time**	**3950.**	**Hour/year**	**often 13**	**Assessment according to collected data**
4	**Failure Probability**			**Frequent 15**	**Assessment according to collected data and analysis from decomposed stem of FTA**

5	Assessed value of technical characteristics of object from the aspect of failure possibility	1633.	Hour/year	High level of failure critic states	Assessment according to collected data from maintenance and analysis from decomposed stem of FTA
		0.41	%		
6	Assessed value of possible hazards from the aspect of protection at work			Serious 40	Assessment according to analysis of decomposed stem of FTA and collected data
7	Number of operators in process	1+2+1+1+1 +1+ 1+1+1	Operator in process	Satisfying	System operator+fitter+electrician+electronics engineer+lubrication fitter+unqualified worker+prevention worker+shift foreman+collected data
8	Number of top events work shifts	3	24 hours	Maximum time potential as critical factor	Efficient work 11.5hours/days
9	Critical potentials of process in risk structure	Buildup		Endagered system in the high level zone, (4).	
		Vibrations		Endagered system in the extremely high level zone, (5).	
		Impacts		Endagered system in the extremely high level zone, (5).	
		Fatigue		Endagered system in the high level zone, (4).	
		Deformations		Endagered system in the modium level zone, (3).	
		Fractures		Endagered system in the medium level zone, (3).	
		Inclinations		Endagered system in the medium level zone, (3).	
		Damage		Endagered system in the medium level zone, (3).	
		Breaking		Endagered system in the medium level zone, (3).	
		Wear		Endagered system in the high level zone, (4).	
		Heating		Endagered system in the high level zone(4).	
		Ignition		Endagered system in the high level zone, (4).	
		Lubrication chemicals		Endagered system in the high level zone(4).	
		Bimetal protection		Endagered system in the high level zone, (4).	
		Electro/magnetic protection		Endagered system in the high level zone , (4).	
		Conact interruption		Endagered system in the high level zone (4).	
		Sizstem of warning		Endangered system in the extremely high level zone, (5).	
		Video surveillance		Endangered system in the medium level zone, (3).	
		Coal dust		Endangered system in the high level zone, (4).	
		Toxicological agents		Endangered system in the medium level zone, (3).	
		Qualitz		Endangered system in the high level zone, (4).	
		Control during process		Endangered system in the low level zone, (2).	
		Process operator		Endangered system in the vmedium level zone (3).	
		Voltage overloading		Endangered system in the extremely high level zone, (5).	
		Components of PCL		Endangered system in thehigh level zone (5).	
10	Critical potentials of health hazard of process operators EHL-enormously high level HL-high level	Serious injuries EHL 5		Death (falling, sliding, falling into funnel, conveyor) arms and legs fractures, head injuries, burns, other injuries	
		Slight injuries EHL 5		Blows and contusion of limbs, slight burns	
		Diseases EHL 5		Of respiratory organs, aggressive coal dust and other materials, nervous system	
		Hearing and visual impairment EHL 5		Noise above acceptable level, strong light, and electro-magnetic radiation.	
		Burns HL 4		Danger from fire, fine coal dust as a result of process, possible self—inflammation and inflammation as a result of carelessness	
		Electric shock EHL 5		Working with high and low voltage electricity.	
		Radiation EHL 5		There are critical potentials of electro-magnetic radiation.	
		Toxicological agents EVN 5		There are critical toxicological materials (transformer oils, acids, and other)	
		Falls from the heights EHL 5		There is a real possibility as a result of carelessness and other causes.	
		Corrosive irritants. HL 4		Acids and alkalis in various forms	
		Explosive dust HL 4		Coal dust	
		Operator's incompetence, negligence HL 4		Incompetent work, carelessness while performing work.	
		Failure to take protection at work measures EHL 5		Not wearing protection equipment and personal protection equipment at work	
		Other causes EHL 5		Hidden -unidentified	

6. THE TECHNICAL ASPECT OF THE RISK ANALYSIS

It is by the decomposition of the essential process of coal processing that six sub-processes and twenty sub-process functions have been identified. Each of the sub-process functions has realistically a high level of critical potentials as well as potentials of extremely high destruction level, if the total and complicated operation is concerned. Of all the sub-processes an extremely high risk level has been addressed at the place of coal grinding/crushing, /the index value 1400/. The risk level within the range of high threshold /800-1400/ has been delegated by other sub-processes. This is completely in accordance with the performed partial risk analysis for the complete process of coal processing. The technical and technological aspect of the problem in analytical terms, confirms the real positioning of high risk thresholds in almost all parts of the process. The analysis of individual events of the system for coal processing in over 95% of the cases delegates the zone of high risk threshold, /index 800-1400/. Although the range of this threshold is realistically wide, all the selected events are over /the index 1120/. As this zone is one with an unacceptable risk, it is necessary to delegate the best possible reduction option by the choice of adequate methods for independent operation or their combination, which has been done in the analysis.

Table 2. Presentation of initial and reduced risk level for the complete process of production system of coal processing-Technical aspect, [1].

R. b.	TECHNOLOGICAL PROCESS OF THE THIRD PHASE OF COAL DRY SEPARATION – RISK ANALYSIS – TECHNICAL ASPECT				STATE AND STATUS ASSESSMENT
1	Initial level of risk-index	1120	High risk	Value in the zone of high level risk	Unacceptable risk
2	Reduced level of risk -index	275	Moderate risk	Value in the zone of moderate level risk	Acceptable risk –further work on reduction and maintenance of risk in the low level risk zone is necessary
ANALYSIS PROCESS COMPLETED		INDEX ESTABLISHED		COMMENT ON RISK LEVEL	FINAL COMMENT ON RISK ANALYSIS

7. CONCLUSION

The paper focuses on important issues in relation to the treatment, reduction and managing risks. These are important segments for the successful designing and redesign of the existing technological processes in mining engineering. The aim is to reach the necessary quality standard. In Serbia, the problems of assessing the risk through the implementation of modern models and methods in the production practice of mining engineering have been solved rarely so far. The risk management, The total risk management, The risk managers: new resource categories and profiles, [8]. A new chance within the strategic orientations of companies towards the analysis, reduction, control, monitoring and risk management, [9]. Satisfying the global needs of more and more turbulent and demanding markets/constituents of the system/users and a fruitful way towards business perfection in mining engineering.

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