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Risk Assessment and Managing Technical Systems in case of Mining Industry

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Global dynamics of technological changes are creating the need for modern approaches in evaluating and analyzing risks in the mining industry. Analyzing and managing technical systems in the mining industry is a key factor in relation to their quality. 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, standardization is also of great importance in achieving business goals. The choice and use of the best solutions in the analysis ought to recognize, anticipate, forestall, reduce, and minimize the risks and possible destructive applications. Practical knowledge indicates a major discrepancy and variations in the identification of analytical and methodological approaches to this issue.. The outcome is real statements of typical and non-typical critical states through destructive potentialities. Either directly or indirectly, they cause a considerable disturbance to both, parts of the system and the technological process functioning on the whole. The opportunities of proper control, technical systems and processes risk management exist in reality and can easily be realized. The mining production industry recognizes the need for an organizational and process redesigning strategy as well as raising this issue to similar importance of other functions of management in a company. A realistic view of the present state in the risk analysis shows the need for a rapid transformation of the mining industry . This study puts forward a proposal for the possible approaches and improvements in the mining industry, for the implementation of modern, standardized world trends, (models and methods) regarding the analysis of the technical aspect risk in some of the basic processes in the mining industry. It is the result of the research conducted during 2004 to 2008 in the process of surface exploitation and coil refinement in Serbian mining industry.

Keywords: mining, mining industry, safety, risk, analysis, management

0 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. This is of particular importance for big companies and, in turn, it also puts responsibility on them. The control and management of the work position risk becomes a central category of the logistic operability of the top management. The general context of the problem is the need for making wise strategic decisions while planning long-term. While pursuing business excellence companies' ultimate goal is completing safe, dependable, and profitable work, [1]. Within the technological systems of the mining industry there is a real need for the correct positioning of the issue concerning risk management. 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 reflected in finding a way to minimize typical and atypical states of failure as well as possible, and to accurately detect the destruction levels with full critical potentials for a technician and technological systems in the mining industry.

In the mining industry, analytical and methodological approaches to this problem are both partial and different. In this context, there is a lot of incompatibility and irrationality in the production practice. The outcome of such a state is considerable disturbance to the functioning of

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parts of the system or to the whole system. 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 focused 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 a company must be taken into consideration, [2].

1 RISK TECHNICAL SYSTEM

During its life cycle technological systems and processes are under 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 prejudicial event), [3] and [4]. 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 many and are mainly related to all the influences within/and associated with the system/process itself: design, [5] redesigning, technical, technological, maintaintenance, ecological, technical protection, sociological, economic, and other risks. The risk research carried out in 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, following particular suppositions at an expert level and the highest professional plausibility, [6]. The project focuses on the technical aspect of the risk analysis. The risk can and must be managed. The chances of a risky event occurrence can be reduced to an acceptable level by establishing adequate control. A high-quality analysis, risk assessment, reduction and monitoring are prerequisites for the prevention of the critical potentials in 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 research in the risk analysis, reduction, and monitoring, the production practice of the mining industry recognizes through:

- Development of methodology for the system analysis of the process and the system;
- Development of criteria and processes for implementation of standards which is helpful to the assessment of technical systems risk;
- Development of methodology for the assessment of the influences of all identified aspects of the technologically complex destructive potentials;
- Assessment of the system/process current conditions, as well as the assessment of the real needs for partial or complete redesign and improvement;
- Defining conditions and choosing modes of management of the risk technical system in the mining industry.

We can conclude that formulating an adequate strategy for analysis, monitoring and risk management are very complex issues. Firstly, it is interesting for professional. It requires the consideration of 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 and the mandatory forecast of the near and distant future are always present.

The research conducted around the world proves the need for rapid development, standardization of both existing and new modes and methods for risk analysis, assessment, reduction, and monitoring. Determinative strategies for risk assessment and reduction in the technical system of the mining industry can be recognized through the generic powers that form the development of the process by the strategic actions and integration powers created in an organizational and industrial context.

Fig. 1. shows important variables with generated relations and bonds in the coal processing process.

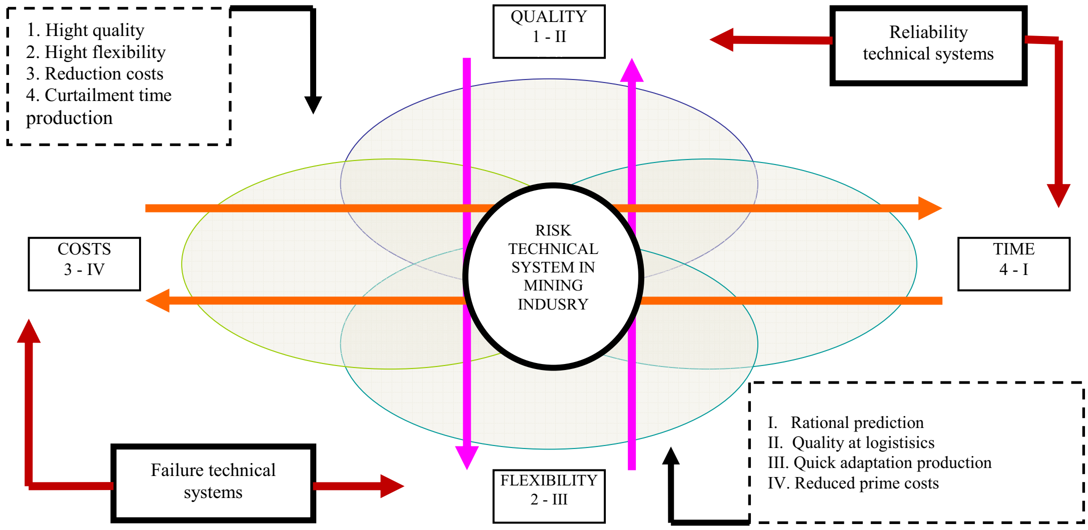

Fig. 1. *Presentation of relations and bonds in coal processing process, customers' demands and aspects of technical systems of mining industry* [2]

The fundamentals of the process are: accomplishment of planned projections, satisfying the demands of customers, as well as ensuring technical systems in the micro - and macro - context. The starting points in generating a lot of relations and bonds are the quality of coal processing, time as the existing technology life cycle parameter, flexibility of processing and cost analysis. The above issues become complex when reliability modes are included and also when viewing the real area of immediate and distant surroundings. When any of the categories mentioned above are excluded, the system compatibility is disturbed in a direct or indirect way, and safe and dependable work is questionable. The choice between the best possible options in the mining industry includes the balance between the expenditures which have been incurred and the use of the selected technology, according to the best results of the selected technology. The explicit role of the expenditure in reducing the risk is noticeable. Negative outcomes and effects concerning the management of the risk are something that should be avoided at all costs.

Risk management will be more transparent by using the standardization procedure, prescribing standards of management of the risk ISO 31000, which is expected to be prescribed in 2008, [7] and [8].

2 PRACTICAL EXPERIENCE CONCERNING RISK ANALYSIS IN THE MINING INDUSTRY

The research conducted 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 practice experience can be characterized as follows: There are good regulations, which create favorable conditions for a change in the present situation regarding positioning, handling, and monitoring the risk of the focused aspects in the mining industry. The use of standardized methods and models, together with good practical experience worldwide, is at the centre of 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 the lack of experts concerning significant and qualitative changes. There are not any licensed risk managers who would join the project teams. There are not any institutions in charge of training and licensing this type of personnel. Furthermore, there is no or very little implementation of modern standardized models and methods for analysis, reduction, monitoring and managing the risk in the production practice of the mining industry. There is a real problem with competence in risk analysis. Improvisation and inadequate treatment are frequent in recognizing the risk in the production practice. In the organizational models of companies, units of risk management are not provided. The risk analysis and assessment are not given enough attention in the company top management strategies. The lack of financial and other logistics for rapid transformations and changes of the existing practice and state of affairs is obvious.

3 FORMALIZATION OF THE PROBLEM OF RISK ANALYSIS CONCERNING COAL PROCESSING

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 a need for reducing risk. The 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 some 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 could be: consciousness, culture, educational problem, training of 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 any risk analyst or a multi-disciplinary team. Proposed events basically seal the continued technological process flow. Therefore, they need 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 a major fault of analysts. A fault can influence the final outcome to a 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 unplanned financial resources.

A safe, secure, and dependable functioning of the system is threatened. Such faults need to be completely avoided. The chosen technological process, coal processing within the third phase of Dry Separation of the Mining Basin "Kolubara" Lazarevac, is fully defined and closed by the following events (Fig. 2).

Distribution station: (1.1. Belt conveyor C-11; 1.2. Distribution bunker; 1.3. Belt conveyor T-240).

Run of mine coal bunker: (2.1. Run of mine coal bunker; 2.2. Coal shoveling machine A-131 and B- 131; Belt conveyor T-132),

Crusher plant: (3.1. Sieve grate 242 A and 242 B; 3.2. Hammer mill 243 A and 243; 3.3. Belt conveyor T-312; 3.4. Belt conveyor T-244) and

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 positioning the risk limit in two directions: the risk system aspect as the variable that influences 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. Accordingly, the characterization of all critical potential of influences is possible.

During the decomposition process the method Fault Tree Analysis (FTA) 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 sometimes also a considerable flexibility, in consideration of the advantages of a multi-variation analysis. Then there is a stem of events production, which is accomplished by using standardized logical symbols. Repeating the steps upto the required amount, 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 occurrence or critical way). In the analysis FTA has determined the probability of events by using logical relations and bonds for calculating a relative risk while redesigning the existing system [9] and [10].

4 EXPERIMENTAL PART AND THE ADOPTED METHODOLOGICAL APPROACH AND THE STARTING POINTS

Design safe 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. They need to be able to take the results of the analysis and expertly develop the engineering solutions to the risk reduction. The safety analyst is responsible for solving all the problems emerging within that context.

Design safe is a guide and an engineering tool where the user's skills, experience and expertise contribute greatly to results. The quality and selection of the data that the analyst enters 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. The tools used in the analysis pay a particular attention to the remaining part of the reduced risk while assessing it, before they focus on the risk levels. The same have been implemented in the subject analysis and assessment (MIL STD 882, ANSI B11, EN 1050, TR3 etc.). One of the most impressive and progressive models was developed by Manuele [4]. At the same time, this is a quantitative model for assessing the most progressive models using the matrix of the dimension 4x4x5 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), (Table 1). In the analysis it for is Design safe tools that is necessary to define the sources of information as well as limitations.

The sources of information for the subject analysis are the following:

- the experience of following the process of the coal processing functioning,
- interviews with subjects who are either direct or indirect participants within the working process,
- testing the collected data,
- the history of failure connected with the process of coal processing at the Dry Separation,
- the available database of RB (Coal Mining Basin) Kolubara, Kolubara Prerada (Kolubara Processing),
- management expert meetings, (the available data),
- notes from scientific gatherings and symposiums whose subject was the risks and safety in mining/the process of coal processing and.
- experts' assessments and suggestions connected with the problems of the risk analysis.

The facts that the analysis of the single decomposed technical units, which form part of the coal processing process, are considered to be a limitation. Within that context the analysis may be considered to be partial. Operative management and employees are generally not accepting of this approach because they fail to recognize the needs for analysis. There are no organizational units for the multidisciplinary approach to the risk problems amongst a 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 structure of their work/failure addressed/delegated.

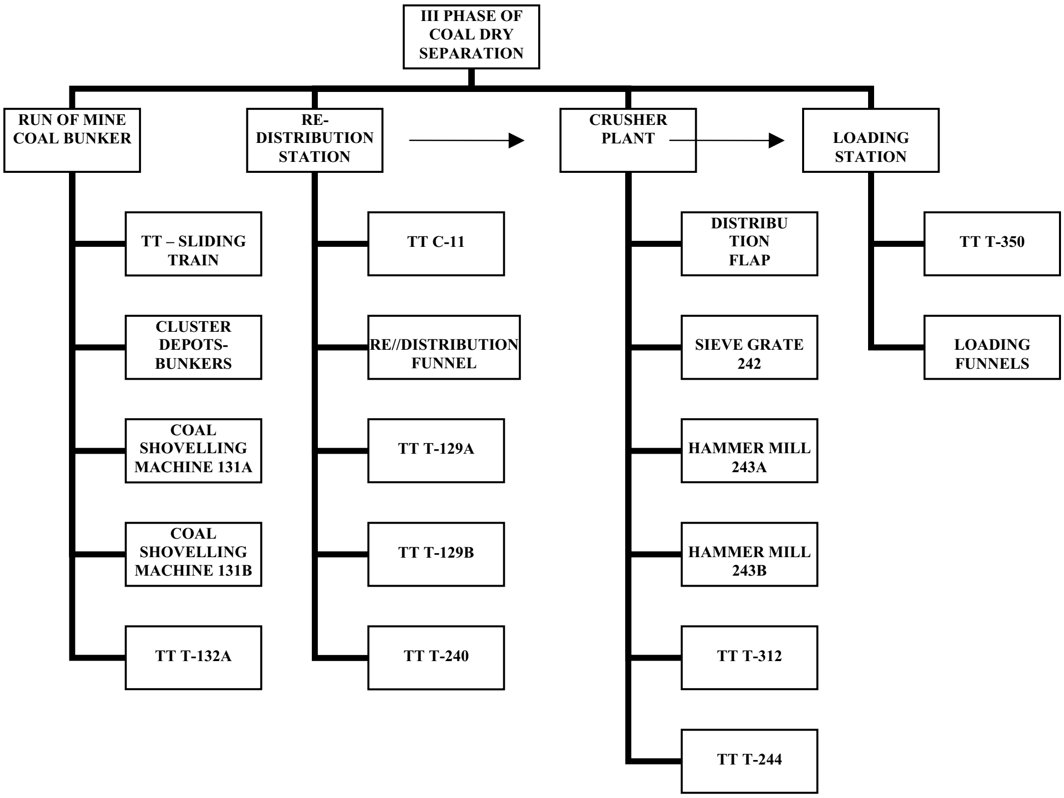

Fig. 2. *Presentation of decomposition bases of the first stage of process - coal processing at Mining Basin "Kolubara"*[2]

Table 1. *The display of the original values of the Quantitative model for the assessment of the risk and the matrix of the dimension 4x4x5* [4]

Manuele Three Factor risk model: assessment severity-exposure frequency-probability							
Assessment severity	Index	Exposure	Index	Probability	Index	Risk level	Index
Catastrophic	50	Frequently	13	Frequent	15	High	> 800
Critical	40	Occasionally	10	Possible	9	Serious	500-800
Moderate	25	Seldom	7	Occasional	4	Moderate	200-500
Low	10	Minimal	4	Minor	1	Low	0-200
				Impossible	0.5		

Chart 2 displays risk analysis with suggested methods for reduction of every mod failure in partial Rotor crusher 1.1.

The following methods of risk reduction are offered:

- Prevention negativism failure model,1.1,
- Replacement of critical parts for each failure model, 1.2.,
- Isolation of every failure model as specific risk, 1.3.

A detailed display of reasons for failure models is presented and resolving technical modes for risk reduction. At the same time risk addressing is executed in the context of delegating authority and responsibility for implementation of suggested technical modes with constant monitoring. The chart also shows final exploitation of risk by using corrective modes and categorizing risk levels [11] and [12].

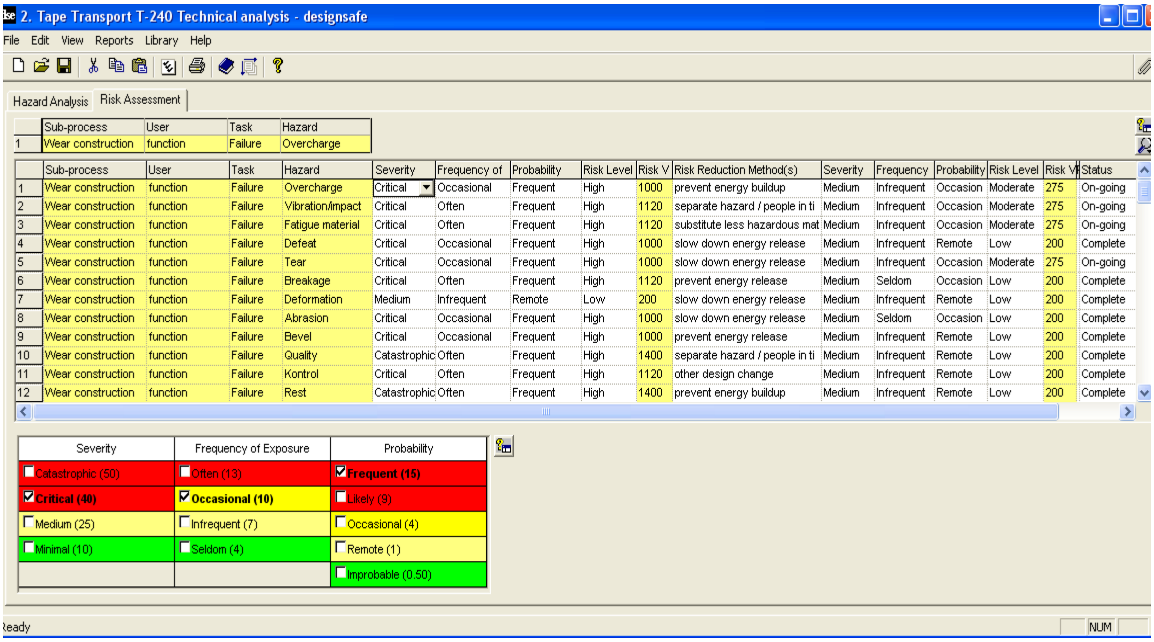

Fig. 3. *Displays input data of starting risk evaluation, suggested measures for reduction, final evaluation and addressing risk for partial HammerCcrusher 243A*

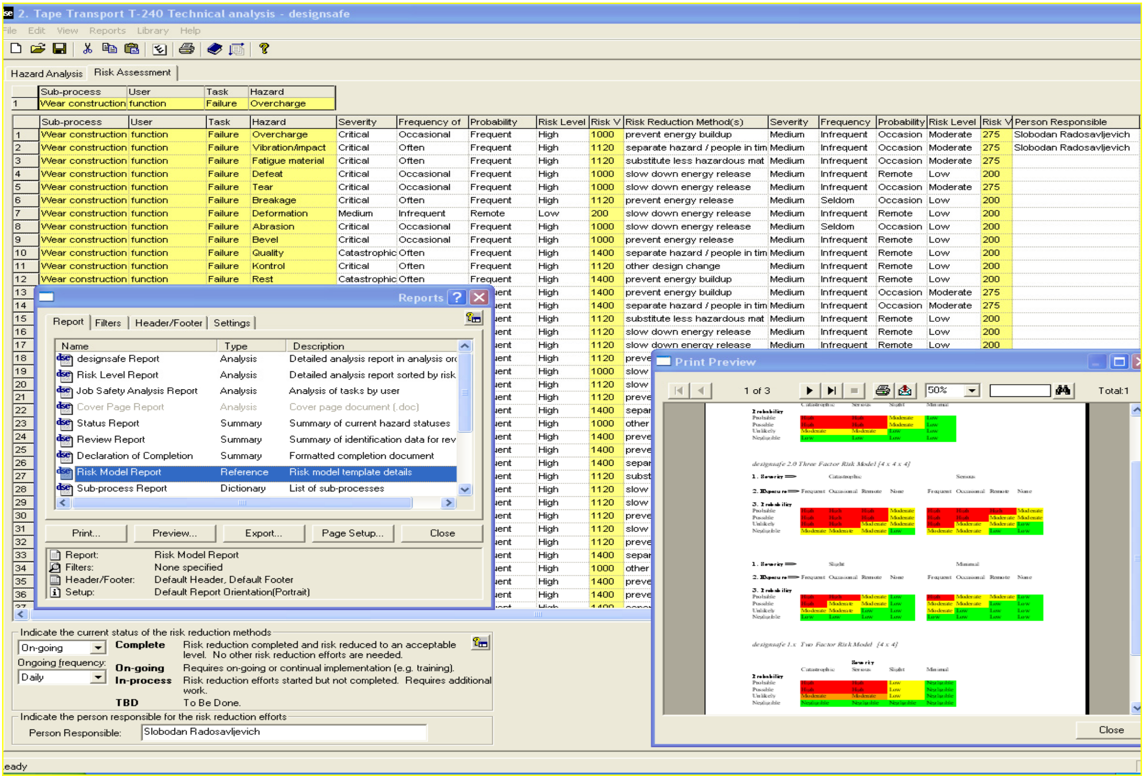

Fig. 4. *Displays documenting and report selection of executed risk evaluation with graphic state positioning for part-piece Hammer Crusher 243A*

Table 2. *Displays risk analysis with method for reduction for Rotor Crusher (1.1), (OG/On-going)*

Hammer crusher 243A: 1.1. Rotor crusher		Fred A. Manuele ”Three Factor risk model”: severity estimate /frequency exposure – probability									
Nature/ mod	Hazard/way failure	Default appraisal			Risk level	Risk reduction method	Final assessment			Risk level	Status
Function	Breakage	C	O	F	1120 hight	Prevent energy buildup 1.1., Substitute less hazardous material 1.2.	M	I	L	400 moderate	OG
Function	Deformation	C	O	L	760 serious	Prevent energy buildup 1.1.	M	O	O	350 moderate	OG
Function	Fatigue materijal	C	O	F	1400 hight	Substitute less hazardous material 1.2.	M	O	L	475 moderate	OG
Function	Damage	C	O	F	1000 higt	Prevent energy buildup 1.1.	M	I	O	275 moderate	OG
Function	Wear	C	O	F	1400 hight	Prevent energy buildup 1.1.	M	I	O	475 moderate	OG
Function	Heating	C	O	F	1400 hight	Prevent energy buildup 1.1.	M	O	L	475 moderate	OG
Function	Skew	C	O	L	760 serious	Prevent energy buildup 1.1.	M	O	O	350 moderate	OG
Function	Overcharge	C	O	F	1400 hight	Separate hazard 1.5.	K	I	O	440 moderate	OG
Function	Vibration/ blow	C	O	F	1120 hight	Separate hazard 1.5.	M	O	O	350 moderate	OG
Function	Blockade	C	O	F	1120 hight	Prevent energy buildup 1.1., Separate hazard 1.5.	M	I	O	350 moderate	OG
Function	Pluck	C	O	L	760 serious	Prevent energy buildup 1.1.	M	I	O	275 moderate	OG
Function	Rest	C	O	L	880 hight	Prevent energy buildup 1.1.	M	I	O	275 moderate	OG

5 RESULTS AND DISCUSSION

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 a realistically high level of critical potential as well as potential of an 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 to 1400) has been delegated by other sub-processes.

The above 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 to 1400). Although the range of this threshold is realistically wide, all the selected events are over (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. The analysis of the process indicates some influences according to the analytical account of each selected event. They have been detected in technical and technological terms and on this basis presented via the modes of possible destructive potentials with the exposition of hazards. The problems that occur most frequently have standard characteristics. Untypical problems are characteristic merely of the selected event or group of events in the sequence of the projected series of the technological line of the process.

The field of risk reduction for the identified aspect is rather large and covers the index from 180 to 1400, (Table 3). Such basis sets a realistically high target threshold for reducing the risk. In such circumstances it is not possible to perform the adequate risk reduction in one attempt and with the application of one method. The reduction has been performed in two or three attempts and two or more methods have been applied.

The following are the most frequent forms of critical potential for failure conditions of the selected events for coal processing system: overloading of the components, substructures and system, vibrations as well as various kinds of impacts, fatigue, material breaking, various kinds of structural damage, fatigue failure, deformation, system wear, curvatures resulting from work instability and unreliability regarding protection, the quality of built-in components, incompetent control - man factor, the operators' incompetence within the system and negligence during the performance of the working activities, the influence of undetected destructive potentials, the influence of the environment and other forms.

The most frequent causes of the previously detected forms of the critical conditions are the following: mechanical breaks of substructures and structures, various kinds of typical and non-typical deformities, bending, twisting, elongations, shearing, breaking, curvatures, material cleavages, cracks, pipes occurring while casting, hidden material deficiencies, corrosion due to the toxicologically aggressive environment or weather conditions, wearing out during which warming and heating of the components occur as a consequence of badly projected conditions, burning at work - rubber, other typical and untypical destructions.

As the causes and the manifested failures are directly interdependent, the field thresholds for the system of coal processing can be extended for the following forms: inadequate dimension, inadequate tolerance, thick/thin roughness, oval, eccentricity, wrong choice of material, insufficient strength/hardness, bad quality thermal treatment, corrosion, inadequate/bad quality protection, high temperature, high/low voltage, insufficient/extremely high loading moment, insufficient/excessive force and the like.

According to the above mentioned, the field of consequences expressed by destructive events can be extended for the following forms: the system does not function, the function is partially reduced, handling and commanding are impeded, the system does not realize the working performance, work breaks, reduced comfort during the system operation, the shortening of life expectancy and vibrations during the system operation.

The analysis of the technological system for coal processing indicates that some destruction can be completely identified on the basis of the standardized and coded kinds of failures for general technical systems in industry and mining engineering. The methods applied in the project for the risk reduction of the technical aspect are the following: the negativity prevention, the preventive replacement of material, preventing the development of negativity, slowing down negativity, the isolation of destruction as a particular risk and projecting new solutions. The proposed methods for the reduction provide in one, two or three steps, the necessary reduction to the limits of the tolerance risk, i.e. the acceptable risk threshold. For some events of the system the acceptable risk is as far as (index 570), which in the upper part of the sequences enters the range of the serious risk threshold. The risk level of the whole system for coal processing, after performing the reduction, reaches the maximum (index 275). The obtained index level does not exceed the moderate risk threshold, hence it can be considered satisfactory and acceptable. It has been stated that the main aim in the project of identifying the risk aspect

Tab. 3. *Presentation of initial and reduced risk level for the complete process of production system of coal processing-Technical aspect,* [2]

Technological process of the third phase of coal Dru Separation-Risk analysis-technical aspect				State and status assessment
Initial level of risk-index	1120	High risk	Value in the zone of high level risk	Unacceptable risk
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

has been achieved. By applying the stated instructions, the analyzed process is found within the zone of the acceptable risk, which guarantees total reliability and safety of the system operating as a whole. The technical modes that should be applied by the chosen methods during the risk reduction are the following: the redesign of the components or of the whole event, the standard and quality while building in, the increased level of control, the adequate supervision, the standard and quality of the purchased material, the replacement of some components with better quality materials, anti-corrosive protection for aggressive environment, preventive and current maintenance, the responsibility/training of operators, the standardization of the system, standard/special procedures for treatments, and other typical and untypical modes [13] and [14].

In addressing the risks, the analysis has proven to be multidisciplinary, which can be concluded on the basis of the structure/number of subjects which have authorized for risk reduction. Minimizing the risk turns out to be necessary and possible in the procedure of designing components, substructures, structures, individually selected events as well as the whole technological system. As an already functioning technical system is in question, it is possible to realize the partial redesign strategy in real time and space. Addressing the risk after the reduction has been performed according to: the designer of the components, substructures, structures, individually selected events or systems, the designer of the process, the constructor, the statics engineer, the chemical engineer, the chemical engineer for welding, the investor, the contractor - installer, the operator, the tire repairman, the locksmith, the electrician, the electronic engineer, the maintenance engineer, the material manager, the material storekeeper, the quality controller, the control supervisor, the expert in coal processing systems, fire prevention engineer, the system manager and the risk analyst. The analysis with the risk reduction has been documented in the database of Kolubara Prerada (Kolubara Processing) and in the written form via listing delivered to all the interested subjects. It is available for necessary analyses, updating and archiving, [7] and [15].

6 CONCLUSION

The paper focuses on important issues in relation to the treatment, reduction and managing risks, [15]. 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 for standard relation.

The problems in assessing the risk through the implementation of modern models and methods in the production practice of mining engineering have so far rarely been solved.

The questions raised indicate the following:

- A different approach to solving the problems of managing risks in mining engineering. Respecting the requirements which are set before the top management within the context of reliability and safety of the working process. The compatibility of the process in case transfers are rationally possible as well as the implementation of the experience from other sectors;

- Raising questions of standardization of the models and methods which are implanted for the analysis and risk reduction;
- The possibilities of applying the analytical and methodological approach to the implementation of modern methods and models in practice, [16];
- Redesigning risk management for the processes of mining engineering;
- Redesigning technical subsystems following the concept of activating the complete logistics of management resources and reaching the standard quality thresholds characteristic of mining engineering;
- Defining the database which is necessary for IS (Information System) of the protection with active involvement of the module (of the Process analysis and risk reduction). The constant risk monitoring for basic processes in mining engineering;
- The necessity for redesign and active usage of the existing IS. Including the risk management in the process courses within the internal and external environment;
- The necessity for staff training, preparation and risk management in mining engineering;
- The necessity for standardization and introducing IMS /Integrated Management System of Quality/ in mining engineering [15], and;
- The necessity for generating the quality of integrated and communicational courses of all structures in mining engineering [17] and [18].

Risk management, total risk management and risk managers: new resource categories and profiles. New chance in company strategies towards the analysis, reduction, control, monitoring and risk management. Satisfying the global needs of increasingly turbulent and demanding markets/constituents of the system/users and a fruitful way towards business perfection in mining engineering [19].

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