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The Development of an Information System for Storage of Spare Parts for Mining Equipment in Open-Pit Mining

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ABSTRACT. Maintenance of equipment in open-pit mining is required to have an according level of preventive maintenance. One of the most important factors having influence on the level of preventive maintenance and also on the level of success in maintenance of equipment in open-pit mining is correct planning, supply and storage of the corresponding spare parts. Correct function of the spare parts department is a condition for good function of the maintenance department, as well as the whole mining system. Introducing information systems to the process of planning, supply and storage, should ensure better function of the maintenance department, and should eliminate the possibility of an error occurring at all. The graphical presentation of the work process was done using a CASE tool, "BP win" which is a software tool for modelling operations within an organisation, its activities and the development of information systems.

РАЗРАБОТВАНЕ НА ИНФОРМАЦИОННА СИСТЕМА ЗА СЪХРАНЕНИЕ НА РЕЗЕРВНИТЕ ЧАСТИ ЗА МИННОТО ОБОРУДВАНЕ В ОТКРИТИЯ ДОБИВ
РЕЗЮМЕ. Експлоатацията на минното оборудване за открит добив е свързана с провеждането на планово-предпазни ремонти. Един от най-важните фактори, който оказва влияние върху успешното провеждане на предпазните ремонти, а също така и върху цялостната експлоатация на оборудването е организацията на дейността по планиране, доставка и съхранение на резервни части. Добре организираната складова и снабдителска дейност е предпоставка за правилното функциониране на планово-предпазната система за ремонт, а също така и за цялостната експлоатация на минната механизация Внедряването на подходяща информационна система за нуждите на складовото стопанство, несъмнено осигурява по-добра организация на ремонтната дейност. В статията се третира проблемът за използването на компютърна програма "BP win" с възможност за графическо представяне и моделиране на операциите и дейностите при разработването на информационната система.

Introduction

Big open-pit mines, like the "Kolubara", its exploitation fields "Tamnava-Istok" and "Tamnava-Zapad", feature big capacity mechanized lines (dredge-self propelled load-haul conveyor-a few transporters with rubber belt conveyors-stacker) (*figure:1*). Standstills in operation of these production lines can cause significant costs, and to prevent this, the corresponding maintenance activities are given due importance.

The primary task of the maintenance of mechanized lines used in open-pit coal mining, is not repairing them, but keeping the system work. Developing a maintenance information system is a necessary prerequisite for efficient and quality maintenance of a technical system.

Basic principles of mining equipment maintenance

Maintenance can be defined as the need to undertake technical and other activities with the primary objective to ensure good working order of equipment in the manufacturing process, together with a minimum of maintenance costs that evolve from standstills due to failure repairs or maintenance-related costs that are not directly caused by standstills.

The purpose of maintenance is to eliminate failures and prevent them from occurring, to ensure that the manufacturing system does function reliably during operation and to eliminate all standstills that could occur in the exploitation process.

Primary objectives of an organized maintenance process are:

- Minimizing cost that emerges from operating standstills caused by unexpected failures,
- Ensuring the necessary reliability level of manufacturing equipment,
- Achieving better product quality,
- Increasing the work productivity.

The above-mentioned objectives of manufacturing equipment maintenance, are based on the level of organization and the way certain maintenance methods and models are used. According to the type of organization, maintenance can be classified as: centralized, de-centralized and combined maintenance.

Basic maintenance procedures include:

1. Basic maintenance carried out by operator
   - Taking over from and delivering device to other operators,
   - Cleaning and washing,
   - Adding fuel, liquid and lubricant,
   - Tightening smaller loose junctions,
   - Monitoring the work of the device using control instruments available.
2. Preventive periodical inspections
   - Periodical inspections and smaller revisions (without special instruments),
   - Anticorrosive protection,
   - Inspections and repairs of smaller volume
3. Control inspections settled by regulation or law
   - Inspection of vessels under pressure and fire-protection devices,
   - Control of conditions at working place and in environment

- Inspection of relay protection,
- Inspection of cranes and lifters,
- Inspection of the geometrical accuracy of machines et al.

4. Lubrication corresponding to:
- Wear and tear of parts,
- Addition, replacement and inspection of oil and lubricants,
- Control of wear and tear level of parts,
- Regeneration of oil and lubricants,

5. Technical diagnostics
- Monitoring the history of condition changes (what was),
- Technical diagnostics of condition (what is now),
- Forecast of technical condition (what will be),
- Technical diagnostics modules,
- Technical diagnostics procedures,
- Expert systems

6. Preventive replacement of system parts
- Replacement based on cost and profit,
- Replacement "according to constant date",
- Replacement "according to constant durability",
- Replacement "according to technical condition",
- Replacement according to level of readiness,
- Replacement according to level of reliability

7. Tracing and removing weak spots
- Algorithm for tracing weak spots or failures,
- Innovations and rationalization

8. Repair and renewal of worn parts
- Repair procedures
- Renewal procedures

9. Preventive periodical repairs
- Small scale (easy) repairs,
- Medium scale repairs

10. General preventive repairs (overhaul and modernization)
- Large scale preventive repairs (general repairs)
- Modernization of technical systems [3]

Therefore, a maintenance procedure comprises a sequence of steps (procedures) essential for preventing a defect from occurring, and for keeping the parameters of the considered equipment's objective function within limits of allowed deviations as long as possible.

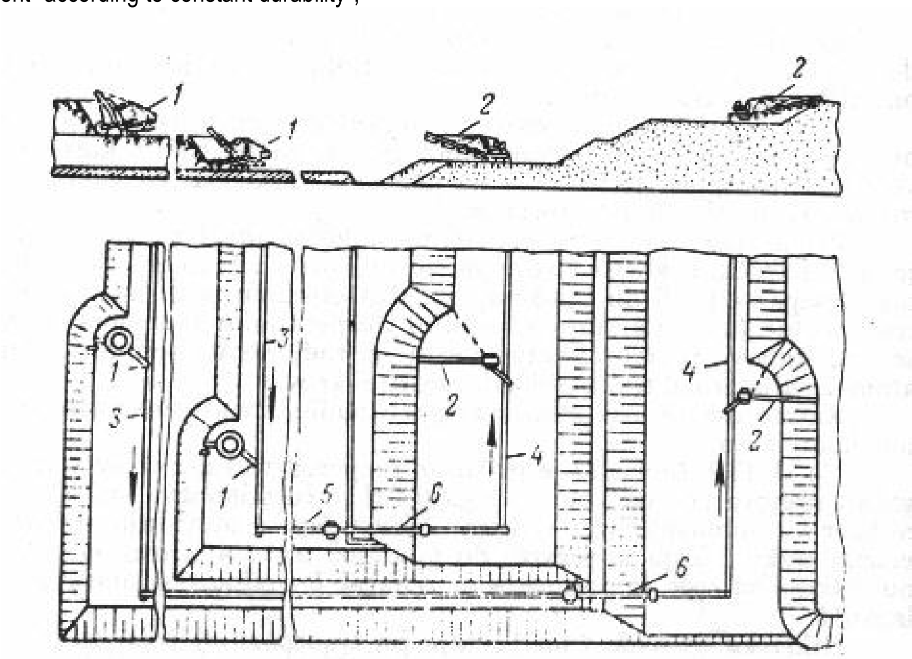


Fig. 1. Schematic representation of an open pit
(1-dredge; 2-stacker; 3-transport belt conveyors; 4-stacking conveyors; 5 and 6-load and haul belt conveyor)

The elements of failure on mining machines

The basic elements, causing mining machine failures in most cases, and also smaller and larger standstills in their operation, are:

Gear damage on mining machines is one of the most frequent causes of failure. Gear damage makes 60% of all damage on mining machines.

Bearing damage is the second-biggest cause of failure on mining machines and it makes 20% of all failures during operation of mining equipment. Bearing failures on dredges and stackers, regarding their dimensions (and high purchasing costs), are an important element of their maintenance.

Shaft damage on mining equipment is mainly caused by the weariness of material, leading to deformation and breaking. Deformation most frequently occurs on bolt grooves and slots.

Conveyor rollers d***amage*** (supporting, surface, suspension) can cause a great number of standstills in open-pit mines. The most frequent damages on conveyor rollers are caused by:
- roller bearings being damaged due to water or dirt entering through their sealing system, which makes 75% of all bearing failures,
- wear and tear of cylinders. Especially exposed to wear and tear are, return and suspension rollers, e.g. their rubber sealing rings.

Due to this fact we can say, that the working life of the bearings, and the conveyor rollers, depends on the quality of the bearing's sealing system and its maintenance (lubrication). The percentage of rollers replaced, in relation to the total number of built-in rollers, during six years of exploitation, is shown in *table 1.*

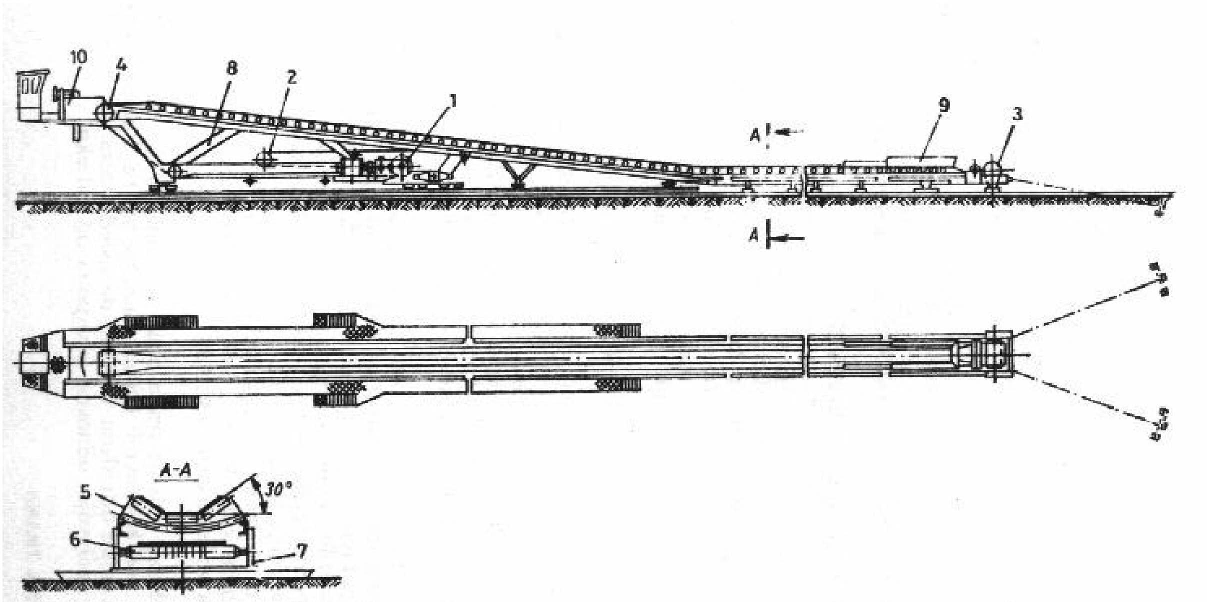
Table 1.
Percentage of cylinders replaced, in relation to the total number of built-in rollers, during six years of exploitation

Manufacturer	Exploitation period (years)					
	1	2	3	4	5	6
Krupp	1	2-3	15	30	70	90-100
NKMZ	3-7	10-17	40	70	100	
DMZ	3	12	30	70	90	100

Conveyor barrels damage in open-pit mines (figure*:2*) most frequently is caused by:

- the weariness of the barrel walls due to extended working time of the conveyor,
- an indentation (this type of damage makes 80% of all standstills of the conveyor),
- a crevice in the steel housing of the barrel (with or without a rubber coating), or housing (barrel body) caused by plastic deformations on the shafts (this type of damage makes 80% of all standstills of the conveyor).

Chain wheel gear damage on mining machines is also a cause of failure. In most cases, the driving and pulling chains are damaged.



***Slika 2.* Schematic representation of disposition by conveyor**
(1-driving unit; 2-strain device; 3-return barrel; 4-main-unloading barrel; 5-rollers on the loaded side; 6-rollers on the return side; 7-supporting framework; 8-support at driving unit; 9-loading hopper; 10-control device)

Spare parts

In order for maintenance to fulfill its function, a certain amount of consumable material has to be available, as are:

- raw material,
- intermediates,
- finished parts
- spare parts
- consumables

The purpose of supplying spare parts is: fast and efficient replacement of a damaged part, and minimizing the time waiting for a certain technical system to be repaired, and to maintain the rationality of business.

Spare parts can be:

- standard spare parts,
- special spare parts, e.g. parts that are manufactured according to a drawing.

The economy of stock costs is important information, since annual stock costs for material and spare parts make more than 25% of the total value of stock, in the following order:

- obsolescence of spare parts and material 10 %
- interest rates on bound assets 8 %
- damage, aging and similar 5%
- storage costs 4%

Spare parts are being kept in stock because parts of technical systems are worn out and stop functioning. In order to prevent production and maintenance standstills, a certain amount of the most frequently worn out parts, has to be available at any time.

The amount of required spare parts can be determined using the following expressions:

1. The minimum amount of required spare parts is determined using:

$$Q\ min = 0{,}4\ t_i\ Z\ q\ /\ Tt \qquad (1)$$

where:
Q min -minimum stock of a single spare part,
t_i -time required for providing the spare part (manufacturing or purchasing it),
Z -number of equipment items where the considered spare part is to be built in,
q -amount of parts per machine (equipment) being maintained,

T_t -average life (working life) of equipment being maintained.

2. The maximum required amount of spare parts is determined using:

$$Q_{max} = Q_{min} + Qe \quad (2)$$

where:
Q max -maximum stock for a single spare part
Qe -cost-effective amount

$$Qe = ((2\ Cu\ q_q) / (Cf\ Cs))^{1/2} \quad (3)$$

where:
Cu -total costs (din/unit),
q_q -amount consumed during the considered period of time (units),
Cf -price per unit (din/unit),
Cs -storage costs

3. The size of the spare parts stock, at which a new amount of spare parts has to be ordered, is called alerting stock amount. The alerting stock amount is calculated from:

$$Qs = Qm\ t_i \quad (4)$$

where:
Qs -alerting stock amount (units)
Qm -expected maximum consumpton (units/year)
t_i -time required to provide a part

Information system

A proper design of information flow within an information system for production equipment maintenance allows a well-timed, precise, adequate, actual and concrete understanding of all the activities, and within them also a detailed single analysis of every planned activity.

Modern terms of production organization state that an information system is a group comprising clearly defined rules, practical experience and working methods where persons, groups (or both) should work on putting the data given into the computer. The computer will process information so as to release information which will enable other persons to make a decision in given business situations.

The Task of the designer of information flow within an information system is to convert, by processing them, input information into output information, useful for decision making. The feedback has the task to control whether the output value is a real value, and if at the output we dont get a real, expected value, the input data is examined and corrected (the existence of an error at input or in processing is examined). There always is a possibility of error in input information and data processing.

An information system is considered good if it disposes of an adequately organized collection of methods which make possible the circulation of data and information through all subsystems and links, while there is a well-timed information feedback to the user.

To establish an information system in order to design the information flow it is necessary to:

- collect data,
- process data,
- save (store) data,
- distribute data and information for use.

All information systems are based on the following elements:

- data input,
- file structure,
- logical procedure,
- forms and documents,
- data processing device,
- output.

The basic task of an information system is to offer relevant information to a business system about the current state of the system, as a decision making basis for the management of the business system. For an information system to function properly, it is necessary, regarding the great number of persons involved, that every participant, without exception, consistently act following the same working methodology, and offer information, necessary for their own tasks and the tasks of other participants in this joint process to be execute in time.

Case tools

CASE (*Computer Aided Software Engineering*) is a software tool for modeling, among other things, the business process within a company, its activities and the modeling of information systems.

Among many of the effects concerning the use of CASE tools, the following can be accented:

- improvement of communication between user and designer,
- less need for changes requested by users,
- significant reduction of maintenance costs,
- Better project management.

The program BP Win is part of a CASE tool and serves for modeling a company's business, its activities, and for designing and developing an information system. BP Win can also be used for the presentation of a company's existing information system, as well as for graphical presentation of organizational and working instructions concerning the system of quality ISO-9000.

With the assistance of BP Win-a the following diagrams could be assembled:

Contextual diagram - Figure 3., shows the basic flow of data and is presented by a process and its links to the surrounding. On it we can see input information flows for a observed process, the output information flows from the observed process, control functions which act upon the observed process and resources necessary for processing incoming information. The contextual diagram is a more general diagram of data flow.

Hierarchical decomposition of the process starts with the definition of the contextual diagram where the whole information system is being treated as one process, and ends in a primitive process e.g. a low-level process for which action diagrams are defined (so-called process sequences).

Data flow diagram - Figure 4., is an assembly of parallel processes and links between them with data flow and data files(archives). It is more detailed than the decomposition diagram and is used where it is possible to define processes, inputs and outputs from the process, , archives and links to other processes and other adjacent data diagrams.

Decomposition diagram - Figure 5., is a graphical presentation which hierarchically describes a process or object which consists of more sub-processes of the same type, and these again divide into sub-processes of the same type e.g. a complex process develops into a hierarchy of sub-processes having the shape of a tree. The root of the tree is a starting process and the last branches present the most simple processes which can not be further divided into sub-processes.

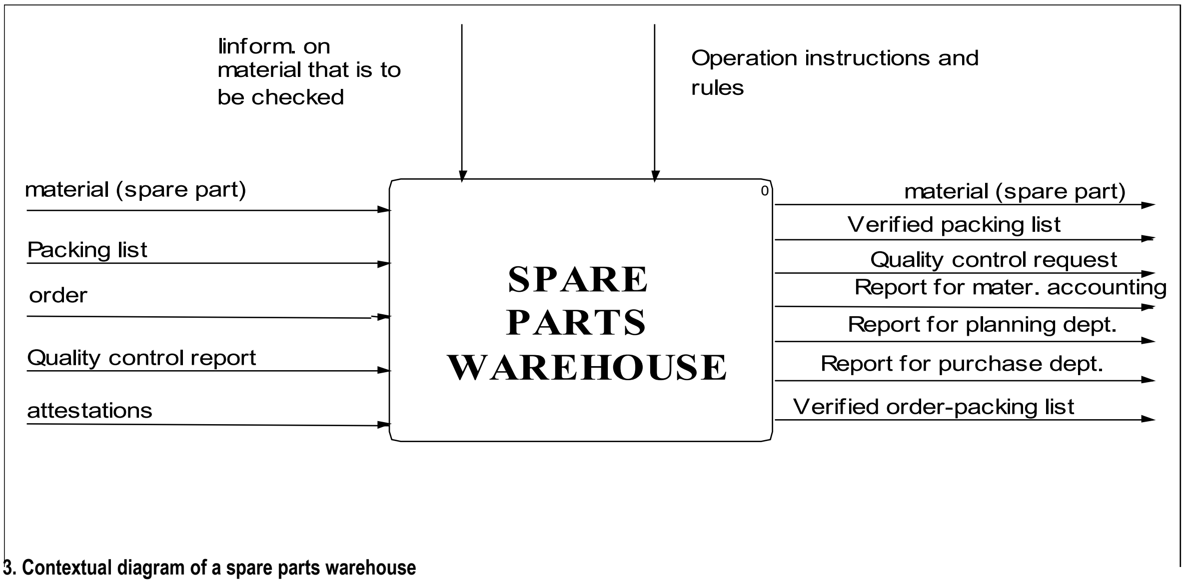


Fig. 3. Contextual diagram of a spare parts warehouse

Conclusion

Combining various maintenance strategies (preventive maintenance, maintenance according to state, and correction maintenance), emphasizing maintenance according to state, and modernizing diagnostic methods (and the corresponding equipment) is a way of successful maintenance of mining machines. By introducing an information system to the mining machines maintenance process, the efficiency of mining machine maintenance management can be increase a lot, and the occurrence of errors in the maintenance process can be prevented, too.

Regardless of the way in which an information system is designed, network planning, software CASE tools or using some other method, the goal always goes down to facilitating and avoiding errors in the design of an information system, i.e. the design of information flow.

The examined design of information flow within the mining machines maintenance process, applying the application of CASE (Computer Aided Software Engineering) software, the program BPwin, on the process of single design of information flow for spare parts as one of the significant elements in all the maintenance activities, is a model which can successfully be applied as well on mining machines maintenance as on resolving similar problems, especially with production activities.

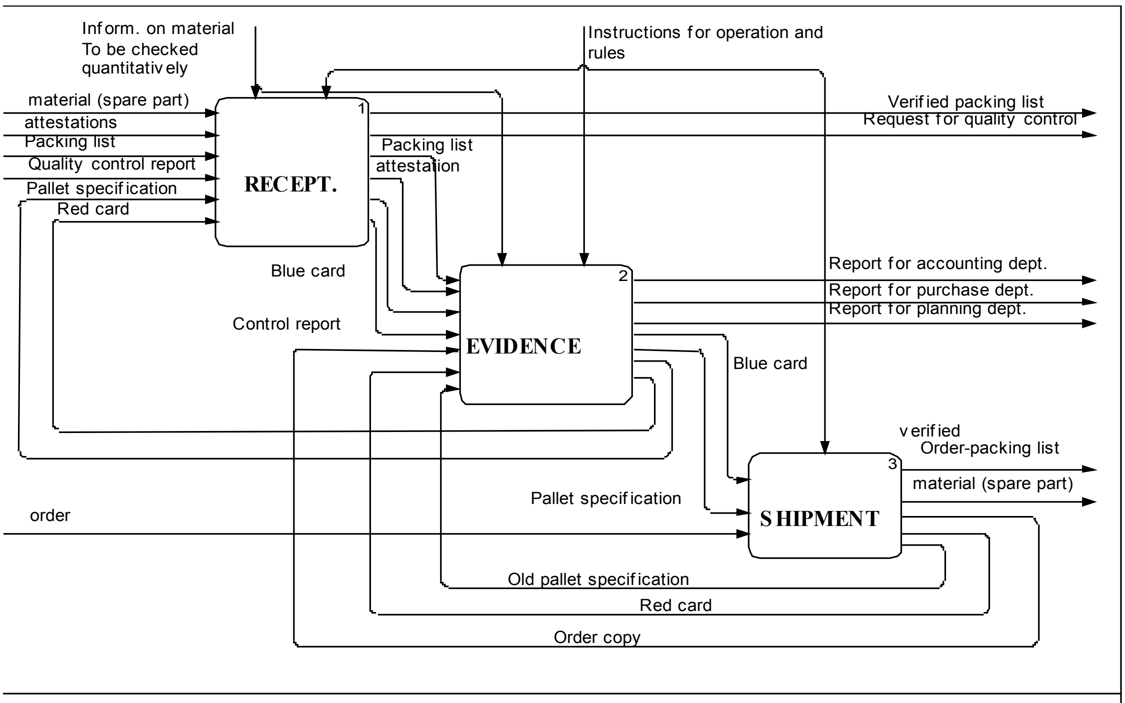


Fig. 4. Spare parts warehouse diagram

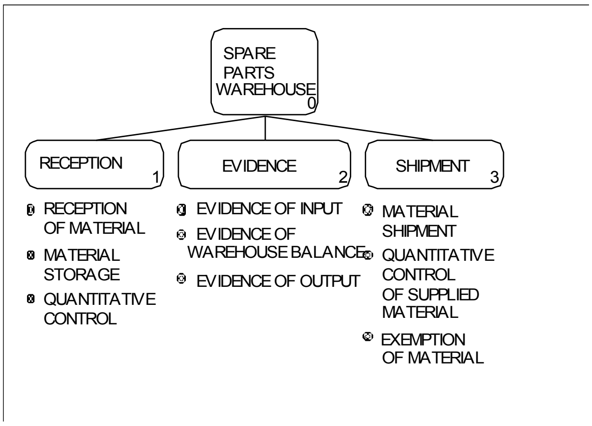


Fig. 5. Decomposition diagram of a spare parts warehouse

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