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RELIABILITY ANALYSIS OF FOREST MACHINES DUE TO FMEA METHOD

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Abstract:
The article deals with the research of operational reliability of forest felling machines with the method FMEA (Failure Mode and Effect Analysis) and its implementation for observed machines in the organization. Forwarders 810D by John Deere were chosen for this research. The research was realized in real operational conditions. Application of the FMEA method allows flexibility in case of unexpected situations and optimization of human potential abilities. FMEA tool is a tool preventing outages operational reliability and preventive tool for ensuring the maintenance of facilities. This paper explores and verifies the operational reliability theory in practical real-world conditions, resulting in a reduction in operating (variable) costs, minimization of failures and readiness and increased performance of observed machines.

Key words: *reliability, FMEA method, forest machines, maintenance*

INTRODUCTION

Recently, forestry in Slovakia has got very fast tendency of research in all levels. Increasing demands on quality of crops treatment in forestry means higher demands on quality and reliability of forest machines and technological devices. Nowadays, the forest economy is based on wide usage of forest machines and devices [9, 10].

High demands on reliability and processing are closely connected to quality demands and demands on reliability of forest machines and technological equipment of them. They are closely connected to treatment of these devices [1]. Treatment of these devices used in forest economy consist of every day operation, treatment and supervising over their running, activities based on implementation of new devices to production, repairing faults and damages, improvement of the technical condition, technical modernization, storage, storage of short term not used forest machines and technological devices and recycling of waste after their lifetime. The supplementation of damages and broken parts by new ones is also very important part of work. Current and perspective stage of mechanization and automation of production in forest economy and their tendencies of growing of production capacities of forest techniques creates one of the most important tasks for operational reliability [11, 12].

There are several methods of information processing regarding to reliability parameters, but some of them are very difficult and in standard operational conditions are not usable. The method of information analysis mentioned below is simple ale precise enough for implementation in real working conditions [2].

FMEA is a step-by-step approach for identifying all possible failures in the design, a manufacturing or assembly process, or a product or service. [9] FMEA may deliver information about: where errors could occur and where risks are hidden. Ideally, FMEA begins during the earliest conceptual stages of design and continues throughout the life of the product or service [3].

RELIABILITY ANALYSING METHOD

The topic of analyses and risk management of the technical devices and processes realized by them as well as questions for their safety assessment is an important part for the system ensuring quality of products and technologies. Risk assessment and mitigation of risks belong to risk management which main role is to eliminate the risks for the maximum possible level [4].

Regarding to risk analysis there are given the following groups of methods:

- inductive (ETA, MA),
- deductive (FTA, FMEA, FMECA).

There are also given other groups of methods as follows:

- qualitative (FMEA, FMECA, FTA),
- quantitative (Methods of block schemes, Statistical modelling, etc.).

Inductive methods (methods ex ante) enable to estimate possible hazards while they analyse reasons which lead to

hazards. Via these methods we can evaluate expected or possible number of events; we can estimate their possible impact and take appropriate measures. Inductive methods mostly use: probability methods and expert estimations.

Probability models work with a risk as with the pure probability unit. This approach is based on the fact that the given factor occurs with a certain probability which we can define on the basis of existing statistical parameters e.g. number of occurrence of the given group of events, time of observation, etc.

Using these models in safety practice is very difficult because of missing statistical data which can help define parameters of probability relationships.

Correct usage of these models is also possible only in cases when conditions and forecasts of given events do not change in time. In the social environment there are input factors or relevant events very variable.

Expert estimations use direct, formal calculation unused and directly unsubstantiated expression of the risk or hazard appearance, definition of its size or significance.

Deductive methods (methods ex post) are based on the analysis of events which has already risen, looking for and searching their causation and mutual interaction between these causations. Their meaning is in enabling creation of type scenario of rising and symptoms of risks of different character and they are the source of process innovation in safety management.

Quantitative methods use numerical evaluation of safety risks by definition of their probability, number, credibility, potential, impacts, etc. These methods can be used especially in cases if there are enough relevant data which can be evaluated statistically. Quantitative methods evaluate risk ratio via two basic elements: probability of negative event creation (negative event) and impact (casualty, lost) which follow this negative event or they are created by it. Quantitative methods then use risk multiplication for evaluation:

$$R = P \cdot D \tag{1}$$

where:

R – represents risk level,

P – represents probability of safety risk,

D – represents result (impact) of safety risk.

Qualitative methods use expert evaluation. These are used in cases if there are missing or it is difficult to define them by numbers (data) for quantitative risk evaluation. Via these methods there is possible to evaluate risk e.g. like acceptable or non-acceptable, low, medium and high. Such evaluation of individual events uses subjective probability which expresses the ratio of personal persuasion about appearance of evaluated event regarding to defined factors. Verbal description of probability is for the majority of users understandable and more acceptable. Relationship between numerical and verbal description is mutual but it is not a legal standard and every user can understand it different way according to the own preferences [5, 6].

MATERIALS AND METHOD

The research was held in cooperation with the service department of machinery production. The main role of the service department is maintenance of machines and technologies used in forest economy. The research consists of data assessment via FMEA method. The goal of FMEA is to analyse potential failures/breakdowns in exact systems within a certain time interval of the observed system to take possible measures or corrective actions to eliminate risks which come with failures.

For decision taking about the range and the way of FMEA application in exact system and exact element of the system there is necessary to think about the purposes which the method is used for. There is necessary to estimate degree of knowledge for negative impacts, failures, breakdowns and their impacts. On the basis of these ideas there is possible to decide about the size of analysis for exact level of the system (i.e. system, subsystem, part group, part).

Material used for research can be divided as follows:

- Researched objects: 5 forwarders by John Deere,
- Characteristics of researched machines (see Table 1) according to Slovak Technical Standard STN 01 0606 (Reliability engineering. Procedure for selection of list of specified reliability measures).

Table 1
Characteristics of researched machines according to STN 01 0606

	Forwarder 810D
Product class	code: 3 (repaired products)
Running time regime	general
Result of the breakdown – reliability class	II. (material loss from the missed task or down-time equal to value of the machine)
Rule for durability of the machine	planned

Failure Mode Effect Analysis (FMEA) is processed according to Slovak Technical Standard STN EN 60 812 – Analysis techniques for system reliability - Procedure for failure mode and effects analysis (FMEA). The standard describes two alternative methods; the method FMEA – "Failure Mode Effect Analysis" and its extended version named the method FMECA – "Failure modes, effects and criticality analysis". According to this standard the method FMEA does not include evaluation of risks of possible breakdowns caused by certain reasons. It represents only a qualitative method. The method FMECA is complemented with assessment of Failure Mode Effect Analysis and probability of its appearance. It is possible to say that FMEA is a defined item for a procedure which does not include criticality analysis. Criticality analysis means evaluation of risks i.e. multiplication of probability of a breakdown and impact which a certain breakdown can cause.

The FMEA method for construction is applied for all failures which occurred more than once. The FMEA method is realized by gradual systematic fulfilling of the FMEA

form (see Table 2) for constructions of the observed machines (forwarders).

For decision taking about the range and the way of FMEA application in the exact system and element it is necessary to think about specific purposes which the method is used for. It is necessary to discuss required degree of knowledge of negative failures and their results. On the basis of these discussions there is necessary to decide about the size of the analysis in constructional level of the system.

The aim of FMEA is to analyse potential failures in the exact system in the certain period of time of the machine lifetime to take appropriate measures to decrease risks which can cause a lot of failures.

There is realized estimation of probability, significance and number of detections of the failure type and its treatment to classes 1-10. The occurrence of the failure means probability or number of failures which can occur due to proposed measure (action).

RESULTS AND DISCUSSIONS

The FMEA method is realized by gradual systematic fulfilling of the FMEA form (Table 2). The form is created in MS Excel for simplification of usage in a company conditions. Then there are obtained data for MR/P created for machines and their constructional groups (defined by a machine producer according to the forwarder manual for operation and maintenance) in graphic form: chassis (Fig. 1), gearboxes and gear mechanism (Fig. 2), engine (Fig. 3), lubrication and cooling system of the engine (Fig. 4), electric devices of the machine – sensors (Fig. 5), hydraulic crane (Fig. 6), hydraulic system (Fig. 7), cabin and controlling elements (Fig. 8).

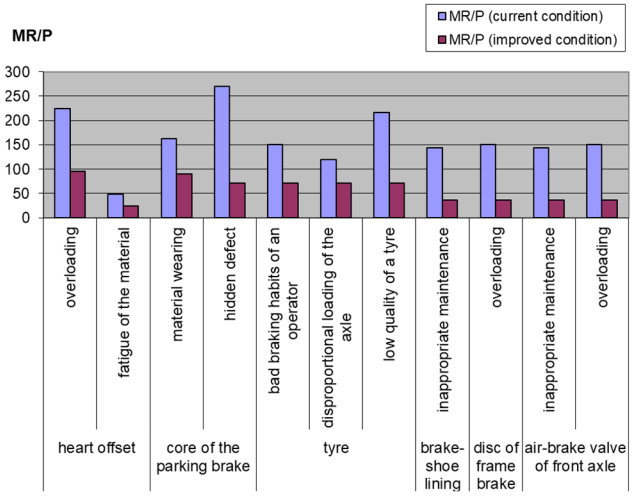

Fig. 1 Demonstration of FMEA construction results for chassis of forwarder 810D

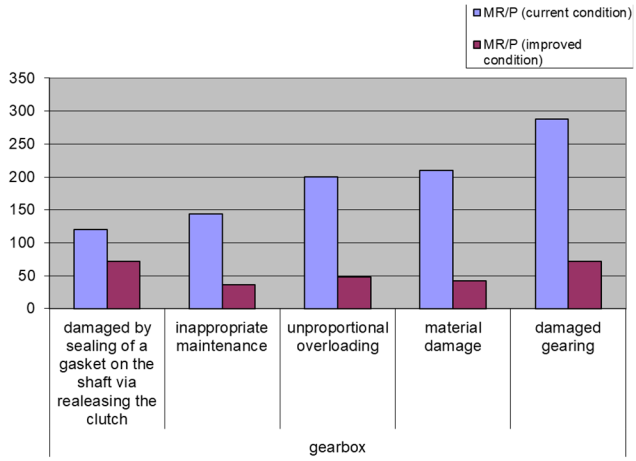

Fig. 2 Demonstration of FMEA construction results for gearboxes and gear mechanisms of forwarder 810D

Table 2

Complete table for FMEA of the machine evaluation

Name of the company (owner):		**Failure Mode Effect Analysis FMEA of the construction (element)**					**Model-type:**						**Part No.:**				
		Supplier of maintenance:			**Re-processed by: Date:**					**Processed by: Date:**			**Name of the part (element):**				
					Current situation							Improved condition				
					Evaluation				Proposed measures							
System	Symptom of the failure	Possible results of the failure	Possible reasons of the failure	Method of detection	Occurrence	Meaning	Adjustment	MR/P	Actions	Responsibility	Taken measures (actions)	Occurrence	Meaning	Adjustment	MR/P

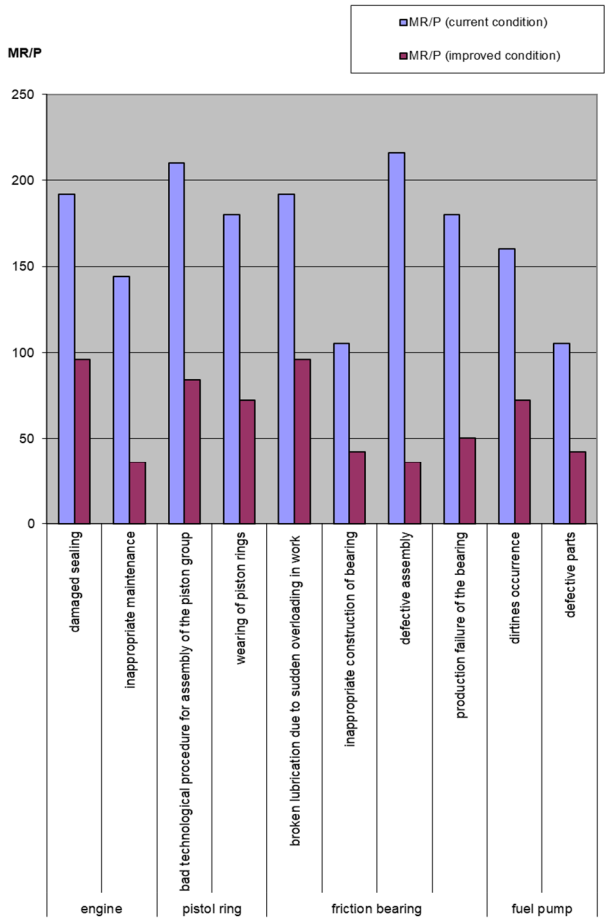

Fig. 3 Demonstration of FMEA construction results for an engine of forwarder 810D pre motor forwarder 810D

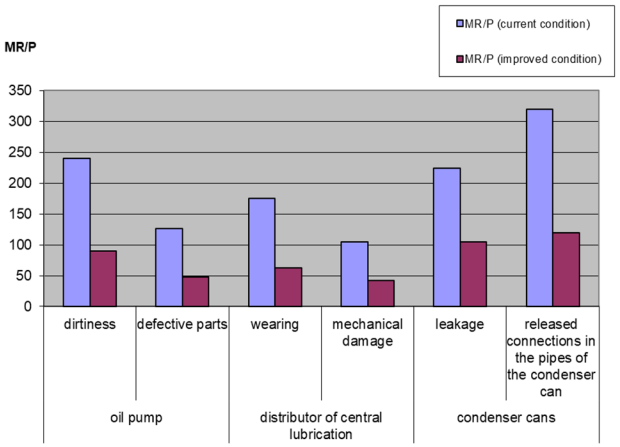

Fig. 4 Demonstration of FMEA construction results for lubrication and cooling system in the engine of forwarder 810D

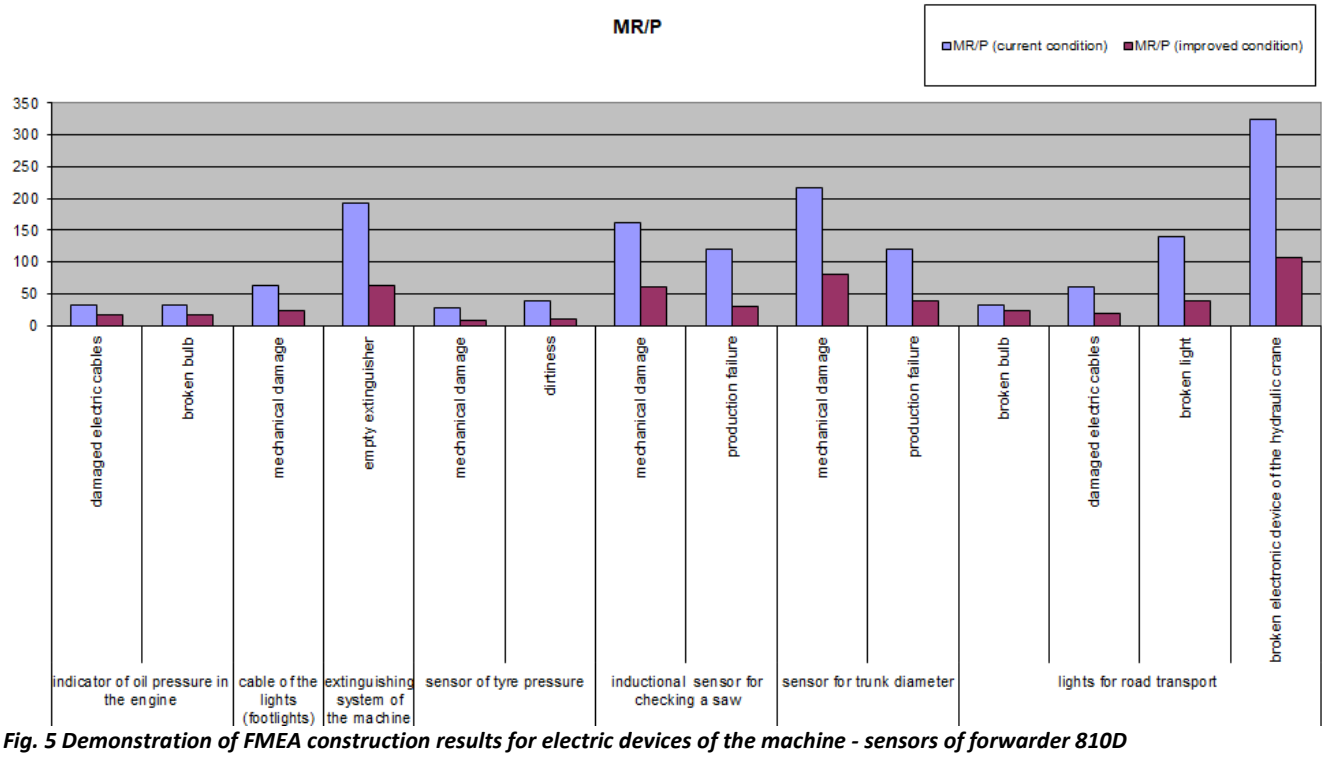

Fig. 5 Demonstration of FMEA construction results for electric devices of the machine - sensors of forwarder 810D

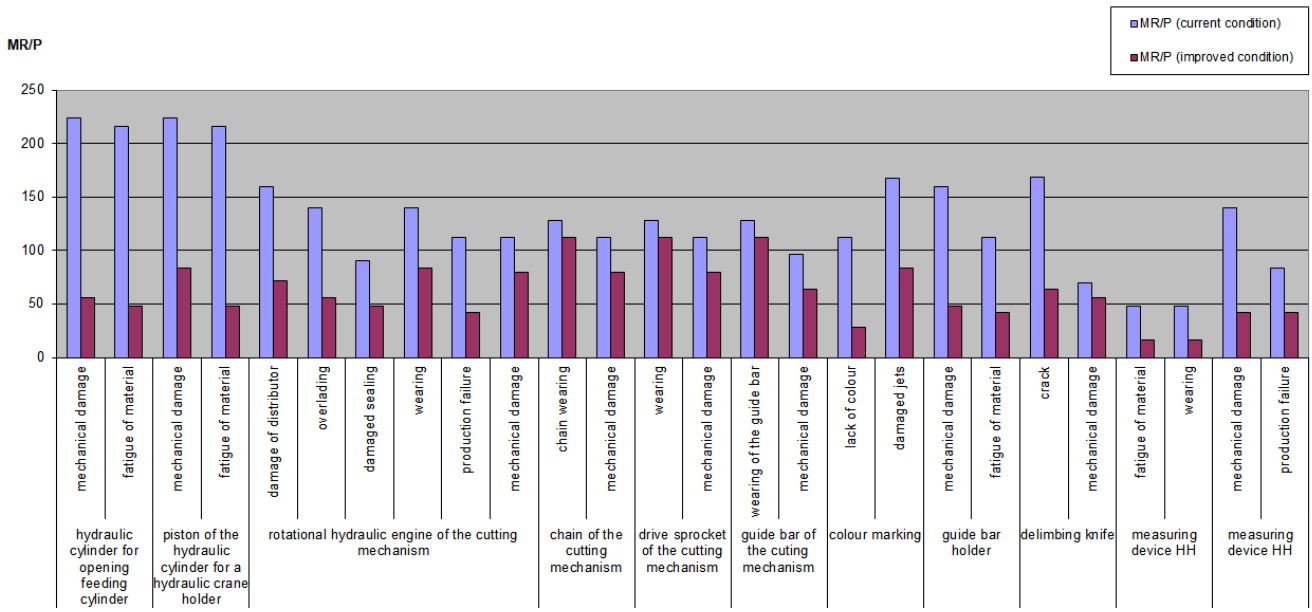

Fig. 6 Demonstration of FMEA construction results for hydraulic crane of forwarder 810D

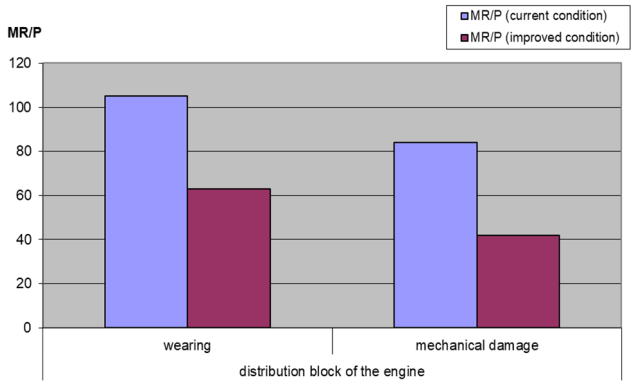

Fig. 7 Demonstration of FMEA construction results for hydraulic system of forwarder 810D

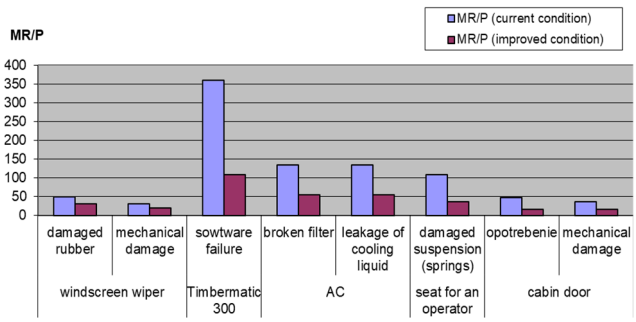

Fig. 8 Demonstration of FMEA construction results for cabin and controlling elements of forwarder 810D

The main idea for the FMEA method implementation rises from the theory that for every symptom of the failure on the lowest level there are analyse possible local or system impacts. Application of FMEA presents: analysis of constructional kinds of machines (i.e. forwarders) and all possible failures which a team of employees can define on the basis of their work experience. At the constructional FMEA method the failures are observed on the level of components. There are not researched mutual functional interactions of individual components. The procedure is based on risk value (MR/P) as the result of multiplication between probability of the failure, significance of the failure and probability of detection.

Corrective measures are set and results are evaluated until the level of risk is not lower or the same as acceptable level of risk (acceptable level) for individual causes (objectives) of each system. Acceptable level of risk is qualified as the decision to accept results and probability of the exact risk. The maximum level of MR/P for FMEA method is 1000 points. As acceptable level of risk there are set 500 points which are not obtained in current analysis.

The FMEA method is realized as a team work of specialists representing maintenance (day and week maintenance steps) and repairs.

The evaluated objects are divided into groups, subgroups, parts and components. There are asked questions focused on probability of raising the failure for every symbol (symptom) where during observation of operational conditions during the research period of time was cause a failure minimum once. In the team of specialists there were solved questions of a failure probability and possible causes, significance of the failure for a user and detection possibilities. Significance of the failure was taken to consideration also the downtime due to the total downtime of the machine with emphasis on loss of profit. The answers were obtained from recent experience of individual specialists and results of operational reliability while individual probabilities were evaluated by values according to criteria mentioned in the Slovak Technical Standard STN EN 60 812 – Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA).

There are compared results obtained during evaluation and final results and on the basis of the final result of the acceptable risk there are taken appropriate measures which bring positive improvements. For better understanding the results are demonstrated in the graphical form. These results create a part of a document which reflects progress and conditions of analysed objects and processes in the company. This progress enables to evaluate the machines and objects in time i.e. to get progress for future. It enables horizontal and vertical design of FMEA records. The records in vertical level enable to analyse new and new findings. The positive point of this

method is a team work which helps share knowledge and experience obtained during machines running.

CONCLUSION

Final data from operational reliability are further used for implementation of FMEA method and maintenance. They are use as input data. There are mostly failures collected during research. The data are treated according to the system given by a producer.

The characteristics of the machine used in the real conditions in accordance with defined properties define the quality which should be obtained. The user mostly requires durability of machines in operation. During research and technical lifetime of the machine there is durability verified mostly by statistical methods. The meaning of quality is supported by operational reliability. It gets also a special dimension and it is longer lifetime [7, 8].

Application of FMEA method enables bigger flexibility in case of unexpected situations and optimation of human abilities. At the application of FMEA there are always a lot of problems to solve. They can be summarized as fear from changes, illogical ideas during analysing, missing data or knowledge which can create insufficient scheme of reliability. For successful implementation and realization of this task in other companies there can be recommended following points:

- Preparation of the realization plan for application of FMEA method,
- Creation of experienced and skilled working team,
- Creation of scheme of operational reliability (definition of researched groups within the machine, etc.),
- Analysis of possible failures and causes,
- Proposal of possible measures,
- Repetition of analysis to obtain acceptable level of risk,
- Implementation of results into practice and documentation of observed machines and devices,
- To do taken measures in real conditions which will bring the positive input of taken measures .

FMEA method is a tool for elimination of downtime in operational reliability system and a preventive too for ensuring maintenance of objects. Recommendations rising up from the method are very wide. The first recommendation is preventive activity in the system of maintenance. In the future with higher age of machines there is necessary to re-evaluate and set up shorter terms of operational maintenance for machines because it is defined by a curve of failures intensity. For easier diagnostics of individual elements in the system it is useful to implement new and modern methods of technical diagnostics.

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