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CONTRIBUTION TO MATHEMATICAL MODELING OF COMPLEX TECHNICAL SYSTEMS MAINTAINABILITY

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ABSTRACT
Maintainability can be expressed as probability that some system will be preserved or returned into funcional condition, under designed circumstances, during given period of time, if maintenance is performed in accordance with designed procedures.. That is internal characteristic of technical system related to easier, safe, and economical performance of maintenance activities, with providing certain functional parameters.
Since malfunction time, caused by maintenance, is basis for maintainability analysis, it will be presented in this project, mathematical model for calculation of this characteristic, taking as example mining equipment in coal mine "Banovici".
Keywords: mathematical modeling, maintainability, technical systems

1. INTRODUCTION

Maintainability is one of system designing parameters, which has to be carefully considered, together with other parameters of construction. System capability to be maintained, i.e. kept operational or returned into "OPERATIONAL" stage, is also important for system to be useful, as it is capability for reliable performance of given function. Maintainability contains those activities which are taken during some system development for its efficient maintenance in the period of operation. Evaluation of technical systems maintainability is mostly done to be able to predict maintainability in some future moment of time.
In the period of technical systems and maintenance procedures development, it is developed new approach for MAINTAINABILITY "PO" as characteristic, which define possibility that certain designed maintenance procedure will be performed in given time, in given condition of the enviroment, and with minimum real cost [1]. Maintainability is on that way mostly related to:

- principle of system structure simplicity and their convenient composing,
- quality of system building,
- conditions of maintenance procedures performance, and
- level of function organization on relation system-enviroment, i.e. level of integral systematic support-logistic of the system.

Maintainability as scientific discipline is based on certain science facts as follows [1]:

- maintainability is result of team efforts who are dealing with design, exploatation ad maintanance.
- maintainability can not be defined separately for each part, but together for all system parts and for complete system,
- maintainability is defined, predicted, measured, and applied in designing procedure and system testing,

- components of system effectivness are closely connected to maintainability program,
- maintainability increases system design technology, making easy machining and assembly, and provide better exploatation conditions.

2. THEORETICAL ASSUMPTIONS

Modeling consists of mathematical description of physical, technology, economical, and other system processes. Results of mathematical modeling are mathematical models, or if not emphasized, only models, which can be analytic, stohastic, numerical, graphic, statistical, and others. Modeling is mathematical description of changing parameters law of processes or systems in certain time and space. Main goal of mathematical modeling is defining interaction of input parameters (primary) and output parameters (secondary). First parameters define conditions of process conduction, and second parameters define results ofprocess. That show that secondary parameters Y_i depend pf primary parameters X_i, i.e. $Y_i=f(X_i)$. It is defined by modeling relation of input-output parameters.

Identification of input-output maintainability parameters is showed in figure 1.

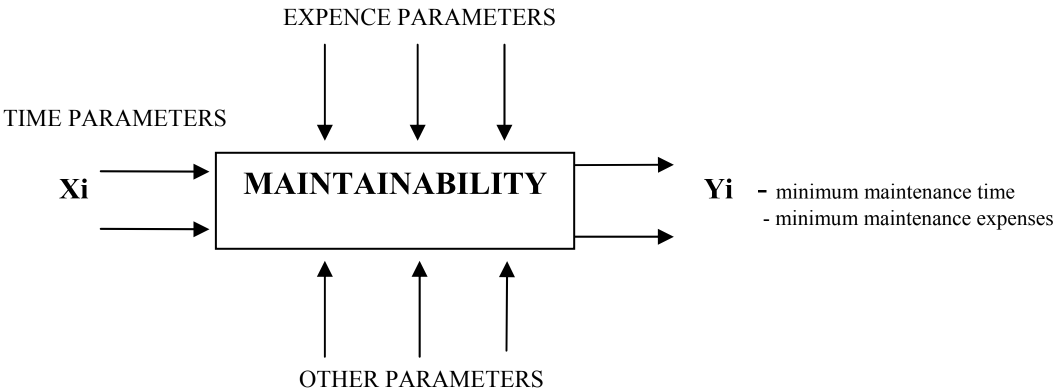

Figure 1. Block schematic of maintainability

Generaly, maintainability can be measured with combination [1,2]:

- time necessary for prooving breakdown,
- time necessary for maintenance,
- working time of maintenance operators,
- maintenance activity frequency,
- maintenance expences, and
- elements of integral system support.

Cummulative function of minimum intervals ″BREAKDOWN″is obtained from expression (1)[1,2,3]:

$$PO(t_o)=\int_0^{t_{01}} f(t_o)dt_o \qquad ...(1)$$

Where is: t_o- maintenance procedure time (″BREAKDOWN″),

$f(t_o)$- function od minimum intervals density ″BREAKDOWN″,

and it represents possibility of conduction maintenance procedures in given conditions- i.e.maintainability.

Experimantal data of active periods of mechanical systems, are not influenced by organization, and they shows that function of minimum intervals density ″BREAKDOWN″ often follows line of logarithm-normal distribution, and it is obtained from expression (2):

$$PO(t_o)=\int_{0}^{t_{01}} \frac{1}{t_o \cdot \sigma \cdot \sqrt{2\pi}} \cdot e^{-\frac{1}{2}\left(\frac{\ln t_o - \nu_{\ln}}{\sigma}\right)^2} \qquad ...(2)$$

As many factors influence previous times, requests for maintainability could be defined as cumulative in following area: components election, standardization, convenience for testing, assembly and disassembly, convenience for changing parts, accessibility, convenience for operating, fastening elements, ergonomy, protection during maintenance, etc.

3. EKSPERIMENTAL RESEARCH

3.1. Plan of the experiment

Research is conducted on PK-Čubrić, RMU-Banovići, on excavator dregline MARION 7400 (5). For conducting goal function, it has been done following:

- it is designed technical system (excavator),
- there are defined research parameters,
- there are defined breakdowns,
- there are defined causes of breakdown,
- it is defined condition timetable,
- it is made evaluation (calculation) of maintainability,

3.1.1. Condition timetable

Condition timetable is result of working process and result of maintenance procedure process, and it presents basis for evaluation of maintainability in the working process. Observation time is 30 months,what presents basis for making condition timetable. Observed group of occurrence is representative enough for complete system, since it credibly represents all occurrence in exploatation in different geomechanical and climatical conditions (table 1).

Table 1. Working and maintenance data of excavator MARION 7400 (5)

M -7400 (5)	MONTHS																														TOTAL [h]
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
t_{od}[h]	24	156	32	38	22	184	142	42	67	2	10	243	389	3	66	16	63	10	9	55	44	2	115	5	14	23	10	8	112	2	1908
t_{ur}[h]	720	588	688	706	698	560	602	630	677	718	734	477	355	741	654	728	657	734	735	617	700	718	629	715	730	721	710	736	608	742	20.028

Breakdown time is basis for maintainability evaluation. Breakdown times data, i.e. maintenance data are taken form the condition timetable. Those data are then sorted i.e. arranged according preselected criterion, what resulted in sorted empirical data. Values for maintenance time are sorted to form variation line $t_{01} \leq t_{02} \leq \cdots \leq t_{0N}$, where t_{01}= min t_{0i} i t_{0N} =max t_{0i}, a $R_N=t_{0N}-t_{01}$ is variation interval of maintenance t_0. Also, for each group of data it is determined is total number of intervals z and interval width Δt. Than, there are calculated empirical function of maintainability according formula number (1) and maintainability function according to logonormal distribution formula number (2).It is conducted testing according "d-test" for trust level α=0,05. Maintainability data for excavator MARION 7400 (5) are presented in figure 2. For calculation of maintainability, it is used special software

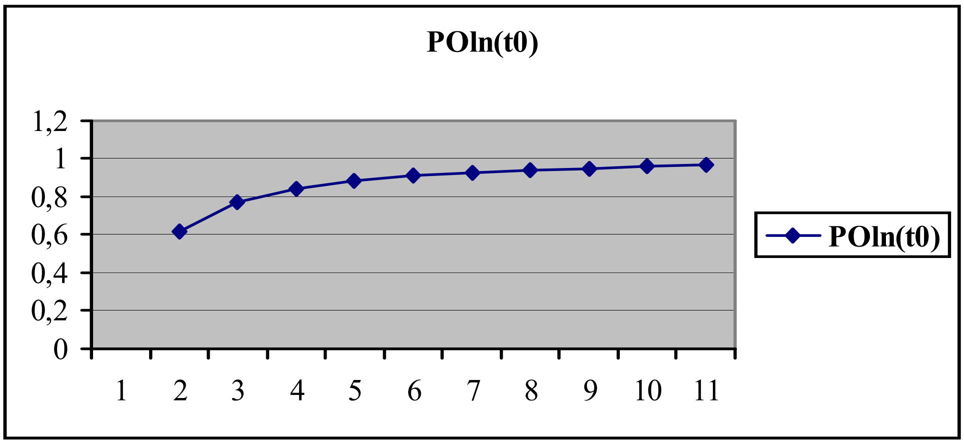

Figure 2. Diagram PO for excavator Marion-7400(5)

4. CONCLUSION

By monitoring condition of MARION 7400 (5) excavator, it is made timetable of condition with goal to calculate maintainability. After sorting data about maintenance time, it is calculated maintainability with special program. Result data for maintainability are presented in diagram. It is obvious that maintainability evaluation during operation is useful for end user and for manufacturers of technical systems, because on that way it is obtained feedback for end user and for manufacturer about activities which should be taken in the future to reduce maintenance time and to increase maintainability.

Directions of further research should be focused to create and estimate mathematical models of influenced factors (quality elements of construction – convenience for assembly and disassembly, accessibility, convenience for testing and diagnosis, changebility, convenience for operating) for maintainability of complex technical systems.

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