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CONTRIBUTION TO ANALYSIS OF OPERATIVE READINESS OF COMPLEX TECHNICAL SYSTEMS

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ABSTRACT
System operative readiness is probability for system, if used under specified condition, to function satisfactory in any moment of time or it is ready for operation when requested.. It means that basis for determination of operative readiness is total time which contains storing time, free time, operation time, and breakdown time. High value of operative readiness is preferable indeed, but it is important to know the way it is achieved. If it is result of high availability, it is than good since in that case breakdown time is short comparing it with operating time. But, if operative readiness is result of mainly short period of system operation, (long free time), than there will be situation that system free time is used as compensation for poor availability, what is not good and economic solution.
There will be presented influence of individual times on operative readiness on the example of technical systems in Coal Mine "Banovici".
Keywords: analysis, operative readiness, complex technical systems

1. INTRODUCTION

Technical systems represent integrated complex, where integration means elements connection and interaction according to criterion function, and relation between elements and their characteristics. This further means that elements quality is not enough for system functioning, but completely defined relations between them. System correctness is system technical condition where it complies to all functional requirements, prescribed by technical documentation. For description of maintenance positive influence on technical systems, where breakdown time is permited, it is introduced operative readiness function.

Analysis of technical systems operative readiness as probability that technical system will act in certain moment of time, ie when it is expected, is very important in production process. During its lifetime, technical systems can be in condition "OPERATIVE", in condition "BREAKDOWN" or in some condition between those two. Since operative readiness is related to moment when it is required for technical system to be operative, it is very important to know current system condition. Also, it is important to know if system was used or in stand by condition, before starting operation. If system was used, its condition is known and system starting is not uncertain. If system is stored in the warehouse (stand by condition), its condition is generally not known, so it is uncertain whether it will be able to start to operate or not. Beside starting basic function, system starting is characterized by transient effects (load increase during acceleration, friction increase because of pure / no lubrication, increased starting current and voltage because of decreased resistance, transient effects in electronic elements) of system components.

2. THEORETICAL ASSUMPTIONS

2.1. Main concept and definition

System operative readiness is according [1], that system, if used under specified condition, is funcioning satisfactory in any moment of time, or it is ready for use when it is required. It means that basis for operative readiness determination is total time which contains storing time, free time, operative time and breakdown time. These times are defined on following way: storing time is time of system while it is in the warehouse as spare part, and it is assumed it is in operative condition, free time is time where no system operation is required, and this time can or can not be part of system breakdown – depending if system is in operative or non operative condition, operative time represents time in which system is functioning satisfactory, and finaly breakdown time represents period of time where system is non operative. This time contains active maintenance time, logistic and administrative time.

In contrast to system affectivness, which considers probability during time interval, operative readiness considers probability in moment of time. Beside, while system effectiveness takes into account integrated system capability (accuracy, power, etc.), operative readiness considers only system readiness for certain task in given moment of time. So it can be writen:

$$OG = \frac{t_k + t_{nk}}{t_k + t_{nk} + t_z} \qquad ...(1)$$

where are introduced letters for marking times: t_k – operative time, t_{nk} – time when system is not operating, but it is ready for use, and i t_z – breakdown time. High value of operative readiness indeed desirable, but it is important to know how it is achieved. If it is result of high availability, than it is good, because in that case, system breakdown time is low compairing it with operating time ie. maintenance does not cause unplaned system standstill. But, if operative readiness is result of very rare system operating (high free time), or high changebility level maintenance, by keeping spare systems stored (high storing time), where availability is low, than system free time and storing time are used as compenzation for pure availability, what is not good and economical solution.

According [2], readiness represents probability that system will successfuly start operating and enter in the area of established criterion function tolerated deviation in given time and given enviroment condition, where established criterion function can be maximum performance (max. power, max. speed, max. quantity), max. quality (optimum values, max. efficiency and min. working cycle time), and max. economy (min. production cost, max. profit).

According [3], readiness can be defined on many ways, depending of aproach and analysis goals. Generaly, it can be writen:

$$G(t) = \frac{t_r}{t} = \frac{t_r}{t_r + t_o} = \frac{\sum t_{ri}}{\sum t_{ri} + \sum t_{oi}} \qquad ...(2)$$

where is: G(t) – readiness function, t_r – operating time, t_o – breakdown time, t – total observing time. Since, operating time and breakdown time are complex time categories, readiness definition can be presented on other ways, related to certain periods from time table. There should be pay attention on terms internal and realised readines. Internal readiness is defined related to active maintenance time, no matter if it is preventive or proactive maintenance. Realised readiness has wider sense. In this case, beside active maintenance time, analysis contain stand by time, mostly related to spare parts.

3. EXPERIMENTAL RESEARCH

3.1. Research plan

Research has been conducted in open pit «Cubric» of coal mine «Banovici», on hydraulic excavator TEREX RH-120 (1). Following has beed done for target function realization:

- defined technical system (excavator),
- defined research parameters,
- defined breakdowns,
- defined breakdowns causes,
- defined condition time table,
- conducted calculation and presented influence of certain times on operative readiness value.

3.1.1. Condition time table

Basis for technical systems operative readiness analysis is condition timt table ie. event genesis. Technical systems condition time table enables to establish for observed period of time: number of condition «OPERATIVE» apperance, and condition «BREAKDOWN» apperance, breakdown cause time by category and size, by direction of breakdown cause effect, and other parameters in function of need and established information system.

System condition time table is limited by other same condition, way of system design, and by level of design complexity. Colected and analysed data is presented in table 1.

Table 1. Data of operation and breakdown of hydraulic excavator TEREX – RH 120

Mjesec	Maksimalno mogući ostvareni sati	Planirani sati ispravnosti	Ostvareni sati ispravnosti	Ostvareni efektivni sati	Raspoloživost (%) (Sati ispravnosti)	Raspoloživost (%) (Efektivni sati)	ZASTOJI (h): Podmazivanje	Mašinska opravka	Elektro opravka	Čekanje na mašinsku opravku	Čekanje na elektro opravku	Servis	Remonti	Zastoji tehničke prirode
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Januar	744	550	728	558	97,85	75	1	4	10			1		16
Februar	672	0	433,5	338	64,51	50,3	2	43	2	182,5	7	2		238,5
Mart	744	550	721	546,5	96,91	73,45	20		3					23
April	720	550	690	562,5	95,83	78,13	2	13	1	5	2	7		30
Maj	744	550	725	424,5	97,45	57,08		7	5	7				19
Juni	720	550	666	509	92,5	70,69	1	12,5	5,5	24	6	5		54
Juli	744	550	570	400	76,61	53,76	2	14	1	143	14			174
August	744	550	708	512	95,16	68,82	3	20	5			8		36
Septembar	720	500	698	531,5	96,67	73,82	3	6	9	6				24
Oktobar	744	500	679	485	91,26	65,19	2	15,5	15	10,5	16	6		65
Novembar	720	500	714	470	99,17	65,28	1	2	1			2		6
Decembar	744	500	404	248	54,3	33,33	1	49,5	3	269	1,5	16		340
Suma	8760	5850	7735	5585	88,29	63,76	38	186,5	60,5	647	48,5	47	0	1026

Mjesec	rezerva	Ned. vagona	Ned. kamiona	Miniranje	Ned. struje	Trasa	Kabl	Mehanizacija	Uslovi	Odmor	Transp.	Praznik	Primopr.	Ostali zastoji	Ukupan zbir zastoja
1	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Januar			42	1	3	24	2			61	7	30		170	186
Februar			28	1,5	1	16			1	42,5	5,5			95,5	334
Mart			29	1	2	28			1	72,5	19	24		174,5	197,5
April			30		1	6	2	2	3	70,5	13			127,5	157,5
Maj	11		152	2	15	16	8	4		82,5	6	24		300,5	319,5
Juni			44	0,5	12,5	8,5	12	0,5		74,5	4,5			157	211
Juli	2		42	1	1	19	11		28	60	6			170	344
August			78,5	2	12	12	4		9	70,5	8			196	232
Septembar			56	2	3	14	6	2	6	71,5	5			164,5	188,5
Oktobar			62		11,5	6,5	12		18	78,5	5,5			194	259
Novembar			92		9	13	8	2	39	71	10			244	250
Decembar	25		56		2	8,5		2	6	37,5	20			158	498
Suma	38	0	709,5	11	73	189,5	65	12,5	111	772,5	109,5	78	0	2150	3175

According to expression (1) basis for operative readiness calculation are following time which values are taken from table 1: t_k = 5585 [h] – time of usage (realized effectual hours for period of one year), t_{nk} = 2150 [h] – time when system is not in use, but ready for usage (other breakdown), t_z = 1026 [h] – time of breakdowns (technical breakdowns). When these times are included in expression (1) result is value for hydraulic excavator operative readiness:

$$OG = \frac{5585 + 2150}{5585 + 2150 + 1026} = 0{,}88 \text{ ili } 88\% \qquad \ldots(3)$$

By analyzing result, it can be concluded that operative readiness of excavator Terex RH-120 has high value and it is result of operating time high value ie. High availability what should be always goal in every company. If further analyzed times in above formula, it can be noticed there is possibility for increasing operative readiness by increasing usage time instead of free time, which is in this case extremely high (2150 h).

4. CONCLUSION

Technical systems operative readiness is very important characteristic which has much influence on their effectiveness. This term is often used in practice in different ways, as available hours or certain expersions which contain certain time significant for technical systems exploation period. As it is mentioned in theoretical assumptions, different authors define this term on similar way. There are certain differences, depends which times are used for operative readiness calculation. Also, it is very important to monitor condition time table (event genesis) to make any analysis of operative readiness in production process. On the example of one technical system in coal mine «Banovici» it is conducted calculation and presented influence of individual times on operative readiness value.

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