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RESEARCH ARTICLE

Study on the level of operational reliability of diesel engines for backhoe loaders

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Abstract

In the present study the main numerical characteristics of the reliability indicators for the Komatsu SAA4D104E-1 engines of the KOMATSU WB93R-5 backhoe loader have been determined, and the laws of resource allocation have been established.

To study the level of reliability of machines, a methodology for experimental research has been developed, where the complex, comparative and formal methods, as well as the systematic, cybernetic and statistical approach have been used. It has been found that increasing the level of reliability of the engine elements can be improved by increasing the quality and timeliness of the repair and maintenance activities and compliance with the rules of operation.

This study is a continuation of a study conducted by the author.

Keywords

reliability, units, assemblies, systems, engines, excavators, maintenance, repair

Introduction

In the current stage of economic development, especially relevant is the problem of increasing the efficiency of machinery, used as the active part of the main production assets, and determining the production capacity of the business organization.

As the technical level of the machines increases, their complexity and productivity increase, as well as the price (Kozlovsky et al., 1998; Mirotin, 2000; Chervonyi et al., 1972). The main trend, however, is the clear relative share of the service complex in the overall balance of productive forces that is constantly growing.

Significant reduction of costs in the service complex can be achieved by optimizing the structure and parameters of the system for maintenance and repair of equipment with different methods and models. This requires studying the numerical characteristics of the reliability indicators of the elements of machines / units, parts and assemblies / in order to develop an effective system for maintenance and repair, ensuring efficient use of machines.

The aim of the research is to determine the main numerical characteristics of the reliability indicators of the engines of KOMATSUWB93R-5 backhoe loaders. This study is a continuation of our previous study (Madzhov, 2019), which in the future will track how the reliability characteristics of engines change with age.

Materials and methods

To study the characteristics of reliability indicators, a methodology for experimental research was developed, which used the complex, comparative and formal methods, as well as the systematic, cybernetic and statistical approach (Mihov et al., 2012; Spiridonov et al., 1981; Skovorodin et al., 1990; Lukinsky, 2000; Mirotin et al., 2000; Mikhovet al., 2012;).

The methodology of the experimental research (Fig. 1) is based on active and passive methods of conducting the experiment.

Monitoring planning means the selection of the site, the conditions for conducting operational observations and the monitoring plan (establishing the number of monitoring sites and the duration of the monitoring).

According to the research plan, the latter are divided into the following main groups: [NUN]; [NUT], [NUr], [NRT], [NRr]; where U means a plan in which failed objects are not replaced by new “Unrepaired”, R - means a plan in which failed objects are replaced by new or repaired “Repaired”.

Within the limits of this classification, the following plans are also used: [1*RT*] – object of testing is one product, which, in case of refusal, is replaced with a new or repaired for fixed production Ti;

[1*RT*] - the object of testing is one product which, if it fails, is replaced by a new one or repaired up to a fixed number of failures r;

[*NUT* (r=0)], [*NRT* (r=0)]– the object of the test is N products, and the ones that have been replaced or not during production T no failures have been registered.

The process of occurrence of failures and change of the state of the elements of the object of study has a random (stochastic) nature. To assess the level of reliability of the elements, specific and complex indicators are used, which are based on statistical information. Obtaining the statistical characteristics of the indicators is based on methods of probability theory and mathematical statistics. The systematic approach is applied to choose the best solution in the presence of several possible options.

The study was performed in the conditions in which the machines operate: a set of natural, climatic, production, technical, economic, organizational and social factors

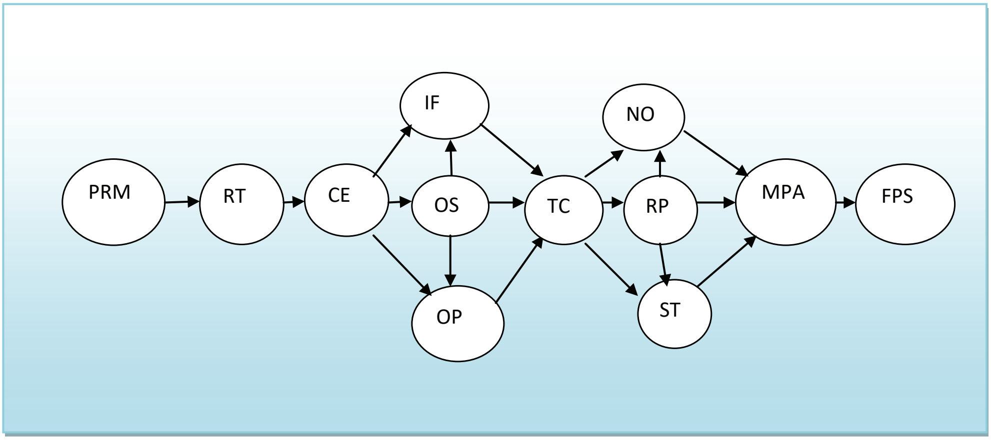

Figure 1. Structure and interrelationship of the elements of the methodology for the experimental study of the level of reliability of the machines: PRM - purpose of the research methodology; RT - research tasks; CE-criteria evaluation of the condition of the site; OS - object of study; IF- input factors; OP - output parameters; TC - testing conditions; RP - research plan; NO - number of objects; ST - study time; MPA-methods for processing and analysis of test results; FPS - form of presentation of study results.

influencing the intensity of changes in the parameters of their condition. The survey was conducted for the territory of the Republic of Bulgaria with excavator loaders of the company "Kirov" AD in Sofia and Sofia region. The object of study were: 180 excavator loaders, working all year round, and the nominal working fund is 1896 hours per year; monthly - 158 hours. The study was conducted for 2 years in the period 2014 – 2015.

The object of research are the same 180 excavator loaders, studied in the previous 4 years for the period 2010 – 2014. Therefore, the aim of this study is to supplement the information on the reliability of the site and to increase the reliability of indicators and numerical characteristics of the reliability properties (Madzhov, 2019). A student test was used to prove the statistical significance of the main numerical characteristics of the indicators of reliability of research for both periods.

The following four main stages can be identified in each test: test planning; conducting the test; processing of the test result; analysis of the result and choice of solution (Lukinsky, 2000; Mihovet al., 2012; Spiridonovet al., 1981; Skovorodinet al., 1990; Howard et al., 1998)

In this study we will focus mainly on the analysis of research results and proposals for theory and practice.

Basic information on SAA4D104E-1 engine malfunctions of KOMATSU WB93R-5 backhoe loaders is classified according to the following main features: origin, cause of occurrence, complexity of removal, type of elements, consequences of refusals, the nature of manifestation and manner of removal.

The information received is from direct observations and information maps from January 2014 until December 2015. The data were collected according to the developed methodology of the experimental study, classified by elements and grouped according to the following classification features, properties and reliability indicators.

Results and discussion

Distribution of refusals by reasons of occurrence (quality of workmanship; construction) active defects, violated rules of exploitation, prolonged exploitation. The wear and tear, the quality of the repair are shown in Table 1.

Table 1. Percentage distribution of failures by reason of occurrence

Causes of failures	**Percentage,%**
Duration of operation	44.25
Natural wear	8.25
Quality of workmanship	6.36
Structural deficiencies	3.24
Violation of the rules of operation	26.25
Quality of repair	11.65

From the analysis of the types of refusals due to their origin, we found that the highest number of refusals due to long-term operation is 44%. Secondly - 26% are failures due to non-compliance with the rules for using the machines.

From the analysis of the information on the reliability of the engine elements of the KOMATSU WB93R-5 excavator backhoe loader, we have concluded that the highest percentage is those of failures of the elements of the fuel system. Tables 2 and 3 give the distribution of the failures of the elements of the fuel system. The distribution of the refusals according to the external manifestation is shown in Table 2, and by units and aggregates - in Table 3:

It has been established that the share of malfunctions of the elements of the fuel system on the level of reliability of the engine is different and this is more substantial after an engine overhaul, given the different degrees of recovery of their resource.

Investigation of the faultlessness of the elements of the fuel system of the excavators

The reliability of the fuel system of the engines was evaluated according to the indicators: workmanship among the failures and the flow of refusals and characteristics: average number of refusals $\overline{m}$ (t); parameter of failures flow *w(t)* and the work between the failures $\bar{t}_i$.

Table 2. External manifestation of failures

№	Rejected elements and external manifestation	% of refusals
A	**Disclaimer of details and assemblies**	
1.	Camshaft bearing	24.22
2.	Violation of the tightness of the sealant	12.06
3.	Fuel supply pump	3.25
4.	Spring on the leaking valve	3.29
5.	Pusher spring	2.89
6.	Regulator connector	2.39
B	**External manifestation of failures**	
7.	Increasing the inequality of supply	15.08
8.	Reducing the minimum cycle rate	14.23
9.	Reduction of the frequency of rotation and the beginning of the activation of the regulator	6.35
10.	Decrease in the degree of enrichment	16.24

Table 3. Breakdown of combustion system failures by units and unit*s*

Units and aggregates	**Number of engine failures**	
	to major repairs	**between major repairs**
Fuel pump	0.32	0.57
Nozzles	0.66	0.68
Fuel line for high pressure	0.50	0.48
Fuel line for low pressure	0.74	1.68
Filter for rough cleaning of fuel	-	0.09
Filter for fine cleaning of fuel	0.29	0.13
All on the engine	2.46	3.23

The values of the numerical characteristics of the indicators are given in Table 4. The analysis of the data shows the level of reliability of the elements of the fuel system up to overhauls about 2 times higher than between repairs.

The workmanship between the orders is divided according to Gauss's law. The hypothesis of Gauss's law is not rejected as a level of significance $\alpha = 0{,}0$ and degree of freedom k = 2. The main numerical characteristics of the production among the failures are $\bar{t}_i$ = 858.7 moto hours; σ = 284.35; ϑ = 0.18. This means that this evidence can be used in further research and to model the processes of maintaining the performance of the studied backhoe loaders.

Table 4. Characteristics of the combustion system reliability

Characteristic of impunity	Designation	Values	
		up to an overhaul	between the overhauls
Average number of failures per 3000 motorcycle hours	$\overline{m}$	3.70	7.80
Response flow parameter, 1/-hour x10^{-5}	$w(t)$	119	230
Work between failures, moto hours	$\bar{t}_i$	858.7	439.4

Table 5. Main numerical characteristics of the operation until combustion system elements failure

№	Description	Main numeric characteristics moto h.		
		$\bar{t}.10^3$	$\sigma.10^3$	ϑ
1	High-pressure fuel line	145.1	31.0	0.21
2	Pipe line outlet nozzle, kit	45.9	12.0	0.26
3	Pipe pipeline overflow, kit	58.9	13.1	0.22
4	Pipe to the filter, kit	49.0	6.0	0.12
5	Pipe to the pump, kit	28.9	6.0	0.21
6	Fuel filter for rough cleaning	46.6	14.0	0.30
7	Fuel filter, kit	38.7	10.0	0.01
8	Fuel filter spring	28.4	3.0	0.10
9	Bolt on the rotating knee	31.1	4.1	0.13
10	Sealing ring	10.5	2.50	0.24
11	Filter with console	89.9	22.0	0.25
12	Reflector	0.86	0.20	0.23
13	Filtering element	0.98	0.40	0.41
14	Winged profile, kit	19.5	9.2	0.47
15	Needle on the blow hole	10.5	1.30	0.12

Table 6. Basic numerical characteristics, parameters, and resource distribution laws of Komatsu SAA4D104E-1 elements of Komatsu WB93R-5 Backhoe Loaders

№	Elements	Estimates of the main numerical characteristics and parameters		
		top	σ	V
1	Engine	20708	11920	0.472
2	cylindrical head	22398	7330	0.33
3	Nozzle	14259	6830	0.48
4	Fuel Pump	24787	12740	0.51
5	fuel injection pump	24927	9420	0.38
6	Oil Pump	42359	14828	0.35
7	Water pump	21488	12044	0,56
8	Radiator	27838	8524	0.31

Table 7. Gamma percentage resource elements in Komatsu SAA4D104E-1

№	Elements	80% gamma- resource, l
1.	Engine	13344
2.	cylindrical head	18970
3.	Nozzle	7892
4.	Fuel Pump	19955
5.	fuel injection pump	17858
6.	Oil Pump	29785
7.	Water pump	10784

Table 8. Characteristics of the combustion system durability

Durability characteristic	Designation	Values	
		up to an overhaul	between the overhauls
Resource, moto hours	T	5428	1375
Gamma percentage resource, moto hours	$T_{\gamma\text{-}0.80}$	4889	1070
Exploitation period, yearly	T_e	8,45	4,08
Gamma percentage exploitation term, yearly	$T_{e\gamma\text{-}0.80}$	7,80	2,54

Table 9. Timing for the replacement of Komatsu SAA4D104E-1 engine elements on KOMATSU WB93R-5Backhoe Loaders

№	Elements	Average discharge	Number of workers	Standard Replacement Time man-hours t_{cp}		Replacement time according to experts		
						σ	V_x	
1	*Engine*	3.5	2	3.80	(7.50)	11.0	3.0	0.27
2	*Cylindrical head*	3.3	2	3.78	(7.55)	4.0	1.2	0.3
3	*Nozzle*	3.6	2	0.38	(0.76)	0.25	0.1	0.4
4	*Fuel pump*	3.5	2	3.80	(7.50)	1.6	0.7	0.44
5	*Fuel injection pump*	2.5	1	0.27	(0.27)	0.3	0.2	0.67
6	Oil Pump	2.5	1	0.18	(0.18)	2.0	0.8	0.4
7	*Water Pump*	2.7	2	2.31	(4.62)	2.2	0.7	0.32
8	*Radiator*	3.4	2	1.93	(3.86)	3.0	0.5	0.17

Numerical characteristics and parameters of the laws of distribution of expression up to the failure of elements of fuel system are presented in Table 5.

The main numerical characteristics of the parameters of the laws for distribution of resources of The Komatsu SAA4D104E-1 engine units and components of the KOMATSU WB93R-5 backhoe loader are determined according to the experimental method. The total study and are given in Table 6, and the gamma percentage resource at γ = 80% - Table persons 7.

The analysis of the data in Table 7 shows that 80% of the engine's life up to overhaul is smaller than the normative value about 1.5 times and between overhauls - 9.5 – 10 times.

Investigation of the main indicators of repair of the elements of the engine elements Komatsu SAA4D104E-1 backhoe loader KOMATSU WB93R-5.

Investigation and determination of the time for replacement of the elements of the tractors under conditions The work of partial mechanization of repair and maintenance work was carried out according to methods, given in the methodology for experimental research, and the basics. These numerical characteristics and conditions for replacement of units and units of the engine are given in the Table 9.

Conclusions

It was found that the predominant number of failures 44% of the fuel system of Komatsu SAA4D104E-1 engines on KOMATSU WB93R-5 backhoe loaders are due to prolonged operation of the machines or violation of operating rules - 26%.

The law of distribution of the resource of the main elements of the Komatsu SAA4D104E-1 engine has been established. Pearson's criterion confirms that it is distributed according to Gauss's law of distribution, which is also confirmed by the values of the coefficient of variation of the studied reliability indicators.

Increasing the level of reliability of the engine elements can be improved by improving the quality and timeliness of the repair and maintenance activities and compliance with the rules of operation.

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