Accounting of random processes when adjusting the overhaul life of machines for reclamation

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Abstract. Application of procedure modeling a physical process in virtual medium jointly mathematical apparatus allows obtaining forecast parameters of the technical condition. Goal of the study is development of predictive assessment of failure risks for machines with a different overhaul life. Accounting of load characteristics for reclamation machine was explained; development of guidelines on formation of info-analytic basis for the unit machine operation was realized. In particular, the period for maintainability can be distinguished, in this case, the reverse nature of the transition seems to be true that reset the previous operation period and return the value of operating life to initial state. For example, the implementation of the return transition according to the values of moral aging is not possible. Further studies are oriented on development of a methodology for monitoring of variation in the technical condition of a unit machine at a hierarchical level, by combination of risk-failure data for individual parts, assemblies, systems, and for entire system of machine. Electronic diagnostic system for collection of data about a current state of the technical system, combined with a computational model of the intensity of change compared to the basic end values, will allow designing predictive models of failure risks.

1 Introduction

The problem, concerning a collaboration between production structure and research community is an integral part of technical and technological breakthrough that is necessary to improve a social stability in Russia. Documentarily, this necessity is noted in the almost all strategic development programs. Strategic development of production process without upgrading and modernization of machines and technologies is slow down or, in many cases, stopped. So, the logical conclusion is the technical and technological modernization should be supported financially. Scientific review demonstrates a significant federal budget costs (up to 10 trillion rubles) for the program realization. For example, in 2018, about 10 trillion rubles were allocated to agricultural industries from the budget financing. That allowed buying about 17639 units of agricultural machinery of different purpose [1–3].

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Goal of research is to study predictive assessment of failure risks for machines with a different overhaul life as well as with a long period of operational capability (10 years at least).

2 Operating life reliability and upgrading of reclamation machines

Disbursing budget funds is controlled and limited by normative requirements, i.e. choosing of machines for melioration is accomplished with the construction power classifier (KSR) and estimate documents are formed according to the Unified City Real Estate Service (EGRN). The algorithm includes not only the choice of a machine according to technical parameters, but also the calculation of the of using material resources efficiency, i.e. a model of forecast assessment of operating life of the equipment without additional investment (Fig. 1).

Fig. 1. The algorithm of the machines choosing to use the KBR.

Among a lot of factors effecting on operational efficiency of machines, the 3 key factors are the followings:

- natural and climate conditions of the environment for the machine operation;
- constructive perfection level of machines, their level of reliability and durability;
- the skill of the operator, when the machine operating.

Earlier studies determined that the loads per unit of machine, during a reclamation technological operations in the Central Federal District (Russia) is 5 times higher than for similar ones applied in Canada.

In Russia, a comparison of these loads on machines applied in the Central Federal District and the Amur Region is 2,5 times different. The authors propose to take this fact

into account by introducing a generalized index for assessing the processes of the influence of the functioning environment on the decrease in machine performance [2, 3].

It seems clear that, when substantiating the operational life of machine and its units, as well as predictive risk-failure management of operable state support it is required to obtain a scientifically based adjustment of the basic guidelines applying the calculation of various load conditions.

It seems that the development of a model of the factor influence of negative processes will allow development predictive recommendations to avoid risk-failures of machine systems and to avoid additional expenses for operating materials, as well as to avoid an increasing costs associated with the repair works [4, 5].

3 Model for calculating and adjusting the machine operational life

Average operating life for technological machines is provided by manufacturer for a normal service conditions (T_{ni}). In machine engineering operational life before usage was calculated taking into account two interrepair cycles (100 % of overhaul life before full repairs and 80 % of overhaul life after full repairs).

Based on typical operating conditions and timely high-quality periodic service actions to maintain an operable state, overhaul life is represented by the equation (1):

$$T_L = \frac{T_{Ev.L} \cdot (1 + C)}{8760 \cdot k_y \cdot k_d \cdot k_s}, \quad T_L = \frac{9600(1 + 0,8)}{8760 \cdot 0,55 \cdot 0,6 \cdot 0,6} = 10 \text{ years}. \quad (1)$$

where T_L - is the machine operating life, years;

$T_{Ev.L}$ - is average the machine overhaul life, determined by manufacturer;

C - is interrepair cycle reduction coefficient; $C = 0,8$.

For a calculation, the normal operation of the machine was accepted, with overhaul life of 9600 motor hours per a year. Operational factors are the followings: per a year $k_y = 0,55$; per a day $k_d = 0,6$; per a working shift $k_s = 0,6$. The result confirms the 10-year period of operation life of the machines, determined by a manufacturer is a normal value [5].

Further, it is required to determine the loss of a machine's life, basing on a typical operating conditions and timely high-quality periodic service actions to maintain an operational state. Theoretically, the operation of the machine is not allowed if the reducing in operational life is higher than 20%. It is due to economic inefficiency, although, in practice, the machines are operated.

The machine owners, keeping profitability at an acceptable level by repair works, justify the continuation of their operation after a 10 years of operating period.

According to the data of leading scientists [3] concerning to the technical condition of the machine for all period of operation as well as the statistical data of reducing in operational life during a physical depreciation the infogram was plotted (Fig. 2)

Fig. 2. Infogram of change in functional efficiency of machine (from 100 % level) and physical depreciation (in %) during a 10-year operating period.

The infogram is presented by the two following curves: 1 — this curve is responsible for reducing in operational life for a 10-year period at the rate of 20 % of annual reduction; 2 — this curve is responsible for a physical depreciation at the rate of 20 % of annual reduction. The idealized model includes determination the dynamics of reducing in operational life, but the gentle curves in Fig. 2 do not take in account the service periods of system, which increased the operational life by the amount of approximation of the parameter value to the reference one (gamma-percentile life is ~ 80 %).

Analysis of studies of leading scientists [6-9] demonstrate that solving engineering problems of optimizing the reliability of systems and machine components when obtaining confidence-based probability characteristics inevitably face to random processes. Application of procedure modeling a physical process in virtual medium jointly mathematical apparatus allows obtaining forecast parameters of the technical condition.

Coordinating the frequency of service and repair works with the theory of Markov processes, the assumption of the time interval (overhaul life) that is typical for the transition of an element from one state to another one (failure-operating capability) was made. An additional assumption is the comparison of the frequency of operation of the machine during technological processes and the stable operation of all systems of the machine.

Mathematically it is described by the equation (2):

$$S_0 \xrightarrow{\lambda} S_1 \xrightarrow{\mu} S_2 \dots \xrightarrow{i} S_n, \tag{2}$$

where $S_0; S_1; S_2 \dots; S_n$ are the system condition;

$\lambda; \mu; i$ is an event that identifies a transition from one state to another one.

The quantitative value of the "transition probability" in certain time intervals is the following:

$$S_0 \cong P_0(\tau); S_1 \cong P_1(\tau); S_2 \cong P_2(\tau); S_n \cong P_n(\tau).$$

The transition state level is varied. In particular, the period for maintainability can be distinguished. In this case, the reverse nature of the transition seems to be true that reset the previous operation period and return the value of operating life to initial state. It is difficult

to realize, due to the multi factorial nature of the return factors. For example, the implementation of the return transition according to the values of moral aging is not possible.

Taking into account a big impact of operational environment factors for technological complexes of reclamation machines the calculation of the change in operating life was made taking into account the service and repair works for a conditional machine (Fig. 3).

Fig. 3. The dynamics of changes in a machine operating life, taking into account the maintaining technologies application.

The curves plotted (Fig. 3) demonstrate the minimal specified value of operating life of machine depending on applied estimated value. Results of calculation provide a step-like curve for operating life parameter. Typical variations in overhaul life parameter are noted as a suffering double line. They allow establishment a relationship between annual overhaul life and operating life determined by a manufacturer. It should be noted that average value of a machine operating life doesn't allow assessment operating life of a major units and aggregates. That is a key uncertainty factor.

4 Results and discussions

Further studies are oriented on development of a methodology for monitoring of variation in the technical condition of a unit machine at a hierarchical level, by combination of risk-failure data for individual parts, assemblies, systems, and for entire system of machine. Electronic diagnostic system for collection of data about a current state of the technical system, combined with a computational model of the intensity of change compared to the basic e values, will allow designing predictive models of failure risks [8-15].

5 Conclusions

In considering the priorities when choosing a machine manufacturer, their constructive adaptability to operating conditions in various regions of the Russian Federation should be taken into account.

The recommended system for maintaining the operating capability of reclamation machines should take into account the load characteristics for a unit machine.

It is required to develop guidelines of creation of information and analytical base of the operation of reclamation machines and machines for building works. It allows:

- For manufacture: to create a common database of typical factors, identification characteristics of working conditions as well as to perform a machine modernization, extending its service life for significant periods with a guaranteed level of reliability for the all operation period;
- For user: to reduce the costs for extending operational life of machine, to increase their productivity and quality of work, as well as to get information about the prospective profitability of a unit machine for the all operational period.

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