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METHOD OF CONSUMPTION IN SPARE PARTS FOR MACHINE REPAIR

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Problem Statement. The system of material and technical support for the machine and tractor fleet has a significant impact on its operational readiness. The efficiency of machinery operation can be enhanced through the development of new methods or the improvement of existing approaches for forecasting the required quantity of spare parts, which represent temporarily unused economic resources. Inventory levels must not exceed established norms, and spare parts should not remain in storage for extended periods without utilization, in order to avoid immobilization of the enterprise's working capital. Conversely, excessive reduction of spare part inventories poses the risk of increased costs associated with prolonged downtime due to the absence of necessary components for repair. Therefore, determining the optimal quantity and nomenclature of spare parts is one of the priority tasks in managing operating costs and improving the technical readiness of machinery.

Research Materials. The factors influencing the formation of spare part inventories can be classified into four groups: design-related, operational, technological, and organizational [1].

A comprehensive solution to the problem of assessing spare part requirements necessitates the identification of patterns governing the wear rate of key machine assemblies. All factors contributing to the wear of components and assemblies can be divided into two groups:

Group 1 – speed and load regime factors: pressure and relative velocity of the working surfaces in contact. Group 2 – technological and operational factors: quality of assembly and adjustment, type and quality of fuels and lubricants used, frequency of maintenance, driving practices, and similar parameters.

Analysis of the factors affecting spare part inventory formation has established that the most influential variables are: intensity of machine utilization, reliability of aggregates, assemblies, and components, fleet size and age, as well as cumulative operating hours since commissioning.

The forecasted demand for spare parts of a specific designation for a machine fleet of size N_M in the upcoming year Z can, in simplified form, be calculated using the following formula:

$$Z = \frac{W_P \cdot N_M \cdot n}{t}, \quad (1)$$

where W_P – average annual operating time of a single machine of a given brand;

n – number of components of a specific designation installed on one machine;

t – service life of a component until it reaches its wear limit.

The prediction of spare part requirements is complicated by:

- the probabilistic nature of the distribution of service lives of operating components;
- the heterogeneous age structure of the machine fleet.

It is evident that as machines age, the number of components requiring replacement increases. Machine aging, associated with chronological service life, contributes to accelerated wear of components due to distortions in structural geometry and degradation of base elements (e.g., loss of axis parallelism, misalignment of mating surfaces, wear of bearing seats, etc.).

The principal methods employed include:

- statistical methods (based on accounting records, monitoring, and specialized observations);
- analytical methods (probabilistic approaches, econometric and mathematical models, solutions to static optimization problems);
- research methods (simulation modeling, forecasting, and queuing theory) [2].

Among these, statistical forecasting methods are predominant. They rely on probabilistic characteristics of the distribution of component service lives and involve

1) establishing the initial distribution of component service life and its variation with aging;

2) analytically determining the probability of spare part demand for each year of machine operation;

3) assessing the age composition of the machine fleet during the forecast period;

4) calculating annual spare part requirements for future years.

The service life of components is determined through micrometric measurements and statistical analysis of replacement data obtained during repairs and technical maintenance.

All machine components can be divided into two groups:

- components with a constant average service life during pre-repair and inter-repair periods;
- components with a decreasing average service life after successive replacements.

For components of the first group, it must be considered that the probability of replacement in the n-th period, installed during the i-th time interval, $P_P(X_n)$, is equal to the probability of replacement in the $(n-i)$-th interval of the initial distribution, $P_P(X_{n-1})$.

To calculate spare part requirements for the entire machine fleet, the fleet is divided into age groups $m_1, m_2, \ldots, m_n$. In general form, the demand for spare parts of a given designation is expressed as

$$Z = \sum_{n=1}^{T_O} m_{n-k} \sum_{i=1}^{n} P_{\mathrm{P}}(x_{n-i}) \int_{i=1}^{i} f(x)dx \, , \tag{2}$$

where T_O – service life of the machine, in years;

k – forecast year counted from the moment of calculation;

m_{n-k} – number of machines belonging to the $(n\text{-}k)$-th age group at the moment of calculation;

$f(x)$ – probability density function of the component's resource, which remains constant over any period and is defined for the pre-repair interval.

For the second group of spare parts, it is necessary to determine the probabilistic characteristics of the dispersion of component resources after each replacement. However, if one assumes that the distribution law remains unchanged, an alternative approach emerges: the regularity of changes in the mean resource after each replacement can be studied as a function of time [3]. By determining the number of replacements for each year and grouping the machine fleet by age, it becomes possible to forecast the demand for spare parts while accounting for the impact of machine aging on their resource:

$$Z = \sum_{n=1}^{T_O} m_{n-k} \cdot P_{\mathrm{P}}(x_n) \, . \tag{3}$$

Conclusions. The solution to the problem of forming a reserve of spare parts in service enterprises has a direct impact on the efficiency of machine utilization. For calculating the reserve of spare parts, a statistical method can be applied that takes into account both operating hours and time.

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