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Development of the Method for Individual Forecasting of Technical State of Logging Machines

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Abstract*: *The appearance of reliability engineering is connected with the study of functional dependencies and quantitative relationships between failures and their causes, as well as the development of calculation methods. Processing of statistical materials in the field of reliability requires the development of existing statistical methods and leads to the rise of statistical characteristics of reliability and the patterns of failures, which serve as the basic formation of the statistical reliability theory. The generalization of statistical materials on failures and the development of recommendations for improving the reliability of products cause the determination of mathematical laws governing the failures, as well as the development of methods for measuring reliability and engineering calculations of its indicators. The study of the physical causes of failures, patterns of aging and strength of materials, the influence of various external and internal effects on the performance of products, is the subject of the physical reliability theory. The main cause of failures of logging machines is various processes of destruction, leading to irreversible changes in structural elements. These changes are caused by wear, accumulation of deformation and fatigue, corrosion, diffusion of one material into another, etc. In one logging machine and even in the same structural element, these processes are superimposed, they interact with each other, and ultimately cause a change in the parameters characterizing the technical condition. It can be concluded that, at present, as a rule, information about changes in the technical parameters of machines in operation is not being recorded. As a result, it is not possible to determine the initial vector process. Therefore, at the first stage, it is supposed to determine it by statistical modeling and estimate the forecast coefficients. Then, using the information received from maintenance and repair for each machine, specify the forecast factors, i.e. solve the problem of individual forecasting in an adaptive way.

Index Terms*: *forecasting, reliability, wear, operation, performance, technical state.

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I. INTRODUCTION

Changing the parameters of the technical condition of logging machines occurs as a result of random destruction processes in materials: wear, fatigue, yield, corrosion, etc. Works of various authors consider idealized models of processes for changing the values of operating parameters covering various situations that occur in real objects. All models, regardless of their physical nature, are called wear models, and wear is understood as an irreversible process of changing the parameter of an irreversible parameter.

II. PROPOSED METHODOLOGY

A. Block Diagram

The simplest assumption about the change of an irreversible parameter $\eta(t)$ is that for each item it is non-random and linear in nature (Fig. 1). The randomness in changing $\eta(t)$ is that the coefficient α in the equation:

$$\eta(t) = \alpha t + \beta \tag{1}$$

is a random variable determined by the initial state of each item. Obviously, α is the change rate:

$$\alpha = \frac{d\eta(t)}{dt} = \varphi(t)\cdot \tag{2}$$

If a failure occurs when $\eta(t) \geq$ M, then the failure-free time τ is determined by the formula:

$$\tau = \frac{M - \beta}{\alpha}. \tag{2}$$

Another assumption regarding the change in the irreversible parameter $\eta(t)$ is that the wear rate of individual item changes and the changes are random in nature. Consequently, the wear curve of an individual item cannot be deterministically extrapolated to the future from the results of past observations. One can only express a probabilistic judgment about the further nature of the wear curve. In this case specific to wear curves is that they are intertwined (Fig. 2).

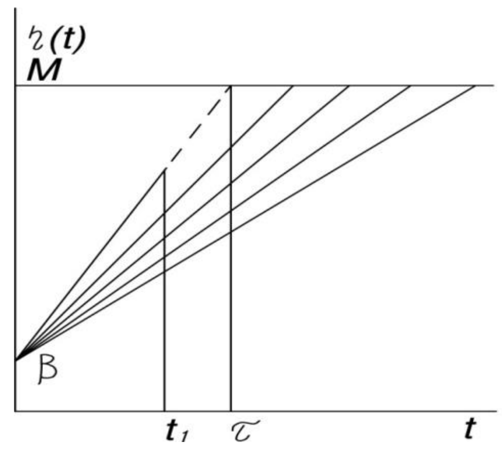

Fig. 1. Linear wear implementation from time

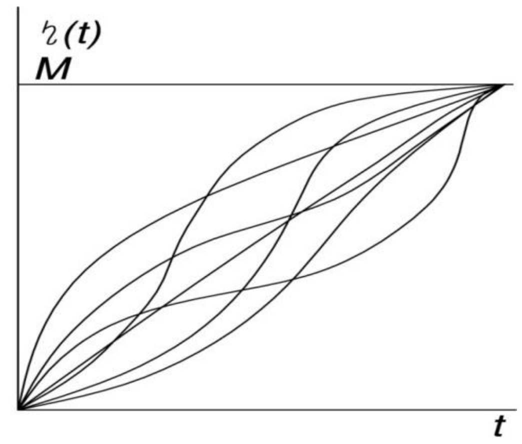

Fig. 2. Wear implementation as a random function of operation

The considered situations are the opposite. While the future behavior of the implementation of $\eta(t)$ in Fig. 1 is completely determined by its past, then the future behavior of the implementation of $\eta(t)$ in Fig. 2 is almost independent of the past. The described situations are quite rare explicitly. In most cases, both types of wear occur.

The dependence of the increase in wear on the operation duration for the most common case is usually expressed by the curve proposed by V.F. Lorentz [1]. This curve has three sections corresponding to the three periods of the process flow: running-in, normal or steady wear, and period of enhanced, accidental wear. It is assumed that the wear rate during the second period remains approximately constant and that catastrophic wear occurs after reaching a certain critical point. Such nature of the dependence of the wear value on time turned out to be applicable for a large number of different friction sites, which became the basis for wide recognition of the “Lorentz curve”.

Later it was revealed that in a number of cases the wear process differs from the “Lorenz curve”. Some authors [2, 3] presented several possible options for the connection between the wear value (wear rate) and the operation duration of the friction pair (Fig. 3).

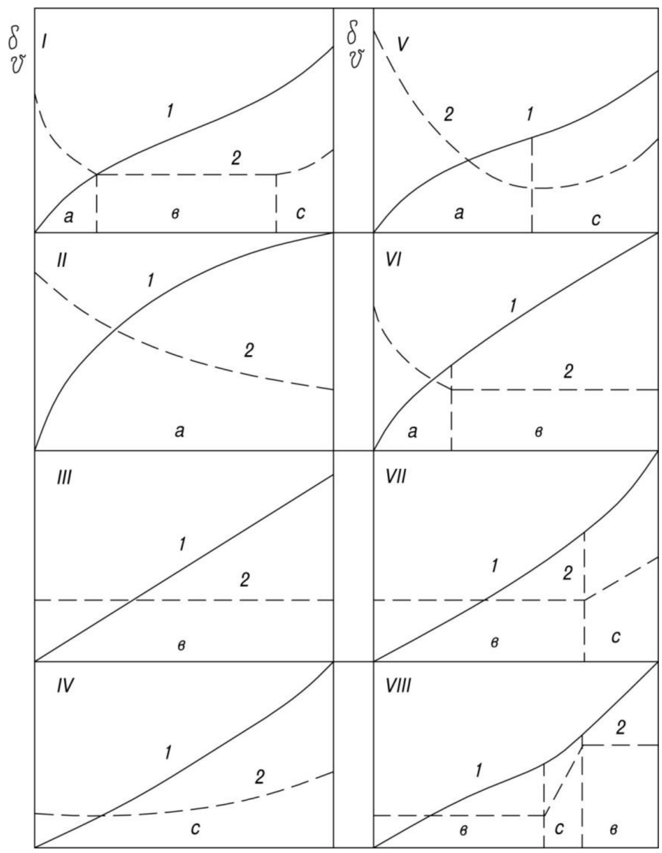

Fig. 3. Diagrams of possible dependencies of wear value and wear rate on the operation duration of the friction pair: 1 – wear; 2 – wear rate; a, b, c, – periods of the process

The change in wear rate after the end of the running-in is due to several reasons. These reasons can be non-random, for example, a regular change in the contact area of parts, the physical properties of the material of parts, dynamic loads and lubrication conditions, etc. Random reasons include a non-stationary operation of the machine, fluctuations in the properties of materials, parts and lubricating oil, temperature, humidity and dustiness of the environment, qualifications of staff and many other factors that cannot be taken into account. Therefore, the process of accumulation of wear of machine parts has a large dispersion and should be considered as random.

At present, the science of friction and wear does not provide sufficient grounds for choosing the type of correlation between wear and operating time. Therefore, the type of correlation equation is chosen, as a rule, depending on the nature of the location of the experimental points. To establish the correlation between wear and operating time, statistical processing of the results of changes in wear of parts after various periods of operation is performed. At the same time, given that there is a type of correlation equation, its parameters are found by the least squares method. In some cases, the equation of a straight line is taken as a correlation equation [1], in others, non-linear equations are used. The parabola equation is proposed as a correlation equation.

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$$Y(t) = K\sqrt{t} \quad (4)$$

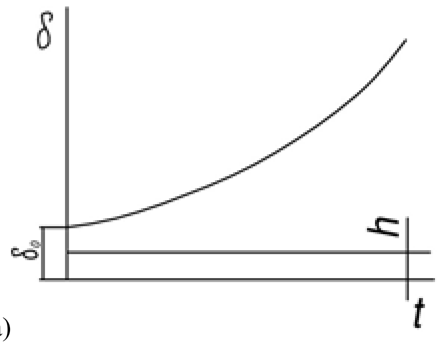
where $Y(t)$ – wear; K – a constant; t – running hours.

To express the dependence of the wear of a part on the running hours under conditions of normal wear, I.B. Tartakovsky [4, 5] proposed an empirical equation:

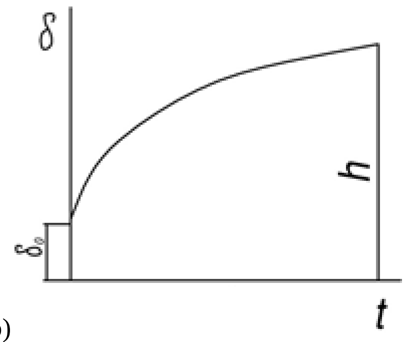
$$t = A\lg\frac{h+\delta}{h+\delta_0}, \quad (5)$$

where t – the duration of work of a part in hours; A – the coefficient of durability; h – the shift of the wear curve, equal to the distance from the asymptote of the wear curve to the nominal line, with the opposite sign; δ and δ_0 – current and initial deviation of the part size from the nominal.

The above-mentioned equation is suitable not only for describing the process of normal wear but also for the running-in process. The positive value of the coefficient A corresponds to the normal wear mode (Fig. 4a), the negative one – to the running-in mode (Fig. 4b).



a)



b)

Fig. 4. The dependence of wear on the part on the operation duration

It is known that in the operation of the coefficients of variation of resources of various elements of machines can take values from 0.3 to 1 [6]. Therefore, the choice of the approximating function for the minimum value of the coefficient of variation does not seem to be sufficiently justified.

B. Algorithm

In the statistical approach to the study of processes of wear information, the information about the types of distribution of wear parts are of great importance.

Tartakovsky [7] assumes that if the initial deviations of dimensions are distributed over the tolerance field normally and the wear obeys the normal law, then the distribution of deviations of the dimensions of parts after the operation will be normal.

An analysis of the state of the issue (stage I) shows that further improvement of reliability management methods requires a fundamentally new approach that considers the age composition and structure of the logging machines, as well as the design features and operating conditions. The basis of this approach can be individual forecasting of the technical state of logging machines, which creates a scientific basis for solving the tasks of maintenance scheduling (MS) and repair, inventory management, and optimal operational planning of processes for preparing MS and repair. This, finally, will significantly reduce the cost of ensuring the health of car parks, as well as downtime for technical reasons.

The main part of the second stage (stage II) is the development of a method for individual forecasting of the technical condition of logging machines. To study the patterns of change in the technical state of the elements of the structures of logging machines in operation, it is necessary to develop a stochastic model that takes into account the physical nature of the processes of destruction, manufacturing technology, and operating conditions. To determine the parameters of random processes of application of the technical condition and temporal characteristics of the recovery processes of logging machines, it is required to develop a methodology for statistical analysis of information on the reliability of logging machines in the dialogue mode with the information system.

At the third stage (stage III) with the use of the developed methodology, it is necessary to perform:

– checking of the adequacy of the stochastic model to the actual processes of changing the technical state of elements of logging machines in operation;
– analysis of the performance of methods for predicting indicators of reliability of elements of logging machines based on modeling the processes of destruction;
– experimental study of the performance of the method of individual forecasting of the technical state of logging machines in operation.

In order to study the state of the issue in practice, test the effectiveness and develop recommendations for the subsequent implementation of the research results, it is required:

– to perform the analysis of the maintenance and repair system of the logging machines;
– to identify the causes and estimate the duration of the above-standard downtime of logging machines under repair.

As a result of theoretical and experimental research (stage IV) it is necessary:

– to develop a general method for individual forecasting the technical state of logging machines;
– to assess the accuracy of the method of individual prediction of failures of elements of logging machines under operation;
– to develop a technology for the formation of an information base for the implementation of individual forecasting of the technical condition of logging machines

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The calculation of economic efficiency should be made taking into account the experimental assessment of the implementation effect of the operational reliability management of logging machines, based on individual forecasting, and the cost of implementing the research results.

III. RESULT ANALYSIS

The starting point in the development of the method of individual forecasting was that the technical condition of logging machines at any time can be characterized by the following set of parameters $X(ti)=\{X_{1j}, X_{2j}, X_{3j}, \ldots, X_{mj}\}$, allowing to determine the state of individual elements (i=1, 2, …,m). As a result of an accidental operation (for example, conditions and modes of operation, quality of maintenance and repair, qualification of operators, etc.) and a large number of operational factors, the technical condition of the logging machine changes. In this regard, the rules of changes in the output parameters $X_i(t)$ are formed due to the occurrence of random processes of destruction of the logging machines' structural elements.

Let us present the process of changing the technical condition of logging machines in the form of a matrix of random values of parameters characterizing the technical condition of individual elements (i=1, 2, …,m) at discrete moments of time ($t_j= t_j$-1+Δt, j=1, 2,…,n) as a random vector process X(t):

$$X(t)=\begin{pmatrix} X_{11} & X_{12} & \cdots & X_{1j} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2j} & \cdots & X_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ X_{i1} & X_{i2} & \cdots & X_{ij} & \cdots & X_{in} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ X_{m1} & X_{m2} & \cdots & X_{mj} & \cdots & X_{mn} \end{pmatrix} \quad (6)$$

where m is the number of elements limiting the reliability of logging machines; n is the number of measurements of the values of the process of changing the technical condition of the logging machine.

The efficiency of the logging machine will be considered as a plurality of states G, defined by sets of random values of parameters $X_j=\{X_{1j}, X_{2j}, X_{3j}, \ldots, X_{mj}\}^T$, under which failure does not occur. Thus, a state X_j belonging to the plurality *G* ($X_j \in G$) means that a logging machine at a time t_j is operating. The limits of the plurality G are determined by the maximum permissible values of parameters $X_n=\{X_1^n, X_2^n, \ldots, X_m^n\}^T$. Any parameter $X_i(t)$ exceeding the limits of the plurality G means the failure of the i-th element of the logging machine.

The main task of individual forecasting of the technical condition of the machines is to determine the moments of time t_k, when at least one of the parameters $X_i(t)$ exceeds the limits of the plurality G of at least one of the parameters $X_i(t)$, in other words, when the condition is true (Fig. 5).

$$X_i(t) \le X_i^n, i=1,2,\ldots,m. \quad (7)$$

Various processes of destruction in the structural elements of machines during operation (wear, deformation, corrosion, etc.) cause failures. These processes overlap, interact with each other and ultimately cause a change in the technical state. Therefore, the value of the parameter of the technical condition *i*-th of the element of the logging machine at time t_j can be determined based on the following expression:

$$X_{ij}=X_{io}+\Sigma_{k=1}^{j}\varphi_i(t_k)\Delta t, \quad (8)$$

where X_{io} – the initial value of the parameter; $\varphi_i(t_k)$ – the value of the random function of the speed of the process of changing the technical state of the *i*-th structural element on the *i*-th interval.

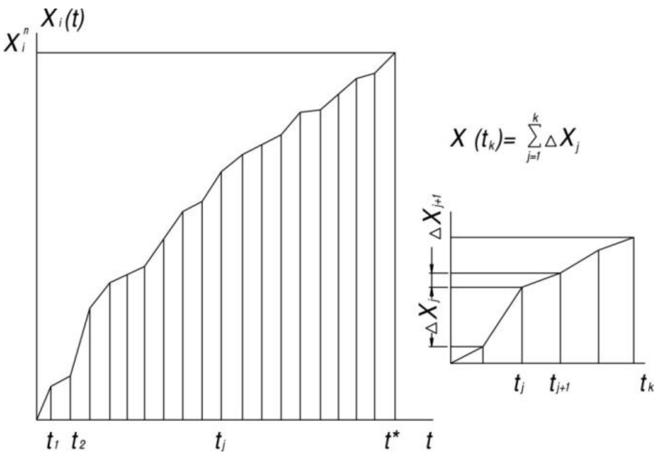

Fig. 5. Implementation of the changing process of the technical state parameter

When developing the method of individual forecasting, the following theoretical assumptions were used.

The rate of change of each parameter of the technical state is a random process that can be described by the expression:

$$\varphi_i(t)=V_i(t)\times\rho_i(t), \quad (9)$$

where $V_i(t)$ is some deterministic function; $\rho_i(t)$ is a random process with the property of stationarity.

It follows from the expression (9) that the mathematical expectation of the process $M[\rho_i(t)]$ doesn't depend on time t and the correlation function $R(t - S)$ depends on the difference $t - S$ (Fig. 6). This representation of the rate of change of each parameter of the technical condition is real enough for most logging machine elements (about 80%) whose failures are associated with wear. Moreover, the wear process has the property of strong mixing, i.e. asymptotic independence of increments of wear.

The change in the value of each parameter of the technical state $\Delta X_{ij}=X_{ij}+1-X_{ij}\,(j=1,2,\ldots,n)$ for equal periods of time Δ*t*, is a random process that can be represented as

$$\Delta X_i(t)=\varphi_i(t)\Delta t=V_i(t)\times\rho_i(t)\times\Delta t. \quad (10)$$

This random process, in turn, can be transformed, by dividing the right and the left parts of the deterministic function $V_i(t)$, to a stationary form:

$$\Delta Z_i(t)=\frac{\Delta X_i(t)}{V_i(t)}=\rho_i(t)\times\Delta t. \quad (11)$$

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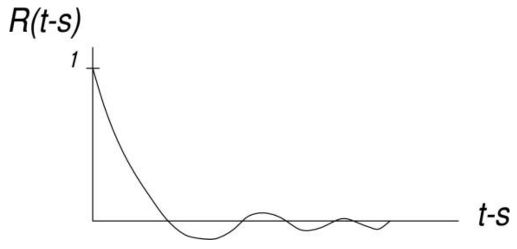

Fig. 6. The behavior scheme of the normalized correlation function of a random process under a strong mixing property

In general, the vector process $X(t)$ can also be converted to a stationary form accordingly.

$$\Delta Z(t)=\begin{pmatrix}\Delta Z_{11} & \Delta Z_{12} & \cdots & \Delta Z_{1j} & \cdots & \Delta Z_{1n}\\ \Delta Z_{21} & \Delta Z_{22} & \cdots & \Delta Z_{2j} & \cdots & \Delta Z_{2n}\\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots\\ \Delta Z_{i1} & \Delta Z_{i2} & \cdots & \Delta Z_{ij} & \cdots & \Delta Z_{in}\\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots\\ \Delta Z_{m1} & \Delta Z_{m2} & \cdots & \Delta Z_{mj} & \cdots & \Delta Z_{mn}\end{pmatrix} \quad (12)$$

where

$$\Delta Z_{ij}=\frac{x_{ij+1}-x_{ij}}{v_{ij}}. \quad (13)$$

The well-known theory of Academician A.N. Kolgomorov [5] about the possibility of representing some future value of a stationary random process as a linear combination of the previous values of this process is used as the next theoretical prerequisite. In this case, data of previous predictions can be used for the purpose of forecasting:

$$\Delta Z^*_{i,n+1}=\Sigma_{l=0}^{p-1}\Delta Z_{i,n-l}\times a_{i,l+1}+\Sigma_{l=0}^{g-1}\Delta Z^*_{i,l+1}\times b_{i,l+1}, \quad (14)$$

where p is the number of recent observations used; g is the number of previous forecasts used.

The last premise is that the changes in one of the processes $\Delta X_i(t)$ can be explained by changes in the other components of the vector $X(t)$ at past times. In other words, it is assumed that there is a correlation between the $\Delta Z_i(t)$ processes. This assumption, as a rule, is valid for the processes of changing output parameters. The presence of such properties explains the use in the forecast $\Delta Z_i^*(t)$ of statistical data on other processes of the vector $\Delta Z(t)$, i.e. multidimensional forecasting techniques.

$$\Delta Z^*_{i,n+1}=\Sigma_{k=1}^{m}\Delta Z_{k,n-l}\times a_{i,k,l+1}+\Sigma_{k=1}^{m}\Sigma_{l=0}^{g-1}\Delta Z^*_{k,n-l}\times b_{i,k,l+1}. \quad (15)$$

In matrix form, this expression looks like:

$$\Delta Z^*_{i,n+1}=\left|\Delta Z^T \quad \Delta Z^{*T}\right|\times\left|\frac{A_i}{B_i}\right|, \quad (16)$$

where $A_i=\{A_{i1}^T,\ldots,A_{im}^T\}$ $A_{ik}^T=\{a_{ik1},\ldots,a_{ikp}\}$

$B_i=\{B_{i1}^T,\ldots,B_{im}^T\}$ $B_{ik}^T=\{b_{ik1},\ldots,b_{ikp}\}$

$\Delta Z^T=\{\Delta Z_1,\ldots,\Delta Z_m\}$

$\Delta Z_k=\{\Delta Z_{kn},\Delta Z_{kn-1},\ldots,\Delta Z_{kn-p+1}\}^T$

$$\Delta Z^{*T}=\{\Delta Z_1^*,\ldots,\Delta Z_m^*\}$$
$$\Delta Z_k^*=\{\Delta Z_{kn}^*,\Delta Z_{kn-1}^*,\ldots,\Delta Z_{kn-p+1}^*\}^T \quad (17)$$

In the last expressions, triple indices are introduced, for example, a_{1kj} – is the coefficient at the j-th observed value of the k-th constituent process in the equation of the prediction of the i-th constituent process.

Estimates for the coefficients $C_i=[Ai \mid Bi]^T$ are found by the least squares method:

$$\Sigma_{j=0}^{i}(\Delta Z_{in-j}-\Delta Z^*_{in-j})2\to\min. \quad (18)$$

It uses the system of equations:

$$\overline{\Delta Z_i^*}=\Sigma_k\left\|\Delta Z\right\|kA_{ik}+\Sigma_k\left\|\Delta Z^*\right\|kB_{ik}. \quad (19)$$

The system of conditional equations of this type is compiled on the basis of statistical material using the sliding interval method and is designated as

$$\overline{\Delta Z_i^*}=\{\Delta Z_{in}^*,\Delta Z_{in-1}^*,\ldots,\Delta Z_{in-l+1}^*\}^T \quad (20)$$

In practical calculations, the following condition must be met:

$$l>>m(p-g), \quad (21)$$

which is an expression of the law of large numbers in relation to the problem being solved.

The information matrices in equation (19) are:

$$\left\|\Delta Z\right\|=\begin{bmatrix}\Delta Z_{kn-1} & \Delta Z_{kn-2} & \cdots & \Delta Z_{kn-p}\\ \Delta Z_{kn-1} & \Delta Z_{kn-3} & \cdots & \Delta Z_{kn-p-1}\\ \cdots & \cdots & \cdots & \cdots\\ \Delta Z_{kn-l} & \Delta Z_{kn-l-1} & \cdots & \Delta Z_{kn-l-p+1}\end{bmatrix} \quad (22)$$

$$\left\|\Delta Z^*\right\|=\begin{bmatrix}\Delta Z^*_{kn-1} & \Delta Z^*_{kn-2} & \cdots & \Delta Z^*_{kn-q}\\ \Delta Z^*_{kn-2} & \Delta Z^*_{kn-3} & \cdots & \Delta Z^*_{kn-q-1}\\ \cdots & \cdots & \cdots & \cdots\\ \Delta Z^*_{kn-l} & \Delta Z^*_{kn-l-1} & \cdots & \Delta Z^*_{kn-l-q+1}\end{bmatrix} \quad (23)$$

The abbreviated notation of equations (19) in the matrix form takes the form

$$\overline{\Delta Z_i^*}=\left[\left\|\Delta Z\right\|\vdots\left\|\Delta Z^*\right\|\right]\left[\frac{A_i}{B_i}\right]. \quad (24)$$

Compose the normal equations, and get the system to determine the desired coefficients:

$$C_i=(\{\Delta Z\}_T\{\Delta Z\})-1\{\Delta Z\}_T\overline{\Delta Z_i}, \quad (25)$$

where $\{\Delta Z\}=[\Delta Z \mid \Delta Z^*]$ – is a block information matrix of dimension $l*m\,(p+g)$;

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$\overline{\Delta Z_i} = \{\Delta Z_{in}, \ldots, \Delta Z_{in-l+1}\}^{T}$ – a column vector obtained from the latest observations of the process $X_i(t)$.

The coefficients $C_i=[A_i \mid B_i]^T$ found by expression (25) are used to predict the i-th component of the vector process $\Delta Z(t)$ in equation (15). For the prediction of other components, the procedure for determining the coefficient is similar.

Thus, individual forecasting of the technical condition of the machine consists in estimating the values of the vector process $X^*(t)$ for future moments of time t_{n+1}, t_{n+2}, … and identifying situations when at least one of the components of the process $X^*(t)$ the condition is fulfilled:

$$X^*_{in+l} = X_{in} + \Sigma_{k=1}^{l} \Delta Z_{in+k} V_{in+k} \geq X_i^n, \tag{27}$$

where $i = 1, 2, \ldots, m$.

In this case, the predicted moment of failure of the i-th element of the machine is determined by the formula:

$$t^* = t_n + l\Delta t. \tag{27}$$

The generalization of statistical materials on failures and the development of recommendations for improving the reliability of products cause the determination of mathematical laws governing the failures, as well as the development of methods for measuring reliability and engineering calculations of its indicators. The study of the physical causes of failures, patterns of aging and strength of materials, the influence of various external and internal effects on the performance of products, is the subject of the physical reliability theory. The presented material allows one to specify the coefficients of the technical condition forecast for each machine, i.e. solve the problem of individual forecasting of its technical state.

IV. CONCLUSION

The analysis of the above-mentioned leads to a conclusion that at present, as a rule, there is no record of information about changes in the technical parameters of machines in operation. It is usually impossible to determine the initial vector process $X(t)$. Therefore, at the first stage, it is suggested to determine it by statistical modeling and estimate the forecast coefficients. Then, using the information obtained for each machine during maintenance and repair, specify the prediction coefficients, i.e. solve the problem of individual forecasting in an adaptive way.

REFERENCES

1. T. Bially, Mc. A. Laughlin and C. Weinstein, IEEE Trans. *On Commun* 9, 1980, pp. 1478-90.
2. A.V. Skrypnikov, V.G. Kozlov, A.N. Belyaev and E.V. Chernyshova, “Theoretical Foundations of the Method of Designing a Clothoid Track with Approximation of Succession of Points”, in: E. Popkova, V. Ostrovskaya (eds) *Perspectives on the Use of New Information and Communication Technology (ICT) in the Modern Economy*. ISC 2017. Advances in Intelligent Systems and Computing, Vol 726. Springer, Cham, 2019.
3. V.G. Kozlov, V.A. Gulevsky, A.V. Skrypnikov, V.S. Logoyda and A.S. Menzhulova, “Method of Individual Forecasting of Technical State of Logging Machines”. *IOP Conference Series: Materials Science and Engineering*, 327(4), 2018, 042056.
4. O. Berestnev, Y. Soliterman and A. Goman, “Development of Scientific Bases of Forecasting and Reliability Increasement of Mechanisms and Machines — One of the Key Problems of Engineering Science”. *International Symposium on History of Machines and Mechanisms Proceedings*, 2000, pp. 325-332.
5. K. Park, Y. Hwang, S. Seo, M. Asce and H. Seo, “Quantitative Assessment of Environmental Impacts on Life Cycle of Highways”. *Journal of Construction Engineering and Management* 129 (1), 2003, pp. 25–31.
6. P. Kopriva, “*Vybrane problemy teorie apdehilvesty*”. Lausch-mann 99, 1990.
7. Skrypnikov A.V., Dorokhin S.V., Kozlov V.G., Chernyshova E.V. “Mathematical Model of Statistical Identification of Car Transport Informational Provision”. *Journal of Engineering and Applied Sciences*, 12(2), 2017, pp. 511-515

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