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Development of technology and methodology for monitoring the technical condition of metal-cutting machines

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Abstract. This work was carried out with the aim of developing the basic provisions of an automated vibration monitoring system for metal-cutting equipment. The paper presents the theoretical foundations of vibration monitoring technology, which uses regular measurements of vibration parameters, their frequency analysis, and mathematical modeling of degradation processes in machines. Vibration monitoring technology allows to determine the time points necessary for repair and maintenance of equipment based on its actual condition. Applications of vibration monitoring are reducing losses associated with equipment failures and reducing maintenance and repair costs, as well as increasing the safety of work. The most relevant is the implementation of a vibration monitoring system when diagnosing the technical condition of bearings and gears (metal-cutting machines, hydraulic systems). As a result of the research, diagnostic models of changes in the technical condition of metal-cutting machines and vibration characteristics of typical defects were obtained. A method has been developed for assessing the dynamic quality of metal-cutting machines using a complex quality indicator determined by measuring and analyzing the spectral characteristics of vibration signals.

1 Introduction

Vibration is a "by-product" of any operating machine. It is well known that the higher the vibration level, the worse its condition and excessive growth of vibration leads to failure of the machine or its component. Vibration parameters depend on such basic defects as imbalance of rotors, increased gaps in places where parts are mated, disruption of mechanical connections, etc. On the other hand, an increase in vibration intensity causes increased wear of equipment, and therefore reliability indicators, and therefore from this point of view control and monitoring of the vibration state is of interest [1-4].

The purpose of using vibration monitoring is to reduce losses associated with equipment failures and reduce maintenance and repair costs, as well as increase the safety of work. This goal can be achieved in two ways:

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1) By improving the design and manufacturing quality of the machine;
2) Improving the maintenance and repair system.

At the same time, the best method is obviously when maintenance and repairs are carried out before the onset of an emergency. It is also advisable to foresee in advance what impacts are required to restore the machine to operational condition.

The assigned tasks can be solved based on obtaining information about the state of the machine without disassembling and dismantling it. At the same time, the question of first importance, which largely determines the success of the task, is the choice of parameters that best reflect the state of the machine and its individual components.

Many years of experience in operating machinery with rotating parts shows that such a symptom is the level of vibration [1].

2 Materials and methods

The task of assessing the technical condition of metal-cutting equipment is particularly relevant, first of all, in view of the specifics of machine-building production. Here, first of all, the task arises of monitoring the technical condition of metal-cutting equipment at all stages of the life cycle, which will make it possible to determine the residual life of the machine at any time and provide a guarantee that the machine will perform a certain amount of work in a fixed time with a calculated probability.

In Figure 1 A situation is schematically depicted that illustrates the effectiveness of using vibration monitoring for metal-cutting machines.

This figure shows the resource distribution function of machines of the same size. As can be seen from the figure, improving the quality of machine operation can be achieved in various ways. Firstly, by reducing dispersion, which is achieved either by changing the design or improving the quality of parts, which is usually associated with large capital costs. Secondly, due to the rational use during operation of the potential capabilities inherent in the machine. To do this, it is necessary to have information about the current state of the machine as a whole and its individual components, to be able to identify the main degradation processes and their impact on the functionality of the machine. It is the solution to the second problem that is feasible through the implementation of a vibration monitoring system for a metal-cutting machine.

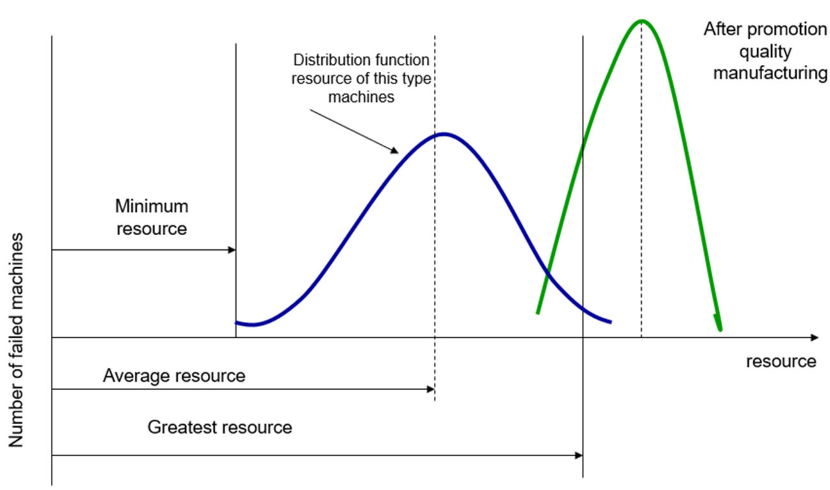

Fig. 1. The effectiveness of vibration monitoring for metal-cutting machines. Machine resource distribution.

The vibration monitoring system can be used at all stages of the machine's life cycle: during its development (finishing the machine based on the results of vibration control of a prototype by detuning from resonances, introducing and adjusting dampers, improving the dynamic characteristics of the structure); during its production to control the quality of manufacture (input control of components, for example, electric motors, gearboxes and output control of assembled products), and, finally, at the operation stage (quality control of installation and repair, control of adjustment accuracy), as well as for carrying out maintenance on based on individual monitoring of the condition of machines and forecasting their service life.

Based on the analysis of foreign scientific and technical sources, experience in other branches of technology (mechanical engineering, aircraft engineering, shipbuilding, printing, oil and gas industry, energy), today we can confidently say that the use of a vibration monitoring system leads to the following positive results [4-7]:

1. Reducing the likelihood of an accident.
2. Prevention of sudden equipment failures.
3. To check the technical condition of the machinery, there is no need to disassemble it.
4. Increasing the economic performance of the enterprise by reducing product losses due to unplanned downtime and reducing repair costs.
5. It turns out to be possible to take timely and effective measures to increase the resource of limiting nodes.
6. It becomes possible to switch from calendar scheduled maintenance to maintenance based on diagnostic conditions.
7. The dynamic quality of machines increases, and their noise level decreases.

At the same time, the costs associated with the implementation of a vibration monitoring system are relatively small.

In the process of performing its functions, any machine wears out the associated parts. This is reflected in the change in the dynamic quality of the machine, i.e., its vibration activity increases. Therefore, by properly measuring and analyzing the vibration signal generated by interacting parts, it is possible to judge the wear processes and, by taking timely action, control the wear processes.

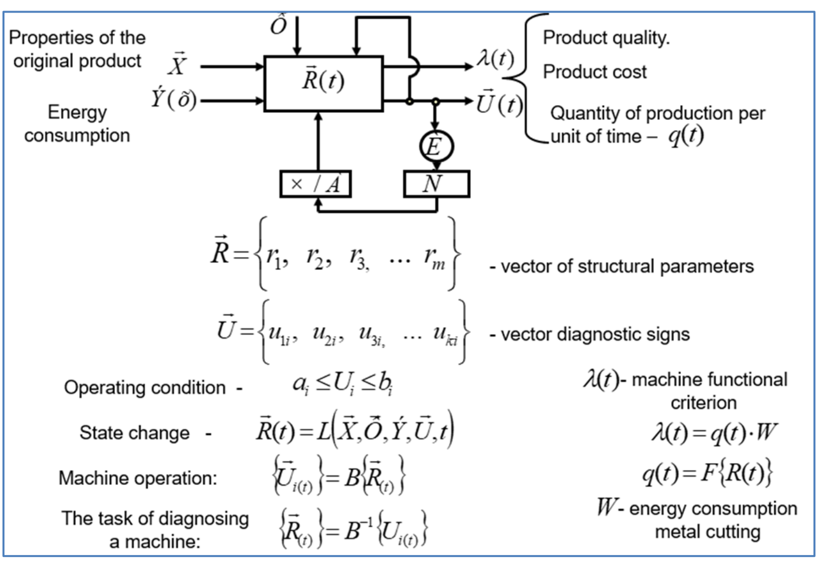

Fig. 2. Active monitoring of the technical condition of an object.

In Figure 2. - a control object, which is a machine designed to perform a certain technological process (for example, a metal-cutting machine). The technical condition of this machine will be characterized by a multidimensional vector Y (P_1, P_2, ... P_n) where - P_1, P_2, ... P_n - are the structural parameters of all its elements, taking into account the accuracy of their manufacture, surface quality, friction, etc.

The multidimensional vector $X_0(a_1, a_2, ... a_n)$ takes into account the quantity and properties of the product entering the machine input (for example, hardness, roughness); vector X (b_1, b_2, ... b_n) characterizes the quantity and properties of the output product. The multidimensional vector Z (a_1, a_2, ... a_n) reflects the state of the process equipment. Here a_1, a_2, a_n are vibration parameters measured at various points of the machine.

The influence of vibrations on changes in the technical condition of the machine is shown by a feedback loop. In the event that vibration is measured, for which the measuring device (MD) is used, and vibration analysis (VA) is carried out, automatically or manually controlling the machine in order to maintain dynamic quality at a given level, then a feedback loop is implemented. The implementation of this communication circuit is the task of the vibration monitoring system [4-7].

3 Results and discussion

Below are examples of the use of vibration monitoring systems developed by us for various production tasks.

By the state of an object, we mean a set of state parameters S_1, S_2, ... S_n, characterizing the essential properties of the elements of the object and their connections, forming the n-dimensional vector S_n (S_1, S_2, ... S_n) of the state.

Assessment of the technical condition can be carried out based on the results of direct measurement of state parameters or by indirect signs - diagnostic signals, characterized by a generalized vector Y_m (y_1, y_2, ... y_n), if the state parameters are not accessible to direct control, and the parameters of diagnostic signals X_1, X_2, … X_m can be measured directly. We can say that information about the technical condition of an object is contained in encoded form in the parameters of the diagnostic signal. The functioning of an object with this approach can be considered as a process of encoding an m-dimensional vector signal.

The vibration monitoring method consists in the fact that the technical condition is determined not by the state vector S_n, which has n components and associated with the diagnostic signal vector Y_m, containing m components, but by a specially defined vector of diagnostic signals Y, which has an arbitrary number of components available for direct measurement, and sufficiently reflecting the technical condition of the object. This approach does not require disassembling the machine, which is known to have a negative impact on its performance and can be called control in the space of vibration features. The main task when using it is to select a minimum set of features in the space of diagnostic signals that sufficiently fully reflect the technical condition of the test object. The state parameters S_1, S_2, … S_n are not determined with this approach, and not only their values are not significant, but also their quantity and nomenclature. The diagnostic parameter gives an integral characteristic of the technical condition of the object.

An example of such control is monitoring the vibration state of a certain mechanism based on the vibration level in a standard frequency band and comparing it with the standard value. Determining the frequency band in which the vibration level increases most intensively make it possible to limit the class of possible causes of failure.

In the general case, the vector of vibration signs can be associated with a vector of states

$$Y_m = A \cdot S_n \tag{1}$$

Where - A is an operator associated with the method of operation of the object.

The task of determining the components S_1, S_2, ... S_n of the state vector based on measurements of vibration signal parameters represents the task of vibroacoustic diagnostics

$$S_n = A^{-1} \cdot Y_k \tag{2}$$

where - A^{-1} is the inverse operator.

This task is called object identification.

Technical condition of the object, i.e., the complete minimum set of state parameters characterizing the structural and functional properties of an object in state space or the corresponding minimum set of diagnostic parameters can vary from one object to another, even in the case of objects of the same type, as a result of manufacturing errors and associated variations in structural parameters (the size of gaps in connections, imbalance of rotating masses, misalignment, etc.).

During operation, the vector state may change due to various types of wear, deformation, etc., this will be reflected in a change in the vector signal Y_K:

$$Y_k(y_1, y_2, \ldots\ldots, y_k, t) = A \cdot S \cdot (S_1, S_2, \ldots\ldots S_m, t)$$

With a change in time, one (or several) state parameters can reach the limiting value S~, while the object passes from a normal state to a limiting state, characterized by the vector S_m ~. According to (2), the limit state in the state space can be associated with the limit vector – signal

$$Y_k\left(y_1, y_2, \ldots\ldots, y_k t_p\right)$$

where - t_p is the operating time during which the limit state of the conditional resource is reached.

It should be noted that often the value of the limit values of state parameters is assigned based on the inadmissibility of the occurrence of intense vibrations. An example of this can be: the designation of maximum clearance values in bearings, requirements for the quality of balancing of rotors, etc. It is believed that with an increase in the level of vibration, the likelihood of failure of a mechanism or machine as a result of breakdowns or due to intense wear increases. Therefore, in cases where, as a result of changes in structural parameters, dynamic loads change significantly, causing a change in reliability, it is more correct to normalize the values of vibration parameters that are directly related to reliability indicators, as well as monitor their changes in order to predict the occurrence of a limit state. This is the main task of vibration monitoring.

To solve this problem, the most difficult question is to find an algorithm for determining the vector signal Y_K, which, given limited and often insufficient information about the object, would make it possible to most accurately and reliably judge changes in the state space, allowing early detection of defects developing in the object.

In some cases, depending on the design and operating conditions of the object, such algorithms can be simple (for example, finding the root mean square value of vibration velocity in a standard frequency range) or much more complex: for example, based on the Fourier transform, Hilbert transform, spectral analysis, energy measurement pulses, statistical recognition methods, etc.

In the most general form, the problem of vibration monitoring can be formulated as follows. Due to various degradation processes developing in individual elements of operating machines in accordance with the second law of thermodynamics, the entropy of a technical system increases and, as a result, the machine eventually goes from a working state to an inoperative state. The lower the rate of increase of entropy, the more work the machine can do, the more benefits it can bring, and therefore, the higher its quality. It is well known in cybernetics that the only way to slow down the upward tendency of entropy is by obtaining useful information about the system.

Vibration monitoring systems are created to obtain such information. The quality of the vibration monitoring system is ultimately determined by how much the rate of entropy growth decreases, i.e., the increase in useful work that a machine can perform over its maximum service life.

The requirements for such a system, which largely determine its quality, boil down to the following:

1. Accuracy of monitoring results.
2. Timeliness of monitoring results.
3. Reliability of monitoring results.
4. Detection of incipient defects at early stages.
5. Processing and storing a large amount of information.

Such an information-measuring system can reduce the rate of entropy growth in three possible ways:

1. Selection from the entire variety of machines of the same type with the required reliability indicators (quality control task).
2. Determination of points in time to restore working condition (adjustment, replacement of individual elements, resumption of lubrication, etc.)
3. Effective identification of elements limiting the life of the machine and making design changes (use of new wear-resistant materials, use of surface-active additives to lubricants, changes in fits, etc.)

Depending on the problem being solved, the choice of diagnostic features is also determined. The best requirement for diagnostic signs is their sensitivity to changes in parameters that most affect the quality of functioning of the controlled object. Moreover, these signs must be invariant to other parameters (for example, modes and external conditions of machine operation, external random disturbances, etc.)

Either single absolute indicators (for example, the root mean square value of vibration velocity in a certain frequency band), or multidimensional values (harmonic amplitudes at various frequencies), or combinations of various parameters can be used as diagnostic signs.

When monitoring manufacturing defects in a machine with rotating parts, such as gearboxes and electric motors, at the operating stage, it is advisable to use low-frequency vibration parameters, which are recorded under certain operating modes, as diagnostic signs. It is often useful to monitor the vibration characteristics of an object during transient processes during acceleration or coasting of the machine. In these cases, it is sufficient to simply maintain the same experimental conditions.

Using low-frequency vibration, it is possible to quite effectively analyze possible manufacturing errors in rolling bearings and gears, balancing errors, assembly defects, etc.

The low-frequency region is (0.5, ... 5) f where - f is the rotation frequency, i.e., the main rotor speed of the machine. Vibration diagnostics of this kind should be carried out at the manufacturer. Or during acceptance control at the consumer. Moreover, it is advisable to provide each critical product with a vibration passport of the spectral characteristics.

On the contrary, installation defects, and especially defects that develop during operation due to wear or other irreversible processes, often turn out to be advisable to monitor by changes in high-frequency vibrations in the range of 10 ... 15 kHz.

High-frequency vibrations as a diagnostic signal have a number of advantages compared to low-frequency vibrations. Firstly, the parameters of the high-frequency signal are most sensitive to such processes as deterioration of the lubricity of oil, deterioration of lubrication conditions, friction and wear processes as a result of which, as a rule, a random vibration signal occurs, as well as for detecting the development of fatigue damage to bearing elements, the occurrence of cavitation processes in hydraulic systems, etc. Secondly, choosing high-frequency vibration as a diagnostic signal allows you to quite simply separate different sources of vibration in space, for example, separate the signals of different bearings, different bearing units, because High-frequency vibration attenuates most strongly as it propagates. Thus, the choice of high-frequency vibration as a diagnostic signal can provide a larger signal-to-noise value when monitoring changes in the state of an object during operation.

A normally functioning gear train, even in the absence of defects, can have very noticeable vibration activity. In this case, oscillations occur in a wide range of frequencies and can have a very complex composition and character.

Fluctuations in gears, including normally functioning ones, are a consequence of two main reasons - errors in the manufacture and assembly (installation) of gears and periodically changing tooth rigidity during the meshing phase.

When recording vibroacoustic signals generated by gear pairs, it is necessary to take into account the characteristic features of their operation.

1. Manufacturing errors consist of constant and variable errors in the tooth pitch. Installation errors manifest themselves in the form of violations of the alignment of shafts and misalignment of their axes, violation of side clearances, etc.

Periodic changes in the rigidity of the teeth and a constant error in the meshing pitch cause the appearance of oscillations in the vibration of the gear transmission at the tooth frequency and its harmonics

$$f_z = z_1 f_{r1} = z_2 f_{r2}$$

where - z_1, z_2 are the number of teeth; f_{r1}, f_{r2} – rotation speeds of the mating wheels.

Variable error in the engagement pitch and misalignment (distortions of the shaft axes) cause vibration at the rotational speeds of the shafts of both wheels and (or) at modulation frequencies

$$kf_{r1}, kf_{r2}, and\ mf_z \pm kf_{r1}, mf_z \pm kf_{r2}$$

(where - k, n, m = 1, 2,...).

2. The gear cutting error of each of the wheels of the gear pair leads to vibration associated with the number of teeth of the index wheel of the gear cutting machine by the equation

$$f_g = z_g k f_r$$

where - z_g is the number of teeth on the index wheel of a gear cutting machine, k=1,2, ...

3. The amplitude of harmonics in the spectrum caused by vibrations from gear pairs largely depends on the load transmitted by the gear pair. At idle speed, the gear pair generates a very weak signal, comparable to the noise of the vibration analyzer itself. With increasing forces transmitted by the gearbox, the amount of vibration from the gearing increases. This feature of the operation of a gear pair requires, in order to identify trends in changes in the technical condition of the gearbox, measurements under the same, preferably large, load. If measurements that differ in time are carried out at different loads of the gearbox, then all the results of these measurements will be unsuitable for comparative analysis when searching for changes that have occurred in the gearbox.

4. Often, so-called intermediate frequency components (f_m) can appear in the vibration spectrum of a gear transmission, usually appearing in multipliers approximately halfway between the rotor speed of the high-speed wheel and the gear frequency. Intermediate frequency components are a series of components that are multiples or non-multiple of the rotational speed of the gears. This vibration has an insufficiently clear mechanical nature. Although there are several theories that explain its occurrence, none of them combines all the facts related to the behavior of intermediate frequency components. The most preferable assumption is that the root causes of the occurrence of these frequency components are the natural frequencies of the gear elements, and it is very likely that they are the result of resonant excitation, for example, during vibration-impact processes in the meshing. In some cases, monitoring the amplitudes of intermediate frequency components can serve as a very sensitive primary indicator of the onset of various defects in a gear drive. At the same time, the amplitudes of intermediate frequency components are very sensitive to changes in the operating conditions of the unit, especially to changes in the load of the unit, and the relationship between the intensity of vibration attributable to these components and the magnitude of the load can be nonlinear and almost always unstable. Therefore, using the

amplitudes of intermediate frequencies as a parameter for assessing the technical condition and residual life of a gear transmission is not always the correct method.

5. Vibration from re-coupling of teeth is non-stationary in the sense that it consists of several phases of "rolling", more precisely, "sliding" of tooth over tooth, which differ for different types of gearing. Each of these phases excites oscillations of different frequencies, close in frequency to the frequency of re-coupling of the teeth. Each of the teeth, due to its specific differences from other teeth, generates its own frequencies.

This is also compounded by the fact that pairs of "mutually rolling" teeth are constantly changing. This usually leads to the appearance of a noise component in the vibration spectrum of the gear transmission, the dispersion of which changes with operating time in accordance with the development of local wear, i.e., decreases during the running-in process of the wheels, is practically unchanged during normal operation over a sufficiently long period of time and grows exponentially in the process of intense wear - the so-called "pink noise". This term in technology usually refers to a mixture of oscillations of different frequencies in a limited frequency range, in contrast to "white noise" - a mixture of oscillations with the same amplitude over the entire frequency range.

6. Very often, "pink noise" occurs not only at the frequency of re-coupling of teeth, but also at the frequency of the natural resonances of the elements of a gear pair or gearbox. This occurs for the following reason. Micro impacts in the gearing excite vibrations over a fairly wide range, but the maximum amplitude of vibrations will be, which fully corresponds to the standard physical picture of vibrations, at the natural resonance frequency of one or another closely located gearbox element. This self-resonance frequency is determined by the design of the gearbox. It is necessary to use diagnostics of the state of a gear pair not by the frequency of tooth re-coupling, but by the natural resonance frequencies of the gearbox elements when diagnosing the technical condition of high-speed multipliers, where the frequency of re-coupling of teeth can be very high and the vibroacoustic signal will be greatly attenuated. Registration of the high-frequency component of vibration generated by the gear pair of the multiplier is difficult due to the large damping decrement of high-frequency vibrations, especially in bearing clearances.

7. The noise component in the vibration spectrum can, superimposed on discrete natural frequencies of gear parts, cause resonance and the appearance of new spectral components. This can also be caused, for example, by the occurrence of parametric resonance in spur gears when separated vibration-impact oscillatory modes appear.

Frequencies of the components of the vibration spectrum and its envelope, used to detect and identify defects in gears using periodic vibration measurements (diagnostic signs)

Table 1. Frequencies characteristic of gear defects in in-line gearboxes.

Frequency	Type of defect manufacturing	Type of defect assemblies	Type of defect wear and tear
f_r	Imbalance	-	-
$k\times f_{r1}$ и $k\times f_{r2}$ (k = 1,2, less often 3 and 4), $m\times f_z \pm n\times f_r$ (m, n=1,2…)	Variable pitch error engagement	Misalignment (shaft misalignment)	-
$k\times f_r$ k= 1, 2...20 and higher	-	Increased lateral clearance between wheels	-
f_z	Constant error engagement pitch	-	-
$k\times f_z$, $k\times f_r$ noise growth Components $m\times f_m \pm n\times f_r$	-	-	Abrasive wear

(m, n=1,2…)			
$k \times f_r$, $m \times f_z \pm n \times f_r$, $m \times f_m \pm n \times f_r$ (Amplitude fluctuation, n= 0,1,2...)	-	-	Chipping teeth
$k \times f_r$, $m \times f_z \pm n \times f_r$, $m \times f_m \pm n \times f_r$ (Amplitude fluctuation, n =0,1,2...), growth of the noise component	-	-	Cracks and/or broken teeth

Forecasting the technical condition will make it possible to make the transition from calendar-based maintenance to maintenance based on technical condition, which can provide greater economic benefits. State prediction involves predicting either the state of an object at a predicted point in time, or the time interval during which the object will not change its state, i.e., will not move from the area of features characterized by the vector S_1 to the area with the feature vector S_1.

The most widely used methods for predicting the technical condition of machines are those based on extrapolation of retrospective data on the condition of an object obtained during vibration monitoring under operating conditions. To obtain data on changes in state during operation during vibration monitoring, trend analysis or, in other words, trend analysis is carried out. The task of predicting the state of technical objects is the analytical determination of the multidimensional vector of states S_n (S_1, S_2, … S_n) or diagnostic signals Y_K ($У_1$, $У_2$, … $У_k$) measured at moments t_1, t_2, … t_i, … t_m, it is necessary to determine their values at moments $t_j(j = m + 1, \dots, m + 1)$. The vector of predicted values $Y_m(t_j)$ at time t_j is represented as a function of several variables

$$Y_m(t_j) = F[\hat{A}, Y_k(t_i), \hat{C}, V(t_j)] \tag{3}$$

Where - $\hat{A}$ - operator for converting basic variables into predicted ones;

$Y_k(t_i)$ - vector of retrospective quantities measured at moments $t_1, t_2, \dots t_i, \dots . t_m$, if at the time of making the forecast $t - t_m$

$\hat{C}$ - forecasting operator reflecting the action of new factors when $t > t_m$ (at $t<t_m$ the influence of these factors is insignificant);

V (t_j) - forecast error.

A model of type (3) describes two types of processes determined by the influence of different factors, namely: those that continue at which $\hat{C} \to 0$, and those that begin (end) at which $\hat{A} \to 0$. In ongoing processes, gradual development prevails over discreteness, while beginning processes are themselves the result of abrupt change.

Most often, for vibration monitoring tasks of mining equipment, models are used in which $\hat{C} \to 0$, i.e.

$$Y(t_i) = F[\hat{A}, Y(t_i), V(t_j)]$$

The task of predicting the technical condition of an object using analytical methods is to obtain an array of retrospective values of the predicted parameter $Y(t_i)$, analyze it and identify a trend in the form of an approximating time function, determine the predicted value of the parameter $Y(t_j)$ and the forecast error. Then, based on the signal vector $Y(t_j)$ found as a result of the forecast, a conclusion is made about whether the object belongs to the normal state S_1 or the defective state S_2.

Finding the regression function Y(t) = f(t), which approximates the curve of changes in the analyzed process over time, plays a crucial role in the forecasting problem, since it essentially determines the results of trend extrapolation.

In problems of predicting the state of mining equipment using a vibration signal, the regression function Y(t) is usually approximated by a polynomial

$$Y(t) = b_0 + b_1 \cdot t + \ldots . + b_1 \cdot t^1 + \ldots + b_m t^m \quad (4)$$

where - b_0, ... b_m - regression coefficients determined from the results of measuring the parameter Y(t).

Coefficients b_1 of equation (4) with the accepted shape of the curve are determined in a standard way using the least squares method. The mathematical support for solving this problem is quite well developed.

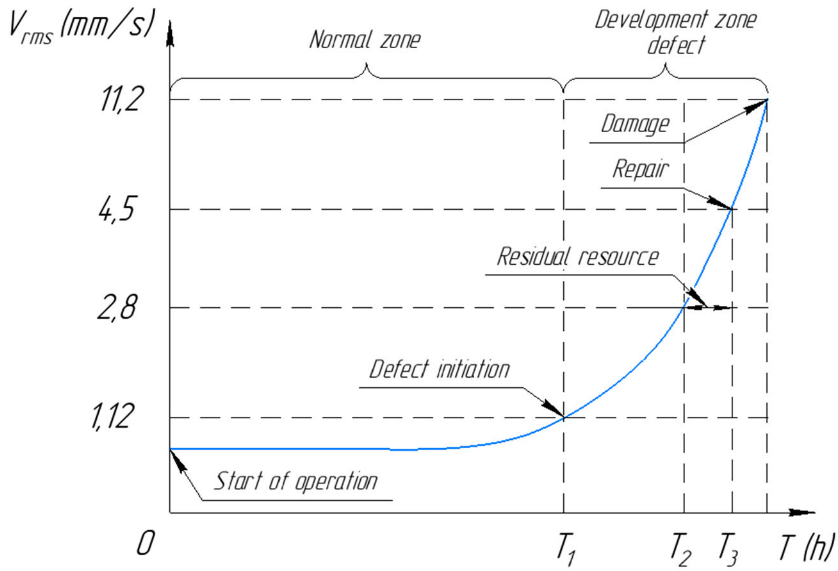

Fig. 3. Changes in the diagnostic parameter over time using polynomial linearization of the second degree, to estimate the residual life of gears of normal metal-cutting machines.

In Figure 3 During the initial period of operation, stable operation is observed. At the moment corresponding to the point, the wear rate increases, caused by an increase in the radial clearance. The onset of the moment corresponding to the point is accompanied by fatigue damage to the teeth of the gear wheels, which in turn causes an increase in the frequency components in the envelope spectrum and is accompanied by an increase in the rate of decrease of the generalized vibration parameter.

4 Conclusion

Based on the above, it can be argued that the level of vibration of a machine and its individual components clearly determines its technical condition.

Monitoring and monitoring the level of vibration parameters allows us to determine the nature of malfunctions in the mechanical and electromechanical systems of metal-cutting machines.

Analysis of the frequency spectrum of vibration parameters makes it possible to identify a faulty element of a mechanical or electromechanical system.

The most relevant is the introduction of a vibration monitoring system when diagnosing the technical condition of bearings and gears (metal-cutting machines, gearboxes, hydraulic systems).

A method has been developed for assessing the dynamic quality of metal-cutting machines using a complex quality indicator determined by measuring and analyzing the spectral characteristics of vibration signals.

As a result of the research, diagnostic models of changes in the technical condition of metal-cutting machines and vibration characteristics of typical defects were obtained.

References

1. Sh. Yakhshiev, I. Egamberdiev, A. Mamadiyarov, Kh. Ashurov, N. Khamroev, Res. Eng. Struct. Mater. **9**, 1 (2022)
2. A. Mamadiyarov, Theoretical & Applied Science. **90**, 325 (2020)
3. I. Egamberdiyev, U. Ochilov, N. Karimova, Texa. Jour. of Engg. and Tech. **20** (2023)
4. Doniyor Toshbotirovich, Material protection **64**, 161 (2023)
5. A. Zhumaev, K. Baranovsky, Yu. Mansurov, Kh. Akhmedov, Chernye Metally **2**, 4 (2022)
6. N. Karimova, U. Ochilov, Sh.Yakhshiev, I. Egamberdiev, E3S Web of Conferences **471** 02021 (2024)
7. B. Mardonov, Z. Oripov, R. Muminov, J. Ravshanov, N. Jo'rayev, E3S Web of Conferences **417** 06001 (2023).