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CONTROL OF TECHNICAL SYSTEMS BASED ON PREDICTION OF THEIR INDIVIDUAL RESOURCE

Contex. The actual task of forecasting an individual resource of a variety of design and design of technical systems was solved.

Objective. The purpose of the work is to develop a methodology for managing the operation of complex technical systems based on the forecasting of their individual resource.

Method. Modern management methods allow you to make advance management decisions to prevent accidents and the consequent technogenic catastrophes. These decisions are based on extrapolating the value of the monitored signal to the maximum permissible level. However, the norms are compiled based on average statistical data, which can only relate to a controlled sample of the machine with a certain degree of probability. This is the cause of errors in predicting the moment when this sample is stopped for repairs. This problem is especially urgent for complex and responsible technical systems manufactured in small series or even in single specimens. Such systems do not have statistical data to create these norms.

To solve this problem, another management methodology was developed that excludes the extrapolation procedure and allows determining the operating time of the technical system prior to repair based on the identification results of the model, describing the time variation of the value of the monitored parameter

Results. The methodology of management of technical systems is developed, ensuring the control of their current technical condition based on information on their individual resource. The methodology was used to control the gradual deterioration of the technical state of the hydro turbine, which resulted in its catastrophic destruction.

Conclusions. The performed calculations confirmed the efficiency of the proposed methodology for managing the operation of technical systems based on the forecasting of their individual resource, which makes it possible to recommend it for use in practice when solving problems of controlling the operation of complex technical systems, thus preventing their accidents, often leading to man-made disasters. Prospects for further research will be the development of a forecasting - diagnostic complex, the software of which reflects the algorithm for applying the developed methodology of forecasting an individual resource of various designs and designation of technical systems.

Keywords: control, individual resource, software product, rotor systems, resource forecast, identification, information signal trend, mathematical model, defect-free period, condition of supervised equipment.

NOMENCLATURE

VSS is vibration Severity Standards;

Ve is effective vibration rate;

[*Ve*] is vibration velocity effective level according to VSS;

Δ is both way gap between the shaft neck and sliding bearing sleeve;

n is number of revolutions ;

$\overline{Ve}$ is mathematical expectation of an effective vibration rate;

σ_V is standard distribution deviation;

$\overline{T}_r$ is machine resource predictive value;

ΔTr is life prediction variation ;

$\Delta[Ve]$ is machine bearing capacity variation;

H(*P*) is quintile of the normal distribution;

σ_{-1}, σ_i is the structural material fatigue limit and the current mechanical stresses value, respectively, for a symmetric cycle loading;

N_0, N_i is basic cycles number and the number of cycles that material can withstand at the mechanical stresses equal to the fatigue limit σ_{-1}, and at mechanical stresses σ_i, accordingly;

m is rate of the curve fatigue;

α is angle of inclination of the fatigue curve;

N_{LIFE} is total working life;

n_i is accrued operating time ;

A is oscillation amplitude;

t is operation time;

f_{LOAD} is certain repetition frequency;

k_{LOAD} is equipment load factor ;

ψ is the conversion factor (3600x24) in terms of calendar day and (3600x24x365) in terms of calendar years;

T_{RES} is required residual life;

T_{LIFE} is total calendar working life;

λ is exponent;

k is the approximating amount of data ($k > 2$);

T_{LB} is most probable value of the working life (lower border of a predicting time);

t_{CUR} is operating time of the machine at the time of the current control;

P is the machine reliability;

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Q is the probability of stopping the machine at the time of the current control;

δ is estimation error;

$\overline{A}$ is the degree change of the vibration level;

Ve_0 is the effective level of vibration velocity recorded at initial controlling;

μ, γ is coefficients of proportionality;

$[Ve]_{CR}$ is the maximum permissible level of effective vibration rate by vibration severity standards;

$\overline{V}$ is dimensionless rate of change of the monitored parameter;

T_{PPR} is the operating time before the next preventive maintenance;

T_{PR} is the predictable operating time before repair due to the unacceptable defect development degree;

t_0 is the operating time at initial controlling;

ξ is the weigh coefficient;

η is number of parameters, describing the monitored signal.

INTRODUCTION

The object of the study is the process of controlling technical systems based on the forecasting of their individual resource.

The number of man – made disasters in the world is growing because of the imperfection of methods for predicting the residual resource of various in design and designation of technical systems. The existing methods of controlling the technical condition of the controlled equipment are guided by the use of average statistical data on the maximum permissible value of the monitored parameter, which often leads to control errors.

The subject of the research is the methods of forecasting the individual resource of technical systems used in the control of their technical condition.

The purpose of this work was to develop a method for controlling technical systems based on the forecasting of their individual resource, carried out based on the identification of the trend model of the information signal generated by technical systems in the process of their operation.

1 LITERATURE REVIEW

There are a number of methods for assessing the resource of technical systems. So, for example, with probabilistic methods of calculating a resource, the number of intersections represents the operating time of an object under load by a centered process of zero level with the sign of the derivative greater than zero. This process is described by mathematical expectation and standard deviation. The representation of random and other processes using the indicated parameters makes it possible to describe, for example, the results of fatigue tests obtained under various types of loading (harmonic, polychromic, random, mixed) [1].

Parametric methods for assessing the condition and residual life of metal structures based on the non-destructive testing methods performed during the whole life cycle [2].

As a model for the distribution of failures of mechanical products, a monotonic diffusion distribution is used, which makes it possible to obtain the mathematical expectation of the residual resource [3].

One possible way of calculating the resource allocation is to use individual fatigue curves in the form of quintiles of the corresponding probability values [4, 5]. There are two possible approaches to the construction of such curves: direct and reverse. A direct approach is to find the resource allocation and determine the actual behavior of the samples based on these distributions. There is also a reverse approach to modeling the fatigue phenomenon. If resource distributions obtained based on are given tests, it is necessary to find random objects responsible for the fatigue behavior of the samples [6].

In determining the residual resource, methods based on the analysis of time series are widely used. These methods allow obtaining resource forecasts in the near future [7, 8].

However, these methods make it possible to obtain a satisfactory forecast only for relatively “stable” data, the trends of which are not prone to a drastic change. Consequently, their application is most suitable in conditions of stable operation of technical systems.

The analysis of the methods for estimating the remaining resource showed the advisability of further improving the methods for more accurate detection of faults in products at an early stage of operation. Estimation of the residual resource using such techniques is characterized by the use of a large number of multifactor dependencies, which excludes the expansion of the database in real time. Thus, the creation of techniques for obtaining the most informative signs of the technical state of the control object with the aim of further predicting the probability of failure of an object is an urgent task.

2 PROBLEM STATEMENT

There are two parts of the problem in controlling technical systems: diagnostics of the machine current state and predicting the onset of machine critical state and its stop for the repairs.

Many diagnosticians have been working and continue to work successfully at the solution of the first part of the task [9–11]. However, the second part of the problem as the most important for responsible machines has not found its effective solution yet. Prediction of source based on the analysis of development defects rate allows making management decisions in order to prevent accidents and technological disasters and to optimize the algorithm for repair of industrial equipment in real time.

The extrapolation methods are most commonly used methods for predict the service life of machines. This type of methods based on the definition the parameters of the approximating function, performed by the processing result of time series, which consist of the machine vibration levels, accumulated during periodic measurements of its oscillations. Further, the approximating function graph prolong to its intersection with maximum permissible vibration velocity effective level $[Ve]$ according to *VSS* [12]. The point of the abscissa intersection is a predictable life of the machine.

VSS represent the average statistical data of machines vibration with its nature of the disadvantage prediction method. That is why *VSS* relate to concerned sample machine only with a certain probability and condition of the model of machine viewed at present moment. For example, standards for third class machines shown on a linear diagram in Figure 1. There is principle of levels distribution of effective values vibration rate of that class rotate machine. The machine has the following parameters:

- shaft diameter is 100 mm;
- the number of revolutions n = 3000 rev/min;
- rotor mounted on sliding bearings.

The calculations performed in case where the slide bearing has H8/f8 landing class, which provides double amplitude variation of the gap Δ between the bushing and the shaft in the interval from 36/2 to 125/2 microns. The distribution principle of the machine vibration level generated by rotor limit movement in the sliding bearing gap when there is shaft neck running in around the circumference of the sleeve was obtained by “Monte Carlo” method. Effective vibration level calculated, using the following formula:

$$Ve = \Delta \frac{\pi n}{30} \frac{1}{\sqrt{2}} 10^{-3} \text{, mm/sec} . \qquad (1)$$

The following parameters of the normal distribution of vibration levels were obtained through the following calculation: Δ= 18…62.5 microns, n = 3000 rev/min, $\overline{Ve}$ = 9 mm/c; σ_V = 2.9 mm/c, ν = 0.32. The gap in the sliding bearings could be exhaust at the vibration level that does not reach the maximum permissible by standards in 77.8% of machines. This is shown in Figure 1. This leads to the fact that the vibration level as diagnostic feature, does not reach the maximum permissible by the standards ($[Ve]_{CR}$ = 11.2 mm/sec [12]), and machine bearings tests damaging limit load. Conversely, a stop for repairs due to the sliding bearings can be premature in 22% of cases, when reached the maximum level of vibration, and if the other machine components defects were missing at this time.

Manufacturing tolerances on the machine components leads not only to variations in machine vibration levels of its bearing capacity, but there is also the reason for predict resource of machine errors.

Consider the reason of these errors, when linear approximation function used at the prediction (see Figure 2):

$$Ve = \mu \cdot t \text{, mm/sec} \qquad (2)$$

Solving the equation (2) by t, and assuming, that the vibration level is equal to the maximum allowable value of the norms $[Ve]_{CR}$ in its left part, we obtain a demonstration of the machine resource predictive value:

$$\overline{Tr} = \frac{[Ve]_{CR}}{\mu} . \qquad (3)$$

By linking up the life prediction variation ΔTr with machine bearing capacity variation $\Delta[Ve]$ by previously known relation, the formula is:

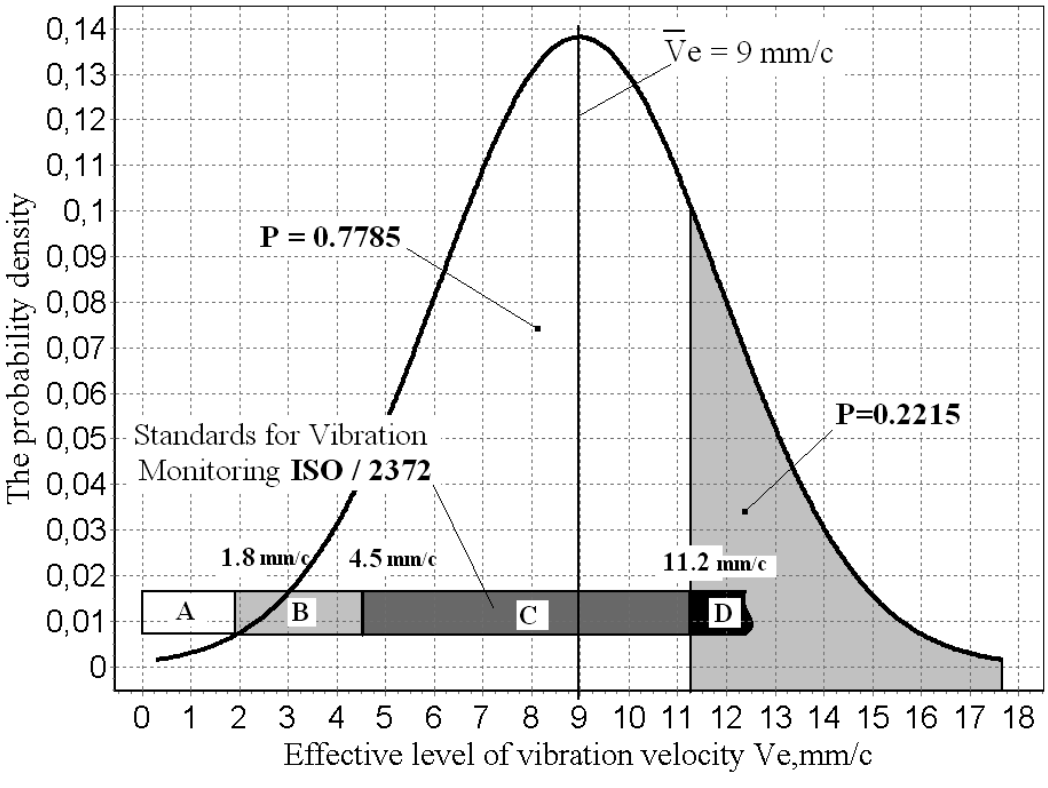

Figure 1 – The distribution principle of the effective vibration rate values and VSS

$$\Delta Tr = \frac{dTr}{dVe}\Delta[Ve] = \frac{1}{\mu}\Delta[Ve]. \qquad (4)$$

To simplify the demonstration (4) needs to divide the left and right parts of the equation (3).

$$\frac{\Delta Tr}{\overline{Tr}} = \frac{1}{\mu}\Delta[Ve]\frac{\mu}{[Ve]} = \frac{\Delta[Ve]}{[Ve]} = \nu. \qquad (5)$$

We solve the equation (5) relatively to prediction variation.

$$\Delta Tr = \nu \cdot \overline{Tr}. \qquad (6)$$

Taking into account the equation (6), prediction could be write in the following form

$$Tr = \overline{Tr} \pm H(P)\Delta Tr = \overline{Tr} \pm \nu H(P)\overline{Tr}. \qquad (7)$$

The equation (7) shows that the estimated forecast of the machine service life is 100 days. In fact, the actual service life varies with the probability 0.95 (H(0.95) = 1.645).from 47.4 to 152.6 days (see Figure 2). This difference between the real and calculated resources of the machine reduces idea of its prediction to zero. In this connection, it can be research for new prediction methods without any disadvantages. Thus, the analytical dependence should be use as an approximation function, reflecting the fracture mechanics of machines.

3 MATERIALS AND METHODS

Generally, machines operate in conditions of alternating force action and therefore their working life determined by the metal fatigue as well as depends on the load level and the duration of its action. Dependence of permissible mechanical stresses level of the number of cycles represented in the form of a fatigue curve (see Figure 3), which described by the following [13] equation:

$$\frac{\sigma_i}{\sigma_{-1}} = \left(\frac{N_0}{N_i}\right)^{\frac{1}{m}}. \qquad (8)$$

The equation (1) on the sloping part of the curve during the stress change from σ_1 to σ_i can be rewritten in the following way:

$$\frac{\sigma_i}{\sigma_1} = \left(\frac{N_1}{N_i}\right)^{\frac{1}{m}}. \qquad (9)$$

Residual life could be formulated through total working life N_{LIFE} that has the construction and accrued operating time n_i.

$$\frac{\sigma_i}{\sigma_1} = \left(\frac{N_{LIFE} - n_1}{N_{LIFE} - n_i}\right)^{\frac{1}{m}}. \qquad (10)$$

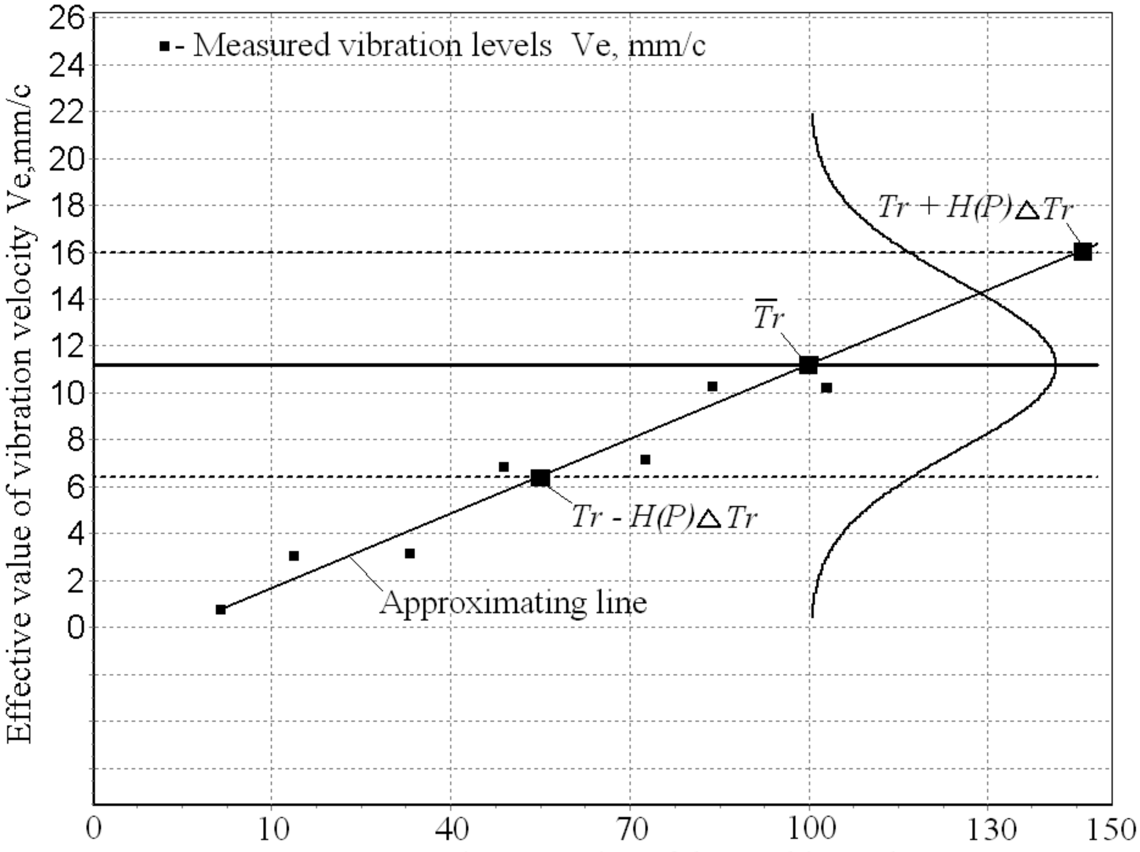

Figure 2 – Working life machine prediction at its bearing capacity variation

The Graph of the function (10) in Figure 4 shows a mirror reflection of the graph (9) in Figure 3. With increase of the number of operating cycle's n the mechanical stresses values σ submitted on the Graph (10) also growth.

The transition from the mechanical stresses to the oscillation amplitude *A* and from cycles to operation time *t* is necessary for practical usage of the formula (10). The nonlinear dependence between the oscillation amplitude *A* and a mechanical stress describes the equation below:

$$A = \gamma \cdot \sigma^{\beta}, \text{ mm/sec.} \tag{11}$$

The certain repetition frequency f_{LOAD} and the equipment load factor k_{LOAD} characterize effect of load. Instead of the number of cycles by entering a conversion factor the astronomical time (hours, days and years) is easily detect the operating time t_i:

$$t_i = \frac{n_i}{\psi \cdot f_{LOAD} \cdot \kappa_{LOAD}}. \tag{12}$$

The required residual life T_{RES} expressed through the total calendar working life T_{LIFE} and current operating time t_i:

$$T_{RES} = T_{LIFE} - t_i, \tag{13}$$

Total calendar working life T_{LIFE} can be express through the resource in cycles N_{LIFE}:

$$T_{LIFE} = \frac{N_{LIFE}}{\psi \cdot f_{LOAD} \cdot \kappa_{LOAD}}. \tag{14}$$

If the formulas (11–14) into (10) substitute, an expression relating the oscillation amplitude A with the current operating time t_i and its working life T_{LIFE} taken:

$$A(t) = A_1 \left(\frac{T_{LIFE} - t_1}{T_{LIFE} - t_i} \right)^{\lambda}. \tag{15}$$

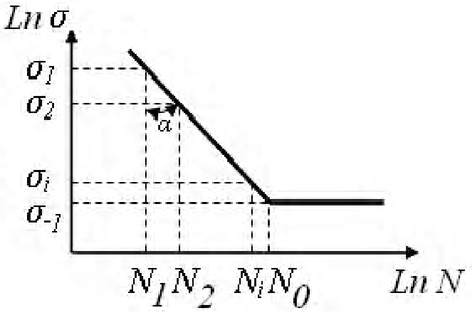

Figure 3 – The fatigue curve on a logarithmic scale

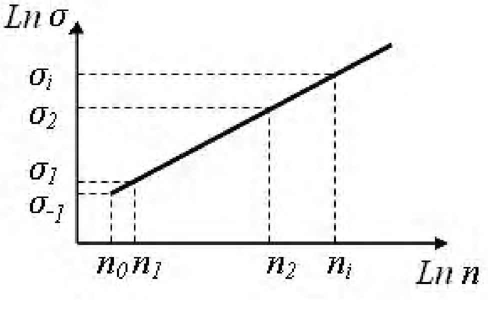

Figure 4 – Graph of the function (10) on a logarithmic scale

Required residual life and the exponent $\lambda = \frac{\beta}{m}$ determined parameters by computer approximation of regular monitoring vibration machines data. Functional minimum is determined during this processing:

$$U = \sum_{i=1}^{k} \left[\frac{A_i}{A_1} - \left(\frac{T_{LIFE} - t_1}{T_{LIFE} - t_i} \right)^{\lambda} \right]^2. \tag{16}$$

One can apply the estimation range of the resource predict. Minimize the functional (16) allows to define the top border of this interval. The most probable value of the working life considered as the lower border, calculated by the formula below:

$$T_{LB} = Q \cdot t_{CUR} + T_{LIFE} \cdot P. \tag{17}$$

Parameters *P* and *Q* are calculated based on the results of the resource definition ($P = e^{-\frac{t_{CUR}}{T_{LIFE}}}$, $Q = 1 - P$).

The equation (15) is an approximation model, obtained by transforming equation (8), that describes the fatigue curve. It seems reasonable to say that it was received proceeding from physical grounds. In contrast to the universal approach, when the approximation of the experimental data used graphics analytical dependences, selected on the base on formal mathematical considerations. The equation obtained because of the fatigue curve; therefore, it reflects the mechanics of destruction and its raise reliability of the prediction machine working life. The resource of the machine is a key parameter used to evaluate the criticality degree of the technical condition. However, to raise the reliability of diagnosis, the number of parameters describing the diagnostic feature could be increase.

Known from the information theory, that the system state estimation error δ is inversely proportional to the square root from the number of parameters, used to describe it.

$$\delta \approx \frac{1}{\sqrt{\eta}}. \tag{18}$$

Generally, the controlled signal described by a single parameter – its value. However, it does not provide information on the dynamics of deterioration of the machine. In this case, there are two parameters that describing the controlled signal: value of the signal *A* and the rate change of the its value *V* as an indicator of degradation of the machine technical condition. When the number of parameters, describing the monitored signal, increased to two, an error in estimating the state of the machine decreased by 30%.

For convenience, the size of the controlled parameter and the rate of its change lead to a dimensionless form. In this case, they range from zero to one. Complex (19) varies in the same range and these parameters includes in the complex as summands with weight coefficients.

$$F = \xi \cdot \overline{A} + (1 - \xi) \cdot \overline{V}. \tag{19}$$

Degree change of the vibration level:

$$\overline{A} = \frac{Ve - Ve_0}{[Ve]_{CR} - Ve_0} . \quad (20)$$

Dimensionless rate of change in the control feature:

$$\overline{V} = \frac{T_{PPR} - t_0}{T_{PR} - t_0} . \quad (21)$$

Recognition procedure of the defect development degree is comparing the actual value of the complex F with its boundary values (Table 1). Standard complex values shown in the Table 1. Typical values are dimensionless geometric progression with the denominator $q = \sqrt[5]{10}$. Similar geometric series of preferred numbers *R5* [15] are used in *VSS* [12].

The maximum value of complex F_{MAX} among the all calculated controlled machine defects used to estimate the degree of the machine criticality condition as a whole. Boundary values of machine condition characteristics as a whole presented in the Table 2.

4 EXPERIMENTS

The effectiveness of the developed methodology for forecasting the resource of a technical system in the process of controlling its state is demonstrated by the example of the destroyed turbine of Sayano-Shushenskaya (HPP). In the example, the state of the turbine is analyzed on the eve of its catastrophic destruction. The levels and dates of vibration measurements of the turbine, shown in Figure 5, were used, as input data for predicting the turbine's operating time before its failure.

Table 1 – Normalized degree of defect development and the corresponding boundary values of the complex F

No defect	The degree of defect			
	below average	the average	above average	inadmissible
$0 < F \le 0,25$	$0,25 < F \le 0,41$	$0,41 < F \le 0,63$	$0,63 < F < 1,0$	$F \ge 1,0$

Table 2 – Normalized conditions of the machine as a whole and the standard values of the complex F_{MAX}

No defect	Condition of machine			
	serviceable	able-bodied	should be improved	needs repair
$0 < F_{MAX} \le 0,25$	$0,25 < F_{MAX} \le 0,41$	$0,41 < F_{MAX} \le 0,63$	$0,63 < F_{MAX} < 1,0$	$F_{MAX} \ge 1,0$

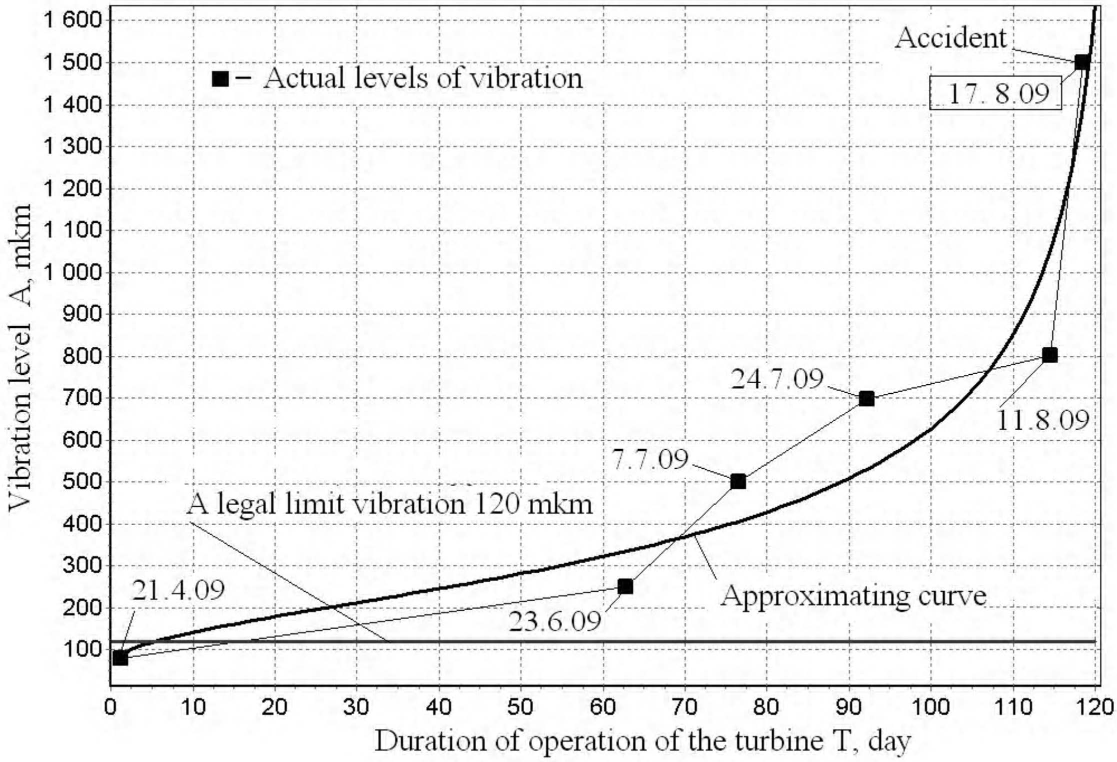

Figure 5 – Results of vibration control of hydraulic unit and its function approximation mapping the fracture mechanics of the metal

5 RESULTS

The diagnostic reports shown in Table 3. The information, given in these reports, indicates that the technical condition of the turbine deteriorated over time.

6 DISCUSSION

The results of the diagnosis show that two months before the disaster (17.8.09) in the protocol dated 23.06.09 was indicate that the degree of development of the imbalance of the rotor was "above average" and the operating time before repair was 2–3 weeks. The subsequent reports indicated that needed to stop the turbine and prediction working life was negative therefore stopping time for a repair was lost.

CONCLUSION

In the article, using the example of rotary machines, the results of research on developing a new methodology for controlling the operation of technical systems are presented.

The scientific novelty of the research results outlined in the article is that for the first time in the practice of controlling technical systems, it is wise to develop an entirely new methodology for predicting their individual resource, which allows to purposefully controlling the duration of system operation during the inter-repair period.

The practical significance of the results obtained is that the use of the methodology of forecasting an individual resource of a controlled system in the management of technical systems allows timely stopping them for repairs, which in the practice of their operation prevents accidents and subsequent technogenic catastrophes.

Prospects for further research are the development of a software product that reflects the algorithm of a new control methodology and the creation based on this product of an automated control system.

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Table 3 – Diagnosing reports

Date of diagnosis	Defect type and its characteristics	Hours before failure, T, day	Diagnosis of the machine
21.4.09	**Rotor imbalance:** the degree of development of the defect: **– above average**	–	Machine requires **inspection**. Reason: **– rotor imbalance**
23.6.09	**Rotor imbalance:** the degree of development of the defect: **– above average**	12–19	Machine requires **inspection**. Reason: **– rotor imbalance**
7.7.09	**Rotor imbalance:** the degree of development of the defect: **– above average**	8…17	Machine requires **inspection**. Reason: **– rotor imbalance**
24.7.09	**Rotor imbalance:** the degree of development of the defect: **– inadmissible**	25 …22	The machine **must be repaired.** Reason: **– rotor imbalance**
11.8.09	**Rotor imbalance:** the degree of development of the defect: **– inadmissible**	31…27	The machine **must be repaired.** Reason: **– rotor imbalance**
17. 8.09	**Rotor imbalance:** the degree of development of the defect**:** **– inadmissible**	**54…50**	The machine **must be repaired.** Reason: **– rotor imbalance**

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УПРАВЛІННЯ ТЕХНІЧНИМИ СИСТЕМАМИ НА ОСНОВІ ПРОГНОЗУВАННЯ ЇХ ІНДИВІДУАЛЬНОГО РЕСУРСУ

Актуальність. Вирішено актуальне завдання прогнозування індивідуального ресурсу різноманітних по конструкції і призначенню технічних систем.

Мета роботи – розробка методології управління роботою складних технічних систем на основі прогнозування їх індивідуального ресурсу.

Метод. Сучасні методи управління дозволяють заздалегідь приймати управлінські рішення для запобігання аварій і наступних за цим техногенних катастроф. Ці рішення ґрунтуються на екстраполяції величини контрольованого сигналу до гранично допустимого за нормами рівня. Однак норми складені на основі середньо статистичних даних, які можуть тільки з певною часткою ймовірності ставитися до контрольованого зразком машини. Це є причиною помилок при прогнозуванні моменту зупинки даного зразка на ремонт. Особливо актуальна ця проблема для складних і відповідальних технічних систем, виготовлених малими серіями або взагалі в одиничних екземплярах. У подібних систем статистичні дані для створення зазначених норм відсутні. Для вирішення даної проблеми була розроблена інша методологія управління, яка виключає процедуру екстраполяції і дозволяє визначати напрацювання технічної системи до ремонту за результатами ідентифікації моделі, яка описує зміну в часі величини контрольованого параметра.

Результати. Розроблено методологію управління технічними системами, що забезпечує контроль їх поточного технічного стану на основі інформації про їх індивідуальний ресурс. Методологія була використана при контролі за поступовим погіршенням технічного стану гідротурбіни, що закінчилося її катастрофічним руйнуванням.

Висновки. Проведені розрахунки підтвердили працездатність запропонованої методології управління роботою технічних систем на основі прогнозування їх індивідуального ресурсу, що дозволяє рекомендувати її для використання на практиці при вирішенні завдань управління роботою складних технічних систем, запобігаючи тим самим їх аварії, яки часто призводять до техногенних катастроф. Перспективи подальших досліджень будуть спрямовані на розробку прогнозно-діагностичного комплексу, програмне забезпечення якого буде відображати алгоритм застосування розробленої методології прогнозування індивідуального ресурсу різноманітних по конструкції і призначенню технічних систем.

Ключові слова: управління, індивідуальний ресурс, програмний продукт, роторні системи, прогноз ресурсу, ідентифікація, тренд інформаційного сигналу, математична модель, період бездефектної роботи, стан піднаглядного обладнання.

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УПРАВЛЕНИЕ ТЕХНИЧЕСКИМИ СИСТЕМАМИ НА ОСНОВЕ ПРОГНОЗИРОВАНИЯ ИХ ПРОГНОЗИРОВАНИЯ ИХ ИНДИВИДУАЛЬНОГО РЕСУРСА

Актуальность. Решена актуальная задача прогнозирования индивидуального ресурса разнообразных по конструкции и назначению технических систем.

Цель работы – разработка методологии управления работой сложных технических систем на основе прогнозирования их индивидуального ресурса.

Метод. Современные методы управления позволяют заранее принимать управленческие решения для предотвращения аварий и следующих за этим техногенных катастроф. Эти решения основываются на экстраполяции величины контролируемого сигнала до предельно допустимого по нормам уровня. Однако нормы составлены на основе средне статистических данных, которые могут только с определенной долей вероятности относиться к контролируемому образцу машины. Это является причиной ошибок при прогнозировании момента остановки данного образца на ремонт. Особенно актуальна эта проблема для сложных и ответственных технических систем, изготовляемых малыми сериями или вообще в единичных экземплярах. У подобных систем статистические данные для создания указанных норм отсутствуют.Для решения данной проблемы была разработана иная методология управления, которая исключает процедуру экстраполяции и позволяет определять наработку технической системы до ремонта по результатам идентификации модели, описывающей изменение во времени величины контролируемого параметра

Результаты. Разработана методология управления техническими системами, обеспечивающая контроль их текущего технического состояния на основе информации об их индивидуальном ресурсе. Методология была использована при контроле за постепенным ухудшением технического состояния гидротурбины, закончившегося ее катастрофическим разрушением.

Выводы. Проведенные расчеты подтвердили работоспособность предложенной методологии управления работой технических систем на основе прогнозирования их индивидуального ресурса, что позволяет рекомендовать ее для использования на практике при решении задач управления работой сложных технических систем, предотвращая тем самым их аварии, часто приводящие к техногенным катастрофам. Перспективы дальнейших исследований будут заключаться в разработке прогнозно-диагностического комплекса, программное обеспечение которого отражает алгоритм применения разработанной методологии прогнозирования индивидуального ресурса разнообразных по конструкции и назначению технических систем.

Ключевые слова: управление, индивидуальный ресурс, программный продукт, роторные системы, прогноз ресурса, идентификация, тренд информационного сигнала, математическая модель, период бездефектной работы, состояние поднадзорного оборудования.

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