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HARDWARE COMPLEXES FOR TECHNICAL CONTROL OF TECHNICAL CONDITION PARAMETERS OF SELF-PROPELLED SPRAYERS

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Abstract. The main indicator used for reliability research is hardware systems of technical control of parameters of technical condition of self-propelled sprayers, which means the probability that a self-propelled sprayer will be operational at any time, except for planned periods during which the use of self-propelled sprayers is not expected. Derivation of analytical expression for hardware systems of technical control of parameters of technical condition of self-propelled sprayers is a rather time-consuming operation. The complexity increases with the complication of the graph, ie in an effort to take into account more technical conditions, factors that affect the process of technical control of self-propelled sprayers. Therefore, it is advisable to solve the problem of such a plan using a simulation model. Using the stateflow modeling tool of the MatLab software package, a model has been developed that allows modeling discrete-event models. Model of self-propelled sprayers among Stateflow for estimating the coefficient of readiness during technical control of programs. The results of simulation modeling are the values of hardware complexes of technical control of parameters of technical condition of self-propelled sprayers in various technical control programs, which allows to draw conclusions about the influence of technical control program of self-propelled sprayers on the readiness factor. It is quite justified in cases when the technical control differs only in the place of measurement of the parameter of technical condition, and the means of measurement are the same. The author found that the hardware systems of technical control of the parameters of the technical condition of self-propelled sprayers are sensitive to errors of the second kind in this case. Ways of further research are found in the study of other programs of technical control of self-propelled sprayers, in which the readiness factor is sensitive to the probability of errors of the first kind.

Key words: simulation model, parameter, self-propelled sprayer, technical control, technical condition.

Introduction

The analysis of existing instrumental and software systems for determining the operational characteristics of technical objects of self-propelled sprayers was carried out [1].

The methods of mathematical modeling of the states of the technical object of self-propelled sprayers are analyzed [2].

The advantages of using an acoustic signal coming from the investigated technical object of self-propelled sprayers in order to identify the operational state are determined [3].

The methods of filtering, spectral and wavelet analysis and artificial intelligence algorithms that allow automatic processing of audio signals are analyzed [4].

Formulation of problem

The analysis of existing complexes of vibro-acoustic analysis of technical objects of self-propelled sprayers was carried out [5]. The advantages and disadvantages of these software systems are revealed [6].

Known software package Discriminant, designed to analyze the state of the mechanisms of the cyclic type [7]. The complex implements a set of methods for analyzing the results of vibroacoustic measurements:

- the method of S-discriminants, which implements a multiband analysis of vibration signals clipped in amplitude and is used for early detection of changes in the vibration signal under study [8];
- methods of spectral analysis for the study of the spectral characteristics of the vibration signal [9];
- methods of statistical analysis [10].

One of the main features of the software package is the implementation of wide possibilities for post-processing the results of the calculations [11]. The software package allows you to identify trends in vibration signal changes [12], formulate hypotheses linking these changes with the technical condition of the equipment [13], and test these hypotheses using the results of several alternative analysis methods [14]. Thus, the software package solves not only monitoring tasks [15], but also identifies individual problems of diagnosing the control object [16]. For example, sharp changes in the value of the S-discriminant in any of the frequency bands indicate the occurrence of technical problems in the operation of the test object [17]. Using the result of the analysis of the frequency distribution of the vibration signal [18] and the dependence of this distribution on the operating time, it is possible to test various hypotheses that explain the increase in the values of S-discriminants [19].

The complex does not implement automatic diagnostics.

Analysis of recent research results

Known software-tool complex for diagnosing the technical condition of Watson [20]. This complex ensures the collection, storage and processing of measurement information coming from sensors when conducting research on the service characteristics of engineering products [21]. With the help of this complex it is possible to produce: vibration monitoring; diagnostics; sorting and comparative evaluation of the quality characteristics of engineering products; identify the causes of deviations in performance characteristics from the specified ones and carry out their refinement, which makes it possible to reduce the volume and terms of tests created and studied samples of complex technical systems [22]. The disadvantage of this complex is the lack of automatic diagnostics of components and assemblies [23].

A known system of vibroacoustic monitoring of the technical condition of reciprocating machines [24]. Functionality of this complex: determination of vibration velocity and vibration displacement signals; analysis of the spectral characteristics of the signal; analysis of the spectral composition of the signal envelope; correlation analysis; determination of damping properties of structural elements; time-frequency signal analysis and detection [25]. The software package implements a new method for linking frequency-time representations of signals to the phase of machine operation, which is used in the synthesis and calculation of a frequency-time quadratic detector for monitoring the technical condition of the object under study, which does not require additional hardware [26]. The operator completely determines the set and sequence of actions performed on the signals, choosing the fragments of the signal that are of interest to him and setting the transformation function [27].

The disadvantage of this complex is the need for complete control of the analysis process by a person [9]. The inability to diagnose technical objects of non-reciprocating action [2].

The analysis of existing complexes showed the need to create a software and hardware complex that can automatically determine the state of a technical object, be able to clean diagnostic signals from noise, and also adapt to diagnosing a wide range of technical objects [17].

Works are devoted to the study of methods of mathematical modeling of the states of technical objects. There are several types of models that can be used to describe the properties of some given signal [11]. These types of models can be divided into a class of deterministic and a class of stochastic models. Deterministic models use some known specific properties of the signal. For example, the signal may look like a sinusoid, or it may be represented as a sum of exponentials [3]. In such cases, determining the signal model is not a difficult task, since for this it is only necessary to estimate the values of its parameters, such as amplitude, frequency, phase, exponent, etc. The second class of models are stochastic models that describe the stochastic properties of the signal [14]. These models include Gaussian processes, Markov processes, hidden Markov processes, Bayesian networks, neural networks, etc. These stochastic models are based on the assumption that the signal can be described by some parametric random process and that the parameters of this process can be estimated with a sufficient degree of accuracy [7].

The state of the technical system is determined using a set of parameters or features. The studied parameters are characterized by physical quantities that have a continuous distribution of feature values [2].

The set of parameters x_n, characterizing the state of the technical object, forms a set of parameters [24]:

$$X = \{x_1, x_2, \dots, x_n\} \quad (1)$$

The observed real state of the object corresponds to the actual values of the parameters, due to which, as a result, each instance of the object corresponds to a set of parameters [9].

For research, the range of possible values of the measured parameter is divided into intervals, and the main thing is the presence of the parameter in this interval. The result of a quantitative study can be represented as a feature that takes several possible states [19].

In general, the sign of k_n is the result of observation, which can be expressed in one of the digits. We are interested in systems in which states are characterized by a set of features [1].

A sign that has one possible state $(n = 1)$ is single-digit. It does not carry any practical value, and is not considered in the problem of determining the state of an object [25].

The statement of the recognition problem in the probabilistic approach is as follows:

- there is a system that is in one of n random states D_i. The possible states of the system (D_i diagnoses) are assumed to be known a priori [14];
- a set of parameters X is known, each of which characterizes the state of the system with a certain probability [2];
- it is required to build a decision rule, with the help of which the result of the inspection of a technical object is determined [9];
- it is desirable to assess the reliability of the decision and the degree of risk of an erroneous decision [21].

In the deterministic approach, the recognition problem can be conveniently formulated as follows:

- if the system is characterized by a multidimensional vector, then any state of this system is a point in the n-dimensional space of parameters (features) [8];
- it is assumed that each possible diagnosis D_i corresponds to some area of the considered feature space [4];
- it is required to find a decision rule, according to which the presented (implemented in the object under study) vector X will be assigned to a certain area of diagnoses [22].

Thus, in the deterministic approach, the problem of recognition is reduced to the distribution of the feature space into areas of diagnoses [18].

The areas of diagnoses in the deterministic approach are usually considered non-overlapping, i.e. the probability of one diagnosis is equal to one, and the probability of others is zero. Similarly, it is assumed that each feature either occurs in a given diagnosis or is absent.

Purpose of research

Purpose of research is description of the analytical position of the evaluation of hardware complexes for technical control of the technical condition of self-propelled sprayers.

Research results

Probabilistic recognition methods are more general, but require a much larger amount of preliminary information. However, the results obtained using these methods are more accurate. In the case of building systems for monitoring phenomena, the probabilistic approach is the most promising.

Tire noise is a continuous, non-stationary signal distorted by interference and reverberation of vehicle components and assemblies, aerodynamic noise.

Therefore, it is relevant to develop a mathematical model for determining the state of tires by analyzing the sound signal. The signal model can be used to create a system that will optimally remove noise and these distortions. Second, the signal model is important because it provides information about the source of the signal (the operating state of the bus that generated the signal). Not having direct access to the bus. This property is especially important, since the cost of diagnosing a tire is very high. With a good signal model, you can simulate the source and study it with the degree of accuracy that such simulations provide. And finally, the most significant reason for the use of signal models is that in practice they often provide exceptionally good results, enabling the effective implementation of important practical systems of prediction, recognition, and identification.

With a non-contact method for determining the state of the tire during operation, noise is always present in the recorded signals, so the first stage of signal processing should be associated with the removal of noise.

To obtain a clean signal that excludes noise, various filtering methods are used. Direct Filtration Method:

$$s + n \to Filter \to \hat{S}$$

where s – signal, n – noise, $\hat{S}$ – cleaned signal.

Usually, direct filtering is used as methods for obtaining a clean signal. In this case, two approaches are usually used for direct filtering.

In the case when the structure of the signal and noise is known, fixed filters are usually used that pass the frequencies containing the signal and block the frequencies corresponding to the noise.

To clean the signals of technical objects, which in most cases are non-linear, non-stationary, from ambient noise, adaptive filtering is used. Filtering does not require any prior information about signal and noise properties.

The adaptive filter automatically adjusts to the noise impulse response to minimize the error. The criterion for assessing the quality of filtration is the mean square error.

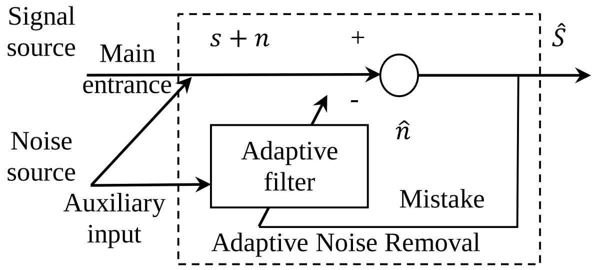

Fig. 1. Scheme of the adaptive filter

As shown in fig. 1 adaptive filter has two inputs: main and auxiliary. The signal under study $s + n$ is fed to the main input.

A noise signal n_0 is applied to the auxiliary input. This noise signal is not correlated with the main signal, but has a relationship with the noise component n. The noise n_0, passing through the adaptive filter, is converted to $\hat{n}$ in order to approximate the noise contained in the signal n. This noise is subtracted, and the signal $\hat{S}$ is obtained at the filter output.

The goal of the output noise filtering system is to obtain the signal $\hat{S} = s + n - \hat{n}$, which will be the best approximation to the signal s, in connection with which the calculated result at the output again passes through the adaptive filter, where the least squares method minimizes the discrepancy between the result and reference signal s.

Let us represent s, n_0, $\hat{n}$ and y as statistically stationary, and having arithmetic means equal to zero. The signal s is uncorrelated with n_0 and $\hat{n}$, but $\hat{n}$ is correlated with n_0, then:

$$\hat{S} = s + n - \hat{n} \to \hat{S}^2 = s^2 + (n - \hat{n})^2 - 2 \cdot s \cdot (n - \hat{n}). \quad (2)$$

Hence the signal energy at the output $E[\hat{S}^2]$ is equal to:

$$E[\hat{S}^2] = E[s^2] + E[(n - \hat{n})^2] - 2 \cdot E[s \cdot (n - \hat{n})] = E[s^2] + E[(n - \hat{n})^2] \quad (3)$$

The signal energy $E[s^2]$ will not be distorted if the filter is set to minimize $E[\hat{s}^2]$:

$$minE[\hat{s}^2] = E[s^2] + minE[(n - \hat{n})^2]. \quad (4)$$

Herefore, if the filter is set to minimize the energy of the output signal $E[\hat{s}^2]$, then the energy of the noise component of the signal $E[(n - \hat{n})^2]$ will also be minimal.

Since the output signal remains stationary, the expression is true:

$$(s - \hat{s}) = (n - \hat{n}). \quad (5)$$

This corresponds to the condition that $\hat{s}$ is the best approximation to s by the method of least squares.

Consider the filtering algorithm. Let the input discrete random signal $s(x)$ be processed by a non-recursive discrete filter of N order, the coefficients of which are represented by the vector $(w_0, w_1, \dots, w_n)^T$. Then the output of the filter is:

$$\hat{s}(x) = u^T(x) \cdot w, \quad (6)$$

where $u(x) = [s(x), s(x-1), \dots, s(x-N)]^T$ the content vector of the filter delay line per step. In addition, there is an exemplary signal $d(x)$.

The error during reproduction of this signal will be equal to:

$$e(x) = d(x) - \hat{s}(x) = d(x) - u^T(x) \cdot w. \quad (7)$$

It is necessary to choose such coefficients w that would minimize the expression (7). Thus, the optimization problem is reduced to the following expression:

$$J(w) = min[e^2(x)]. \quad (8)$$

The square of the error is:

$$e^2(x) = [d(x) - u^T(x) \cdot w]^2 = d^2(x) - 2 \cdot d(x) \cdot u^T(x) \cdot w + w^T \cdot u(x) \cdot u^T(x) \cdot w. \quad (9)$$

Averaging this expression statistically we get:

$$J(w) = \overline{e^2(x)} = \overline{d^2(x)} - \overline{2 \cdot d(x) \cdot u^T(x) \cdot w} + \overline{w^T \cdot u(x) \cdot u^T(x) \cdot w}, \quad (10)$$

where $\overline{d^2(x)} = \sigma^2$ – mean square of the reference signal, $\overline{d(x) \cdot u^T(x)} = k^T$ – the transposed vector k of the correlation between the reference signal sample and the contents of the filter delay line.

$\overline{u(x) \cdot u^T(x)} = R_s(m)$ – signal correlation matrix with dimensions $(N+1) \cdot (N+1)$. It looks like:

$$R_s(m) = \begin{bmatrix} R_s(0)\ R_s(1)\ R_s(2)\ \dots\ R_s(N) \\ R_s(0)\ R_s(0)\ R_s(2)\ \dots\ R_s(N-1) \\ R_s(2)\ R_s(1)\ R_s(2)\ \dots\ R_s(N-2) \\ \vdots\ \vdots\ \vdots\ \ddots\ \vdots \\ R_s(N)\ R_s(N-1)\ R_s(N-2) \dots\ R_s(0) \end{bmatrix} \quad (11)$$

where $R_s(m) = s(x) \cdot s(x-m)$ – random process correlation function $\{s(x)\}$. Taking into account the new notation, (10) takes the form:

$$J(w) = \sigma^2 - 2 \cdot k^T \cdot w + w^T \cdot R_s(m) \cdot w. \quad (12)$$

One of the most common adaptation algorithms is the least mean squares method. In this case, the vector of filter coefficients $w(x)$ must be updated recursively:

$$w(x+1) = w(x) - 0{,}5 \cdot \mu \cdot grad[J(w\{x\})] = w\{x\} + \mu \cdot k - \mu \cdot R_s(m) \cdot w\{x\} \quad (13)$$

where $grad[J(w\{x\})] = 2 \cdot k - 2 \cdot R_s(m) \cdot w\{x\}$ – gradient vector; μ – gradient step.

The algorithm converges if $0 < \mu < (2 \cdot \lambda_{max}^{-1})$, where λ_{max} – the maximum eigenvalue of the correlation matrix $R_s(x)$. In practice, to calculate the gradient, it is enough to know the estimates of the values $R_s(x)$ and the vector k. The simplest such estimates will be the instantaneous values of the correlation matrix and the cross-correlation vector:

$$\widehat{R_s}(x) = u(x) \cdot u^T(x),\ \hat{k}(x) = d(x) \cdot u(x). \quad (14)$$

The using such estimates, expression (13) takes the form:

$$w(x+1) = w(x) + \mu \cdot d(x) \cdot u(x) - \mu \cdot u(x) \cdot u^T(x) \cdot w(x) = w(x) + \mu \cdot u(x) \cdot u(x)[d(x) - u^T(x) \cdot w(x)] \quad (15)$$

The expression in brackets, according to (10), is the difference between the reference signal and the output signal of the filter at step x, which is the filter error $e(x)$. Then expression (15) takes the form:

$$w(x+1) = w(x) + \mu \cdot u(x) \cdot e(x). \quad (16)$$

The algorithm based on expression (16) is called LMS (Least Mean Square, least squares method). LMS convergence analysis shows that the upper step limit in this case is smaller than when using true gradient values.

$$\mu_{max} = 2 \cdot (\textstyle\sum_k \lambda_k)^{-1} = 2 \cdot [(N+1) \cdot \sigma^2]^{-1}, \quad (17)$$

where λ_k – eigenvalues of the correlation matrix $R_s(m)$, and σ^2 – the mean square of the filter input.

The main advantage of the LMS algorithm is its extreme computational simplicity - to adjust the filter coefficients, $(N+1)$ pairs of multiplication and addition operations are performed at each step.

Based on the analysis carried out, it can be concluded that in order to solve the problem of developing mathematical modeling methods for automating the process of analyzing the technical condition of an object of self-propelled sprayers from ambient noise, the adaptive filtering method is suitable, since, unlike conventional filters, cleaning by removing certain frequencies corresponding to noise component of the signal, the adaptive filter adapts to changing noise characteristics, which makes it possible to achieve effective signal filtering under conditions of randomly changing noise components. This method should be used to filter the acoustic signal from ambient noise in mathematical modeling to automate the process of analyzing the technical condition of an object of self-propelled sprayers.

Conclusions

1. The most promising systems for analyzing the technical object of self-propelled sprayers are in-place diagnostic systems by removing sound or vibration information. There is a need to develop mathematical modeling methods to automate the process of analyzing the technical condition of an object of self-propelled sprayers in order to increase its efficiency.

2. The study of modeling methods has shown that the most promising approach in solving the problem of determining the technical condition of an object is a probabilistic one. This method is universal, but requires much more preliminary information than the deterministic approach. Nevertheless, the results obtained within the framework of the probabilistic approach are more accurate, which is the key point in creating a system for determining the state of a technical object.

3. Analysis of existing software and hardware systems showed that with a wide range of mathematical tools for analyzing signals, the results of diagnosing technical systems of self-propelled sprayers, these complexes allow monitoring the current state, but do not solve the issues of automatically determining the state of a technical object, and therefore there is a need creation of a software package for automatic determination of the state of the technical object of self-propelled sprayers.

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АППАРАТНЫЕ КОМПЛЕКСЫ ТЕХНИЧЕСКОГО КОНТРОЛЯ ПАРАМЕТРОВ ТЕХНИЧЕСКОГО СОСТОЯНИЯ САМОХОДНЫХ ОПРЫСКИВАТЕЛЕЙ

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Аннотация. Основным показателем, используемым для исследования надежности, являются аппаратные комплексы технического контроля параметров технического состояния самоходных опрыскивателей, под которым понимается вероятность того, что самоходный опрыскиватель окажется в работоспособном состоянии в произвольный момент времени, кроме запланированных периодов, в течение которых применение самоходных опрыскивателей по назначению не предусматривается. . Вывод аналитического выражения для аппаратных комплексов технического контроля параметров технического состояния самоходных опрыскивателей – довольно трудоемкая операция. Трудоемкость растет с усложнением графа, то есть при стремлении учесть больше технических состояний, факторов, влияющих на процесс технического контроля самоходных опрыскивателей. В этой связи решение задачи такого плана целесообразно проводить с помощью имитационной модели. С помощью инструмента моделирования Stateflow программного пакета MatLab разработана модель, позволяющая моделировать дискретно-событийные модели. Модель самоходных опрыскивателей среди Stateflow для оценки коэффициента готовности при проведении технического контроля над программами. Результатами имитационного моделирования являются значения аппаратных комплексов технического контроля параметров технического состояния самоходных опрыскивателей при различных программах технического контроля, что позволяет сделать вывод о влиянии программы технического контроля на самоходные опрыскиватели на значение коэффициента готовности. Вполне обоснованы в случаях, когда технический контроль отличается только местом измерения параметра технического состояния, а средства измерения при этом одинаковы. Автором установлено, что аппаратные комплексы технического контроля параметров технического состояния самоходных опрыскивателей чувствительны к ошибке второго рода в данном случае. Пути дальнейших исследований встречаются в исследовании других программ технического контроля самоходных опрыскивателей, в которых коэффициент готовности чувствителен к вероятности ошибок первого рода.

Ключевые слова: имитационная модель, параметр, самоходный опрыскиватель, технический контроль, техническое состояние.

АПАРАТНІ КОМПЛЕКСИ ТЕХНІЧНОГО КОНТРОЛЮ ПАРАМЕТРІВ ТЕХНІЧНОГО СТАНУ САМОХІДНИХ ОБПРИСКУВАЧІВ

І. С. Любченко

Анотація. Основним показником, що використовується для дослідження надійності є апаратні комплекси технічного контролю параметрів технічного стану самохідних обприскувачів, під яким розуміється ймовірність того, що самохідний обприскувач опиниться у працездатному стані у довільний момент часу, крім запланованих періодів, протягом яких застосування самохідних обприскувачів за призначенням не передбачається. Виведення аналітичного виразу для апаратних комплексів технічного контролю параметрів технічного стану самохідних обприскувачів – досить трудомістка операція. Трудомісткість зростає з ускладненням графа, тобто при прагненні врахувати більше технічних станів, чинників, які впливають процес технічного контролю самохідних обприскувачів. У зв’язку з цим розв’язання задачі такого плану доцільно проводити за допомогою імітаційної моделі. За допомогою інструменту моделювання Stateflow програмного пакету MatLab розроблено модель, яка дозволяє моделювати дискретно-подійні моделі. Модель самохідних обприскувачів серед Stateflow для оцінювання коефіцієнта готовності під час проведення технічного контролю за програмами. Результатами імітаційного моделювання є значення апаратних комплексів технічного контролю параметрів технічного стану самохідних обприскувачів при різних програмах технічного контроля, що дозволяє зробити висновки про вплив програми технічного контролю самохідних обприскувачів на значення коефіцієнта готовності. Цілком обґрунтовано у випадках, коли технічний контроль відрізняється лише місцем вимірювання параметру технічного стану, а засоби вимірювання при цьому однакові. Авторкою встановлено, що апаратні комплекси технічного контролю параметрів технічного стану самохідних обприскувачів чутливі до помилки другого роду в даному випадку. Шляхи подальших досліджень зустрічаються у дослідженні інших програм технічного контролю самохідних обприскувачів, у яких коефіцієнт готовності чутливий до ймовірності помилок першого роду.

Ключові слова: імітаційна модель, параметр, самохідний обприскувач, технічний контроль, технічний стан.

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