

MODERNIZATION OF EXPERT SYSTEM BASED ON THE THEORY OF IDENTIFICATION MEASUREMENT

МОДЕРНИЗАЦИЯ ЭКСПЕРТНОЙ СИСТЕМЫ НА ОСНОВЕ ТЕОРИИ ИНДЕНТИФИКАЦИОННЫХ ИЗМЕРЕНИЙ

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Abstract: *The article presents the results of research in improving the reliability of the vibration-based diagnostics test results of industrial equipment. It is possible to achieve such results through the modernization of the expert system by applying the theory of identification measurement signals. It is proposed the conversion of vibration signals into the table clusters of standard names with known distribution laws. The technique of intelligent processing of vibration signals and measurable technology to create a special database connection clusters of quantitative and qualitative evaluation of a diagnostic condition of the equipment are considered in the article.*

KEYWORDS: VIBRATION DIAGNOSTICS, EXPERT SYSTEMS, COMPUTER APPLIANCES, IDENTIFICATION OF MEASUREMENT

1. Introduction

Many years of practical experience has shown that vibration method is one of the most informative in order to control the technical condition of machinery components.

The term "analysis of vibration signals" [1] involve the study of the functional dependence of the measured vibration parameters from one or more independent variables, moreover, time, frequency, spatial coordinate or the serial number in the group of independent vibration measurements are used more often as variables.

There are many methods for the analysis and processing of vibration signals [2]. Conventionally, they are divided into two groups according to the parametric representation:

- in the time domain: mathematical analysis of the waveform and the natural oscillations, statistical and correlation analysis;
- in the frequency domain: filtering, spectral and cepstral analysis, spectral analysis of the envelope, etc.

At present, on the basis of the above methods there is the introduction of "intellectualization" in vibration diagnostic equipment through the creation of expert systems for the condition monitoring and diagnostic of vehicles and machinery using wireless technology.

At present, the effect of the introduction of the expert systems for the condition monitoring and diagnostic of equipment is significant and is as follows [3]:

- reducing the amount and cost of repairs in 2-4 times;
- decrease in the quantity of spare parts due to a previously known nomenclature;
- decrease in the total duration of repairs, because they are planned in advance;
- exclusion of replacing non-defective parts.

Temporary and frequency analysis methods of vibration signals are implemented in the expert system. Quantitative vibration settings: vibro, velocity and acceleration are defined due to the temporary methods. When they are compared with the established critical values by a decision of the need to repair and remedy the defect equipment.

The basis of the frequency methods are the following: the analysis of the spectral envelope, the shock pulse method, the control of the state in a given frequency band, the analysis of the direct spectrum, etc. The main way to solve the vibration diagnostics involves the ability of frequency filtering of the informative component of the measurement signal, which then could be used as diagnostic indicators.

In particular, the appearance of the equipment defect is accompanied by a harmonic component in vibration signals of a certain frequency and amplitude, the proportional degree of a

defect influence. Consequently, the defect type and degree of wear can be set by filtering of vibration signals.

Despite the advantages of the expert systems use for vibration diagnostics, their work is considered to be insufficiently effective, as only 60-70% of the defects are recognized, the forecast accuracy reaches 0.6, they are highly specialized [4, 5]. The main reasons for the ineffectiveness of the existing expert systems are:

- significant methodological difficulties in building of an expertise database that reflect the skills of experienced professionals - experts;
- the complexity of creating a knowledge base and database, which would take into account all external actions of random disturbing factors, incomplete information about the object state, fuzzy information, vague judgments and decisions of administrative staff;
- the effect of the nature of the dynamics of industrial activity: change of the objects and products position in the space or change the status of objects and materials in time connected with the treatment processes;
- in spite of the significant advances in the field of artificial intelligence (AI), there is still a certain technological gap between technical developments, the AI software, and the possibilities of their practical application more widely;
- diagnosis and control of the state are carried out only on the statistical parameters of vibration and power consumption, however, more effective diagnosis and monitoring should be carried out on the dynamic changes of the parameters.

The authors propose to increase the effectiveness of vibration diagnostics of expert systems by applying the theory of identification measurement tools (ThIMT) to eliminate the above-mentioned reasons.

2. Preconditions and means for resolving the problem

ThIMT - a suite of intelligent technologies (methods and computer tools) identification, recognition and digital signal processing [6, 7]. The ThIMT content are the form measurement technology - the distribution of the instantaneous values and variability - the distribution of temporary signal intervals and its characteristics with the processing of the identification parameters in the structure of global standards using the identification scale (Figure 1), consisting of identification parameters testers (IdP-testers), database (DB) and the logic analyzer (LA).

IdP-testers convert the arrays of input signal characteristics of the IdP (identification parameters), which properties are subjected to the principles of scale invariance, equivalence and coherent order.

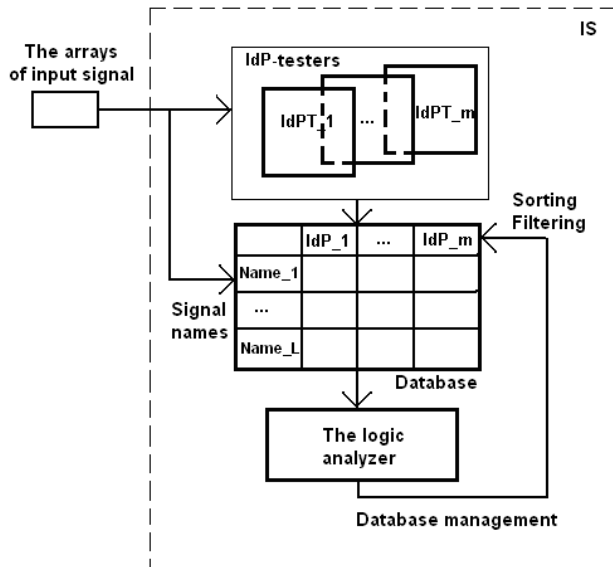


Fig. 1 Block diagram of the identification scale (IS)

Built-in database contains the values of identification parameters and the assorted names of shapes and variability of standards. The standards can act as signal characteristics of the object of certain conditions or signals with known distribution laws.

LA work is built on the issue of expert assessments (qualitative and quantitative), or recommendations of the identification measurement signal research and its characteristics, the use of methods and algorithms for sorting and filtering standards, comparison of the identification parameters of signals with reference values.

The feature of identification measurement is the ability to identify and recognize common characteristics of the composite signal and its increments: time, spectral, probability, correlation, wavelet, and most importantly, linguistic.

For research it is used the expert diagnostic system software, "IDS Kamerton- D" [8], developed by "ROS" scientific and production enterprise.

In contrast to the existing, the expert systems "ROS" SPE can be regarded as a class of intelligent systems with the following functions: measurement registration, automatic detection of object parameters, predicting failures and defects, making recommendations on the maintenance, preservation and maintenance of archive measurement records.

Mean square value (MSV) is used in orthogonal directions in the frequency range from 10 Hz to 1 kHz as parameters for the study of vibration, MSV vibration displacement and vibration acceleration in the relevant frequency band is exposed additional rationing.

Temporal and spectral characteristics of the vibration in orthogonal directions are formed as a diagnostic result. Examples of the diagnostic results at different measuring points on the centrifugal pump NM 12500-210 №12 of the pump unit are shown in Figure 2 - the real time characteristics of vibration signals and in Figure 3 - spectral characteristics of acceleration.

As seen in Figure 2, the temporal characteristics of vibration signals have a complex shape containing stationary and non-stationary components and describe their mathematical relations, internal linking structure of signals, is difficult.

However, using data ThIMT measuring signals are systematized and are suitable for the identification and recognition.

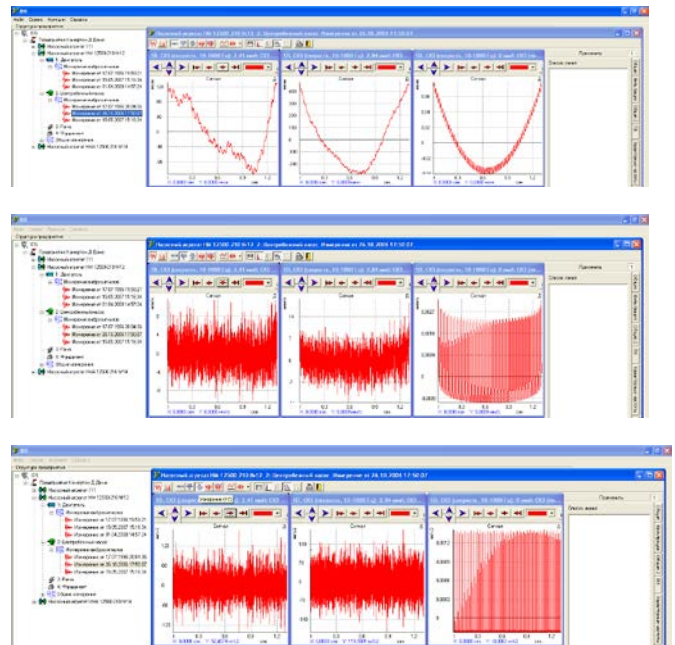


Fig. 2 The diagnostic signals in a centrifugal pump, the pump unit HM 12500-210 №12: the top row - characteristics of vibration displacement, medium - vibration, lower - acceleration.

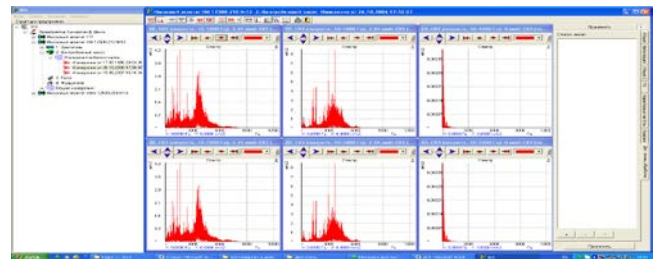


Fig. 3 Spectral characteristics of acceleration in the centrifugal pump, the pump unit NM 12500-210 №12

3. Results and discussion

The authors have been developed the intelligent computer system for the research. Its structure (Figure 4) was based on the main provisions of the theory of identification measurement and consists of a signal reader (SR), an identification signal analyzer (ISA), the comparator (C), the database of the reference signal (DBRS) tabular and hierarchical classifier (TC-HC), and the interpreter.

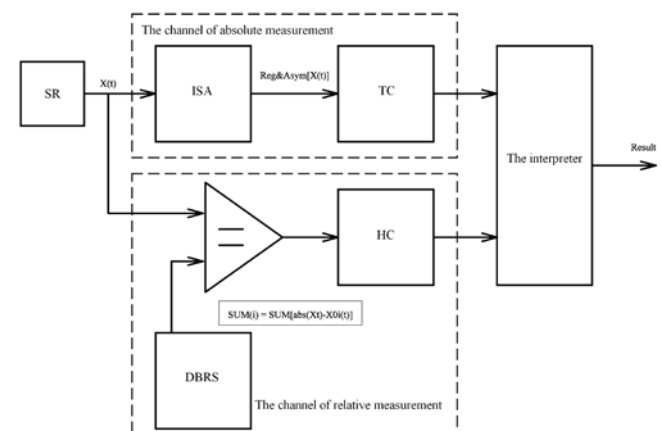


Fig. 4 Structural Studies scheme

The developed system is embedded in an expert system diagnostic software, "IDS Kamerton-D". The temporal characteristics of vibration signals from the software module "IDS Kamerton-D" are entered in an intelligent system with the help of the SR.

The test signals are analyzed by two channels: absolute and relative measurement (CAM and CRM). ISA unit measures some integrated identification parameters of signals, using which is possible to build a two-dimensional tabular classification (TC unit) – which was not used during the research.

The Comparator and DBRS are used to measure variations of the input signals from the system of 17 reference signals with the known distributions of instantaneous values: 2mod – two-modal; asin – arcsine; bern-l – Bernoulli, left; bern-r – Bernoulli, right; binom – binomial; even – uniform; exp-l – exponential, left; exp-r – exponential, right; GAMM – gamma; gaus – normal; kosh – Cauchy; lapl – bilateral exponential; pois – Poisson; rele – Rayleigh; simp – triangular; trap – trapezoidal distribution.

To estimate the total variance values study and reference signals have the same number of samples. The table of the average deviations values of all standards is automatically created as a result of the analysis. The HC unit sorts the reference signals of deviations for each of the input signals in order to be constructed then the classification tree out of the standard names.

The structure of the research system has been implemented as a computer device in LabVIEW environment. A number of relational databases has been produced in the form of tables in the EXCEL environment of identification measurement results – form view of temporal characteristics by different parameters as a result of the research. All of them are quite informative for coding, identification and detection of vibration signals.

In the interpreter (Figure 4), by sorting and filtering of database records, it is possible to build linear and tree classification linking signals filenames with diagnosable state of the object.

As a result of the research, the authors of the project developed the research computer device implementing data mining based on the identification measurements. A computer device is an intellectual analyzer, because it contains a built-in database of standards – assorted distribution of instantaneous values, automatically adjusts to a certain volume of the test sample of the input signal.

Figure 5 shows the front panel of the intellectual system. Vibration signals are automatically entered with the software module "IDS Kamerton-D" of the multi-channel diagnostic system.

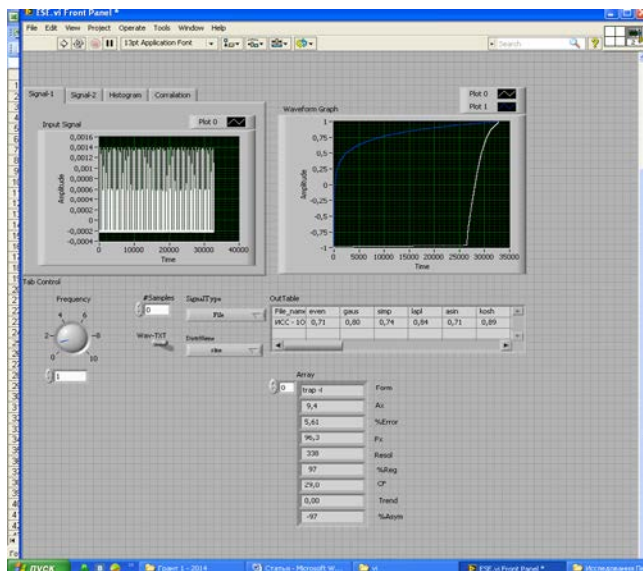


Fig. 5 Front Panel of the designed computer device

The monitor displays shows:
- a form of research signal;

- quantitative characteristics of the signal, required for analysis (amplitude, frequency characteristic, identifying the parameters of shape and variability of signal indicators and trend randomness, etc.);

- standard names of deviations from the distributions of instantaneous values of the test signal.

A lot of the time characteristics of vibration signals had been received as a result of the research. Their analysis of identification measurements using led to the following conclusions.

1. All items of diagnosis objects and every complex shaped vibration signal on the principle of assignment of the standard name with minimal deviation to the studied temporal characteristics can be represented in the form of a table cluster LC $[N * M]$ – identification table with linguistic characteristics of LD (the names of standards with known distribution laws). Each cluster of N – number of control points, M – the number of measurement parameters.

Table 1 shows examples of 4-cluster table 2 elements (motor and pump) with two characteristic states: "defect-free state" and "Defect - bearing runout" pump set HM 12500-210 №12. For each cluster table $N = 6$, $M = 3$.

Table 1: Examples of table clusters states NM 12500-210 №12

< Defect-free state >						
CP	Motor			Pump		
	D_V	V_V	a_V	D_V	V_V	a_V
1V	fract	fract	simp	even	gaus	gaus
1O	rele	fract	simp	rele	rele	gaus
1P	rele	rele	simp	even	gaus	lapl
2V	rele	even	simp	even	gaus	gaus
2O	even	kosh	simp	rele	rele	exp-l
2P	trap	trap	simp	even	gaus	exp-l
< Defect - bearing runout >						
	Motor			Pump		
	D_V	V_V	a_V	D_V	V_V	a_V
1V	gamm	fract	simp	pois	fract	even
1O	pois	rele	simp	rele	gaus	even
1P	rele	rele	rele	gaus	even	lapl
2V	even	even	simp	rele	gaus	gaus
2O	even	kosh	pois	gaus	gaus	exp-l
2P	kosh	rele	simp	exp-l	even	exp-r

* D_V – vibration displacement, V_V – velocity, a_V – vibration acceleration, CP – control points

2. Cluster representation of the objects elements state of diagnostics by the linguistic characteristics is convenient for the constructing of the volumetric bases of vibration diagnostic information data, thus to work with clusters it is required a simple mathematical apparatus.

3. Cluster representation of complex vibration signals has led to the possibility of modernization of the existing expert system (EES). Modernize EES structure is shown in Figure 6.

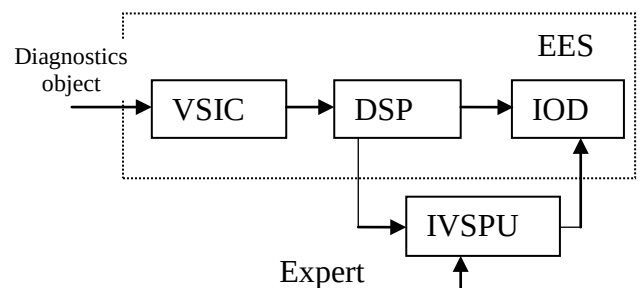


Fig. 6 Modernize expert system

EES includes the following elements: a block of vibration acoustic sensors with information converters (VSIC), multi-channel diagnostic signal processing (DSP) and an information output

display (IOD). Modernization was carried out by the inclusion of additional intellectual vibration signals processing unit (IVSPU), built on the basis of the developed computer device (Figure 5) with minor structural changes to be embedded into the EES.

In the diagnosis of EES it operates independently of IVSPU according to the established techniques and algorithms by the expert system developers, providing the expert with a diagnostic information in the form of graphs and numerical values of vibration parameters.

IVSPU operates in two modes: training and diagnostics. In the first case, it is created a special base table clusters LC [N * M] E (I) describing the state and defects of the diagnosed equipment and which subsequently act as standard. The initial information to create the database is a recommendation of an expert in non-destructive testing and diagnostics of the results obtained with the help of EES.

In the diagnostic mode, the analyzed signal is converted to a table cluster LC [N * M] X. With the method of element-wise comparison of the test cluster with clusters of standards recorded in the database, with LC [N * M] X = LC [N * M] E (I) the operator is provided a description of the equipment state with possible defects and recommendations for their elimination. In the absence of overlapping clusters IVSPU goes into teaching mode.

Thus it is conducted a comprehensive diagnosis with EES and intellectual processing of vibration diagnostic signals on the basis of identification measurements.

4. Conclusion

Modernization of vibration diagnostic expert system based on the application of the theory of identification measurement signals allow to offer a computer device that implements the conversion of vibrations into the table clusters. In this way it is possible to perform intelligent processing of vibration signals and create a special measurable database of clusters connection with quantitative and qualitative assessment of the complex objects state. The device is a complete intelligent device that is compatible with real multi-channel diagnostic complex software, "IDS Kamerton-D". During the experimental work it was found that the efficiency of diagnosis and monitoring is increasing. In particular, when the pump unit is studied, NM 12500-210 №12 accuracy assessment of the state and the probability of detection of defects increased by an average of 10%.

Intellectual power of the computer device depends on the number of used standards. Do this requires a number of technical measures for software modernization. However, in this form, the system allows us to solve many problems associated with the quantitative and qualitative assessment of the complex objects state.

It is considered the possibility of the developed technique using for the diagnosis of another type of equipment: pumping units, compressors and other rotating oil and gas equipment.

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5. Literature

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