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Features of measurement and processing of vibration signals registered on the moving parts of electrical machines

Abstract. *Measurement and processing of vibration signals registered on the moving parts of the electrical machines using the diagnostic information-measuring system that uses Bluetooth wireless standard for the transmission of the measured data from moving parts of electrical machine is discussed.*

Streszczenie. *W artykule opisano pomiar I przetwarzanie sygnałów odpowiadających wibracjom ruchomych części maszyn elektrycznych z wykorzystaniem standardu Bluetooth do przesyłania danych pomiarowych (**Proces pomiaru wibracji ruchomych części maszyn elektrycznych**).*

Keywords: vibration diagnostics, statistical methods, electrical machines, diagnostic expert systems.
Słowa kluczowe: in this line the Editor inserts Polish translation of keywords.

Introduction

When creating information-measuring systems (IMS) of diagnostics an important task is the adaptation of the developed mathematical model of the object of diagnostics in order to more accurately justification the diagnostic features.

In [1,2,4,5] reviewed the stages of construction and practical application of IMS of diagnostics moving parts of power machines using a wireless channel of Bluetooth standard for transmission of measured data from the block of sensors [4]. Created IMS of diagnostics allows research on the availability of certain types of defects in power machines that are diagnosed [5].

Problem statement and purpose of research

The aim of this work is research of vibration signals measured from the moving parts of rotary power machines using IMS vibrodiagnostics, based on the use of the Bluetooth standard for wireless transmission of the diagnostic information to verify the proposed mathematical model of researched signals and experimental verification of the diagnostic signs and assess the reliability of diagnostic results when changing the technical parameters of the IMS sensor unit.

Using an experimental sample of IMS vibrodiagnostics for investigation of the vibration signals

The vibrations at the point of placing an accelerometer on a particular node electrical machine, which is diagnosed in steady mode can be considered as the sum of random signals, coming in this point through different channels of distribution, that is:

$$(1)\quad \xi(t)=\sum_{j=1}^{N} a_j\,\xi_j(t),\quad t\in(-\infty,\infty)$$

where: N- some positive integer, determined by design, technological and operating properties of node, in which distributed vibration wave, aj - weight coefficients, that take into account the attenuation of vibration waves through the appropriate channels. The number N determines the number of resonances in researched node.

Component $\xi_j(t)$, $t\in(-\infty,\infty)$, which is part of (1), is a linear random process [3]. As a result, the process $\xi(t)$ is also a linear random process with certain probabilistic characteristics. The task of diagnostics reduces to the determination diagnostic signs by (1) , calculation and further analysis of statistical estimators and building the solving rules of diagnosing the technical condition and classification of defects in the researched system.

To obtain vibration signals was conducted technical modification of the developed IMS vibrodiagnostics compared to IMS vibrodiagnostics, which is given in [5] and adapt the application package, which provides statistical processing of diagnostic signals and building of resolving rules on diagnostics and classification of possible defects in the moving parts of power machines .

Technical part of IMS is constructed as a modular system that allows, after doing of minor changes, adapt the system for measuring and processing of various types of diagnostic signals. In the present work was conducted the improve block of sensors, which increased the frequency range of the measured vibration signal.

Previous researches by IMS of vibrodiagnostics [1,2,4,5] based on the use sensors of type ADXL202 manufactured by Analog Devices with a range of measuring vibration signal within a range from 0.01 Hz to 6 kHz. In this work executed the modification of the sensor unit and the sensor ADXL202 replaced by sensor ADXL001 manufactured by Analog Devices with a measurement range of vibration signal from 0.01 Hz to 22 kHz. Unlike sensor ADXL202, ADXL001 sensor has an analog output signal. Therefore ADXL001 accelerometer output is connected to 10-bit ADC, which is part of the PIC16F873 microcontroller manufactured by Microchip, by which the measured analog vibration signal converted into a digital signal for its further transmission via radiochannel Bluetooth by block of receiving and processing information. To ensure the measurement unit sensors acceleration on two axes of coordinates were used two sensors ADXL001 on each block of sensors.

After the modification block of sensors and block of receiving and processing information, that comprise the IMS, was performed measuring vibration signals from the moving parts of electric DC machine type P-51. Measurement of vibration signal consisted of two phases, which is the difference in the location block sensors on different nodes of electric machines: on the node of the connecting flange between the shaft of the electrical machine and the shaft bearing unit testing (Option 1) and on the shaft near the rack of plain bearings (Option 2) [5].

Carrying out experimental research

In a first variant of the experiment sensor unit was located at position "Option 1". Electrical machine worked at idle. Measurement of vibrations from node were conducted at a frequency of rotation of motor shaft 200 r/min. During IMS of vibrodiagnostics measured using accelerometers

vibration acceleration in digital form is transmitted via a radio channel to block of reception and processing of the information [2]. During the second variant of experiment block of sensors located in the "Option 2". Operation of electric machines wondered in the same mode of the first option experiment. To test the diagnostic signs and review opportunities to use IMS of vibrodiagnostics for diagnostics, each variant of the experiment was conducted twice: in the standard operating mode the investigated electrical machines and when the emergency work in artificial introducing warp of in the rolling bearing, which is in the node of test bearings. For the decision of a problem of formation of learning sets, the block of reception and processing of the information worked in a mode of learning.

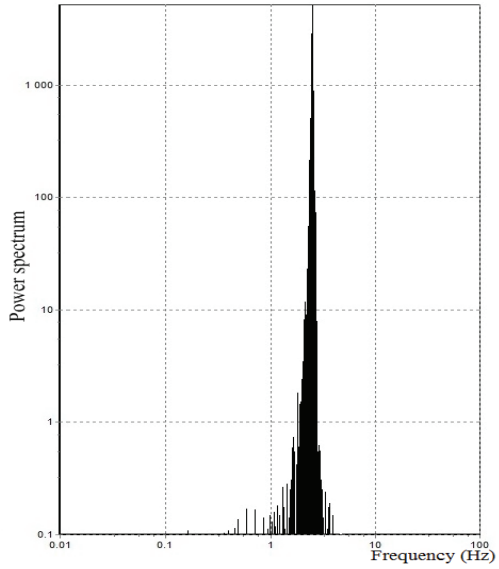

Fig. 1. Standard operating mode

Conducting experimental research in both cases confirmed the identity of the main components of vibration of signal measured from different parts that depend on the parameters of the electric machine during the research and its main characteristics, therefore in Fig. 1 and Fig. 2 presents spectrograms measured at position "Option 1" in the experiment of rolling bearings in standard mode and included warps, respectively.

Forming of learning sets

On the basis of research of mathematical model of vibrations of mobile units of electric machines by results of the lead experiments [2], diagnostic signs of a technical condition of units of power machines which can be used at the correlation analysis have been certain: number of points of extremum S_j, j = 1,2... on the certain interval of correlogram B *(s);* estimations of sizes of factors of attenuation β_j, $j = \overline{1, n}$; an estimation of size of factor of cross correlation R of vibrations of units of power machines; at the spectral analysis: amplitudes and frequencies of the basic maxima of the spectrogram; number of the basic maxima of the spectrogram in the fixed strip of frequencies.

For carrying out of diagnosing with use of such parameters, first of all, it is necessary to choose diagnostic spaces and to generate in the selected spaces of learning sets, which conformability the certain technical conditions of mobile units of researched power machines.

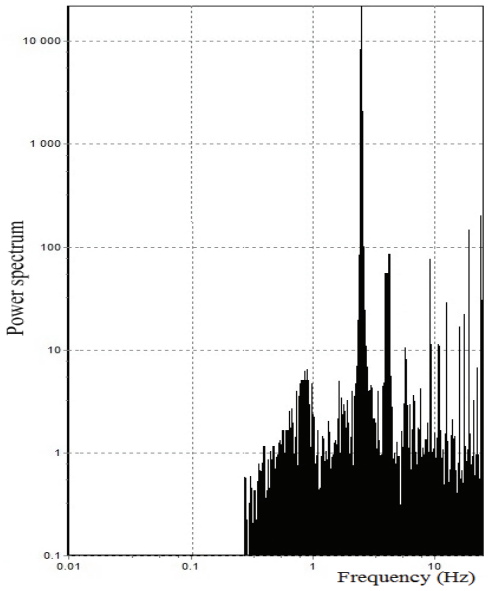

Fig. 2. Operation with warps

According to [3], learning sets is a set of those values of parameters, which correspond to conditionally serviceable condition of object of diagnosing or its condition, connected with presence of one of defects, which are diagnosed.

The source of the diagnostic information creates some process, which depends on diagnostic parameters, everyone with which represents a vector or a scalar. In the elementary case one parameter, which can accept two different values is considered only. Each of these values is answered with one of hypotheses: the basic H0 and alternative or competing H1.

The previous statistical processing is under construction thus, as if it is already known, what hypothesis is true. Being based on such knowledge, entirely certain point in space of supervision turns out. It is supposed, that at this stage some is added additive stochastic a component, which does not depend on hypotheses and which can arise both on an output of a source of the diagnostic information, and during its statistical processing. It creates value of diagnostic parameter, therefore with each hypothetical value of parameter the likelihood law of its distribution communicates.

The space of supervision comprises all possible values of measured parameters, which its can accept during experiment. As a result of influence of handicapes, in space of supervision of set of points, which correspond to different hypotheses, are crossed, and sometimes absolutely coincide. In this connection breakdown of space of supervision on not cross subsets of supervision – images, which correspond to each of hypotheses is done.

For forming learning training sets in diagnostic space has been lead two hundred experiments on research of vibrations of bearing assembly which arise during operation of electric machine П-51. On Fig.3 the introduced training sets constructed by results of the analysis of two hundred spectrograms of vibrations of bearing assembly that was investigated. Training sets represent histograms of number of maxima investigated spectrograms at a level 5. However, training sets are more convenient for building not under histograms, but on curves smoothing them which are included system of the Pearson. Construction of smoothing curves is realized by software which are a part of designed experimental sample of IMS. These programs are in detail described in [2].

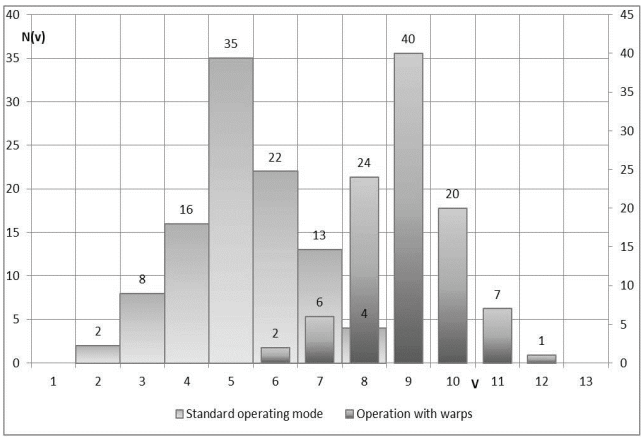

Fig.3. The learning presented in the form of histograms

On Fig.4 curves which smooth histograms of the averaged number maxima of spectrograms of vibrations of bearing assembly are presented. These curves are training sets in one-dimensional diagnostic space. Distribution of number, which corresponds to different conditions of bearing assembly, are displaced one concerning another and have different mathematical expectation:

$\Theta_1 = 4{,}42$ та $\Theta_2 = 8{,}52$.

For definition of a condition bearing assembly by forming on Fig.4 learning sets it is enough to construct deciding rules which are founded on the certain statistical criteria. So, for presented on Fig.4 of learning sets which are described close to normal to the law by curves of density of distribution, it is possible to take advantage well-known in statistics procedure checks of statistical hypotheses by Neumann-Pearson's rule [4].

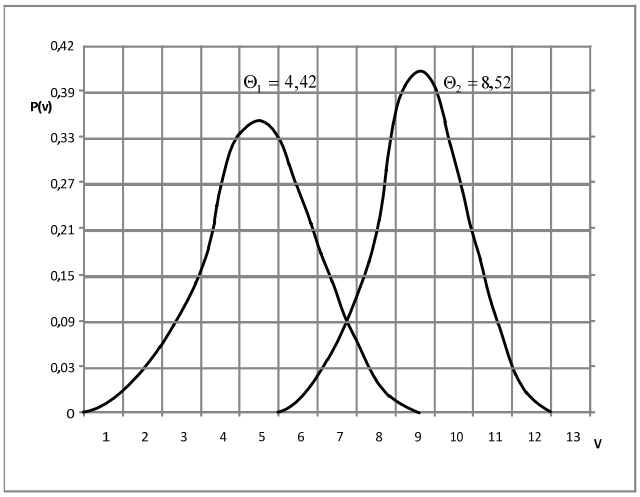

Fig.4 The learning sets presented in the form of curves of density of distribution

Conclusions

- Results of statistical analysis of diagnostic signals, measured at different operating modes of the object of diagnostics, providing the possibility of using IMS to diagnose faults of windings, bearings, magnetic circuit, mechanical imbalance.

- Increased frequency range of the measured vibration signal provided an opportunity to more accurately diagnose and expanded the scope of the IMS.

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