COMPREHENSIVE ASSESSMENT OF SIZE AND QUALITY CHARACTERISTICS OF THE WORKING SURFACES OF MACHINE PARTS

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The article outlines the basis for a new long-term approach to the assessment of size and quality characteristics of the working surfaces of machine parts. Show system relationship quality indicators surfaces and dimensional accuracy of parts. Presented experimental study the link between natural oscillations excited by the details and characteristics of dimensional accuracy and surface quality indicators such as the roughness and microhardness. An original technique based on the analysis of the natural oscillations of the acoustic signals of parts and establish links between their amplitude-frequency characteristics and the sought parameters of accuracy and surface quality of parts. The basis of the new methods is the use of mathematical formalism of neural networks, allowing you to create samples of a hardware implementation of this approach.

В статье изложены основы нового перспективного подхода к оценке размерных и качественных характеристик рабочих поверхностей деталей машин. Показана системная взаимосвязь показателей качества поверхностей и точности размеров деталей. Представлено экспериментальное обоснование существования взаимосвязи между возбуждаемыми собственными колебаниями деталей и их характеристиками точности размеров и такими показателями качества поверхности как шероховатость и микротвердость. Представлена оригинальная методика, основанная на анализе акустических сигналов собственных колебаний деталей и установлении связей между их амплитудно-частотными характеристиками и искомыми показателями точности и качества поверхностей деталей. Основой новых методов является применение математического аппарата нейронных сетей, позволившего создавать образцы аппаратной реализации такого подхода.

У статті викладені основи нового перспективного підходу до оцінки розмірних і якісних характеристик робочих поверхонь деталей машин. Показан системний взаємозв'язок показників якості поверхонь і точності розмірів деталей. Представлено експериментальне обгрунтування існування взаємозв'язку між порушуваними власними коливаннями деталей і їх характеристиками точності розмірів і такими показниками якості поверхні як шорсткість і мікротвердість. Представлено оригінальну методику, що заснована на аналізі акустичних сигналів власних коливань деталей і встановленні зв'язків між їх амплітудно-частотними характеристиками і показниками точності і якості поверхонь деталей. Основою нових методів є застосування математичного апарату нейронних мереж, що дозволив створювати зразки апаратної реалізації такого підходу.

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Improvement of the automated process control devoted quite a large number of scientific publications [2, 4]. Among the many principles and methods of monitoring occupy a special place non-destructive and non-contact methods of control.

One of the process operations is an operation control part dimensions. The importance of control operations in the structure of processes is difficult to overestimate, but their labor input is often a deterrent, need to search for alternative methods of quality control of components [8]. Automation of production processes, provides for control transitions CNC, however, and this step is followed by time-consuming, which also affects the processing performance.

The main problem associated with the improvement of manufacturing engineering products is a problem of increasing the productivity of production output by reducing the time and improve the reliability of control operations. It is necessary to offer a universal method of measuring geometric parameters of complex parts and characteristics of their quality. The solution, in our opinion, is to provide a method of diagnostics products with a sufficient size for the processing accuracy and reliability. To this end, the formulated hypothesis that the effect on the normalized stepwise controlled item is accompanied by its response having specific characteristics, in combination which can diagnose the magnitude and accuracy of dimensions of parts and other characteristics of their quality.

As the effects of a controlled item is proposed to use excited by feeding in the excitation circuit of the electromagnetic pulse caused by the discharge of the capacitor on the circuit inductance, located in close proximity to the controlled items. Since the excitation occurs in the resonant circuit RLC magneto initiates processes in the body parts, they can be fixed in the form of the reflected pulses of different frequencies, depending on the size and detail of the environmental distribution of these signals - metal density, phase composition and other characteristics. The nature of this phenomenon is associated with the occurrence of acoustic emission in metals. Of course, the study of this phenomenon in the light of the formulation of hypotheses theoretical methods is highly complex, and ultimately have a purely local result. Therefore, to study the effect of acoustic emission was decided to carry out pilot studies.

For experimental research capacity of this approach to improving the operations of the complex control of parts created quite simple experimental setup, which is a current source, a capacitive electric energy storage device, the electromagnetic coil to generate a magnetic pulse gap contactor.

The samples were used party details sketch is shown in Fig. 1. With the dimensions indicated in Table 1 below.

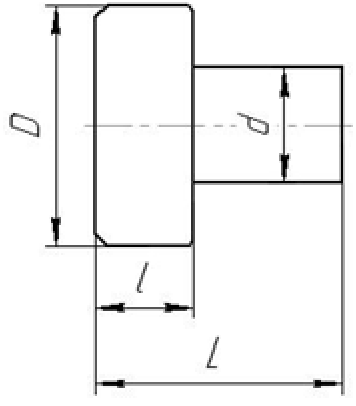

Fig. 1. Drawing of the experimental sample

Table 1

Lot size model details

№	D	d	l	L
1	49,729	29,974	19,970	50,251
2	50,006	29,956	19,979	49,924
…	…	…	…	…
15	49,934	29,938	19,935	49,818

The results of the amplitude-frequency characteristics in graphical and numerical form were recorded on a PC using the software package Scope.exe. Example spectrogram sob-governmental fluctuations samples is shown in Fig. 2.

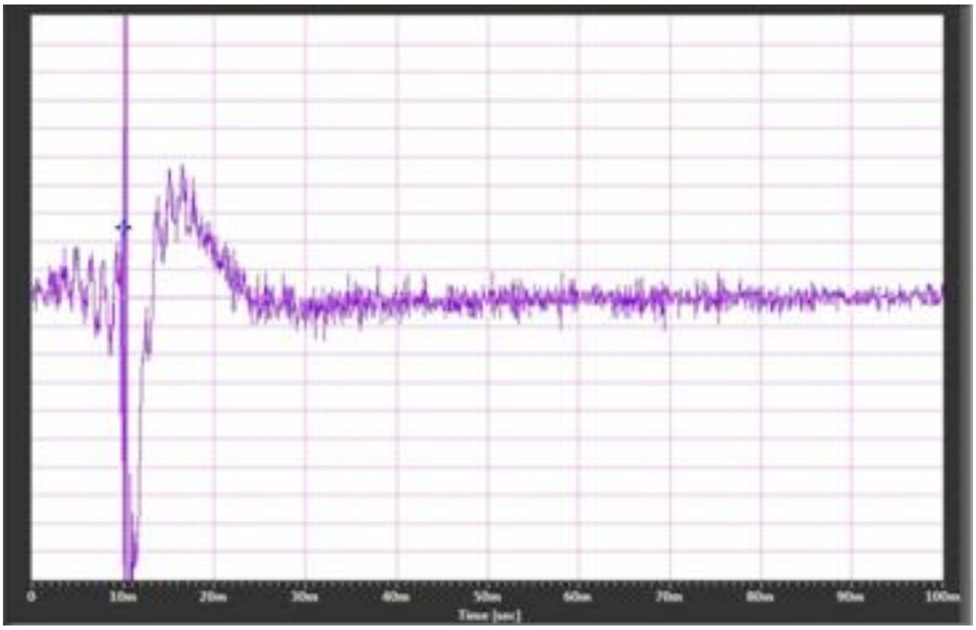

Fig. 2. The spectrogram of natural oscillations of the sample

The same results were obtained in a numerical format as a function of the amplitude of oscillation time (Table 2).

Table 2

Amplitude characteristics of sample

Time	Amplitude
0.0000	-0.009
0.0001	0.045
0.0002	0.014
0.0016	0.022
…	…
0.0998	-0.001
0.0999	0.045
0.0996	-0.024

Based on Fourier transforms data were processed in the amplitude of the frequency, as well as to further exclude errors normalize data. Each value of the amplitude have been assigned values from 0 to 1, where 0 - the minimum value of the amplitude 1 - max and other values - intermediate at a specified interval. The entire band is divided into 20 bands. Amplitudes, trapped in one range, summed to determine the integrated area of the spectrum sub-band. Data for each three measurements were averaged to reduce the error value.

The data obtained was formed a neural network, wherein X - of the amplitude-frequency characteristics of the parts, the input field, and Y - size parts, output field [9]. For this operation, the program used NeuroPro. Pre-built single-layer, two-layer and three-layer neural network comprising neurons 100 in each layer. with each layer with an accuracy of 0.001% Adjustment range of the tuple data of training sample. After the training, the number of networks of neurons, synapses, and inputs are reduced to the minimum number of neurons in each layer (Fig. 3).

As a result, the mathematical models obtained single-layer, two-layer and three-layer neural networks. All input and output fields are described by mathematical formulas that are needed to create the CPU parameter calculation details. Studies have shown that the least number of synapses is typical for a single-layer network. In this case, the processing speed is higher in monolayer network. A mathematical model which allows for two inputs - amplitude with a maximum weight, to determine the set of monitored parameters of parts of any configuration with high precision, the basis for a hardware implementation model. Implementation of the proposed principle of dimensional inspection of parts is possible with programmable microprocessors using verbal description of the conditions for the creation of an industrial unit. Based on these studies established a monitoring device. The scheme of installation is so simple that allows you to control parts in the course of treatment. Detail excited by a drive unit controlling signal - an electromagnetic pulse, which is followed by the response function in the form of the spectrum of the amplitude-frequency characteristics of the part. The amplitude-frequency characteristics of the processed block in processor calculations using further processor unit outputs the work piece dimensions. Thus, the installation cost is much lower in comparison with the other control devices, which is its advantage.

Thus, it is found that the information necessary to determine the size of parts based on the amplitude-frequency characteristics of the response signal when exposed to a pulsed electromagnetic field part material can significantly reduce the amount of information on the basis of a mathematical model of the data signal - 20 out of filter amplitude-frequency characteristics use the 2-3, and each corresponds to the size of its combination of filters. Increasing the number of simultaneously controlled size does not significantly increase the complexity of the model and the number of elements.

Previously we have indicated in our work that the geometric parameters of parts can be identified through the use of spectra of acoustic signals resulting from excitation of these stepped parts shock impacts. These are, in particular, the work, leading to complete group cutting tool insert for incorporation in a large milling and grinding wheels identify [5–7, 11–13]. However, the hypothesis of the relationship and the size of the spectra of acoustic signals allowed to form the basic principles of acoustic diagnostic techniques set features details, including dimensions, surface quality of parts, their physical and mechanical properties (Fig. 3).

We assume that if there is a correlation with the size of the items in the part of the excitation spectrum of the resonant vibrations, and there must be a relationship between a size details. Therefore, to investigate the possibility of acoustic diagnostic characteristics of parts involves two steps:

Stage 1 - study the relationship dimensions dimensional relationships of parts;

Stage 2 - feasibility study acoustic roughness and dimensional control of parts.

For the 1-st phase of the pilot study used a kit of parts in the amount of 100 pieces. The drawing of the experimental sample is shown in Figure 4.

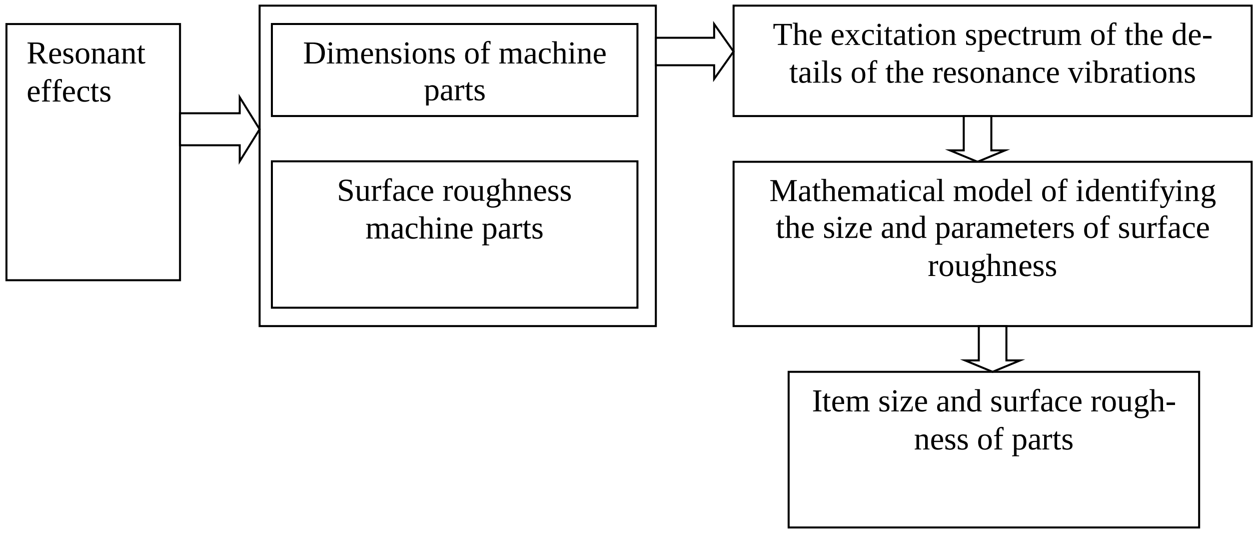

Fig. 3. The concept of acoustic diagnostic techniques sizes and roughness of the work piece surface

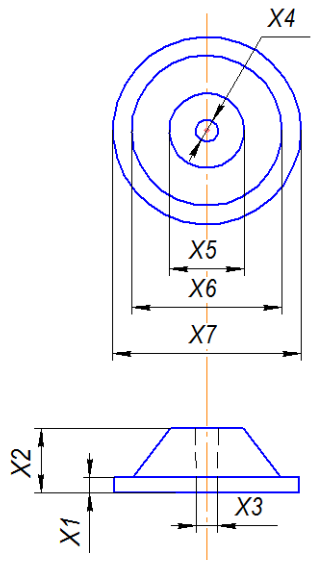

Fig. 4. Drawing of the experimental sample

Values sizes (Xi) and roughness (Yi) parts are summarized in Table 3:

Table 3

Results of measurement sizes (Xi) of indicators and rough parts (Yj)

1	X1	X2	X3	X4	X5	X6	X7	Y1	Y2
2	1,677	9,727	7,560	8,000	14,570	28,320	48,076	4,642	0,769
3	2,340	10,287	7,880	8,030	15,720	31,140	48,738	7,012	0,261
4	1,756	8,836	7,850	8,020	16,820	30,460	47,173	2,402	0,240
5	1,888	10,237	7,190	7,770	17,110	31,580	48,051	1,261	0,652
6	1,684	9,256	7,510	7,990	16,720	31,120	48,011	2,831	1,236
7	1,711	9,639	8,030	8,090	14,620	29,400	48,610	1,021	0,344
8	2,089	10,149	7,650	8,070	15,080	30,290	48,712	7,683	0,929
9	1,805	9,298	7,430	7,900	14,680	28,120	47,944	3,686	0,395
10	1,892	10,479	7,780	7,710	16,690	32,030	48,080	0,861	0,586
:									
98	1,722	9,402	7,650	7,970	15,860	30,950	47,415	3,372	0,611
99	1,781	8,746	7,770	8,140	16,510	30,120	47,406	3,492	0,631
100	1,971	10,079	7,860	7,920	15,230	30,320	48,390	1,294	0,391

According to initial data made the analysis of part dimensions, which consists of size-term and statistical units. Dimensional analysis is performed to spec details where all sizes are divided into two groups: I - related to each other (X1, X2, X5, X6) and II - apparently unrelated to each other dimensions of (X3, X4, X7). The block diagram of such a functional circuit shown in Fig.5.

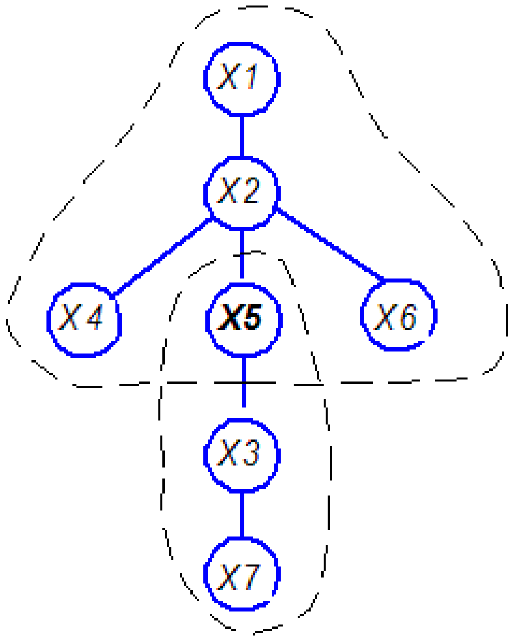

Fig. 5. Functional model size details

Based on analysis of the functional dimension of the chain is highlighted indication X5, linking groups I and II, and sizes are the most informative.

To construct a general model of the relationship dimensions of the part built seven local neural networks (models) with an indication of the significance of the inputs (the size Xi) to form the output values of unit sizes. The results are shown in Table. 4.

Table 4

Odds significance sizes in neural network models

	x1	x2	x3	x4	x5	x6	x7
X1		0	0,84116	0	0	0,15898	0,28334
X2	1		0	1	1	1	0,78928
X3	0	0,53287		0,779	0	0,23535	1
X4	0	0	0		0	0,10524	0,39114
X5	0,25482	0,92257	1	0		0,24394	0
X6	0,25812	1	0,67046	0,26051	0,17101		0
X7	0,26366	0	0	0,52896	0,64566	0,16132	

The data obtained using known neural network package NeuroPro built seven models of neural networks to create a generalized model of neural network homeostat dimensions of machined parts [3], as shown in Fig. 6.

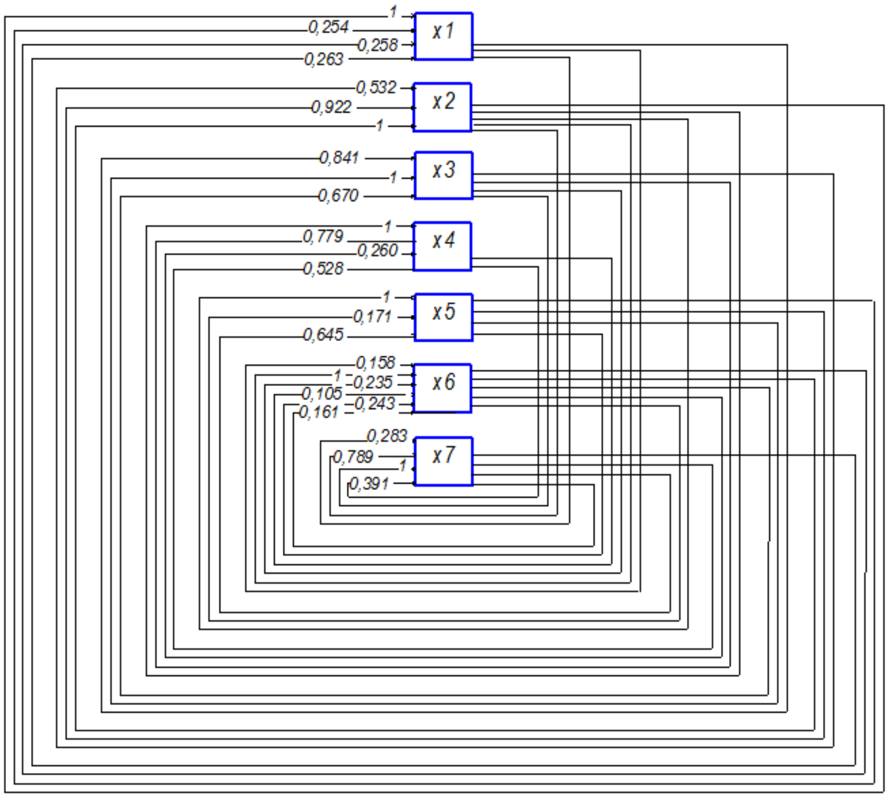

Fig. 6. Nejrosetevoj homeostat relationship sizes machined parts

To construct a model of the correlation values of the correlation coefficients are given in Table. 5.

Table 5

Correlation coefficients workpiece dimensions of machined parts

	x1	x2	x3	x4	x5	x6	x7
X1	1	0,578657	0,307873	0,010358	-0,00106	0,232449	-0,18852
X2	0,578657	1	0,133517	-0,09168	-0,26202	0,410269	-0,05862
X3	0,307873	0,133517	1	0,018081	-0,00047	0,125292	-0,1023
X4	0,010358	-0,09168	0,018081	1	0,103183	0,117343	-0,06554
X5	-0,00106	-0,26202	-0,00047	0,103183	1	0,661266	0,661266
X6	0,232449	0,410269	0,125292	0,117343	0,661266	1	-0,06685
X7	-0,18852	-0,05862	-0,1023	-0,06554	0,018047	-0,06685	1

The results of these studies are built graphs the relationship dimensions of machined parts, and the neural network model reflects a closer relationship than the correlation, characterized by weak bonds

The results of the joint analysis of the NA model and correlation model of the relationship dimensions of the part in the form of a generalized model are shown in Fig.7.

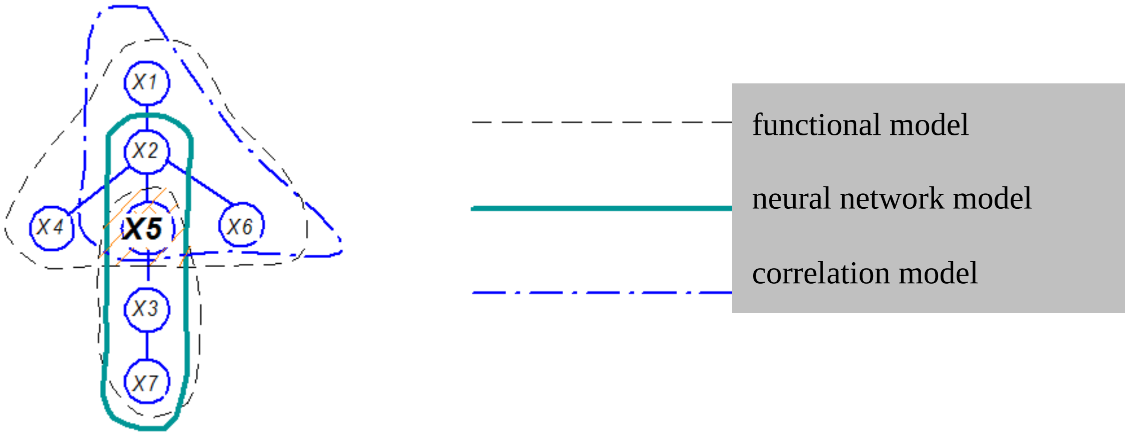

Fig. 7. The generalized model of the relationship dimensions of the treated samples

It follows from the scheme established relationships sizes common to all groups blur-ditch while linking them is the size of the X5. Its measurement allows to predict the accuracy of other sizes. Proven relationship dimensions of the part allows also to conclude that the fundamental possibility of an integrated (simultaneous) control their performance based on the data values of the amplitudes of the frequency spectrum of the identified resonance vibrations details.

For the 2-nd phase of the study used the same batch of parts in the amount of 100 pieces created test bench, comprising: a device fixing parts mounted piezoelectric transducer and a piezoelectric sensor of acoustic signals, audio signals and the generator frequency spectrum analyzer based on the computer's sound card.

The operating principle of the experimental setup is as follows. The sample is pressed from one side piezoelectric transducer, and on the other hand - a piezoelectric sensor. This position sensor and the work piece is securely provided with special clamping design. The generator of "white noise" to the emitter is supplied sound signal which the sensor is fixed to the microphone input of the frequency spectrum analyzer implemented on a personal computer. The resulting digitized frequency spectrum with steps selected duty cycle is part of a tuple of data inputs, and part characteristics Xi and Yi - the remainder of the tuple data sample parts. Thus obtained training set to build neural network model presented a verbal description of the above-mentioned package NeuroPro. The training set is a selection of 80 data tuples. The remaining (Fig.8 and Table. 6) 20 data tuples used for the test sample by means of which the analysis of the adequacy of established neural network model. On Fig. 8 shows an example of the spectrum of a sample and its capture (Table 6).

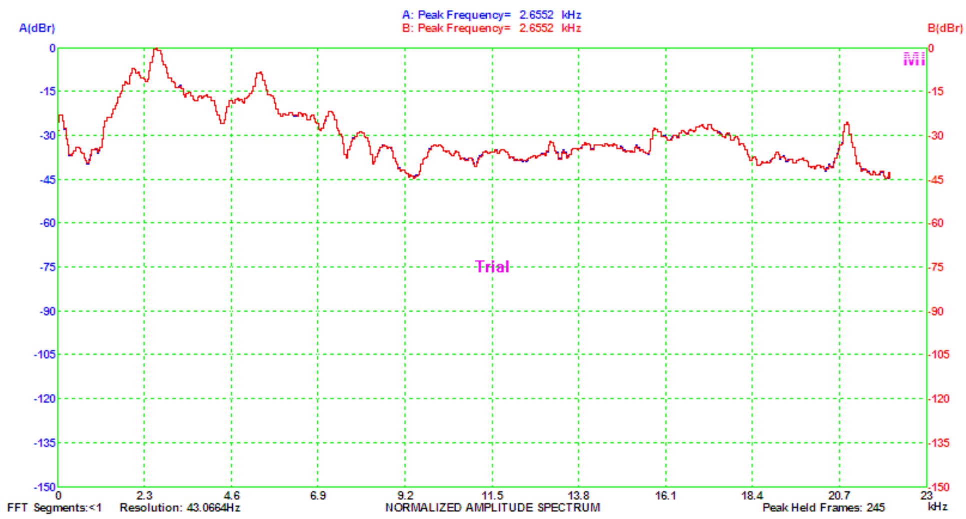

Fig. 8. An example of the spectrum of the acoustic signal of the sample parts

Table 6

The digitized spectrum part at the resonant frequency (Example)

	f_{min}	f_{max}			f_{min}	f_{max}	
x1	0	818,262	-32,5966	x14	11197,26	12015,53	-35,8229
x2	861,3284	1679,59	-28,8732	x15	12058,59	12876,85	-37,7139
x3	1722,656	2540,918	-9,6401	x16	12919,92	13738,18	-35,311
x4	2583,984	3402,246	-8,83679	x17	13781,25	14599,51	-33,5372
x5	3445,312	4263,574	-17,5765	x18	14642,58	15460,84	-34,4977
x6	4306,64	5124,902	-19,6555	x19	15503,9	16322,17	-31,4392
x7	5167,968	5986,23	-15,4515	x20	16365,23	17183,49	-28,3186
x8	6029,296	6847,558	-23,2669	x21	17226,56	18044,82	-29,5857
x9	6890,624	7708,886	-27,7982	x22	18087,89	18906,15	-37,5842
x10	7751,952	8570,214	-32,8641	x23	18949,22	19767,48	-37,8516
x11	8613,28	9431,542	-39,129	x24	19810,54	20628,81	-40,1119
x12	9474,608	10292,87	-36,8023	x25	20671,87	21490,13	-35,5566
x13	10335,94	11154,2	-37,4912				

The verbal description of the mathematical model constructed a neural network model is a description of a 1% accuracy estimates of the size and the surface roughness of the details of the acoustic spectrum. By determining characteristics of components results in their spectra at the resonance frequencies and a comparison of error estimates by comparing the actual size and their predicted values for all the test set (Fig.9).

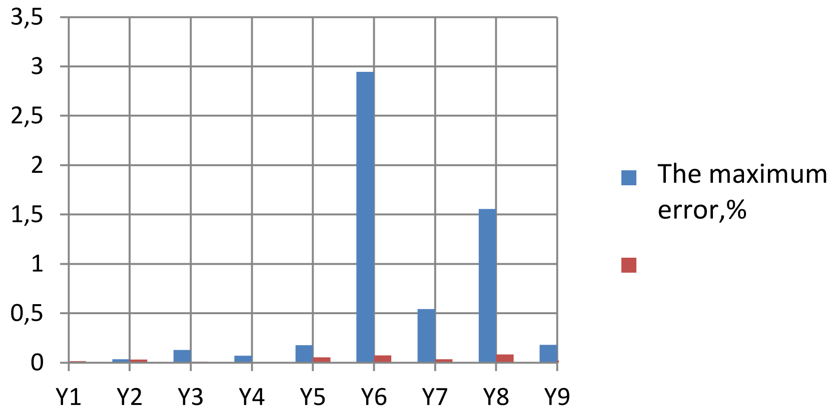

Fig. 9. Errors of assessment by comparing the actual dimensions and their predicted values for all test set for 1% accuracy of neural network model

Thus, it is found that the resonance vibrations of machine parts contain information about their dimension and quality characteristics. It is shown that the retrieval of information about the content of resonant oscillations of parts should be carried out on the basis of their amplitude-frequency spectra. The method of measuring the numerical values of the amplitude-frequency spectra of resonant oscillations details. Proposed and tested method of constructing a mathematical model of a neural network that reflects the relationship of the spectral characteristics of the resonant oscillations of details of the size and quality characteristics of the surface. It was established that for the assessment of values of size and quality surface of the parts is enough to have information about the relative values of the amplitudes of only certain frequency ranges.

CONCLUSIONS

Presented in the monograph material it gives reason to believe that the acoustic detection is more capacious concept than the acoustic control. Acoustic control system presupposes setting boundaries for which it is estimated, and uncertainty of this estimate on the set parameters. Along with the functions of the acoustic monitoring, acoustic diagnosis allows, in particular, to determine such integrated assessment is identical to the products of particular importance to technological tools, objects, regulated durability. In conjunction with the mathematical apparatus of neural networks acoustic diagnostics acquires a number of new features. First of all, it is an opportunity to use the diversity of excited acoustic vibrations reflected all surfaces of machine parts signals in the form of the acoustic spectrum. Further processing of the spectrum reveals a number of individual properties of the object acoustic diagnostics. There are one set of experiments, we confirmed the previously advanced hypothesis that can be formulated as follows: the more complex effect on the object under study, the greater the individual properties and characteristics of the response shall be subject to a complex impact. This statement applies not only to acoustic signals, but also to many others that can cause a commit response to the complex effect. Resonant vibration generating packages with multiple harmonics reflected in the details of the machine is quite good analogue of such complex effects on the diagnostic object. It is of theoretical and practical interest in the use of acoustic devices Diagnostic sources "white noise". However, the results of this study will be covered by us in subsequent works.

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