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METHODIC OF RESEARCH OF FACE RUNOUT OF CIRCULAR SAW IN THE PROCESS OF WOOD SAWING

The face runout of the saw is an important parameter of the equipment, which affects in particular the quality of the product and the durability of the tool. The article describes a well-developed technique for researching the face runout of a saw, which differs by the used sensor, the simplified procedure of its calibration and the method of processing the received signals. The use of computer technology ensures a wide range of settings, displaying results in a convenient format, enables automation of signal processing.
Keywords. Face runout, wood sawing, induction sensor, calibration, technological control.

One of the most common types of woodworking machines is round saw for sawing wood [1]. The energy costs, the precision of the product, the surface roughness, the width of the sawdust largely determine the energy consumption and the amount of wood waste in this operation and in the further processing of the workpiece. The face runout of a disk is one of the main factors of the listed indicators.

Meanwhile, the face runout of a saw is also determined by a set of parameters: constructive, which can be considered unchanged for each sample the machine, and depending on the mode of operation of the equipment, in particular the speed of the feed material. Several mechanisms for influencing the velocity of the face runout of the saw are known, in particular the mechanical stresses and uneven heating of the cutting tool [2]. Changes in the value of the face runout of unloaded saw characterize irreversible deformations in the tool during the period of operation. The same changes that occur in the process of cutting wood, is an indicator of the coherence of the operating mode with the properties of the tool and determine the possibility of obtaining the result of processing the product of a given quality. Consequently, for scientific researches, the determination of face runout of a saw will allow a more detailed study of the tool in the process of cutting wood, and for practice – the monitoring of the state of equipment and modes of its use. In the known means for determining the value of axial beats, electromagnetic position sensors [1] are used. The use of other types of movement data in face runout studies is limited by their principle of action or constructive execution. For example, the possibility of using rheostat and condenser sensors is influenced by the necessity of mechanical connection with the moving object of research; Magnetininductive – the need to attach to the object some elements of the sensor [3, 4].

For a more detailed study of axial impacts with the definition of momental values of its value or the nature of the deformation of the disk is important not only the maximum frequency of conducting measurements of the average value, but also the sensor frequency bandwidth range. The lower frequency of this band is determined by the speed of rotation of the saw, and the upper part is also the possible number of nodal radius of deformed saws. If due to deformation on the saw disk five nodal radii have been formed, then, in calculations to determine the range of discrepancies of the disk with an error of 2%, the operating frequency of the sensor should be 32 times higher than Nyquist frequency: 50*5*2*32= 16 kHz. Taking to account the characteristics of real filters, in order to provide such bandwidth, operating time of sensors using alternating voltage should be 5-10 times higher, which excludes the possibility of using low-frequency devices.

In the electromagnetic sensor, an inductor is used which creates a variable magnetic field of high frequency near the surface of the saw. Depending on the distance between the coil and saw, the part of the magnetic flux that is locked through the ferromagnetic material of this tool and changes the electric inductive resistance of the coil. The advantage of this sensor is the lack of mechanical contact with a moving saw.

To increase the sensitivity of a magnetic sensor, two coils are often used by a differential circuit [1]. The output voltage of this sensor characterizes the distance between the coil and dust. To observe the instantaneous values of the output voltage, use an oscilloscope. The width of the face runout of the saw is determined by the difference between the maximum and minimum amplitudes during one turn of the saw (Fig. 1).

The analysis of the oscillogram of the output voltage of the electromagnetic sensor is complicated by the need to compare both the positive and negative values of the stresses distributed in time (Fig. 1) on a moving oscillogram. You can evaluate the nature of the heterogeneity of the saw in the line of contour of oscillogram. In the drawings, the dotted line separates the signal region corresponding to one rotary dust.

Unresolved questions of face runout control. A well-known method requires the operator to work with complex devices and signals (generator of high frequency voltage, differential sensor, oscilloscope), but does not provide a direct estimate of the value of the face runout, which must be calculated for two values of the amplitudes , determined from the moving image on the oscillograph screen.

The boundary of errors of data taken on the oscilloscope's screen is taken as five percent. Thus, the error limit of determining the value of a face runout , as the difference between the two indicators, exceeds ten percent [3]. It is known that the sensitivity of the electromagnetic sensor depends on the distance to the dust, so to compare the size of the face runout of different pollen it is necessary to calibrate it after each sensor installation . The calibration procedure of this sensor requires a considerable amount of time and special equipment. These difficulties and low accuracy of estimates limit the use of known methods for studying face runout of the saw.

Problem statement To use in practice control of face runout of pollen, it is necessary to improve the known technique, to provide more precise definition of the value of the face runout, to simplify the methods of use and calibration of means of research.

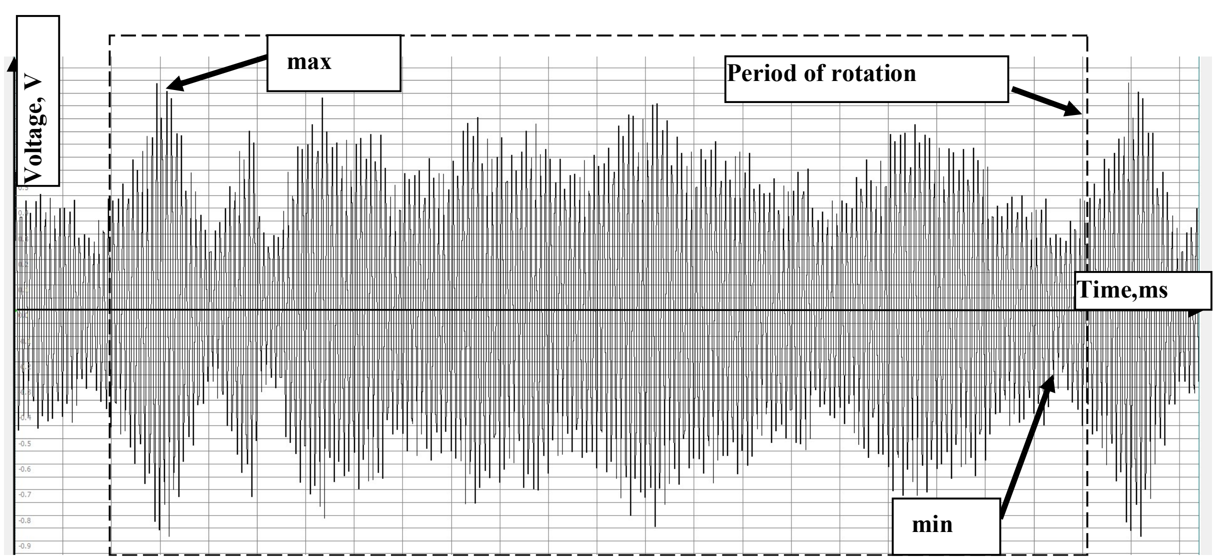

Fig. 1. Voltage at the output of the electromagnetic sensor of position saw

In the method developed by us the principle of electromagnetic induction is used. To form an induction sensor in the vicinity of the saw blade, a permanent magnet is installed, the magnetic field of which partially closes through the saw. The distance between the magnet and the saw is a non-magnetic intermediate, which determines the magnetic flux of a permanent magnet through the saw. Changes of this flow caused by the face runout of the saw are the cause of the electrical voltage in the coil installed in this magnetic flux (Fig. 2). It voltage is proportional to the velocity of flow changes.

The face runout of the saw of the saw is a periodic process and can be represented in the Fourier series:

$$S = \Sigma An \cdot \sin (n \cdot \omega \cdot t + \varphi n), \quad (1)$$

where: S – instantaneous value of the deviation of the saw from the middle position due to the face runout; ω – angular velocity of the saw; t – time; An is the amplitude of n-th harmony of face runout of the saw, n – harmonic number; φn is the angle of displacement of the initial phase of the n-th harmonic.

The results of the calculations show that, if the average distance from the sensor to the disk saw, which is three times the size of the face runout the maximum error of the linear approximation of the dependence of the magnetic flux on the magnitude of the non-magnetic gap is 1%.

$$Smax-Smin <(Smax + Smin) / 6, \quad (2)$$

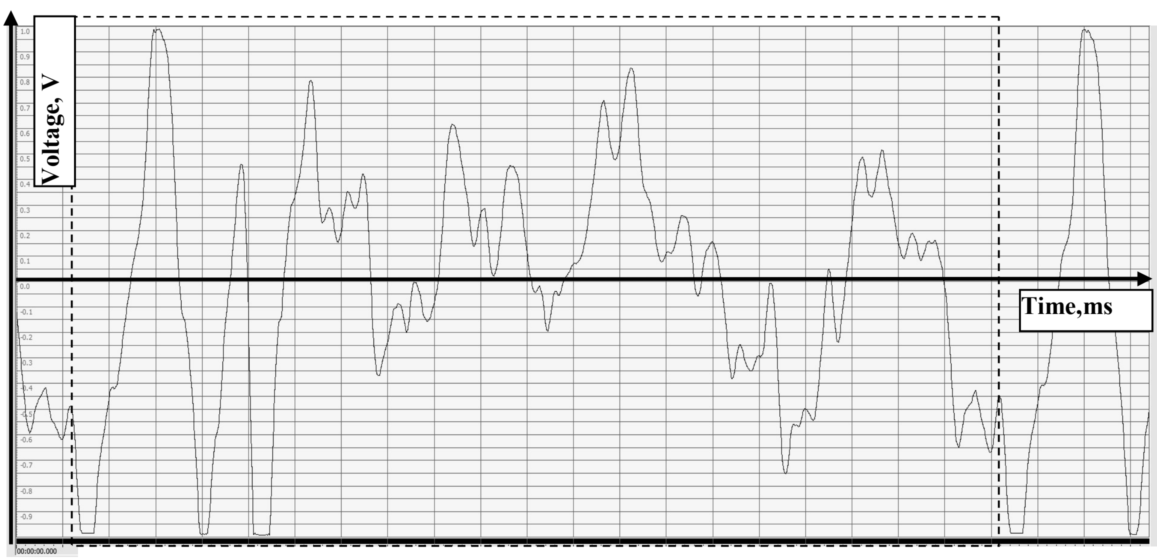

Fig. 2. Signal of the induction sensor from the face runout of the saw

Consequently, voltage of this sensor with high accuracy characterizes the rate of change in the magnitude of the nonmagnetic gap dS / dt:

$$U = k \cdot dS / dt = k \cdot \omega \cdot \Sigma An \cdot n \cdot \sin (n \cdot \omega \cdot t + \varphi n), \quad (3)$$

where: U – induction voltage induced in the winding; k – coefficient taking into account the parameters of the design of the sensor and the method of its installation, as well as linear approximation of the dependence of the magnetic flux on the magnitude of the non-magnetic gap..

The rolling of the asynchronous motor rotor of a saw relative to the magnetic field for modern machines is 3-5% [3]. Therefore, the speed of rotation of the saw during the work changes slightly and in the first approximation the speed of rotation can be considered as a constant. The instability of the rotational frequency of the saw in this case results in an error of measurement of the axial beat ± 1%, which is significantly less than error of the known method . If necessary of reduction of error, frequency of rotation, equal to the frequency of the first harmonic of the induced signal, can be measured and its value is used to correct the results of determining the value of the face runout. The non-stability of the idle speed and the errors generated by it are still much less than the deviation of the rotational speed of the saw during operation.

As a magnetic system with a winding, it is convenient to use the headphone in the offered device. The membrane system headphone with a fixed coil is used as a sensor, removing the membrane, and in the headphone of the dynamic system, it is necessary to fix the position of the coil relative to the magnetic circuit (for example, with glue) and then remove the diffuser to bring the magnetic system to the saw. The compact magnetic headphone system allows you to control the face runout of the saw at different distances from the axis and thus carry out a kind of scanning of the surface of the saw. The closed construction of the magnetic system helps to reduce sensitivity of the sensor to external fields, which results in a low noise level in the received signal (Fig. 2).

The signal received from the induction sensor contains information, but graphically does not reflect the nature of the fluctuations of the saw, because the instantaneous signal values are proportional to the speed of change the axial position of the stick disk. To get information about the saw profile and its changes during operation, it is necessary to process the signal, namely perform the integration and scaling operations.

To perform the mathematical processing of the signal, we used a computer technology and a specialized program GoldWave for processing signals. This program provides a wide range of reception, processing of signal and graphical visualization of the results of computations and signal formatting. To evaluate the nature of the beating of the saw, we used spectral analysis and filtration of the signal of the induction sensor.

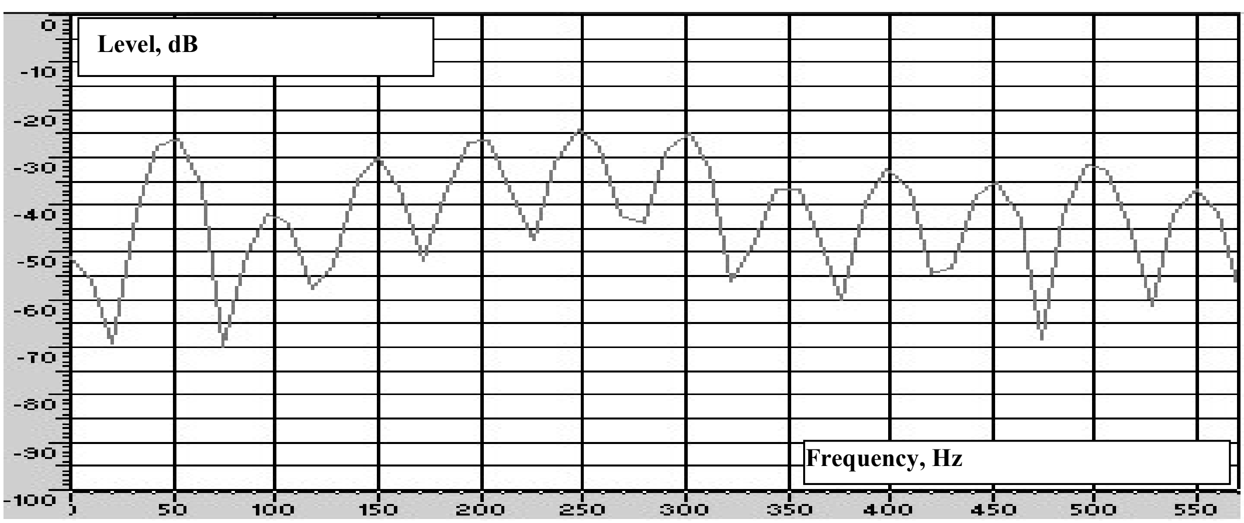

Fig. 3. The spectrum of induction sensor signal

The results of the spectral analysis (Fig. 3) indicate the poliharmonic composition of the received signal and the lawfulness of the Fourier series for its analytical representation. The high level of the fourth, fifth and sixth harmonics, the amplitude of which is practically equal to the amplitude of the first harmonic (the consequence of not the perpendicularity of the saw and the axis of rotation), testify to the multiple bends of the saw disk (nodal radii).

The use of the first-order low frequency filter property to integrate signals in the frequency range higher than the frequency of its cut is used to obtain a deformation profile of a saw disk. Given the uniform rotation of the saw disk in the signal spectrum , generated by this rotation, there are no components with frequencies below the rotational speed. Therefore, the low-pass filter of the first order with the 50Hz frequency limit allows for the integration of the signal of the induction sensor with high accuracy and obtaining a signal corresponding to the instantaneous values of position the saw disk (Fig. 4). The received signal reflects the profile of the saw on the radius of the sensor installation, but without its calibration does not make it possible to determine the value of disk deformation. The standard calibration procedure reduces to setting the dependence of the output voltage of the sensor on the size of the gap between the sensor and the saw blade. To obtain such dependence, multiple measurements of the size of the gap and the voltage level of the transducer are performed by exemplary devices. This method of calibration is burdensome even for scientific research because of the need for exemplary devices and a significant length of procedure.

In the methodic we have developed studying face runout is simplified by the calibration of the sensor. Two measurements of the scale of the filtered signal Ur = U2-U1 (Fig. 4) with the change of the non-magnetic gap to the calibrated value ΔS = S2-S1 are performed for its conducting after the sensor is installed. The value of ΔS in the range of 0.2-1 mm can easily be transmitted using a metal plate, which allows the sensor to be fixed in a position shifted to the thickness of the calibration plate. The relation of difference of the sensor signal in these positions to the thickness of the plate determines the sensitivity of the sensor C in the conditions of use of the sensor:

$$C = (Urs1 - Urs2) / \Delta S \qquad (4),$$

where: C – sensitivity of the sensor; Urs1 and Urs2 the sensor signal in the initial and

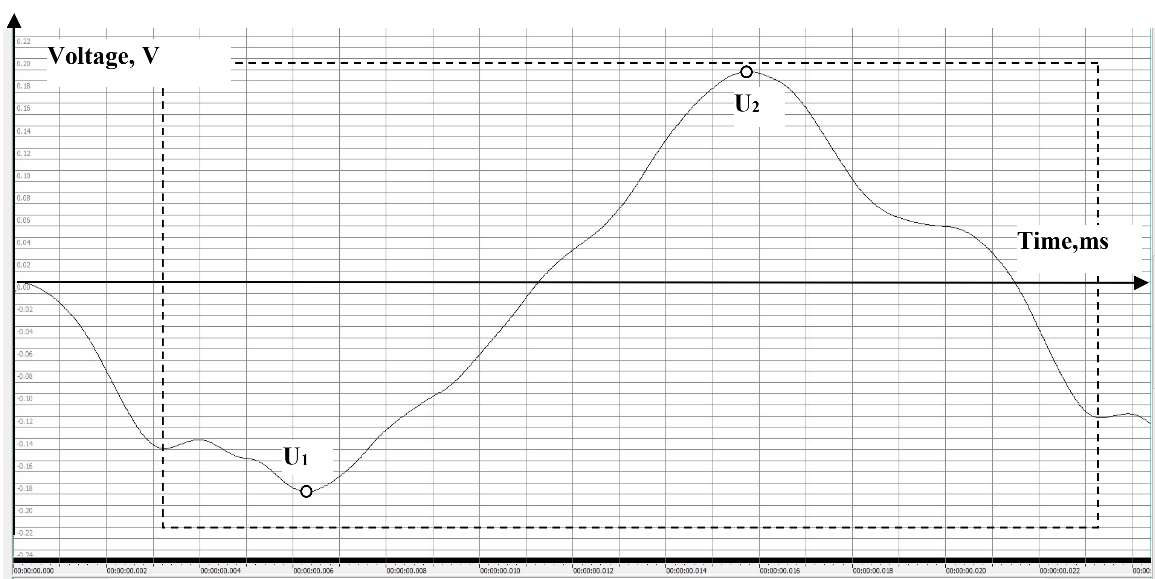

Fig. 4. Filtered signal of the induction sensor

shifted position; ΔS change in the magnitude of the non-magnetic gap.

This calibration procedure of sensitivity of the sensor consists of only two measurements made near the working point by working means of computing using the GoldWave program for fixed level of signal. Possibilities of the used means provided a wide range of amplification of the signal processing channel of the sensor and scaling the received results.

In tests conducted as a sensor tested headphones TON-2 and IE 800 S. Conversion of analog signal to digital was carried out sound card of the computer in 16-bit code with a sampling rate of 16kHz, which allowed the value of a signal with an error of tenths of a percent. These tools allowed not only to calibrate sensors with a sensitivity of 1 to 0.01 mm/V, but also to scale the received signals to represent the oscillograms in the form of a convenient to estimate the value of the face runout of the saw (for example, Figure 4 depicts the disc deviation of the saw in the range of ± 0,1mm) The methodological error of determining the value of the beats according to the developed method is determined by the error of quantization of the signal, which is much smaller than the error of reference on the oscilloscope screen. According to the results of the test, it was discovered that a metodic of researching the face runout was developed. It the metodic:

- ses easy-to-use, robust technical means that enables the primary information to be obtained in a contactless manner, which determines their durability and lack of influence on the subject of research,
- provides high accuracy due to the hardware receiving of numerical values of the signal, which excludes the possibility of a subjective error of the operator; Developed metodic allows to simplify and minimize calibration operations of the sensor;
- makes it possible to analyze deformation of complex form due to the wide bandwidth of used devices and the application for analysis of signals by software means of computer technology;
- suitable for use in automated systems of technological control and regulation, creation of effective means of diagnostics of the condition of the equipment (in particular, the implementation of the developed method allows to implement in the system of control the possibilities the controlling of speed of the supply of wood of modern machine tools [1], will promote the quality of products, increase term of service of the tool and increase of profitability of production).

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Методика дослідження торцевого биття круглої пилки в процесі пиляння деревини

Торцеве биття пилки є важливим параметром обладнання, що впливає зокрема на якість продукції та довговічність інструменту. Описано розроблену методику дослідження торцевого биття пилки, яка відрізняється використаним датчиком, спрощеною процедурою його калібрування та способом обробки отриманих сигналів. Застосування засобів обчислювальної техніки забезпечує широкий діапазон налаштувань, індикацію результатів у зручній формі, дає змогу автоматизації процедури оброблення сигналів.

Ключові слова. Торцеве биття, пиляння деревини, індукційний датчик, калібрування, технологічний контроль