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Selection of informative acoustic emission parameters for determining the wear rate of woodworking equipment in transient modes

A.V. Voitov* 0000-0002-5626-131X, **V.I. D'yakonov** 0000-0002-7787-5054, **Y.O. Gradiskiy** 0000-0002-5226-6252

State Biotechnological University, Kharkiv, Ukraine
**E-mail: K1kavoitov@gmail.com*

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Abstract

The directions of application of the acoustic emission (AE) method for the study of transient processes in tribosystems are considered. woodworking equipment during running-in. The use of this method will allow obtaining information about the condition of friction surfaces and the wear rate during transient processes (running-in) in online mode. To justify choice informative AE parameters analyzed the type of AE - signal frames captured during the transition process at characteristic points. It is shown that when evaluating speed wear in transient modes is best use acoustic emission power radiation. After completion transitional process (steady state of operation), the AE signal frame takes the form that much different from transitional regime. Experimental research presented in the form of experimental dependencies thats reflect average value power of AE signals , where along the axis *X* placed experimental value power signals acoustic emissions from the zone friction , unit measurement – mB^2/s. Along the axis *Y* postponed relevant calculated value speed works dissipation in tribosystems , unit measurement - J/s. Dependence allows for the measured in the process experiment calculate AE power value speed wear in the tribosystem woodworking equipment in real time. To determine maximum values speed wear during the transient process the AE method and the informative parameter - power are justified AE signals. It has been experimentally established that AE power correlates from speed wear woodworking equipment, coefficient correlation R = 0.98 and adequately reflects process Earnings. Received dependencies allow determine speed works dissipation in tribosystems woodworking equipment during the transition process by values power signals acoustic emissions, which allowed us to develop a calculation methodology quantities speed wear in woodworking equipment during training in any point transitional process.

Keywords: tribosystem; speeds wear and tear; acoustic emission; power acoustic radiation; transient processes; woodworking equipment; working out.

Introduction

Modern understanding the nature of friction and wear indicate that this the process is not stationary. Acoustic friction vibration initiated by impact interaction microprotrusions and elastic-plastic deformation surfaces that rub, processes destruction friction connections and structural-phase rearrangement materials, formation and development microcracks in the surface layers of interacting bodies, departments particles wear and tear. Registration acoustic signals allows with high accuracy determine the time of events that are happening, which include elastic interaction microprotrusions connected surfaces, formation and destruction adhesive connections, the emergence microcracks and separation particles wear and tear.

Acoustic emission (AE), as a way diagnostic for mechanical tests, has been widely used since the early 1980s as effective method of obtaining information about the change in the state of the material in the process load. The use of this method will allow to obtain information about the condition of surfaces friction during the transition processes (training) in online mode.

Literature review

Review literary sources, which performed in [1], allows make conclusion that research on acoustic emission diagnosing mechanisms mostly based on the use of signs that come from related industries techniques. Above all it signs discrete emissions: account (number pulses registered during the entire test period); activity (number of pulses per unit time) [2]. What concerns continuous emissions (when individual impulses to distinguish impossible), then it`s characterized by parameters widely used in vibration diagnostics – mean square value, peak factor, and oscillation spectrum [3]. In addition, they use hourly parameters (pulse rise and fall duration) [3], parameters distribution pulses by amplitude and apply wavelet transform [4].

Based on analysis works western scientists [5-11], the author of the work [11] concludes that promising direction research is the justification of acoustic emission signs defects bearings rolling, invariant to the scaling of the signal in amplitude. Due to it because fluctuations attenuation emissions, differences amplitude-frequency characteristics of sensors emissions and others factors that affect the measurement result energy parameters emissions, such as energy, root mean square value, spectrum and wavelet transform result. Listed factors affect the parameters acoustic emissions, when calculating whose is carried out comparing the signal with some threshold level. According to the authors of [11, 14], the procedure for selecting such a level is often not enough formalized or is based on factors that are themselves variable (e.g., the amplifier's own noise or background level emissions). Therefore, when measuring hourly parameters acoustic emissions expedient threshold level choose in accordance to the order of the quantile of the distribution amplitudes that is determined from the condition minimum probabilities errors diagnosing.

Summarizing result analysis completed research by choice informative AE parameters for diagnosing tribosystem woodworking equipment can make conclusion that for registration speed wear in transient modes (during running -in), most informative and invariant parameter can speak AE signal power generated surfaces friction, which are in contact and mutual moving. Power AE signals correlate with the magnitude of the registered amplitudes for a certain time period (level quantization).

Purpose

One of tasks this research is the development of a method and methodology for determining speed wear woodworking equipment in non-stationary modes during online running-in, which will give possibility study transitional processes in different structures tribosystem.

Methods

To justify choice informative AE parameters during control processes wear woodworking equipment we will consider change speed wear tribosystems in process running-in, Fig. 1 and the type of AE - signal frames taken during the transition process (running-in) of the tribosystem at characteristic points, Fig. 2. From the presented signal frames it is clear that The amplitude of AE, hereinafter A*(t)*, can be given as a function valid variable *t*.

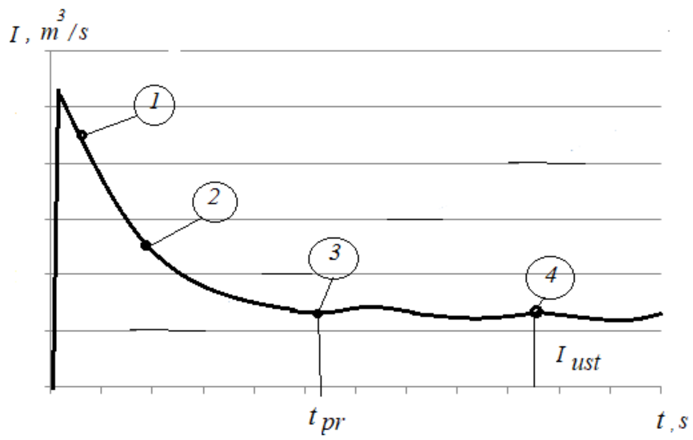

Fig. 1. Nature of change speed wear tribosystems in process running-in: t_{pr} - running-in time; I_{ust} - speed wear after completion running-in: 1-2-3-4 - typical running-in points

After completion transitional process (steady state of operation), the AE signal frame receives view presented in Fig. 2, point 3 and point 4. Study structures of the AE signals presented in Fig. 2 gives foundation to claim that on a permanent basis mode process friction and wear has oscillations.

For selection AE signals from noise most often used frequency filtering and amplitude discrimination [12]. In this work was used amplitude discrimination AE signals, which was carried out by introducing a threshold device into the equipment, which lets out only those signals, amplitude whose exceeds some given level - level discrimination.

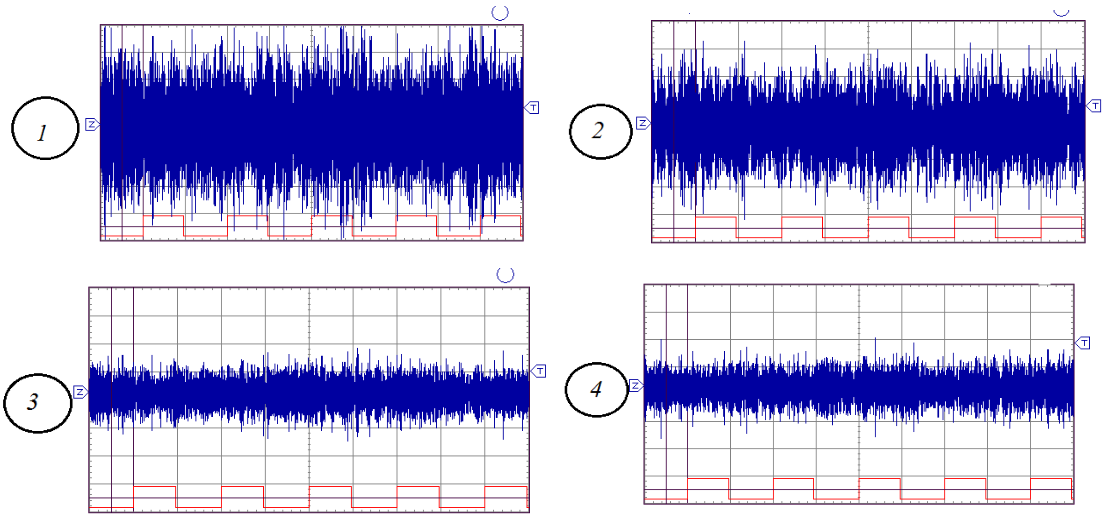

Fig. 2. Frames AE signals at characteristic points on the curve working out according to Fig. 1

Justification equal discrimination was carried out experimentally and is important condition receiving reliable results.

Non-stationary process characteristic because has certain trend development over time and characteristics of such a process depend from the beginning of the countdown and from duration registration. However, for each non-stationary process exist time intervals within which, with a known approximation, this process maybe to be considered stationary and ergodic.

Thus, changing interval integration (assigning enough small interval) when changing frames AE signals, possibly study processes superficial destruction (speeds wear and tear and damage limits) at the stage working out tribosystem.

Random function A*(t)* maybe to be considered by definition stationary, at a certain time interval *t*, if all its probabilistic characteristics do not change under any displacement arguments, from which they depend on the axis *t*. However, one of the main conditions that must be satisfied stationary random function is condition sustainability dispersion.

Therefore, when analyzing transitional processes time interval *t* of amplitude registration AE signals should be chosen so that provided condition sustainability dispersion. This interval in the work is determined experimentally.

Many conducted analyses experiments process working out tribosystems showed that when evaluating speed wear in transient modes is best use acoustic emission power radiation, which was determined by the expression:

$$W_{AE} = \frac{A_{\Sigma}^{2}}{t_{p}}, \tag{1}$$

where A_{Σ}^{2} is the total value of the square of the amplitudes all AE pulses, mV^2 during registration t_P;

t_P is the registration time, s.

Experimental research were carried out in two stages and aimed to determine correlational connection between speed wear – I_v, m^3/h and power signals:

$$W_{AE} = \frac{mB^{2}}{s_{e}}.$$

First stage experimental research aimed to definition functional communication between the listed parameters during the transition process.

Second stage aimed to definition correlation communication between listed above parameters on a constant mode works tribosystems, i.e. after completion transitional process (working in).

Completion working out can determine by stabilization the following parameters transitional process: friction moment M_{tr}, N•m; temperatures elements tribosystems T, °C; minimum dispersion of AE radiation from zones friction - D, mB^2. In this work during the experimental research completion time transitional process was determined by all listed above parameters.

Results

Experimental research were carried out by car friction according to the kinematic scheme "ring-ring", with such combinations materials.

First tribosystem: mobile triboelement steel 40X (45 ... 47 HRC), fixed triboelement Br.AZH 9-4 (90 ... 110 HB).

Second tribosystem: mobile triboelement steel 40X (45 ... 47 HRC), fixed SCM triboelement (293 HB).

Third tribosystem: mobile triboelement steel 40X (45 ... 47 HRC), fixed triboelement steel 40X (45 ... 47 HRC).

For everyone three tribosystem lubricating environment was selected engine oil M-10G_{2k} (E_y = 3.6 • 1014 J/m^3).

Experimental flow chart recording and processing equipment AE signals are presented in Fig. 3.

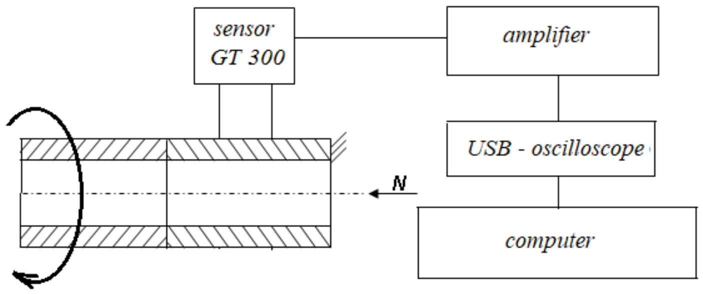

Fig.3. Experimental block diagram recording and processing equipment AE signals

Acoustic signal emissions that generates tribosystem, perceived from a stationary triboelement broadband acoustic sensor emission GT300 (100.. 800 kHz) and enters the amplifier, and from the output amplifier - to the USB oscilloscope PV6501 and then to the computer.

Amplifier consists of an input stage, a three-pole filter high frequencies and an amplifier with adjustable coefficient transmission (1 - 100). General coefficient strengthening reaches 1000. The lower limit of the band transmission amplifier selected equal to 50 kHz, which corresponds low-frequency acoustic sensors emissions that are produced, for example, by the company GlobalTest. Upper band limit transmission selected equal to 1.5 MHz, which surpasses the corresponding serial limit high-frequency sensors acoustic emissions. This restriction related also from increase attenuation elastic waves in metal with increasing frequency.

Strip transmission of the used USB oscilloscope is 20 MHz, which repeatedly exceeds upper limit of the bands sensor and amplifier throughput acoustic emissions. Filter high frequencies are intended for highlighting signals acoustic emissions that have much smaller intensity than AE signals. By weakening the passage AE signals to the USB oscilloscope input 300 times using filter high frequencies and proportionally increasing coefficient reinforcement, it became possible to isolate the acoustic signal emissions with a predominant frequency of 70-600 kHz.

Oscillograph worked in mode wait, scan start threshold marked with the symbol "T" in Fig. 2. Duration previous samples was installed equal to 100 μs, which allows watch the value of the signal that precede exceeding the threshold level. Results acoustic signal measurements emissions with a USB oscilloscope stored in a computer, data that contained in these files are processed programs statistical analysis with definition dispersion of the square of the amplitudes – D_A and the total value of the square of the amplitudes during the registration time - . Having data value according to formula (1) was determined W_{AE}. Registration time t_p was determined experimentally by reproducibility results with equivalent repetitions. When checking homogeneity dispersions aggregates AE signal results at constant mode that equivalently confirmation their reproducibility, under conditions for small sample sizes, ISO 5725 recommends using criterion Cochrane.

Criterion Cochrane allows compare homogeneity dispersions results analysis amplitude AE signals at different points of the transition process.

Test statistic of the criterion Cochrane S_r is determined expression:

$$S_r = \frac{D_{A\max}}{\sum_{i=1}^{n} D_{Ai}}, \quad (2)$$

where D_{Amax} is the largest value dispersion amplitude during the transition process;

n is the number measurements;

D_{Ai} is the current value variances on the i-th experiment.

According to ISO 5725, the hypothesis Homogeneity (reproducibility) is checked according to the following expression:

$$C_p < C_m , \quad (3)$$

where C_p is the calculated value criterion Cochran, formula (2); C_m is the tabular value criterion for a given equal significance [13].

If condition (3) is fulfilled, then it is accepted hypothesis about statistical homogeneity results measurements.

Experimental research were carried out under the following friction modes: load N = 300…1200 N; speed sliding 0.5 m/s.

In progress experiments using recorders machinery friction recorded in time change in friction torque, temperature, and with the help of computer calculated dispersion and power AE signals.

Results experimental research presented in the form of experimental dependencies in Fig. 4, which reflect average value power AE signals for three with the same type of repetitions and three tribosystems with different combination materials, where along the axis *X* placed experimental value power signals acoustic emissions from the zone friction, W_{AE}, formula (1), unit measurement – mB^2/s. Value W_{AE} obtained for different combinations materials in the tribosystem, different loads and speeds sliding. Along the axis *Y* postponed relevant calculated value speed works dissipation in tribosystems W_{tr}, which equal algebraic sum speeds works dissipation in moving and stationary triboelements, unit measurement - J/s. Formulas for calculation W_{tr} presented in [14]:

speed works dissipation in the moving triboelements;

$$W_{mov} = \sigma_{acs} \cdot \dot{\varepsilon}_{mov} \cdot V_{dmov} \cdot J / s. \tag{4}$$

speed works dissipation in a stationary triboelements;

$$W_{mov} = \sigma_{stat} \cdot \dot{\varepsilon}_{stat} \cdot V_{dstat} \cdot J / s. \tag{5}$$

Speed works dissipation in the tribosystem:

$$W_{tr} = W_{mov} + W_{stat} \cdot J / s. \tag{6}$$

In formulas (4) and (5) we assume next designation:

σ_{acs} is the stress on the actual contact spots, Pa;

$\acute{\varepsilon}_{mov}$, $\acute{\varepsilon}_{stat}$ is the speed deformations in movable and stationary triboelements, 1/s;

V_{dmov}, V_{dstat} is the volume material movable and stationary triboelements, which participates in deformation in the process friction, m^3.

Received dependence, Fig. 4, establishes linear relationship between measured in the process experiment power AE signals, formula (1) and speed works dissipation in the tribosystem, formula (6). Using the method of least squares squares was received regressive equation:

$$W_{tr} = 0.033 \cdot W_{AE} \tag{7}$$

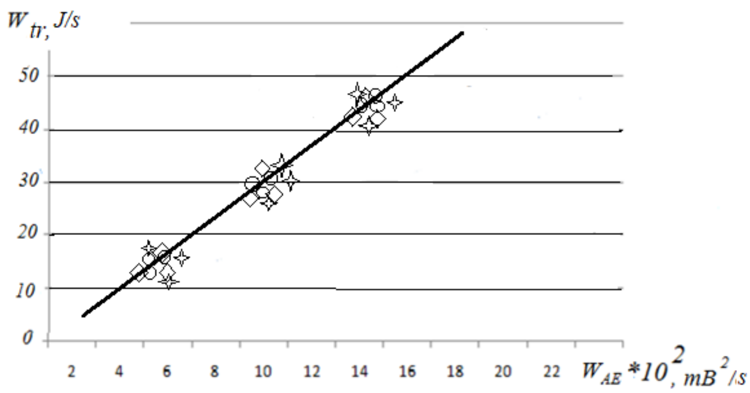

Fig. 4. Dependence changes speed works dissipation in different tribosystems W_{tr} from power signals acoustic emissions from the zone friction W_{AE}

Dependence (7) allows for the measured in the process experiment power AE - W_{AE}, calculate value speed works dissipation in the tribosystem W_{tr}. Using received value W_{tr} and the formula obtained in [13] can be calculate speed wear in the tribosystem in real time:

$$I_v = 6 \cdot 10^{-10} \exp\left(0.795 \cdot 10^{16} \cdot \frac{1}{E_y} \sqrt{\frac{\pi}{\delta_{mov} \cdot \delta_{stat}}} W_{tr}\right), \ m^3 / h, \tag{8}$$

where I_V is the volumetric speed wear, m^3/h in real time;

δ_{mov} and δ_{stat} are coefficients that take into account rheological properties structures material from moving and stationary triboelements.

The second stage experimental research began to determine functional relationship between speed wear I_V and parameters AE - W_{AE} for the specified above tribosystem when changing load on the node friction from 300 N to 1200 N on a stationary mode works tribosystems, i.e. after completion transitional process (running in). Change load leads to change speed works dissipation in tribosystems - W_{tr}.

The purpose of the research is to show that by the value of W_{AE}, mB^2/s, it is possible determine the speed wear I_V, m^3/h.

Research were carried out in stationary friction modes, i.e. depreciation for running-in was not taken into account. For this after completion working in (after stabilization parameters) on the surface friction wells were applied for measurement wear and tear and after carrying out tests for two hours by the method of artificial bases was determined linear wear and tear, which converted into volumetric.

Speed wear was determined by the formula:

$$I_v = \frac{\Delta b \cdot A_H}{t_e}, \; m^3 / h, \tag{9}$$

where Δb is the value of the linear wear, m;

A_H is the area friction triboelement, m^2;

t_e is the time of execution experiment, hours.

Results experimental research are presented in Fig. 5.

We will do it assessment reproducibility results measurements signals acoustic emissions using criterion Cochren, formula (2). Parameters signals acoustic emissions at different values speed works dissipation for dispersion amplitudes and dispersions AE power specified above tribosystem are presented in Table 1.

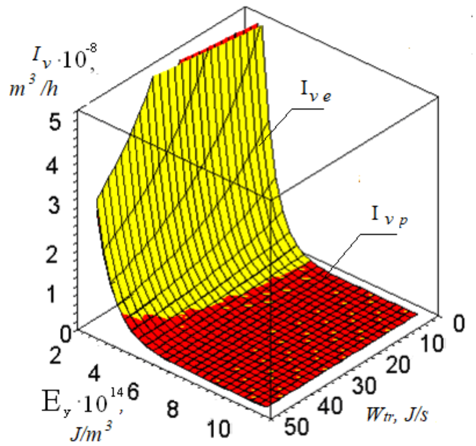

Fig. 5. Estimated I_{Vp} and experimental I_{Ve} surface feedback volumetric speed wear and tear when changing tribological properties lubricating environment E_y and speed works dissipation W_{tr} in tribosystem steel 40X + Br.AJ 9-4

Table 1

Parameters signals acoustic emissions at different values speed works dissipation in tribosystems

W_{tr}, J/s	D_{Amax}	ΣD_{Ai}	S_r	D_{wmax}	ΣD_{wi}	S_r	S_t
10	47.1	60.41	0.764	309.35	461.22	0.695	0.853
20	57.3	70.75	0.764	315.30	460.08	0.715	0.853
30	70.5	91.30	0.785	430.25	572.67	0.720	0.853
40	113.6	144.76	0.795	613.33	822,14	0,755	0,853

Analysis calculated values criterion Cochrane - C_p and tabular values – C_t at a given levels significance level 0.95 (number of evaluated parameters - 2, number repetitions - 10), allows make conclusion that condition (3) is fulfilled, i.e. results measurements homogeneous and reproducible.

For the subjects tribosystem coefficient correlations between dependencies I_V and D_A has R value = 0.96, and for dependencies I_V and W_{AE} has R value = 0.98.

From the analysis presented values in Table 1 it follows that dispersion amplitude and power AE signals adequately reflect process wear and tear and are in functional condition interconnection from speed wear and tear. This allows to put forward assumption that the magnitude of the AE power can be to judge the magnitude of the speed wear at any time during work tribosystems, i.e. in transient regimes.

Practical recommendations: determination method values speed wear during the transition process boils down to the following operations.

1. Conducted trial specific tribosystems and in the process transitional process are registering AE parameters and according to formulas (1) are calculated value power acoustic emissions - W_{AE}.

2. According to the known values W_{AE}, according to expression (7), is calculated value speed works dissipation in the tribosystem at a given time – W_{tr}.

3. Numerical value volumetric speed wear at a given time - I_V is determined by formula (8).

Conclusions

To determine maximum values speed wear during the transition process the AE method and the informative parameter - power are justified AE signals. It has been experimentally established that AE power correlates from speed wear and tear, coefficient correlation R = 0.98 and adequately reflects process working out.

Received dependencies that allow determine speed works dissipation in tribosystems of woodworking equipment during the transition process by values power signals acoustic emissions, which allowed the development of calculation method quantities speed wear during training in any point transitional process.

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Войтов А.В., Д’яконов В.І., Градиський Ю.О. Вибір інформативних параметрів акустичної емісії для визначення інтенсивності зносу деревообробного обладнання в перехідних режимах

Розглянуто напрями застосування методу акустичної емісії (АЕ) для дослідження перехідних процесів у трибосистемах. деревообробного обладнання під час обкатки. Використання даного методу дозволить отримувати інформацію про стан поверхонь тертя та швидкість зношування під час перехідних процесів (обкатки) в режимі онлайн. Для обґрунтування вибору інформативних параметрів АЕ проаналізовано тип АЕ – сигнальні кадри, захоплені в процесі переходу в характерних точках. Показано, що при оцінці швидкісного зносу в перехідних режимах найкраще використовувати потужність випромінювання акустичної емісії. Після завершення перехідного процесу (стаціонарний режим роботи) кадр сигналу АЕ набуває форми, яка сильно відрізняється від перехідного режиму. Експериментальні дослідження представлені у вигляді експериментальних залежностей, що відображають середнє значення потужності сигналів АЕ, де по осі *X* розміщено експериментальне значення потужності сигналів акустичної емісії із зони тертя, одиниці вимірювання – mB^2/c. По осі *Y* відкладене відповідне розрахункове значення швидкості роботи розсіювання в трибосистемах, одиниця вимірювання - Дж/с. Залежність дозволяє за виміряним у технологічному експерименті розрахувати значення потужності АЕ швидкості зносу в трибосистемі деревообробного обладнання в режимі реального часу. Для визначення максимальних значень швидкості зношування під час перехідного процесу обґрунтованими сигналами АЕ є метод АЕ та інформативний параметр – потужність. Експериментально встановлено, що потужність АЕ корелює зі швидкістю зносу деревообробного обладнання, коефіцієнтом кореляції R = 0,98 і адекватно відображає прибуток процесу. Отримані залежності дозволяють визначити швидкість роботи дисипації в трибосистемах деревообробного обладнання під час перехідного процесу за значеннями потужності сигналів акустичної емісії, що дозволило розробити методику розрахунку величин швидкості зносу деревообробного обладнання під час тренування в будь-якій точці перехідного процесу.

Ключові слова: трибосистема; знос; акустична емісія; потужність акустичного випромінювання; перехідні процеси; деревообробне обладнання; розробка.