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EXPERIENCE OF APPLICATION OF VIBROACOUSTIC ANALYSIS TO TESTING OF A REINFORCED CONCRETE BRIDGE ON THE DNISTER RIVER IN ZALISKY VILLAGE

ABSTRACT

A methodology has been developed for the application of vibro-acoustic diagnostics of the technical condition of bridges and their structural elements when carrying out static and dynamic tests of bridges by improving filtering methods and highlighting wavelet transform signal trends.

The object of study is the process of static and dynamic testing of bridges and their structural elements using acoustic emission diagnostics of a technical condition.

The subject of the study is the nature of the development of the process of deformation of reinforced concrete bridge spans under the influence of static and dynamic test loads.

The purpose of the study is to improve the reliability and reliability of the results of static and dynamic tests of bridges using acoustic emission diagnostics of their condition by improving filtering methods and highlighting wavelet transform signal trends. The use of the method of vibro-acoustic emission based on the wavelet transform provides the determination of the characteristics of the formation of acoustic pulses, the determination of the growth and extinction of their amplitudes and the change in frequency characteristics over time. The advantages of using wavelet transform are the possibilities of software implementation of removing noise from the signal and highlighting certain frequency components of the signal as independent components. The equipment for measuring and fixing signals of vibroacoustic emission was developed, which consists of a four-channel recording unit, an external analog-to-digital conversion module, a control laptop, and a size range of wideband piezoelectric transducers integrated on neodymium magnets. The developed vibroacoustic analysis was tested during static and dynamic tests of a reinforced concrete bridge across the river Dniester on the highway M-12, km 28 + 964 near the village Zaliski. The established values of the oscillation frequency of the run beams is the passport characteristics of the bridge and how the input values are used to assess the degree of wear of the span structure during operation. The developed methodology and equipment for vibro-acoustic diagnosis of the technical condition of bridges and their structural elements are recommended for use in related fields, including for the diagnosis of structures and building structures to be tested.

KEYWORDS: bridge, tests, statics, dynamics, vibroacoustics, equipment, transducer, signal, wavelet transforms, noise, trend, frequency, characteristic.

ДОСВІД ЗАСТОСУВАННЯ ВІБРОАКУСТИЧНОГО АНАЛІЗУ ПРИ ВИПРОБУВАННЯХ ЗАЛІЗОБЕТОННОГО МОСТУ ЧЕРЕЗ РІЧКУ ДНІСТЕР В С. ЗАЛІСКИ

АНОТАЦІЯ

Розроблено методологію застосування віброакустичного діагностування технічного стану мостів і їх конструктивних елементів, при проведенні статичних і динамічних випробувань мостів, шляхом удосконалення методів фільтрації та виділення трендів сигналів вейвлет-перетворенням.

Об'єкт дослідження — процес статичних і динамічних випробувань мостів і їх конструктивних елементів з застосуванням акустико-емісійного діагностування технічного стану.

Предмет дослідження — характер розвитку процесу деформування залізобетонних прогонових будов мостів під дією статичних і динамічних випробувальних навантажень.

Мета дослідження — покращенні надійності і достовірності результатів статичних і динамічних випробувань мостів застосуванням акустико-емісійного діагностування їх стану, шляхом удосконалення методів фільтрації та виділенням трендів сигналів вейвлет-перетворенням. Використання методу віброакустичної емісії на основі вейвлет-перетворення забезпечує визначення особливостей формування акустичних імпульсів, визначення показників наростання та згасання їх амплітуд і зміну частотних характеристик в часі. Перевагами у застосуванні вейвлет-перетворенні є можливості програмної реалізації видалення перешкод з сигналу та виділення певних частотних складових сигналу як самостійних компонентів. Розроблено обладнання вимірювання та фіксації сигналів віброакустичної емісії, яке складається з чотирьохканального блока реєстрації, зовнішнього модуля аналого-цифрового перетворення, керуючого ноутбука та типорозмірний ряд інтегрованих на неодимових магнітах широкосмугових п'єзоелектричних перетворювачів. Виконано апробацію розробленого віброакустичного аналізу під час проведення статичних і динамічних випробувань залізобетонного мосту через р. Дністер на автомобільній дорозі М-12, км 28+964 біля с. Заліски. Встановлені значення частот коливань балок прогонів є паспортними характеристиками мосту і як вхідні значення призначені для оцінювання ступеню зносу конструкції прогонових будов в процесі експлуатації. Розроблену методику і обладнання віброакустичного діагностування технічного стану мостів і їх конструктивних елементів, рекомендується для застосування в суміжних областях, в тому числі для діагностування споруд і будівельних конструкцій, що підлягають випробуванням.

КЛЮЧОВІ СЛОВА: міст, випробування, статика, динаміка, віброакустика, обладнання, перетворювач, сигнал, вейвлет-перетворення, перешкода, тренд, частота, характеристика.

ОПЫТ ПРИМЕНЕНИЯ ВИБРОАКУСТИЧЕСКОГО АНАЛИЗА ПРИ ИСПЫТАНИИ ЖЕЛЕЗОБЕТОННОГО МОСТА ЧЕРЕЗ РЕКУ ДНЕСТР В С. ЗАЛИСКИ

АННОТАЦИЯ

Разработана методология применения виброакустического диагностирования технического состояния мостов и их конструктивных элементов, при проведении статических и динамических испытаний мостов, путем усовершенствования методов фильтрации и выделения трендов сигналов вейвлет-преобразованием.

Объект исследования — процесс статических и динамических испытаний мостов и их конструктивных элементов, с применением акустико-эмиссионного диагностирования технического состояния.

Предмет исследования — характер развития процесса деформирования железобетонных пролетных строений мостов под действием статических и динамических испытательных нагрузок.

Цель исследования — улучшение надежности и достоверности результатов статических и динамических испытаний мостов, применением акустико-эмиссионного диагностирования, их состояния путем усовершенствования методов фильтрации и выделением трендов сигналов вейвлет-преобразованием. Использование метода виброакустической эмиссии на основе вейвлет-преобразования, обеспечивает определение особенностей формирования акустических импульсов, определение показателей нарастания и угасания их амплитуд и изменение частотных характеристик во времени. Преимуществами применения вейвлет-преобразования есть возможности программной реализации удаления помех из сигнала и выделения определенных частотных составляющих сигнала в качестве самостоятельных компонентов. Разработано оборудование измерения и фиксации сигналов виброакустической эмиссии, которое состоит из четырехканального блока регистрации, внешнего модуля аналого-цифрового преобразования, управляющего ноутбука и типоразмерный ряд интегрированных на неодимовых магнитах широкополосных пьезоэлектрических преобразователей. Выполнено апробацию разработанного виброакустического анализа при проведении статических и динамических испытаний железобетонного моста через р. Днестр на автомобильной дороге М-12, км 28 + 964 возле с. Залески. Установленные значения частот колебаний балок прогонов являются паспортными характеристиками моста и как входные значения используются для оценки степени износа конструкции пролетных строений в процессе эксплуатации. Разработанная методика и оборудование виброакустического диагностирования технического состояния мостов и их конструктивных элементов рекомендуются для применения в смежных областях, в том числе для диагностирования сооружений и строительных конструкций, подлежащих испытаниям.

КЛЮЧЕВЫЕ СЛОВА: мост, испытания, статика, динамика, виброакустика, оборудование, преобразователь, сигнал, вейвлет-преобразования, помеха, тренд, частота, характеристика.

INTRODUCTION

Increased weight of vehicles with a total mass of up to 40 t [1], exceeds the designed loads at the time of construction of most road bridges (about 74% [2]), leads to structures intensive wear and reduced service life compared to calculated values. Ensuring traffic safety requires reliable data of the actual load capacity of each bridge and a forecast for its change over time. According to current building codes [3, 4], the most effective means of establishing actual capacity and compliance with design requirements is to test bridges, both new and in service, including periods after reconstruction or major repairs. The relevance of the topic to the road industry in Ukraine is improving reliability of static and dynamic testing results of bridges by acoustic emission diagnostics of their condition.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Existing methods of static and dynamic [5, 6] tests with acoustic emission diagnostics of the technical condition of bridges allow to establish presence of defects or damages in the structural elements that reduces bearing capacity. It's impact on the load capacity cannot be taken into account in the calculations. The acoustic emission of destruction as a criterion for the condition of an element allows to establish quantitative limit of the step load and provides practical implementation of non-destructive methods of strength control during testing. Due to its ability to identify fracture events at the initial stage of damage, acoustic emission methods are widely used in the monitoring of building structures [7, 8], machines [9–12], and material testing [13]. Acoustic emission waves generated by the release of energy from a localized source or multiple sources within an object during deformation can provide comprehensive information on the defect's origin. The change in the energy radiation intensity over time, depending on the constant or cyclic force, may provide information on development of such a defect. In references [14, 15], a complex approach to the analysis of a broadband signal of radiation of the running structures of elastic waves caused by a dynamic local change in the structure of reinforced concrete and the movement of the object as a mechanical system, with the determination of the state of the bridge by the ratio of acoustic (high-frequency) energy and vibrational (low frequency component) oscillations - that is vibroacoustic emission. The advantage of this approach is the ability to apply the same methodology to the measurement and analysis of signals in both static and dynamic bridge tests.

Measurement and recording of acoustic emission signals during testing, especially in field conditions, is highly complicated due to formation of interferences in electrical circuits because of sufficiently low energy of the acoustic waves themselves. In [16, 17], methods of overcoming the effect of interference by setting a fixation threshold are presented, but that approaches lead to the loss of acoustic signals information which intensity is close to the intensity of interference.

Insufficient knowledge of the measurement and processing of acoustic and vibration signals prevents the objectivity of determining the condition of bridges and structures.

The object of study is the process of static and dynamic testing of bridges and their structural elements with the use of acoustic-emission diagnostics of technical condition.

The subject of study is the development of the process of deformation of reinforced concrete girder structures by the action of static and dynamic test loads.

The purpose of the study is to improve reliability of the results of static and dynamic testing of bridges by using acoustic emission diagnostics of their condition due to improving methods of filtering and distinguishing trends of wavelet transform signals.

Research Objectives:

- to develop an algorithm for filtering and isolating the signals trends of vibration and acoustic emission by wavelet transformations;
- to develop equipment for measurement and recording of vibroacoustic emission signals for static and dynamic testing of bridges;
- to test the methodology of determining the state of the elements of the bridge structure by the level of vibroacoustic emission signals during static and dynamic testing of bridges.

BASIC MATERIAL AND RESULTS

1. Filtering and highlighting trends and the acoustic component of wavelet transform signals

Fundamental foundations for the use of wavelet transforms were created by I. Dobeshi [18], who formed for the time series *S* length *N* the transformation algorithms: direct

$$W = wave(S) \qquad (1)$$

and inverse

$$S = iwave(W), \qquad (2)$$

where the length of the time series *S* should be $N = length(S) = 2^P$ and the exponent *P* must be an integer and is the length of the signal conversion levels

$$P = \frac{\ln(N)}{\ln(2)}. \qquad (3)$$

The coefficients vector k_i, as a result of the direct wavelet transform $W_i = k_i$, it is makes sense to represent in the form of a matrix with the arrangement on the levels of transformation (rows of the matrix), starting with filling the lowest level

$$coeffs(Level) = submatrix(W, 2^{Level}, 2^{Level} - 1), \quad (4)$$

where $Level=0...P$ — the level number of the transformation matrix;

submatrix(W, ir, jr) — a function that rotates a matrix, which alternately consists of rows of vector *W* elements starting with *ir* length *jr*, so the length of each line from the level $Level=1$ is calculated as

$$p_{Level} = length(\text{coeffs}(Level)) = \frac{2 \cdot TS \cdot N \cdot f_{Level} - 1}{2}, \quad (5)$$

except for the line of the level $Level=0$, for which the length is equal $p_0=2$.

Vibro-acoustic emission signals are fully compliant with time series requirements because they are recorded at a constant sampling rate *f* and, accordingly, at a constant sampling interval

$$f = \frac{1}{TS}. \quad (6)$$

There is a relationship between the conversion level and the oscillation frequency of a component signal at a certain level.

$$f_{Level} = \frac{2 \cdot p_{Level} + 1}{2 \cdot TS \cdot N}. \quad (7)$$

Joining vectors *coeffs(Level)* by rows creates a common wavelet matrix *MW*. Since the lengths of the signal vectors *S* and wavelet coefficients *W* are by definition the same as the number of elements of the wavelet matrix *MW* and there are algorithms for forward and reverse transformation, wavelet transformation is the process of changing the form of representation of numerical data. The wavelet matrix *MW* (see Figure 1a) has a triangular shape with the location of the vertex at the bottom and facing directly to its elements requires a change in indexing according to dependence (4). Therefore, to maintain the uniqueness of the values in the matrix *MW*, we will use element numbering k_i that corresponds to the elements of the vector $W_i = k_i$.

The scheme of arrangement of coefficients at wavelet signal conversion is shown in Figure 1a, for which, for wavelength 3 $T=N \cdot TS$, within the wavelet transform window 1, the coefficients form single wavelets relative to the centers of the intervals within levels 2. It is obvious that the total wavelet waveform will form a three-dimensional signal in the time-frequency plane *t⇔Frequency*.

Major Benefits of wavelet conversion practical application are software implementation options:

- removal of noise from the signal;
- allocation of certain frequency components of the signal as separate components.

Since, by definition, interference is a component of a signal with a random amplitude and a random frequency of realization, in the wavelet transform window (see Figure 1a) the influence of interference will be manifested by a uniform change coefficients k_i values. Thus, setting the noise threshold W_{Noise}, taking into account the influence of the wavelet level, the construction of the wavelet K_{Level} coefficient vector of the noise-free signal can be performed according to the algorithm

$$WDN_i = \begin{vmatrix} W_i & if & |W_i| \geq |K_{Level} \cdot W_{Noise}| \\ 0 & if & else \end{vmatrix}. \quad (8)$$

The interference-cleared signal *SDN* may be recovered from the wavelet reverse vector *WDN* (2).

The selection of signal components in a certain frequency range as separate components is carried out after setting the signal conversion levels for the given lower f_{Low} and upper f_{High} frequency thresholds in accordance with the dependence (7)

$$p_{Threshold} = \left\lceil \frac{2 \cdot TS \cdot N \cdot f_{Threshold} - 1}{2} \right\rceil. \quad (9)$$

Then the vector of the wavelet coefficients of the frequency components of the signal is plotted against

$$WT_i = \begin{vmatrix} WDN_i & if & p_{Low} \leq p_k < p_{High} \\ 0 & if & else \end{vmatrix}. \quad (10)$$

The frequency component signal is also restored from the vector *WT* by reverse wavelet transform (2). A full low frequency component of a signal that is limited in the frequency domain only from above $f_{High} \Leftrightarrow p_{High}$, that is, for which $p_{Low}=0$ is called a signal trend.

An example of processing a fragment of a real vibroacoustic signal *S* is shown in Figure 1b, where the input is rich in interference, signal 1, on the background of which there is a trend of signal 5, has both low frequency component and acoustic pulses 2. The signal *SDN* cleared from interference (8) and (2) is characterized by a pronounced low frequency oscillation 3, on the background of which acoustic pulses are developed 4. In the future, the noise-cleared signal *SDN* according to algorithms (10) and (2) is decomposed into low-frequency component (trend) *STr* — 5 and high-frequency (acoustic) component of the signal *DeTr* — 6. Actually, these components of vibroacoustic further you signal used to analyze the state of an object.

2. Equipment for measurement and recording of vibroacoustic emission signals

In accordance with the methodology outlined above, taking into account the benefits of wavelet signal processing, the equipment for measuring

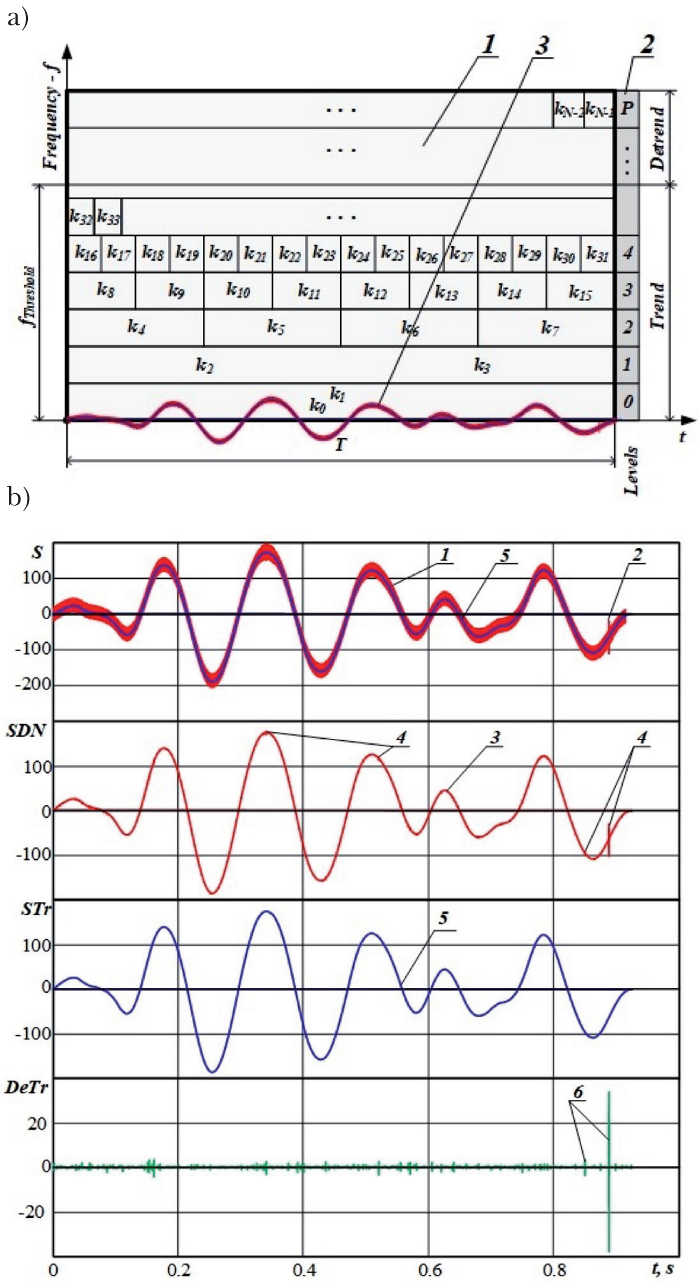


Figure 1 — Schematic diagram of the wavelet transform signal processing

a) scheme of wavelet signal conversion: 1 — wavelet transform window; 2 — levels of transformation; 3 — signal being converted

b) an example of signal processing: 1 — the input vibroacoustic signal; 2 — acoustic pulse; 3 — signal after clearing of noise; 4 — acoustic pulses; 5 — low frequency component (trend) of the signal; 6 — high frequency (acoustic) signal component

and recording of vibroacoustic emission signals was developed. Structurally, the equipment for measuring and recording vibration acoustic signals (Figure 2a) consists of:

- four-channel registration unit, which provides pre-normalized high-precision charge amplifier CA-2614 with a signal frequency up to 96 kHz;
- an external analog-to-digital conversion (ADC) module ADA-1406 with a polling frequency of 50000 Hz for each channel, which enables the detection of manifestations of signals with a frequency up to 25000 Hz;
- Laptop connect to the ADC via a USB cable.

A schematic diagram of a piezoelectric vibroacoustic emission converter is shown in Figure 2b. The converter consists of a housing that uses a neodymium magnet 1, a sleeve 2, a high-frequency piezoelectric element 3, a low-frequency piezoelectric element 4, which is mounted in a bimorphic manner, and a cover 5. The connecting cable is not conventionally shown. Depending on the ratio of the effective diameters *d* and *D* of the elements 3 and 4, the converter is capable of generating vibroacoustic signals of varying intensity in the low-frequency range, which enables rational selection. For application in road test conditions, a standard design series of transducers with numbers 00, 0, 1, 2 and 3 has been developed to record low-frequency vibrations from 0.3 to 60 Hz.

Integration on a neodymium magnet greatly simplifies the installation of the transducer during testing, since retention is only due to the force of gravity to the circuit of the reinforcement through the protective layer of concrete (Figure 2c). Optional magnetic disks may be used to increase weight. To improve the acoustic bond between the transducer and the surface of the reinforced concrete beam, the vaseline No. UA / 8304/01/01 dated 30.11.2018 was used as an acoustically transparent liquid.

In order to increase the reliability of information retention, the measurement results are recorded in a sequence of short files in binary format. The size of a file with is a record of 170 thousand measurements in one channel (approximately 2.6 s) is 262.2 Kbytes. The packages of the measurement results files for each of the tests are subsequently stored in a database and stored on separate archives.

Because the signal sections containing the acoustic activity pulses and vibrations take only a few percent of the measurement program in the total volume of records, they are directed to search, isolate and write to separate files directly. The following fragments of signals when stored and signs of their occurrence: poll number from the beginning of the recording, the frequency of the poll and the signal snippet itself. Examples of file fragments with acoustic pulses and vibrational vibrations are shown in Figure 3.

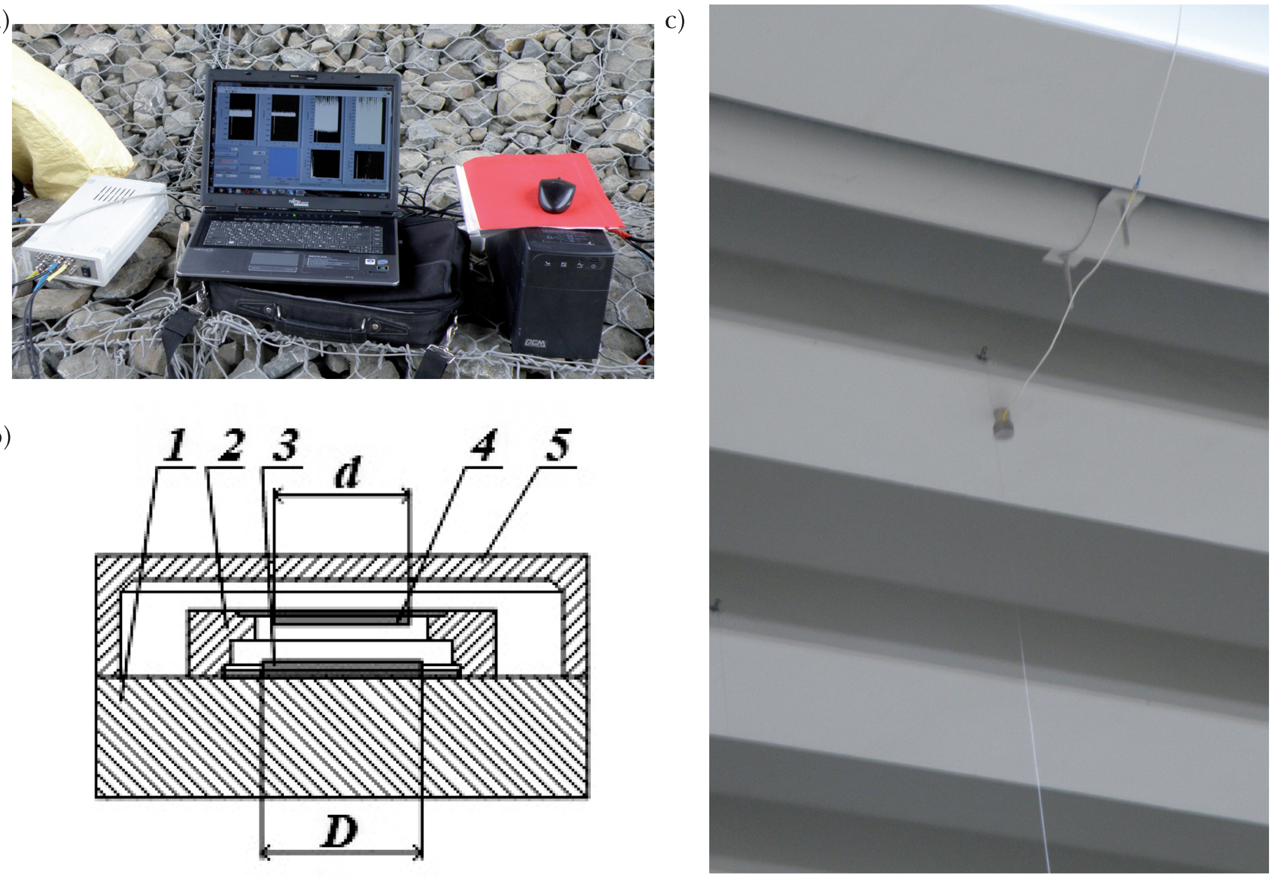


Figure 2 - Equipment for the recording of vibro-acoustic emission signals
a) measuring equipment; b) schematic diagram of the vibro-acoustic emission converter;
c) attaching the piezoelectric transducer to neodymium magnets

The figure shows the oscillation diagrams in units of a 14-bit ADC, the three-dimensional wavelet image (scalogram) of the signal (see Figure 1a) and its amplitude-frequency response (AFC). Comparison of oscillation diagrams with charts provides an opportunity to determine the nature of the dynamics of the process over time and to track changes in the intensity and frequency of oscillations over time.

The application of the wavelet transform measurement and signal processing set provided in this paper greatly simplifies the static and dynamic testing of bridges.

3. Static and dynamic testing of reinforced concrete bridge using vibroacoustic emission methodology

As a test of vibroacoustic analysis, we present the experience of static and dynamic testing of a reinforced concrete bridge. Testing of the bridge over the Dniester River on the national highway M-12 Stryi — Ternopil — Kropyvnytskyi — Znamyanka (through Vinnytsia), km 28 + 964 in the Lviv region (Figure 4) was carried out after reconstruction, the project of which designed under the guidance of the author of the article, included:

- static tests with step load using acoustic emission method according to [5];
- dynamic tests of structures in accordance with [4].

These test methods apply to technical diagnostics of bridges and overpass elements that are on the balance sheet of the State Agency for Highways of Ukraine.

Static tests were carried out for runs No. 1-2 and No. 2-3 and supports No. 3 of supports by step loading of trucks with a total weight of 64 tons (Figure 5). The assessment of the danger of the destruction process in the reinforced concrete beam of the spacer structure at step load according to [5] was carried out according to the criterion of the danger of the development of the destruction process. By this criterion, the value of the exponent was determined by the decision of the step equation

$$E = a \cdot P^{b} , \qquad (11)$$

E - the total value of the accumulated energy of the AE signals during exposure under load at the last and penultimate stages of the load;
P - the value of the load on the running structure at the last and penultimate stages of loading;
a - coefficient of equation.

AE cumulative energy diagrams are calculated as

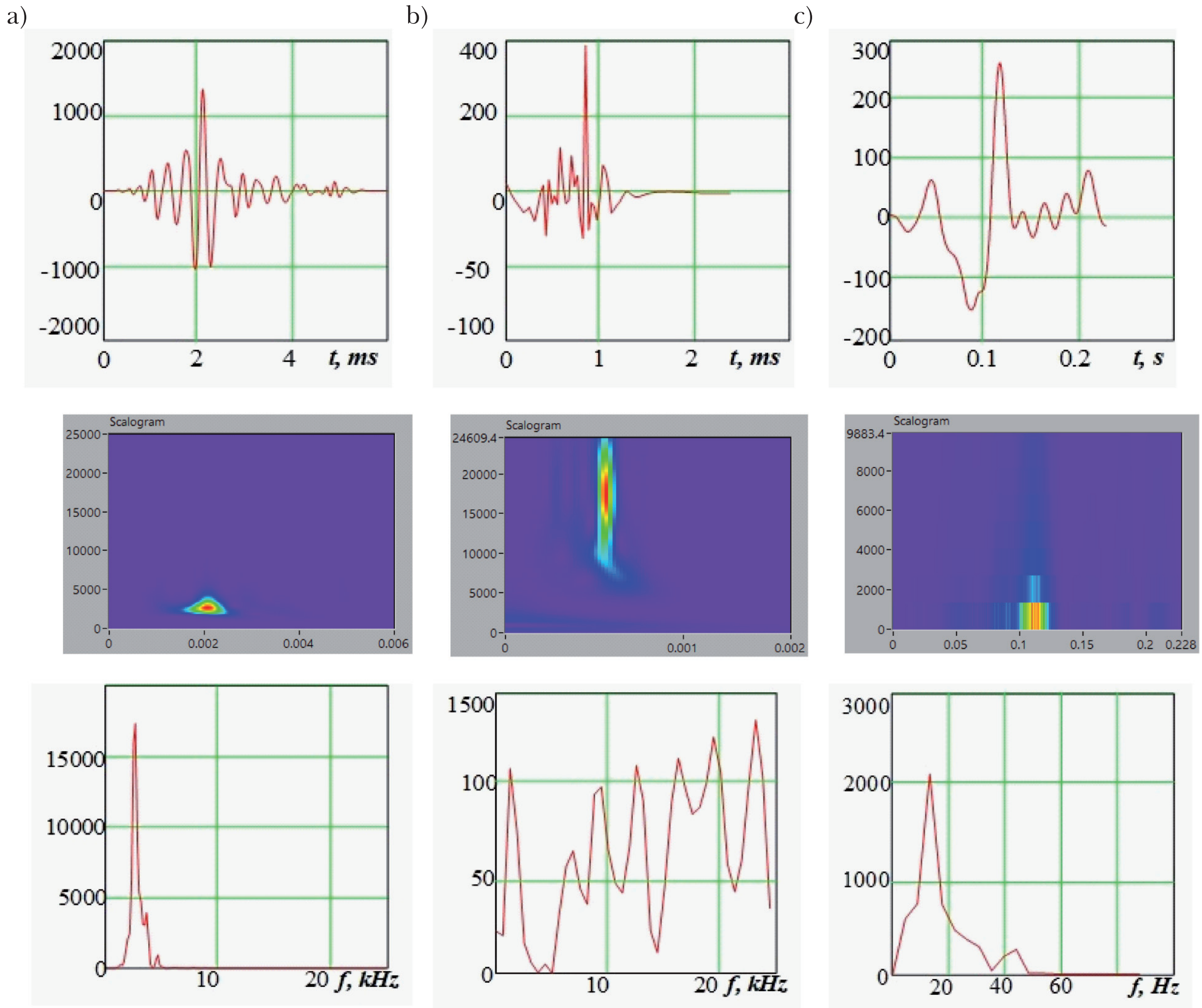


Figure 3 - Fragments of files with vibro-acoustic emission signals
a) an acoustic pulse with a frequency of 2.6 kHz; b) an acoustic pulse with a frequency of 23.7 kHz;
c) vibration pulse with a frequency of 2.52 Hz;

$$E_i = \sum_{k=0}^{i} \left| S_{AE_k} \cdot TS \right| , \qquad (12)$$

S_{AE_k} - the current value of the AE signal recorded by the PVA;

i - number of degree of load (last or penultimate).

Accumulation diagrams of AE energy (Figure 5b) for 6, 7, and 8 schemes of loading of the run structure № 2-3 are constructed to determine the components of equation (11) by the results of measurements. The load circuit 6 of the test No. 2 could not be applied to evaluate the state of the run No. 2-3 and the cumulative energy diagram of AE for it (diagram 3, see Figure 5b) was used to evaluate the condition of the section of the thermally cut back plate above the support No. 3.

Assessment of the beam condition No. 7 of the run structure No. 2-3 was performed on the basis of the results of measurements of the cumulative diagrams of AE energy for loading (Table 1):

- scheme 7, diagram 1 (see Figure 5b);
- scheme 8, diagram 2 (see Figure 5b).

The results of the dequation (11) for the data of diagrams 1 and 2 (see Figure 5b) are given in Table. 2.

As evidenced by the results of calculations, the

Figure 4 - General view of the bridge through river Dnister at State Automobile Highway M-12, km 28+964 in Lviv region

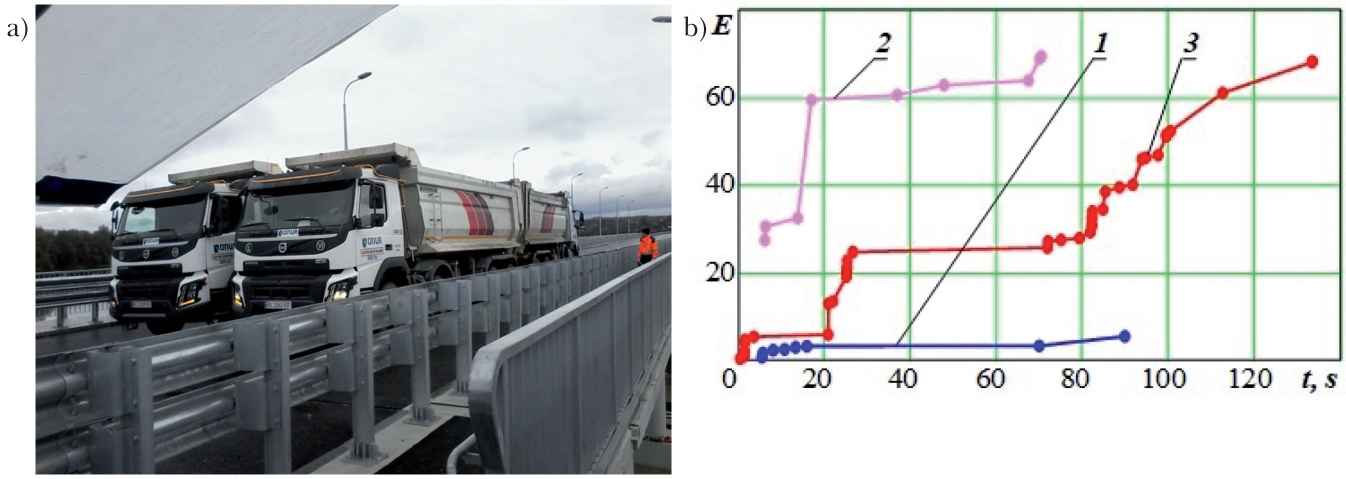


Figure 5 - Static tests of the bridge over the Dniester River
a) establishment of a test load; b) diagrams of acoustic emission energy flow over time:
1 — load of the run No. 2-3 on the left side; 2 — load of run No. 2-3 on the right side;
3 — load support No. 3

value of the exponent for beam No. 7 of the run structure No. 2-3 at load by scheme 7 is 0.779, and at load by scheme 8 is 1.184. Since in both of these cases the value of the exponent does not exceed 3.0, it should be recognized that defects that develop in the structure of the material of the reinforced concrete beam are not dangerous.

Dynamic tests of the bridge over the Dniester river were conducted by recording the vibroacoustic emission signals in beams No. 7 of runs No. 1-2 and No. 2-3 during the movement of the test trucks and the passage of transport in the intervals between the test loads. The vibration acoustic emission signal transducers determined the characteristics of the vertical oscillations of the central points of the beams No. 7, on the lower surface of which they were installed, by the parameters of the low-frequency component of the signals. Examples of vertical oscillation diagrams and their amplitude-frequency characteristics are not shown in Figure 6 for run No. 1-2 — 1 and run No. 2-3 — 2. The values of oscillation frequencies of runner beams during the passage of transport, which make up for run No. 1-2 — 18.75 Hz, and run No. 2-3, are also determined — 15.17 Hz.

According to standard [4] set values of oscillation frequencies of beams in the course of further operation, it is recommended to use as input values for estimation of degree of deterioration of structure of run structures.

Test results of a reinforced concrete bridge over the Dniester river in village Zalisky showed, that the use of vibroacoustic analysis allows to determine the peculiarities of the formation of acoustic pulses, indicators of growth and attenuation of their amplitudes and changes in frequency characteristics over time. The set values of the oscillation frequencies of the beams are the passport characteristics of the bridge and as input values are to be evaluated for the degree of wear of the structure during operation.

The practical result of the work is development of algorithms for filtering and isolating the trends of vibration and acoustic emission wavelet transform signals and the equipment for measuring and recording vibration acoustic emission signals for static and dynamic testing of bridges.

The methodology of determining the state of the elements of the bridge structure by the level of vibroacoustic emission signals during static and dynamic tests was shown to improve and reliability of the results, reducing costs and time of tests themselves.

Table 1 - Total radiation energy of AEи

Load circuit number	Load option	Number of AE events	The total energy of AE
Support No 3			
6	Four trucks over support No. 3	36	681.26
Run No 2-3, beam No 7			
7	Two trucks over the beam No. 7	9	69.39
8	Two trucks over the beam No. 2	8	5.42

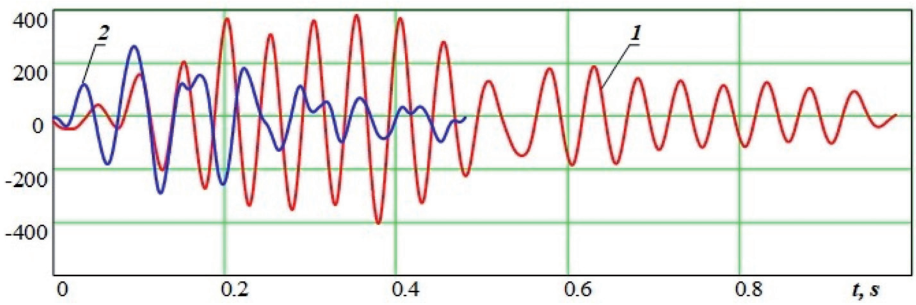
CONCLUSIONS AND PROSPECTS FOR FURTHER DEVELOPMENT

1. Methods of application of vibroacoustic diagnostics of the technical condition of bridges and their structural elements for static and dynamic testing of bridges are developed by means of theoretical and experimental researches by improving the methods of filtering and distinguishing the trends of

Table 1 - Indicators of the state of the beam No. 7 of the running structure No. 2-3

№№	Options for comparing load schemes	Load, t		*a*	*b*
		One truck	Two trucks		
1	Scheme 7	46	92	0.160	0.779
2	Scheme 8	46	92	0.329	1.184

a)



b)

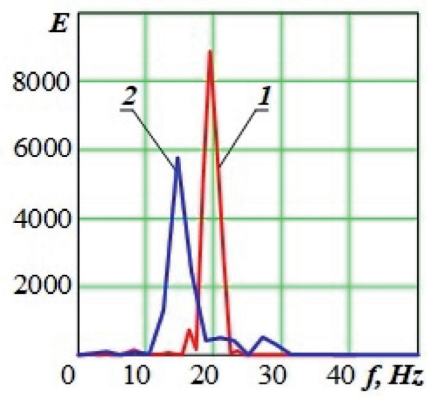


Figure 6 - Dynamic tests of the bridge over the Dniester River
a) diagrams of signals of vertical oscillations of the central point of beams No. 7;
b) Frequency response of vertical oscillations of the central point of beams No. 7:
1 — run No. 1-2; 2 — run No. 2-3

wavelet transform signals. The use of the method of vibroacoustic emission provides the determination of the peculiarities of the formation of acoustic pulses, the determination of the growth and decay of their amplitudes and the change of frequency characteristics over time. The set values of the oscillation frequencies of the beams of the beams are the passport characteristics of the bridge and as input values are to be evaluated for the degree of wear of the structure of the beams during operation.

2. The developed technique of vibroacoustic diagnostics of the technical condition of bridges and their structural elements is recommended for use in adjacent areas, including for the diagnosis of structures and structures to be tested.

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