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Analysis Technique of Spectral Characteristics AE Signals with Application to Monitored for WT

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Abstract

The paper presents the results of an assessment with a range as real AE signals are received at destruction of spot welding, and imitated by means of a AE transducer are given in work, efficiency use of high-frequency area for recognition of AE signals against hindrances is shown. The actuator is excited by an impulse signal instead of a sinewave, and the responses are measured with the PE sensors. The spectral characteristics of AE signals should use broadband transducers with the rise in the PE side of the treble to compensate for PE of the sample, and partly of the signal spectrum, which is reduced the measurement error of the absolute values. The damage could be indicated in an experiment, but it turned out that the sensitivity is low if the damage is not in the path between actuator and sensor. When a machine has a mistake, it leads to energy loss and results in the transformation of sound, heat and the whole performance. The basis of most condition monitoring techniques WT has been constructed by the various features.

Keywords*: acoustic emission, NDT, spectral characteristics, wind turbines, spectral function, PE*

1. Introduction

Acoustic emission (AE) control systems are used variety of sources AE classification according to the degree of danger and the criteria for assessing the state of the object. In these criteria as a measure of danger of the separate act of AE amplitude, energy or number of oscillations of the registered impulse is used [1-2]. However all listed parameters are interconnected and actually reflect only impulse power irrespective of its nature. In this regard use of similar amplitude and power criteria in the situations which are often found in practice when along with signals from a source of AE the powerful acoustic hindrances, for example, caused by processes of friction are registered. One of possible methods of the solution of this problem is use of the spectral characteristics of the AE signal which are adequately reflecting the nature of impulses of issue. The most popular ways of an assessment of spectral density on discrete sequence of counting of a signal are given below [3]. This method only allows detecting existing defects, which classify them not by the size but by the danger levels. That is the most sensible method of nondestructive testing (NDT).

The necessity of AE signal analysis is to be proved in broad band. It is well known that material AE is the process of producing elastic wave, and triggered by local dynamic reconstruction of its structure. It is important to pay attention to the formation and

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development of cracks in the industrial facilities of the emergency and fault. Increased efficiency and reliability of modern industrial equipment with one hand, makes it necessary to use him in conditions close to the limit, and, with another - requires a fairly accurate determination of the stress-strain state in the test facility for timely identification of critical situations and prevent of the destruction. Therefore, an important challenge is the development of various nondestructive control methods for assessing the strength properties of materials in the operation of structures without destroying its integrity [4-5]. Recent decades of experience have shown that the acoustic emission method, which is simple to use, economy, and provides the potential for continuous monitoring of growth, potential defects in the construction and industrial uses.

Most wind turbines (WT) of the machine are three blade units, including the main components, blades and rotor passing energy through the spindle through the transmission of the generator. The spindle is supported in the bearing, and the gearbox is such that the speed of the generator, which is as close to the optimal power generation as possible. Aligned with the direction of the wind is a horizontal pendulum system to control the housing being installed at the top of a tower[6-8].The general idea is to imply a scheme to detect faults occurring which is based on the measured process data in the physical processes. That includes the location of component deterioration, the isolation of the fault location, and the time characteristics of fault. The reliability of wind turbines can be increased to make the construction more powerful. However, the design has resulted in a serious material cost due to the expansion of the current, which is of course not desirable, so that the construction expends more weight. In order to make offshore wind turbines feasible, lighter construction must be designed with higher reliability than the current generation of WT [9-11]. To achieve this grand goal, a more lightweight must be developed more robust material, and then the material scientists have raised a great challenge. Another big progress can be made by the control engineer: the design of the better maintenance plan of the turbine components which can lead to lower costs and higher availability of turbine.

2. Experimental Data

The experiments have been carried out based on quantitative acoustic emitted from the pulse, which have shown that the application of acoustic emission parameters reading is described by the principle that always leads to low accuracy of the study results. The occurrence of errors in the system does not rule out the existence of system errors and it is assumed to be the characteristics of the acoustic emission characteristics of the physical unit. If compared to the unit of the international system of the main acoustic emission measurement unit, it can be seen that the generally accepted acoustic unit is almost never used for acoustic emission description.

The single acoustic impulse in a solid body or on its surface results from transition of a body from one state in another, and can be roughly approximated by step function [12-13]. The sensor perceives fluctuations of some area of a surface, and its signal is an integrated response to these fluctuations and often represents the sum: A single acoustic pulse in the solid or surface arises as a result of the transition of the body from one state to another, and can be roughly approximated by a step function. The sensor senses vibrations of a same surface region, and its signal is an integral response to these fluctuations, and often is the sum of:

$$S(t) = \sum_{i=1}^{\infty} A_{0i} e^{-\alpha_{0i} t} \sin(\omega_{0i} t) \qquad (1)$$

Where ω_{0i} – the natural frequency corresponding to one or another form of fluctuations;

Where α_{0i} – the natural oscillation damping coefficient at this frequency.

Thus, generally it is possible to tell that the signal of AE represents a quasi-harmonic signal or set of such signals with some modulating function. The standard approach in the analysis of a range of such signals is reduced to the analysis of a range of the modulating function. As the bending around change with considerably smaller frequency than the filling function, the range turns out low-frequency. Such approach does not seem absolutely lawful in particular in the analysis of noisy signals. In the form signals of acoustic noise and AE are very similar; however the dynamic range of noise can exceed the level of a useful signal several times. When using the above described approach, the spectral analysis will be undergone only low-frequency bending around and emergence of effect of masking when stronger noise component hides lower component of a signal is possible. For confirmation we will find analytical expression of a range of the signal (2):

$$S(\omega) = \sum_{i=0}^{\infty} \left(\frac{1}{2} e^{i\varphi_{0i}} \frac{A_{0i}}{\alpha_{0i} + j(\omega - \omega_{0i})} + \frac{1}{2} e^{-i\varphi_{0i}} \frac{A_{0i}}{\alpha_{0i} + j(\omega - \omega_{0i})} \right) \tag{2}$$

Where φ_{0i} –initial phase of the signal.

Table 1. Parameters of the Test Signal

i	Parameter			
	Amplitude A_0	Frequency ($\omega_{0i} = 2\pi f_{0i}$) f_0, KHz	Attenuation coefficient α_0	Initial phase φ_0
1	10	10	$2 \cdot 10^3$	$\pi/2$
2	1	300	200	
3	1	400	140	

We will write down a formula 2 for 3 spectral components. In this case we use the parameters listed in Table 1.

$$\begin{aligned} S(w) = 5&\left(\frac{j}{2\cdot10^3 + j\left(\omega - 2\cdot10^4\pi\right)} - \frac{j}{2\cdot10^3 + j\left(\omega - 2\cdot10^4\pi\right)} \right) + \\ +0.5&\left(\frac{j}{2\cdot10^2 + j\left(\omega - 6\cdot10^5\pi\right)} - \frac{j}{2\cdot10^2 + j\left(\omega - 6\cdot10^5\pi\right)} \right) + \\ +0.5&\left(\frac{j}{1.4\cdot10^2 + j\left(\omega - 8\cdot10^5\pi\right)} - \frac{j}{1.4\cdot10^2 + j\left(\omega - 8\cdot10^5\pi\right)} \right) \end{aligned} \tag{3}$$

In Figure 1 the temporary form and ranges of a test signal are presented. Analytical dependence represents, for finding of a discrete range the method of Uelcha on the first 4096 counting was used. At such approach on graphics the bearing frequencies of the mixed harmonious components are accurately distinguishable. Now, following the technique offered by the authors, we will find the spectrum of the low-frequency bending-around temporary form of a signal:

$$\mathrm{S}(t) = \sum_{i=1}^{\infty} A_{0i} e^{-\alpha_{0i} t}, \qquad S(\omega) = \sum_{i=0}^{\infty} \frac{A_{0i}}{\alpha_{0i} + j\omega} \tag{4}$$

After substitution of numerical values:

$$S(\omega) = \frac{10}{2 \cdot 10^3 + j\omega} + \frac{1}{2 \cdot 10^2 + j\omega} + \frac{1}{1.4 \cdot 10^2 + j\omega} \quad (5)$$

$$\Delta_E = t_\alpha(z)\sqrt{\frac{G_E}{z}} \quad (6)$$

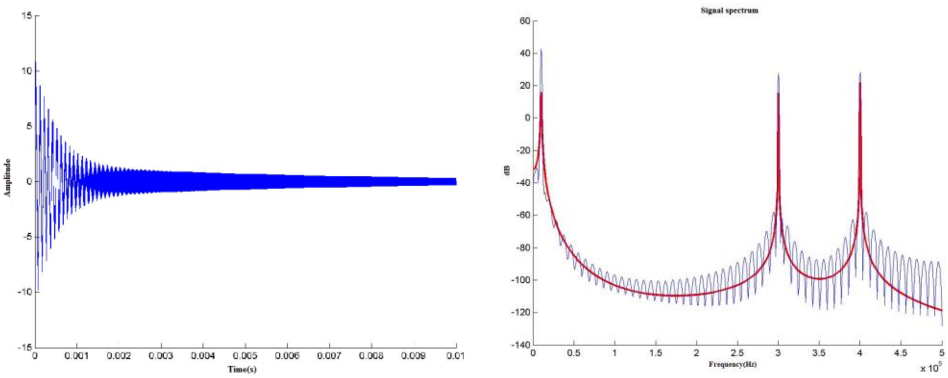

Figure 1. The Test Signal, a Temporary Form (at the left) and Spectrum: a) Received Analytically; b) Welch Received by Method on 4096 Counting (Hamming's Window, 8 Segments, Imposing of 50%)

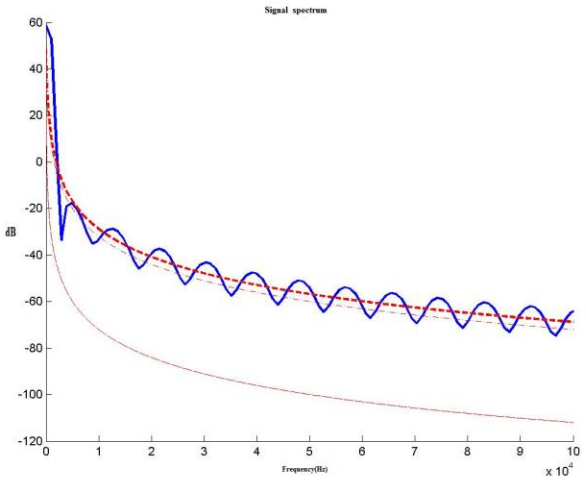

Figure 2. A Low-Frequency Spectrum of the Bending-Around Function of a Test Signal: a) Received Analytically; b) Welch Received by Method on 4096 Counting (Hamming's Window, 8 Segments, Imposing of 50%); c) The Individual Terms of the Analytical Spectrum

In Figure 2 the schedule is shown the modulating function of a signal. Values of all parameters are identical to the previous example, except for the absence of oscillating function. The interval of frequencies in this case is limited 10 kHz, as the remained interval spectral function monotonously decreases.

From this simple example it can be concluded that the analysis of the signal envelope not only to evaluate the fine structure of the spectrum, even if we would know the modulating function of each component individually, so eventually distinguish their contributions to the overall spectrum is difficult.

The presence of noise can only exacerbate the situation. Acoustic signals from processes of impact and friction possess big dynamic range (sometimes reaching 120db), and their experimental characteristic, in turn, is quite well approximated by a spectral characteristic of a Gaussian impulse, that is in the lower strip of frequencies and when imposing there will be an additional concealment of the true process.

3. Results of Pilot Studies

As already mentioned, the use of the spectral characteristics of the AE signal can help not only to detect but classify acoustic processes. To verify this statement, an experiment was performed in Figure 3. On the parallel plate of aluminum alloy 1cm width 10cm, length 30cm establishes joint sensor signal simulator of AE was installed by thickness width in common. The distance between them thus was. Acoustic contact was carried out by means of a greasing layer. The simulator was served by the piezoceramic element (PE) connected to the generator of sequence of rectangular impulses. A source of noise was process of friction of a metal tip about a plate.

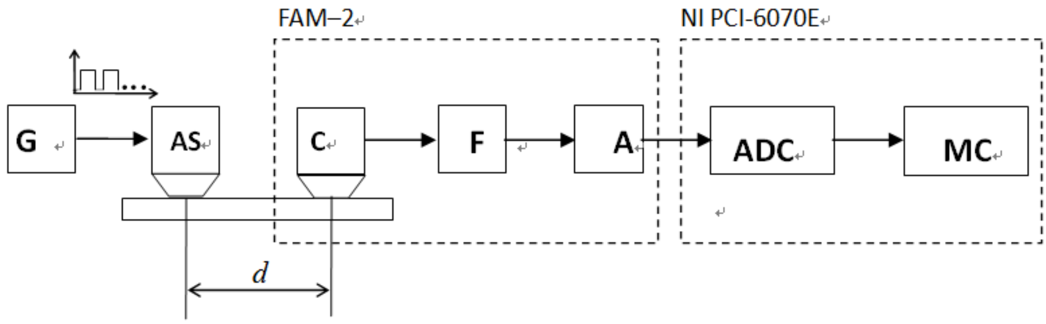

Figure 3. Block Diagram of Installation: G – Generator of Impulses; ASS– AE Signal Simulator; C - Converter; F – Filter; A –Amplifier; ADC – Analog to Digital Conversion; MC – Microcomputer

As shown in Figure 3, the signal from the generator of impulses got on the simulator, which caused the mechanical oscillations of a PE. Through acoustic contact, they extended on object and were registered the reception converter. Duration of an impulse of the generator made 1mks, and the acoustic response corresponding to it registered by the sensor, about 4ms. Further, EMIS-2 installation facilities, the electric signal registered by the sensor passed a preliminary filtration, amplification and fed to the data acquisition board NI PCI-6070E. Frequency of sampling is limited to opportunities of PCI-6070E ADC which is built in a payment, and makes 1Mb/s with 12-bit. As the program interface for data collection the NI LabVIEW environment was used. Directly analysis represents post-processing of the kept analog signal. To verify this statement, an experiment was performed. On the parallel plate of aluminum alloy 1cm width 10cm, length 30cm establishes joint sensor signal simulator and AE. Acoustic coupling was carried out by a layer of grease. The simulator served PE connected to the generator sequence of rectangular pulses. Noise source is the process of rubbing the metal tip on the plate.

In Figure 4 is shown the spectra of an imitating signal which passed through various environments are shown. The experiment was made with the purpose to reveal influence of geometrical forms of a wave guide. Since the beginning there was the signal spectrum which passed directly from the simulator to the sensor. This of a signal possesses the smallest duration that is explained by lack of the intermediate environment. Further, the sensor and the simulator were installed on plane-parallel plates from an aluminum alloy (width 10 cm, height 1 cm, length 25 cm) and the St.3 (width 20 cm, height 0.3 cm, length 20 cm). Apparently, the main energy of a signal settles down in the top strip of frequencies. Thus the lower frequencies most all fade when passing a signal through a thick plate. It is possible to draw a conclusion that at pulse impact on the simulator the signal which energy mainly settles down in the top strip of frequencies is developed, while its component quickly fades with the passage of the object.

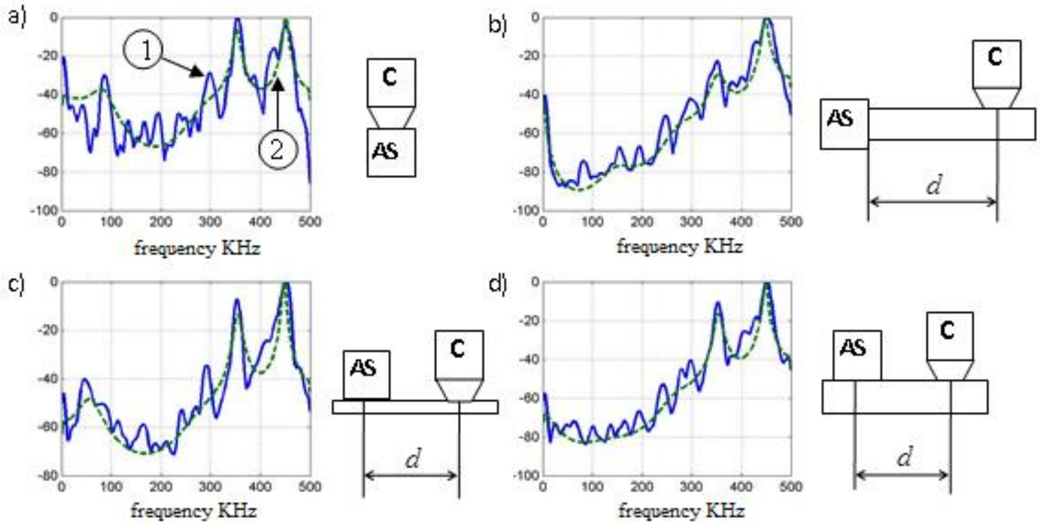

Figure 4. Spectral Characteristics of the Signal Simulator which Passed through Various Environments (D=15cm) Received on 512 Counting: 1) by Method of Uelcha; 2) by the Modified Covariance Method

Accurately allow to define the moment of arrival of an impulse of the simulator two of them: the speed of the account of AE and the spectrogram received by the modified covariance method of the 10th order on each 1024 counting. The ability of AE count rate characteristics distinguish useful even against impulse noise is explained by the predominant high frequency nature of the latter, since the amount depends on the frequency of a predetermined discrimination threshold crossing per unit time. However, although the fact of presence is established almost authentically, to classify impulses as belonging to one and the same source is quite difficult. As a result of the imposition of random noise on the amplitude of the signal count rate can be increased up to two times. Increased efficiency and reliability of modern industrial equipment with one hand, makes it necessary to use him in conditions close to the limit, and, with another - requires a fairly accurate determination of the stress-strain state in the test facility for timely identification of critical situations and prevent the destruction of. Therefore, an important challenge is the development of various non-destructive control methods for assessing the strength properties of materials in the operation of structures without destroying its integrity. The experience of recent decades has shown great potential of the method AE, which is simple to use, economical and provides continuous monitoring of the growth of latent defects in structures during their construction and industrial use.

4. Conclusions

Permission and dispersion of classical methods depends more on the number of samples;

The statistical characteristics of spectral estimates such as dispersion are used in the presence of long data records, and close to the stationary nature of the interference;

As showed the conducted researches, the spectral characteristic of an imitating impulse depends on properties and geometrical forms of object. At change of distance between the transmitter and the receiver, as one would expect, the attenuation of waves becomes stronger, however, the general form and a spectral trace remain virtually unchanged.

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