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Empirical Modelling of Acoustic Emission Impulses

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Acoustic emission nondestructive testing method is very widespread diagnostic method based on phenomena of radiation of acoustic waves during the materials destruction. The main advantages of the method are sensitivity to the crack and possibility of remote testing when sensor installed far from the defect. The main drawback of the method is complexity of data processing. Acoustic emission signals are characterized by the variability of the shape and spectrum associated with the dispersive nature of the propagation of the signal along the waveguide. Uncertainty of the signal waveform and spectrum complicates the development of the data processing methods.

The article proposes an empirical model of the acoustic emission impulse constructed using generalization of experimental data. The use of this model makes it possible to increase the efficiency of noise filtering by comparing the shape and spectrum of acoustic emission impulses and noise at various distances between the defect and the sensor.

***Keywords*: Acoustic emission, waveguide empirical modelling, noise filtering.**

I. INTRODUCTION

Acoustic emission (AE) is the emission of acoustic waves during plastic deformation of solids structures, initiation and propagation of cracks, delaminations and stress corrosion. AE waves propagate through the testing structure and are recorded by piezoelectric sensor installed at a certain distance from the defect on the surface of the testing structure. AE signals arising from the development of defects are, as a rule, discrete impulses of short duration with amplitudes proportional to the size of the structural element of the material being destroyed.

The non-destructive AE testing method is based on the detection, recording and analysis of AE signals. Based on the difference in the arrival times of the AE impulses to various measuring channels at a known propagation velocity of AE waves, the location of the defect that is the source of AE is determined. The activity and intensity of emission assesses the degree of danger of the defect. Typical areas of application of the AE method are the oil, gas and chemical industries, pipe rolling and metallurgical enterprises. The testing structures, as a rule, are trunks, field and process pipelines, pressure vessels and boilers.

Among the various non-destructive testing methods, the AE method is the most complex in terms of data processing. The difficulty in interpreting AE data is explained by the large number of interfering and influencing factors, as well as by the random nature of AE data.

The greatest difficulty is noise filtering. The main type of noise arising from AE testing is the technological noise of the equipment, which is usually of an unsteady nature. In addition, the waveform and spectrum of AE impulses have great variability, which is associated with the dispersive nature of the AE signal propagation, in which its various frequency components propagate at different speeds and for this reason are recorded by sensor with a spread of tens or hundreds of microseconds. With increasing distance between the AE source and the sensor, the rise time and impulse duration increase, and its frequency spectrum is shifted to the low-frequency region. At distances typical of AE testing from one to several tens of meters, the amplitude of the AE impulse decreases by a factor of 1000, and the duration and rise time increase by a factor of 100.

A common method for filtering noise arising from AE testing is wavelet filtering in [1-3], the use of the classical wavelet transform algorithm with threshold coefficient constraint is considered, wavelet filtering algorithm is applied in [4], using the dependent block strategy, which takes into account not only the absolute value of the decomposition coefficient, but also the values of a certain number of neighboring coefficients. The authors of [5] developed a method for filtering acoustic noise based on the application of a Least Mean Squares (LMS) filter to wavelet decomposition coefficients, achieving a drastic improvement in filtering quality. The paper [6] describes the application of the blind adaptive filtering method in an AE system with continuous data recording; filtering is used in the post-processing mode to remove friction noise during AE control in operation. A morphological method for filtering unsteady noises was proposed in [7]; application of morphological operations to signal fragments, such as narrowing and expansion, allows filtering of pulsed noise of short duration. Filtering of unsteady impulse noise based on the distribution function of time intervals is considered in [8-9].A common drawback of the above filtering algorithms is the rather formal nature of the description of the signal and noise model. The filtering efficiency is considered on the basis of particular examples; there is no comparison of the shape of AE impulses with waveguide parameters.

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In this paper, to solve the problem of comparing the shape of the AE impulse to certain distance between defect and sensor, an empirical model of the AE impulse is constructed for the case of a plane waveguide. Industrial facilities that can be considered using this model are technological and trunk pipelines, vessel bodies and reservoirs.

II. EXPERIMENT DESCRIPTION

AE impulse model was constructed on the basis of a synthesis of experimental data obtained in the field condition by simulating the AE source with help of Hsu-Nielsen pencil-lead breakage. The object of the study was technological pipelines with a diameter from 150 to 500 mm and a wall thickness from 8 to 12 mm. At the time of the experiment, the pipelines were filled with liquid, there was no external insulation. For the measurements, the A-Line-32D PCI system produced by INTERUNIS-IT company was used with GT200 sensors and a PAEF-014 preamplifier with a passband of 30-500 kHz and a gain of 26 dB. The maximum distance between the radiation point and the point of registration of the AE impulse was 12 m, the minimum was 0.5 m.

Fig. 1 Trunk and technological pipelines for the study of the acoustic

Figure 2 a-e shows AE impulses corresponding to different distances between the AE source and the sensor. Fig. 2 (a, d) shows the impulse shape and spectrum corresponding to a distance between the source and sensor equal to 1 m, Fig. 2 (b, e) - to a distance of 6 m, and in Fig. 2 (c, f) to a distance of 12 m.

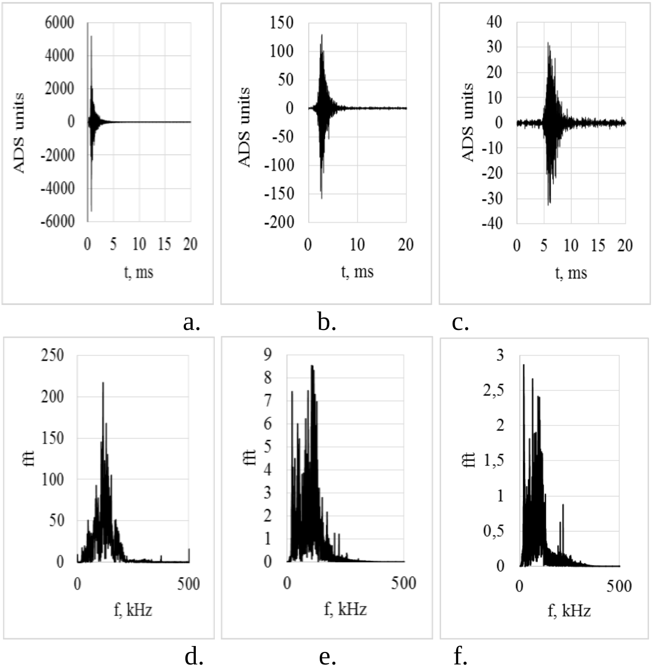


Fig. 2 Change in waveform and spectrum of the AE impulse at various distances

As shown in Fig. 2, as the distance between the source and sensor increases from 1 to 12 m, the waveform and spectrum of the impulse change as follows: the amplitude of the AE impulse decreases by approximately 150 times, the impulse rise time increases by 10 times, and the upper frequency bandwidth of the spectrum decreases approximately by 50%.

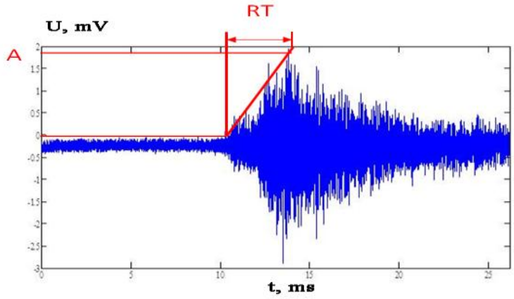
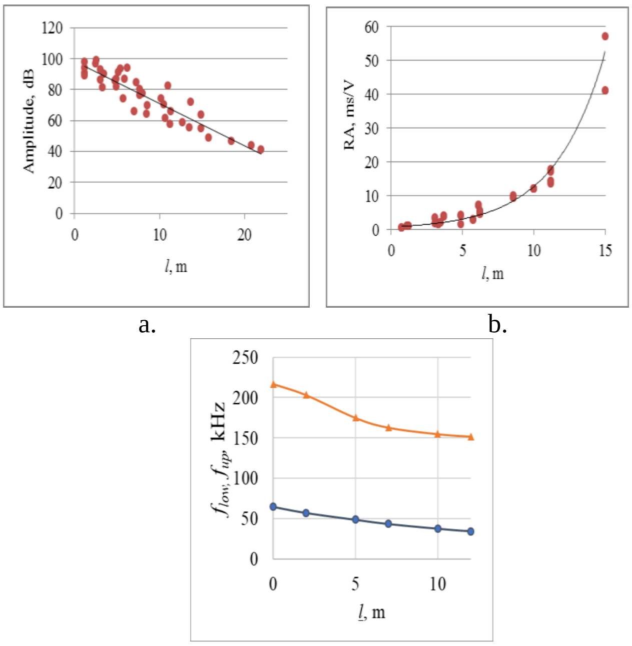


Fig.3 RA parameter calculation

Based on the data shown in Fig. 2, it can be concluded that the nature of the change in the shape and spectrum of the impulse depending on the distance can be described to some extent by three parameters - amplitude *A*, the values of the lower and upper frequencies of the spectrum, and the parameter *RA (rise angle)*. *RA* is a common parameter that characterizes the rate of rise for the leading edge of the AE impulse (Fig.3), $RA=RT/A$, where *RT* is the rise time of the AE signal (ms), *A* is the signal amplitude (V).

III. MODELLING RESULTS

When constructing an empirical model of the waveguide, a large amount of experimental data was analyzed on the order of 500 AE impulses obtained using a Hsu-Nielsen simulator on the technological surface. As a result of the analysis of experimental data, empirical dependences $A(l)$, $RA(l)$ and bandwidth ($f_{low}(l)$, $f_{up}(l)$) were obtained (Fig. 4).



a. b.

c.

Fig.4a. dependence $A(l)$ b. dependence $RA(l)$ c. dependences $f_{low}(l)$ and $f_{up}(l)$

Based on the obtained empirical dependencies, the modeling algorithm was proposed. The main steps of the algorithm are illustrated on Fig.5.

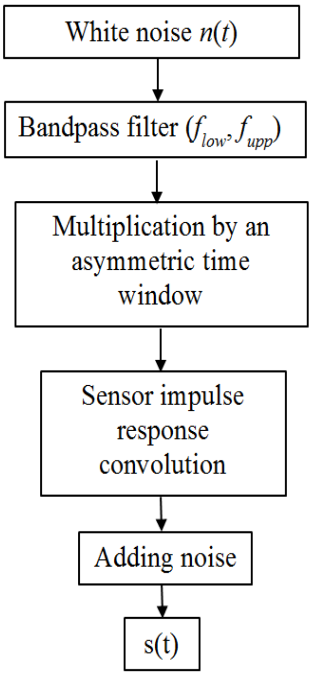
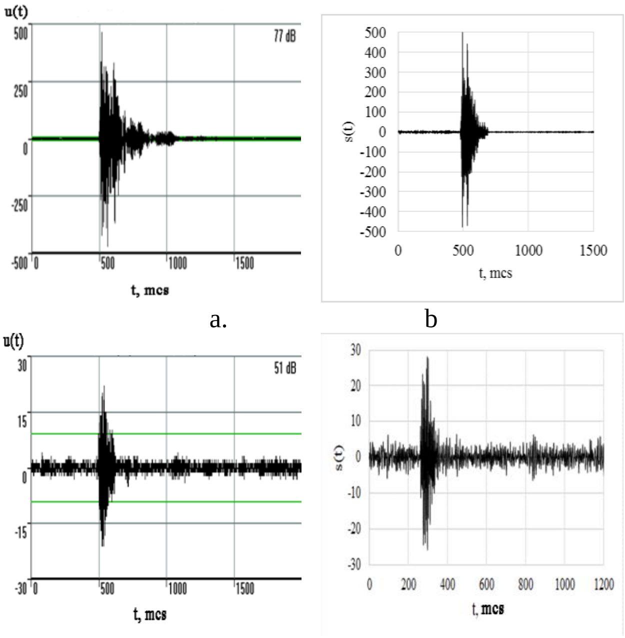


Fig. 5 Block diagram of the empirical modelling of AE impulses

1. The initial signal for the model is white noise n(t)
2. Noise *n(t)* is fed to the input of a bandpass filter with a passband (f_{low}, f_{up}), where f_{low} and f_{up} are frequencies obtained from the empirical dependence.
3. The colored noise is multiplied by an asymmetric time window. The leading edge duration is determined by the parameter $RT=RA \cdot A$, corresponding to the empirical dependencies $RA(l)$ and $A(l)$, and the total duration of the time window is specified as $5 \cdot RT$ as the most characteristic ratio for a typical AE impulse shape.
4. After multiplying by the time window, the signal takes the form of an AE impulse.
5. In order to take into account the influence of a sensor, the next step is the convolution of the impulse signal with the impulse response of the primary sensor.
6. In the last step, noise is optionally added.

Empirical modeling yields impulses of a realistic shape, similar in parameters to real AE impulses. The result of comparing real and model signals is shown in Fig. 6. Fig. 6 (a, c) shows real AE impulses, and Fig. 6 (b, d) shows the simulation results.



a. b

c. d.

Fig. 6 Comparison of the shape of AE impulses and impulses obtained as a result of simulation

IV. CONCLUSION

In the frame of this work, a study of the influence of the property of the acoustic waveguide characteristics on the waveform of the acoustic emission signal was provided. The study was conducted on the basis of experimental data obtained using a Hsu-Nielsen source.

It was found that the main parameters of the signal, depended on the distance, are the amplitude *A*, bandwidth of the frequency spectrum and the parameter *RA*, which determines the rate of increase of the pulse leading edge of the signal.

A method for constructing an empirical model of the AE impulse at various distances between the defect, which is the source of the AE, and the primary sensor, is proposed as a result of this study.

The model is built on the basis of a generalization of experimental data, as a result of which empirical dependences of AE parameters of impulses on distance were constructed.

The application of this model makes it possible to construct more reliable algorithms of acoustic emission data processing.

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