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Acoustic Emission Detection on a Background of Industrial Noise for the Rock Mass Monitoring Systems

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Abstract

In this work principles of modern algorithm construction of detection acoustic emission impulses and preliminary classification of there are sources danger degree are given. Given algorithm is worked out taking in to account modern digital systems of acoustic information processing. It is based on the adaptive changing principle of the discovering level of detection of the useful signal while performing non-standard parameters valuation of danger degree of acoustic emission impulse sources.

Keywords: *acoustic emission, acoustic noise, adaptive signal detection, Nondestructive testing*

1. Introduction

The acoustic emission control as one of methods of nondestructive check has received the big distribution to sphere of test and search of defects for various types of industrial designs (vessels of pressure, pipelines, aviation and space vehicles, railway tanks and cars, and also many other typeset of objects). Specificity basically consists in features of accompanying noise and methods of struggle against them.

As practice has shown, acoustical emission method also has found application for increase of a level of safety at conducting underground mountain workshop on the big depths and in complex mountain geological conditions [1-3]. In the given context the primary goal of a method is the forecast and prevention of dangerous displays of mountain pressure (mountain bump), quite often resulting to catastrophic consequences. In the zones subject to mountain impacts, the ground has the lowered bearing ability owing to what engineering constructions in these places possess the big speed deposits, as causes their destruction. A condition of transition from accelerate deposits to mountain impact is presence of such factors, as a high pressure of a ground at conducting works on the big depths, and also dynamic components in influence on a ground on the part of engineering constructions. The forecast of mountain impacts by method acoustical emission will be to reveal developing defects and breaks. Knowing these sites, it is possible to provide such measures which will exclude a condition of formation of mountain impacts or will prevent destruction of people and technical equipment.

The growing of bond-failure crack is the reason of acoustic issue at rock loading. Thus if in metals steady grow up cracks is limited a small scale interval (steady growth of cracks it is observed while the length of a crack is commensurable with the size of crystal grain) in rock (a file of rocks) the scale interval of alternation quasi-static and dynamic growth of cracks, basically, can reach from the size of mineral grain till the size of blocks of an earth's crust. From here in particular

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follows, that in a geometrical acoustical emission (seismic) Kaiser effect should be observed at various scales of consideration: both in samples, and in scale of mountain development, and in regional scale [4].

2. Experimental Data

The signal from the individual certificate of discrete deformation is known as a signal of explosive type. Such signal possesses sharp forward front and slow attenuation. Pulse signals vary over a wide range under the form, the size and speed of generation depending on type of structure. There is a problem of detection of pulses acoustical emission which in conditions of mountain works is complicated presence of the big spectrum of mechanical noise. Mechanical noise here is understood as fluctuations of a surface of researched object as action of the external reasons not connected with acoustical emission breeds. In practice of the acoustical emission control various algorithms of identification of pulses acoustical emission and systems of classification of their sources on a degree of danger [5-8]. The majority of algorithms have been developed in view of use in structure of unproductive system. In these algorithms as identification parameters, and also measures of danger separate certificate acoustical emission is used amplitude, energy of number octsillyatsy the registered pulse.

The elementary and most widespread algorithm of allocation of a signal consists, in registration of the moment of excess by amplitude of a signal of the established threshold [9-12]. Thus in comparator circuits in a digital kind the target pulse which signals about registration of acoustical emission pulse are generated the level of a threshold is usually adjusted by the operator . This parameter is a key variable which defines sensitivity acoustical emission of a method. Besides depending on type of equipment, sensitivity can be supervised by regulation of factor of amplification of the basic amplifier. The simplest way of an estimation of activity of issue consists in oscillation numbers calculation of crossing by a pulse given by the comparator, the established threshold. The given way depends from magnitude source of signals, and also on acoustic and resonant properties of environment and the gauge.

In more modern systems as identification parameter energy of a signal or power parameter MARSE (Measured Area of the Rectified Signal Envelope) is used. Parameter MARSE known as well as number energy oscillation, is sensitive both to amplitude, and to duration of a signal, therefore recently it has received the big distribution. Besides it is less dependent from the established threshold and working frequency. Total acoustical emission activity should be measured by summation magnitude all registered signals. Among all traditional measured parameters, MARSE in the best way approaches for these purposes.

All listed parameters are interconnected an actually reflect only capacity of a pulse irrespective of its nature. In communication (connection) with these use of similar criteria in practice when alongside with signals from sources acoustical emission powerful acoustic handicaps are registered, for example, caused by drilling of rock, and also work of other powerful mining technical equipment, is possible only after an authentic filtration of signals with use of additional identification attributes.

In traditional methods of registration of pulses acoustical emission, the estimation and decision-making are made concerning some set threshold of the analysis on the researched parameter. Threshold S_1 is set by the operator and is static parameter. At a choice of optimum value for S_1 by an experimental method (in view of the basic handicaps) obvious pulses from growth of crack will be considered only. Other pulses (including breeds generated by a break), appeared under a threshold, for example because of attenuation at distribution, will not be registered by system. For decrease in value of a mistake in the safe party usually use obviously underestimated values of threshold. In this case under condition of strong noising there is situation when $S_1<S_{noise}$, that in turn leads

to an overload of communication lines of system, and also inadequately overestimated estimation of deficiency of controllable object . And only the subsequent detailed analysis of the data after performance of the control allows receiving an authentic estimation of a condition of object. Thus the information on a condition of a file is updated with delay that has a negative effect on the general results of the control directed on a safety of carrying out of underground works.

In connection with the aforesaid use of an adaptive threshold of the discrimination automatically arranged under the current noise level on object is represented rather perspective. The give technique is especially actual for the geocontrol over conducting mining works because as against traditional methods allows to not stop the control even in an operating time of the heavy chisel technical equipment being a source of powerful acoustic handicaps.

The given approach has been realized and approved in structure of the acoustical emission complex for the geomechanical monitoring a file of rocks developed the Russian Academy of Science together with Company “Geotex”. In system as identification parameter at registration of pulses acoustical emission the power parameter MARSE Si calculated in the sliding time window of fixed dimension Y, the (1) have been used.

$$S_i = \begin{cases} s_{i-1} + x_i, i \in [0, Y] \\ s_{i-1} + x_i + x_{i-y}, i \in [Y, Y_{end}] \end{cases} \quad (1)$$

Where x_i- discrete-time signal amplitude value on i reading, S_i - measured area of the rectified signal envelope, Y- dimension of a sliding time window.

Registration of the next pulse occurs at excess in parameter S_i of threshold level S_1 during the time moment of expectation of a pulse, in figure 1. Thus at all stage of functioning of algorithm of identification there is adaptive adjustment S_t according to an average level of noise. It occurs by means of adjusting in the parameter, determining sensitivity of process detection of pulses acoustical emission: a waiting time of absence of signal -T_o, a waiting time of a new signal –T_n, a constant of time of detecting -T_d, a waiting time of the end of a signal before compulsory dump -T_c, and also factor of change of a threshold level of detection of a signal - K. Work values of adjusting parameters are defined (determined) experimentally for each concrete object and depend on type of handicaps and characteristics of sources of pulses acoustical emission .

Functioning of detection algorithm is shared on some stages: expectation of signal of absence, expectation of a signal, and also reception of a signal.

The stage of expectation of absence of signal for a pulse with an index j begins right after the terminations of reception of previous signal acoustical emission with an index j-1. The given stage is characterized by parameter to which defines time in readout during which the pause after reception previous signal is maintained. By the nature the processes causing phenomenon acoustical emission i rock, occur signal to big enough pauses between the next emissions of energy. Therefore expectation of “silence” after reception of the next pulse allows to get rid of some false signals. It in turn enables to arrange a threshold of discrimination S_1 automatically. So, if before the expiration of interval T_o there is an excess by settlement value of a level of detection of signal $S_i > S_1$ there is a chance of threshold size S. New value of a level pays off by multiplication of factor of change of a threshold level of detection of a signal to settlement value of an average level of noise signal S_1 =k*Snoise.

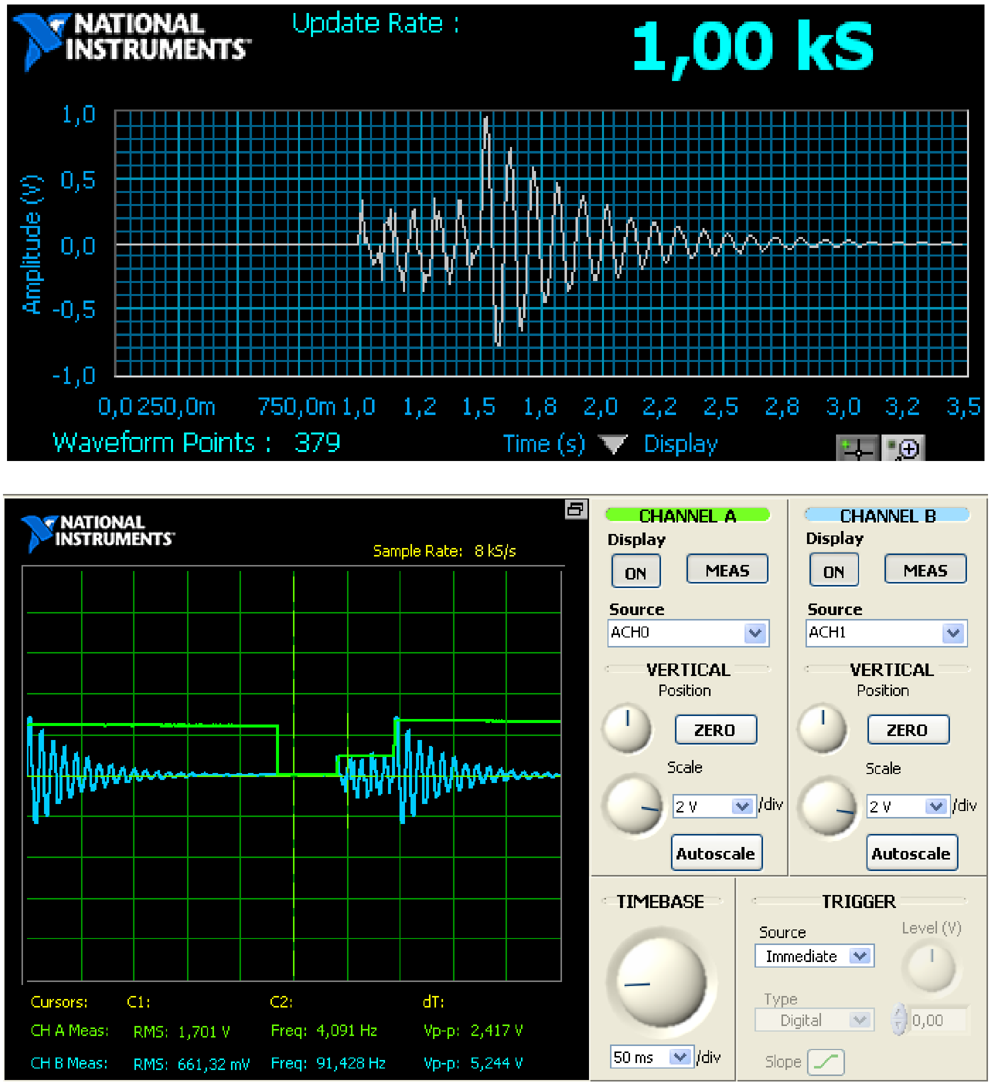

Figure 1. Measured Area of the Rectified Signal Envelop (MARSE) registration

After the termination of an interval expectation of absence of a signal begins stage of expectation of a new signal which duration is defined by parameter T_n. The given stage is necessary avoid unjustified overestimate of a threshold level of detection of a signal and hit of pulses acoustical emission in “a dead zone”. It is supposed that in time T_n pulse acoustical emission (then the stage of expectation of a new signal will be interrupted) will be find out. If it does not occur, on end of readout T_n change of a level of detection of a signal (as well as at the previous stage) and zeroing of counter T_n follows. 2 stage of expectation of a new signal begins. During expectation of next pulse acoustical emission any quantity of intervals T_n, under condition of absence of the found out signals can be counted.

When signal acoustical emission is found out, reception of a pulse with simultaneous calculation of its various parameters and search of the end of signal begins. Settlement parameters allow estimating a degree of the danger, the registered pulse. Danger of a pulse is estimate quantitatively, that allows classifying at enough low degree of danger a pulse as noise.

Detection of the end occurs at use of variable T_d (constant of detecting). During reception of a pulse constant tracking settlement value Si is carried out. At decrease in this value is lower than a level of detection of signal S_1, reckons T_d. If in time T_d there will be no new excess of an identification level the end of a signal is considered found out and the further reception of the form of a pulse stops. If before the expiration of time T_d there will be a new excess pulse acoustical emission is considered yet not finished. Thus the counter is mulled and the further reception of a signal and a search of its end under the same circuit proceeds.

To avoid a situation when the level of a threshold falls below the average level noise reception signal AE proceeds during a waiting time of the end of signal T_c. When interval T_c expires, and the end of a signal and does not manage to be identified, there is a situation determining classification of the accepted signal as noise. Thus, there is an immediate change of level S_1 in time concerning an average level of noise.

As practice has shown effective application of technical equipment of an adaptive threshold is probably only at qualitative enough definition of a degree danger of pulses acoustical emission. Modern development of digital technologies allows carrying out processing and the analysis of the pulses registered high-speed ADC. Therefore there is an opportunity to form additional non-standard informative parameters at a stage of registration of a pulse of which adequately reflect the physical nature of a pulse of issue. As such parameters the factor of a steepness of forward front and a degree of step-type behavior of the wave form can be used [13-15]. One of variants of use of new opportunities of systems AE is the combination of traditional identification parameters of sources of signals on their amplitude and energy with rejection of pulses of handicaps on the above mentioned no conventional parameters.

For a quantitative estimation of a degree of danger of a pulse use of a method of indistinct logic is expedient. In the given criterion of an estimation the small number of parameters and the general character of their dependence is used is obvious enough [16-18]. Besides calculation of a degree of danger on algorithm of indistinct logic is more complex, than with use of usual peas-linear approximation as function of an accessory simple linear functions are used. The quantitative estimation of a degree of danger is made by means of parameter of factor of danger K_d which is function of three variables (2):

$$Kd = f(A,W,J) \tag{2}$$

Where A-peak amplitude of a pulse; W- “the parameter of form” pulse which is defined as a parity (in percentage) an average level of the positive bending around wave form of a pulse and peak amplitude and characterizes a degree of its “continuity” or “step-type behavior”, *i.e.*, a degree of approach of the wave form to the form of “an ideal handicaps >> or to a “ideal” discrete acoustical emission signal (in a limit-delta-function); J-parameter of a steepness of forward front which is defined by the attitude of peak amplitude to duration of forward front of a pulse .

For all three entrance parameters categories “certainly great value” 100, “certainly small value” 0 and “average value” (0,100) are determined. The range of “average” values has ambiguous representation. It defines the probabilistic attitude of size to “big” and “small” to values. Target parameter K_d is defined as the average value probabilistic characteristics of entrance functions.

3. Conclusion

Due to the fact that the process of modeling the signal is long, and you cannot calculate and generate it in real time, the resulting signal is recorded in a file that also allows its reuse and archival for study. Conclusions made are fortified by performed theoretical and experimental analysis of AE signal spectrum properties. Taking into consideration all above mentioned I think that:

The offered techniques of detection and classification of pulses acoustical emission on a background of industrial noise allow at studying characteristics of the form of a signal of a handicap, characteristic for object of the control, effectively enough to found out pulses acoustical emission of various capacity, depending on the attitude of level useful signal to noise level.

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