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CLASSIFICATION OF THE FUNCTIONALITY AND THE SCHEMES OF THE ACOUSTIC EMISSION SOURCES LOCALIZATION

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Abstract. *The classification the functionality and the schemes of the acoustic emission sources localization is presented in the paper. Mathematical support of the coordinate searching of defects and means of their detection are stated.*

Keywords: acoustic emission, localization of defects

KLASYFIKACJA OPISÓW FUNKCJONALNYCH I SCHEMATÓW LOKALIZACJI ŹRÓDEŁ EMISJI AKUSTYCZNEJ

Streszczenie. *W pracy przedstawiono klasyfikację opisów funkcjonalnych i schematów lokalizacji źródeł emisji akustycznej. Przedstawiono podstawy matematyczne określania współrzędnych defektów i sposobów ich wykrywania.*

Słowa kluczowe: emisja akustyczna, lokalizacja defektów

Introduction

Acoustic emission (AE), as a powerful tool for monitoring the condition of the material finds its proper place in the system of non-destructive testing and technical diagnostics. However, there is no summarized data concerning the capabilities, functionality, schemes and peculiarities of the method notwithstanding the fact of their usefulness. This is due to the difficulties in collecting, analyzing and clotting large volume of information, the relevance of which is caused by the prospect of the development and practical orientation of the acoustic emission method. Analysis of the publications on AE monitoring method emphasized the necessity to provide the available material in the form of generalizing terms and classification schemes [1–9].

1. Problem statement

AE method is based on the registration of tension waves at the fast local restructuring of the material structure. The deformation processes are a classic source of AE. They are connected with the increase of defects in the plastic deformation zone. If in the result of loading the local deformation caused by the existence of the defect exceeds the threshold, there is an acoustic emission. The algorithms of calculating the coordinates of the defects are based on the determination of the time difference between the arrival of the acoustic wave and several AE receivers.

The process of generating and detecting of the acoustic wave emission is shown in Figure 1.

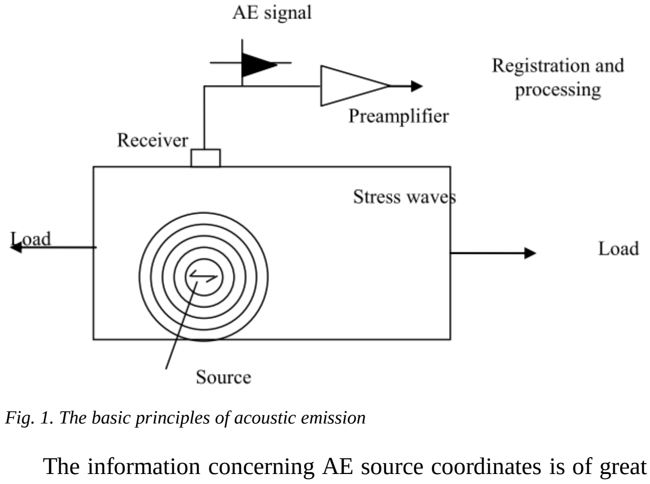

Fig. 1. The basic principles of acoustic emission

The information concerning AE source coordinates is of great practical importance, since the sources are the developing defects in the material structures. It is usually assumed that the source and the defects coordinates coincide. However, defects may have a certain spatial configuration, and be characterized by a plurality of sources.

2. Solution of the problem

The control systems by AE methods, in comparison with traditional methods of non-destructive testing, are distinguished by their functional purpose which is connected with the peculiarities of the work. If the traditional NDT methods based on the sensitivity of various physical properties of materials and products to the structural changes and the physical and mechanical properties of the materials are active, that is they effects the controlled material themselves, the methods of acoustic emission are passive as they are based on determining of the signals during the loading of the structure materials. Comparative analysis of the methods is presented in Table 1.

Table 1. Comparative characteristics of acoustic emission method with the traditional methods of non-destructive testing

Acoustic emission	Methods of non-destructive testing and technical diagnostics
it is passive because it requires no effect on the material	based on exposure to the active material
it requires mandatory loading	does not require loading
each loading is unique	control is reproduced
hypersensitivity to the metal structure	sensitivity to the structure is negligible
it requires access only in mounting position	It requires access to the entire scan area
features developing defects vary in time	product shape and characteristics of the materials do not change after the control
it provides the ability to continuous monitoring of the defect development	implementation of control after stopping production processes
strong influence of noise	strong influence of the product geometry

The functional purpose of AE methods has several features:

- methods of acoustic emission allow to classify defects not according to sizes, but according to the level of danger;
- these methods indicate the development of the unwanted processes;
- coordinates of the defects are determined without scanning the surface of the transducers.

Functionality of AE system methods includes a number of differences, characterized by the expansion of the opportunities not only for the purpose of the defect finding, but also for the diagnosis and continuous monitoring of the development of the defects.

Classification of the functionality and the schemes of the acoustic emission sources localization is shown in Figure 2.

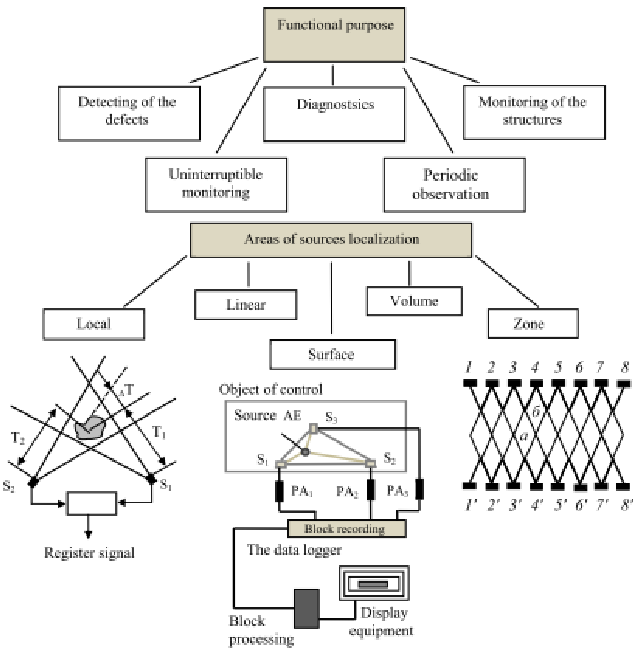

Fig. 2. Classification of functionality and schemes of AE sources localization

Within the proposed classification of the control system AE methods can differ by the type of the applied converters, the schemes of their placement, the methods of processing analog and digital information, the degree of the automatization of the decision-making procedures.

The problem of finding the coordinates of AE sources is a central issue at the controlling stage and is solved by measuring the difference in arrival time of AE signals to the diversity of the group of sensors, with the following determination of the coordinates with the help of computer calculations. However, in many practical cases the source coordinates can be calculated by the analog methods.

Schematic diagram of the localization of acoustic emission sources is shown in Figure 3.

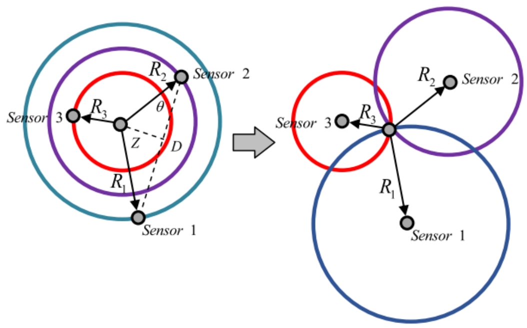

Fig. 3. Localization of acoustic emission sources: D – distance between the sensors 1 and 2; R1 – distance between the sensor 1 and the source of AE; R2 – distance between the sensor 2 and the source of AE; Δ t1,2 – delay in wave sharing between the sensors; θ – angle between R2 and D; Z – normal of D.

The difference between the arrival time of the signal to AE sensor 1 and sensor 2 is determined from the following relationships:

$$\Delta t_{1,2}\upsilon = R_1 - R_2; \quad (1)$$

$$Z = R_2 \sin\theta; \quad (2)$$

$$Z^2 = R_1^2 - (D - R_2)^2 \quad (3)$$

From the formulas (1), (2) and (3) it follows that:

$$R_2 = \frac{1}{2}\frac{D^2 - \Delta t_{1,2}{}^2\upsilon^2}{\Delta t_{1,2}\upsilon + D\cos\theta};$$

This calculation can be repeated considering another pair of sensors. The obtained coordinates allow to determine the source of acoustic emission location on the surface affirmatively.

These relations can be applied in the case of locating acoustic emission sources in the thickness of the material, but the use of four sensors is required.

The system of linear equations for the control with four receivers is:

$$xx_i + yy_i + Rr_i = \frac{x_i^2 + y_i^2 - r_i^2}{2} \quad i = \overline{0,3}$$

where x_i, y_i – the coordinates of the receivers; R – distance from the origin to the defect; r – distance to the receiver of acoustic emission signal.

The coordinates of the defects are calculated by the system of equations:

$$x = \frac{\left(y_2\left(x_1^2 + y_1^2 - r_1(r_1 + 2R)\right)\right) - y\left(x_2^2 + y_2^2 - r_2 + \left(r_2(r_2 + 2R)\right)\right)}{2R\left(x_1 y_2 - x_2 y_1\right)}$$

$$y = \frac{\left(y_2\left(x_1^2 + y_1^2 - r_1(r_1 + 2R)\right)\right) - x\left(x_2^2 + y_1^2 - r_1 + \left(r_1(r_1 + 2R)\right)\right)}{2R\left(x_1 y_2 - x_2 y_1\right)}$$

To locate the source of tension waves it is necessary to locate the necessary number of sensors properly.

The classification of the schemes of the sensors are shown in Figure 4.

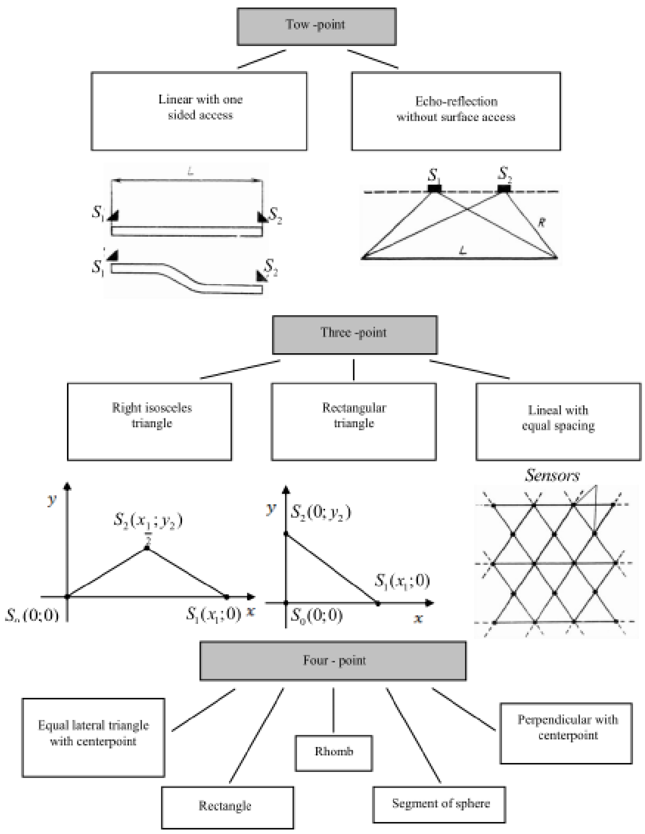

Fig. 4. Diagrams and configuration of the sensors

The basic principles of AE control are to measure the main parameters of the signal which exceeds the threshold level. In the comparator circuit output pulse is digitally generated. Evaluation of the emission activity is to count the number of oscillations of the pulse issued by the comparator. This option depends on the amplitude of the signal sources as well as the acoustic and resonance properties of the medium and the sensor (Figure 5).

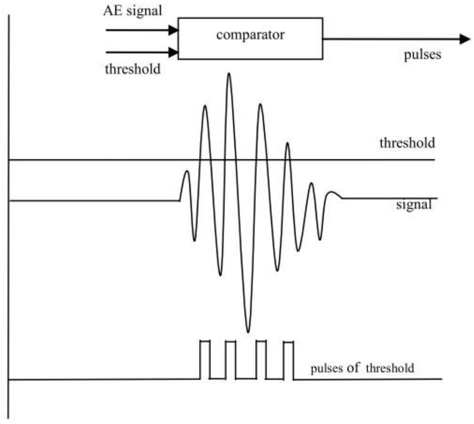

Fig. 5. The principle of AE signal registing

The systems of the acoustic emission monitoring are the complex multi-channel devices, which constitute a set of hardware, computing devices, and specialized software.

The measurement of signal occurs simultaneously on each channel. The highest priority concerns the reading of the measurement channels, immediately after each measurement so that the measuring system is ready to receive the next signal. Sequence of AE signals comes to central processor that coordinates storing, displaying and processing of data (Fig. 6).

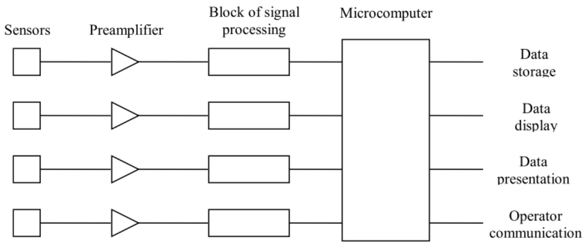

Fig. 6. Block – scheme four channels AE system

The main advantage of such systems is the ability to scale. To control the manufacturing of large size products requires more sensors and signal processing channels, but the principles and methods of information processing are common.

3. Conclusions

The presented classification of the functionality, the schemes of AE sources localization, mathematical support of defect coordinates searching and means of their detection has confirmed that, due to its high sensitivity to the material microstructure AE control has the ability to control the reaction of the material on the applied loading. The method of acoustic emission complements traditional diagnostic methods and provides the necessary information about the dynamics of developing defects.

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