Ways of Improving the Acoustic-Emission Method of Investigation of Properties of Ceramic Materials

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Abstract. The major problems of the nondestructive inspection acoustic emission method are analyzed in the article. The comparative evaluation of the acoustic emission signals effectiveness is conducted. The inappropriateness of the analysis method in the narrow band of frequencies is shown in the article. The comparative results of the acoustic emission signals spectral analysis for different types of ceramic materials are given as an example. The necessity of using spectral analysis methods to increase the accuracy and reliability of results is demonstrated.

Keywords: ceramic materials, nondestructive testing, acoustic-emission diagnostics, spectral analysis, frequency response.

1 Introduction

Material acoustic emission is the process of producing elastic waves, provoked by local dynamic reconstruction of its structure [1]. Acoustic emission method allows detecting and registering of only developing defects, prompting to classify them not by the size but by the danger level. Besides, it is the most sensible method of NDT. All above mentioned gives acoustic emission method undeniable advantage which unfortunately is hard to always realize.

Another difficulty of AE method realization is associated with the fact that technically we are not able to record every AE act separately. We are bound to analyze only the part of a collective process which appears to be above the equipment sensitivity threshold. This fact gives rise to multiple speculations and scientific fantasies. Mostly we can only see the tip of an iceberg and the rest data is left behind-the-scenes, under sensitivity threshold. As a result, even genuine values of such AE signal physical quantities as pulse height and energy are frequently do not allow to establish any correlations. We need comprehensive knowledge of process physics to evaluate the whole process by available data. It is important to realize that forming of the “tip” is indissolubly related to sensibility and frequency characteristic of a converter, method and accuracy of converter positioning, AE properties of a material and wave characteristics of a survey item, as well as to loading dynamics and structural inhomogeneity of the material. We also have to take into consideration that AE formation process is comprised by several simultaneous processes part of which are auxiliary and
depend on environmental conditions. I have recited just part of the factors to be considered in AE signal analysis. It is notable that in 70-80s AE was nicknamed as “black magic” in scientific back rooms.

2 Theoretical Analysis

AE research worker challenge can be substantially simplified by excluding doubtful physical parameters. Only unquestionable parameters should be taken. Let’s try to prove the necessity of AE signal analysis in broad band. It is well-known that material AE is the process of producing elastic waves, provoked by local dynamic reconstruction of its structure [2]. It is important to give much attention to cracks formation and development as emergency situations and breakdowns at industrial facilities are commonly stipulated by formation and further development of cracks in material of the survey item.

Solid body is a random set of structural formations. Viewing it in one scale level it can be considered as a set of grains on the surface of failure. The grains can be of a random shape. Crack development process is easy to consider as a process of successive destruction of its separate structural formations (grains). Every coherent destruction of each grain will have its emission of corresponding AE impulse. Each impulse will have individual properties reflecting grain’s individual shape and size. The sequence of mentioned impulses will thus compose AE process.

From what has been said we can conclude that the energy of AE signal of the developing crack will be irregularly distributed along the frequency band [4]. The irregularity will be of a random nature as every AE signal with its spectrum will be unique composition due to it’s formation and development features. These facts were many times established and this is the reason why energy and amplitude properties of the signal should be measured in broad band, taking into account all frequency components. Besides, while material destruction acoustic waves (AE signals) undergo serious changes when they spread along the survey item. AE signal in receiver point is a sum of signals from different paths. As a result the wave shape becomes distorted and impulse signals duration increases by hundreds and thousand times.

As is well-known, spectrum of signals sum equals sum of spectra, hence effective width of summarized signal spectrum should not increase. However, its distortion is considerable. Transfer properties of the acoustic tract are described by frequency response function (FRF). Classical method of frequency distortion influence exclusion consists of FRF calculation with subsequent adjustment of received signals spectral characteristics. Plane shape objects FRF can be calculated theoretically. Let us do FRF calculations for a long rod.

Metal or ceramic survey item, as well as other items made of high elasticity material can be calculated with high accuracy by linear systems. In a general way spectral characteristic module of the signal taken from converter output is defined by the following formula:

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S_{np}(\omega) = S_n(\omega) \cdot K_{np}(\omega) \cdot K_{np}(\omega),
\]  

(1)