ELECTROMAGNETIC AND ACOUSTIC EMISSION SIGNALS OF COMPOSITE MATERIALS IN THE FREQUENCY DOMAIN

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Abstract: This article provides a description of the acoustic emission (AE) and electromagnetic emission (EME) signals. Signal generation occurs under uniaxial load of composite materials. It describes the experiment conducted for obtaining signals. And it showing the analysis of the digitized signals as waveforms, spectra and spectrograms. According to the analysis were provided appropriate conclusions.

Keywords: electromagnetic emission, acoustic emission, cracks, electric charge, composite materials

1. INTRODUCTION

Signals of electromagnetic and acoustic emissions appear during cracks generation when a solid is exposed to mechanical loading (tensile, compressive, shear, torsion, etc.). Generation of electromagnetic emission is related to electric charge redistribution during cracks creation and development and it is in the frequency range from tenths of Hz up to the gamma radiation. Acoustic emission appears due to release of elastic energy during this process and it is in frequency range of ultrasonic waves [1].

The main advantage of EME and AE is their ability to be detected already in stressed stage, which prevents the macroscopic dislocation in solids. Suitably designed methodology of EME and AE signals measurement, processing and evaluation allows observing the response of stressed materials on applied mechanical load continuously and also allows obtaining the useful information about the processes taking place in the cracks formation in solids.

Since both signals have a stochastic nature and they carry information about processes during cracks development, we can use spectral analyses to diagnose mechanical loaded solids, mainly to describe a process of material failure.

2. MEASUREMENT SYSTEM

A new fully automated set-up for EME and AE signals measurement (Fig. 1) was developed in our laboratory. This system is based on the hydraulic press which provides the specimen mechanical load in the range of 10 kN to 100 kN. The press is electrically controlled by computer via the control voltage being set by card NI PCI-6014.

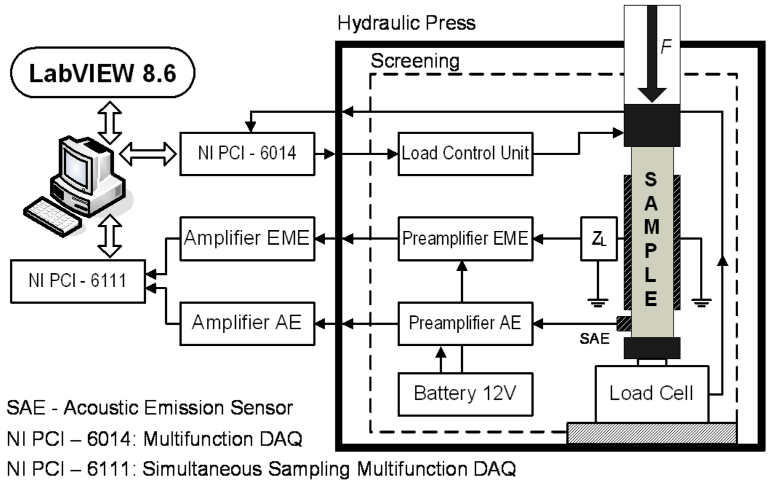

Figure 1: Measurement system.

The mechanical load is measured by a sensitive load cell, which is connected in a Wheatstone bridge. The output voltage from the bridge is measured by the same card in the PC and the resulting value of the applied force is obtained by means of load cell transfer function. A deformation meter is used for sample contraction measuring during compressive stress application. A change of the sample length from the meter is loaded into the computer using by the RS-232 port.

The EME channel consists of a capacitance sensor which dielectric is composed of the stressed sample, a high pass-filter-type load impedance Z_L, a low-noise preamplifier PA31, and an amplifier AM22 with a set of filters. The total EME channel gain is 60 dB, the frequency range is from 30 kHz to 1.2 MHz and the sampling rate is of 5 MHz.

The AE channel consists of a piezoelectric acoustic sensor (30 kHz ~ 1 MHz), the low-noise preamplifier PA31 and the amplifier AM22 with a set of filters. The total AE channel gain is 40 dB, the frequency range is from 30 kHz to 1.2 MHz.

The piezoelectric sensors from different producers are used for AE signals measuring. These sensors meet the requirements of the AE signal frequency band (at least up to 1 MHz).

The capacitance sensor is used to EME signal capturing. In our case, the capacitance sensor is composed of the specially made adjustable bracket with two electrodes, into which we can easily insert the rectangular samples from studied material.

Both signals of EME and AE are sampled by NI PCI-6111 card and transferred to the PC, where further processing is carried out. Whole measurement system is controlled by the PC with software developed under the LabVIEW environment. The complex software package allows finding the typical events in the individual data channels, saving these events as separate files and describing their basic parameters (event start/end time, maximal amplitude, RMS value, energy, etc.). Processing and evaluation of these parameters is taking place simultaneously (in real time) with the measurement process [2, 3].

Signals were digitized at a sampling frequency of 5 MHz. Next, the data were processed in the program Matlab.

2.1. EXPERIMENT

Lineary increasing uniaxial compression up to the load of 85 kN with a rate of 25 N/s was applied to the measured sample.

Figure 2 shows the AE and EME signals. Signal duration is 0.1 seconds. Number of data points is 500000. The sampling frequency is 5 MHz. This signal is from the output of the measurement system.

Figure 3 shows the dependence of the deformation on mechanical load. Linear dependence means the region of the elastic deformation. The deviation from the linear dependence is observed at the last part of the curve, where plastic deformation arises [2, 3].

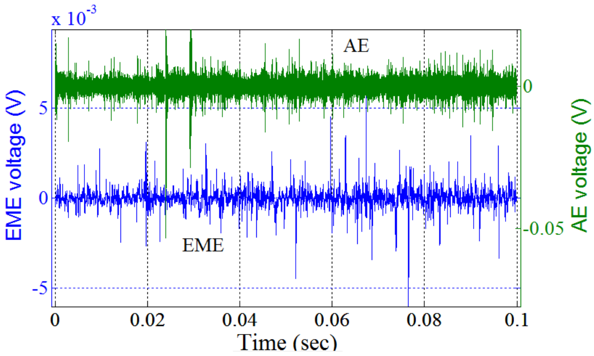

Figure 2: Continuous EME and AE signals, sample V4, applied force 84.6 kN.

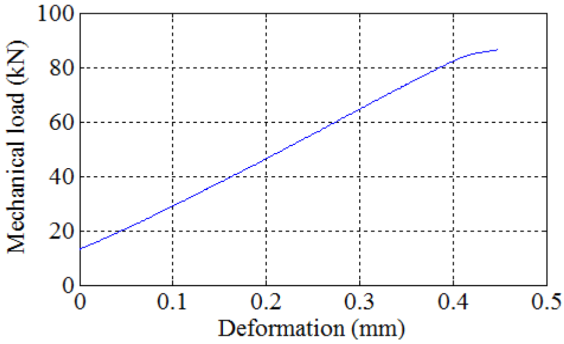

Figure 3: Mechanical load versus sample deformation (contraction).

2.2. SPECTRAL ANALYSIS

The useful tool for EME and AE random signals is spectral analysis. Some of EME signals prove to be of high importance for crack formation diagnostics, because the crack dimension is related to the oscillation frequency and the mechanical wave propagation velocity. The convenient tool for these types of signals is a spectrogram. It represents development of signal spectrum in time.

Figure 4 shows the voltage power spectral density of EME and AE signals (Fig. 2). These signals were modeled in the program Matlab using the function Welch. The window of Hanning type was used to avoid the spectral leakage [4].

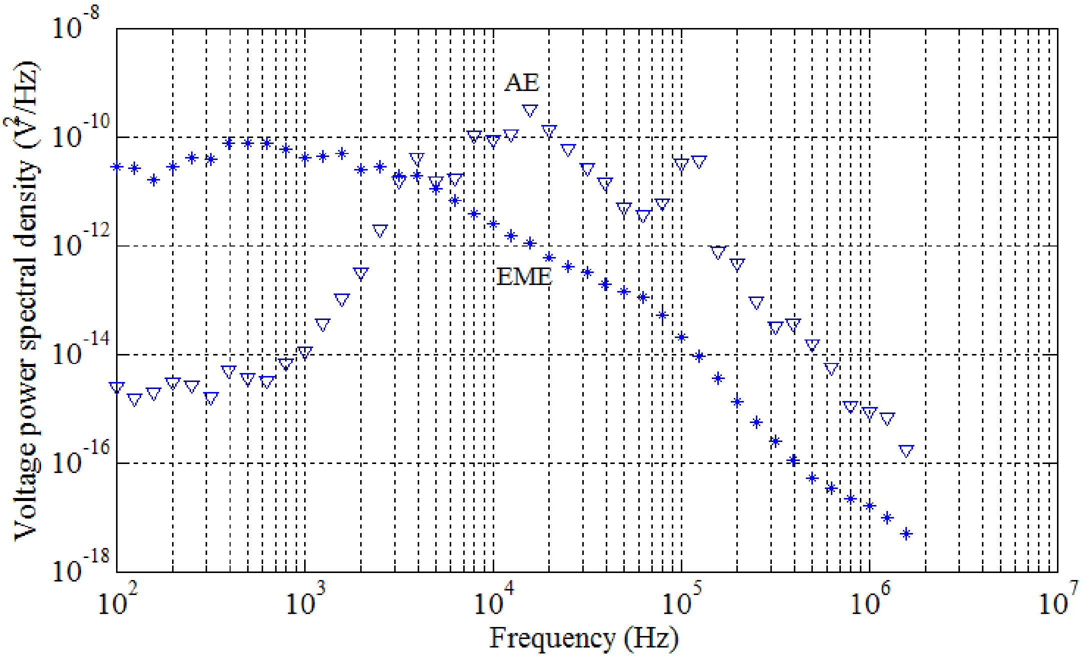

Figure 4: Spectrum of AE signal, mechanical load 52.5 kN, specimen V4.

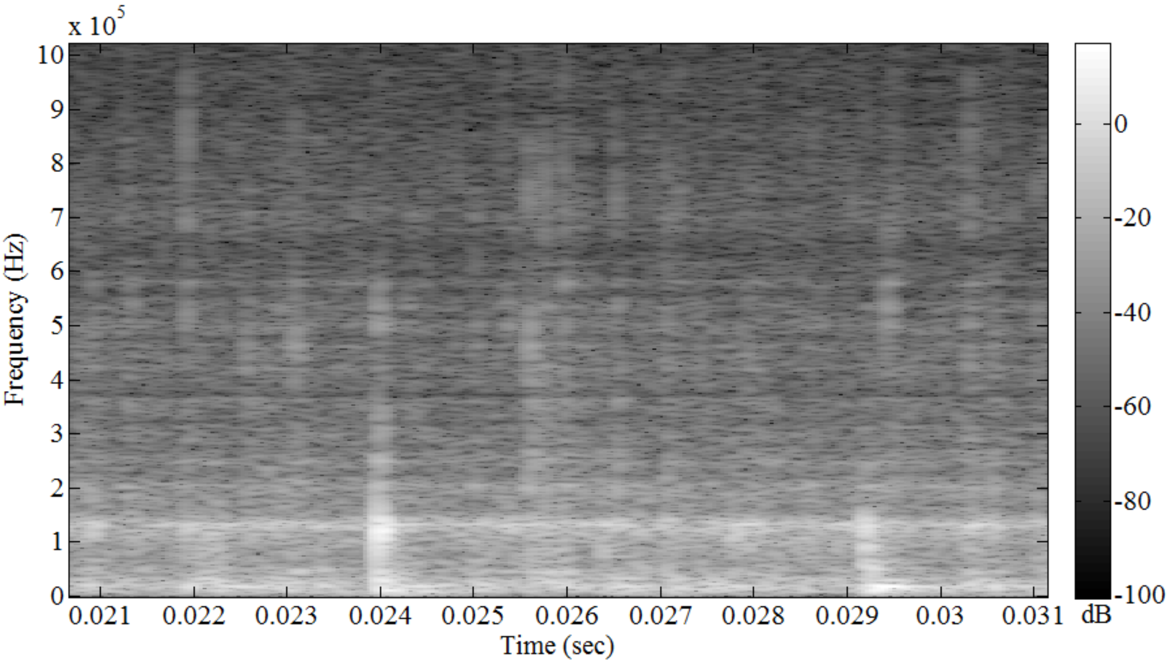

Figure 5: Spectrogram of AE signal.

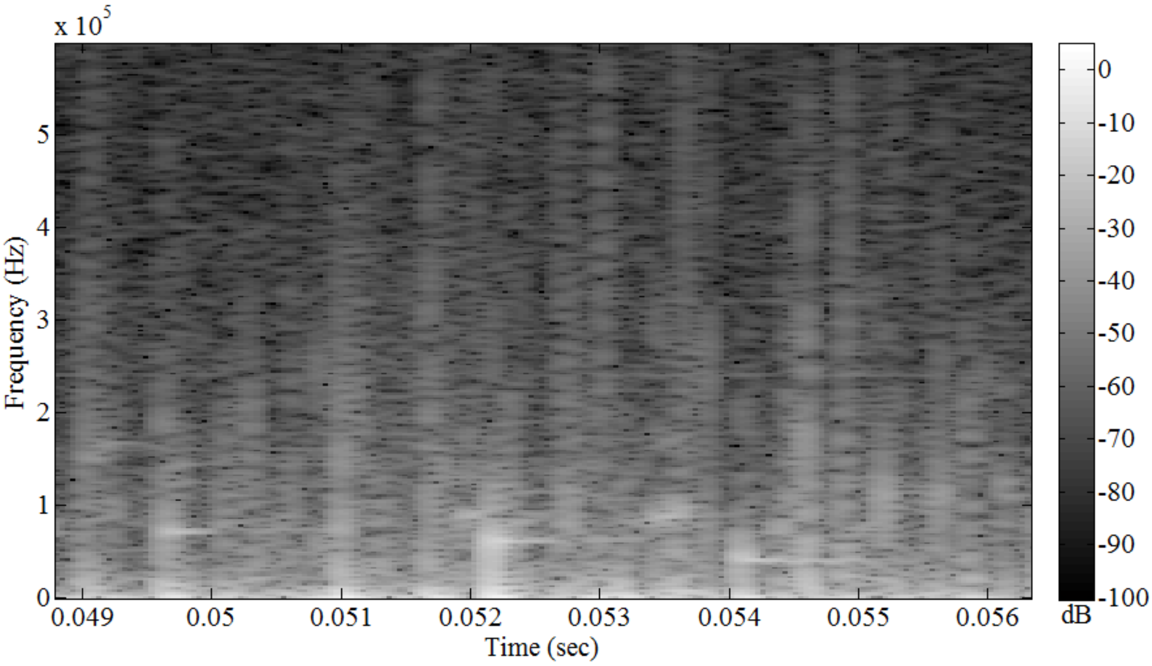

Figure 6: Spectrogram of EME signal.

Spectrograms of EME and AE signal are shown in figure 5 and figure 6. AE signal are often contain dominant frequency component in the band from 120 kHz to 130 kHz. However, frequency components of EME signals in this frequency range are much rarer. They are characterized by significant frequency components at various frequencies, and they can indicate various parameters of generated defects.

Figures 7, 8, 9 and 10 show the AE and EME signals in the time domain, their spectra and the spectrograms of the individual pulses. It should be noted that the signal components of EME attenuate faster than AE at high frequencies. An analysis of individual pulses managed to get some conclusions. Peaks of the spectral components are different for individual EME pulses. Frequency components of the AE signals in most cases do not differ. We didn't found relationship between the frequency components of AE and EME.

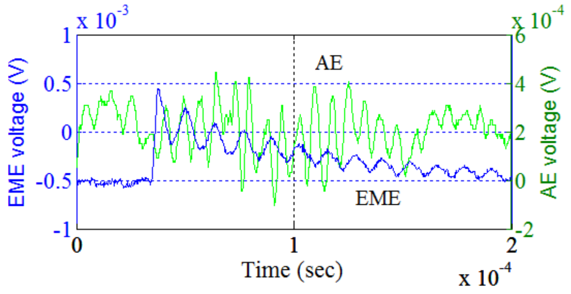

Figure 7: EME and AE waveforms of one AE puls.

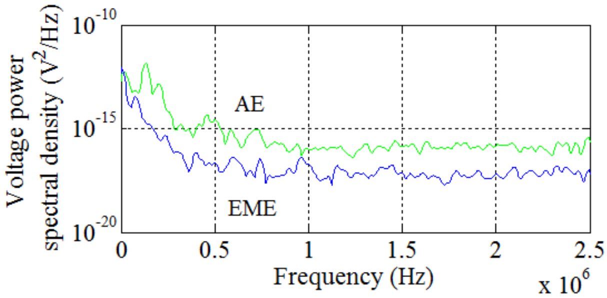

Figure 8: Spectrums of EME and AE signals of one AE puls.

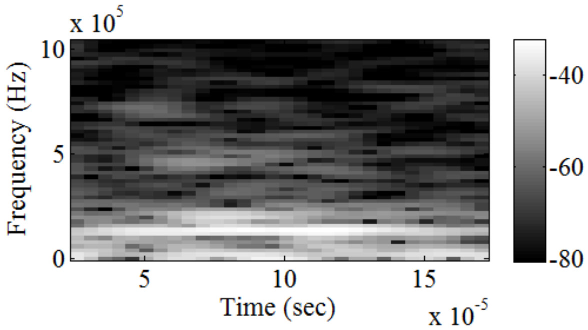

Figure 9: Spectrogram of one AE puls.

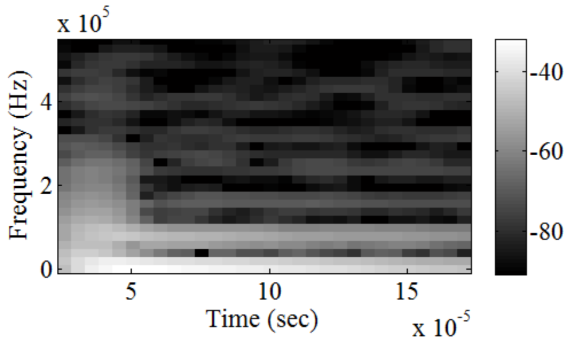

Figure 10: Spectrogram of one EME puls.

3. CONLUSION

AE signal are often contain dominant frequency component in the band from 120 kHz to 130 kHz. Frequency components of EME signals in this frequency range are much rarer. They are characterized by significant frequency components at various frequencies, and they can indicate various parameters of generated defects.

Peaks of the spectral components are different for individual EME pulses. Frequency components of the AE signals in most cases do not differ.

We didn't found relationship between the frequency components of AE and EME.

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