CONTINUAL MULTI-CHANNEL MEASUREMENT OF ELECTROMAGNETIC AND ACOUSTIC EMISSION SIGNALS IN SOLID DIELECTRIC MATERIALS

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ABSTRACT

This paper describes our new principle of an acoustic and electromagnetic emission signals measurement and includes the first experimental results. This new method is based on the continual multi-channel measurement of these stochastic signals, which means that the obtained results will be able to provide more accurate information about the time behavior of signals in individual channels. Hence we are able to trace the effect of the applied mechanical stress on the materials continuously. The code in LabVIEW environment was created for continual multi-channel data acquisition and the obtained data are compiled in MATLAB environment code afterwards.

1. INTRODUCTION

Stochastic electromagnetic and acoustic emission signals may be observed when the solid dielectric materials are mechanically stressed. These signals may be used for indication of micro-crack formations in stressed materials.

The cracks generation in the solids is accompanied by the redistribution of the electric charge. The crack walls are electrically charged and their vibrations produce time variable dipole moments. Hence the individual cracks become electromagnetic field sources, which can be measured by appropriate sensors. This phenomenon use to be called as electromagnetic emission (EME) and it may be triggered by many reasons (for example by external pressure, tensile force, shearing, shocks, etc.) [1].

The signal of the acoustic emission (AE) is generated simultaneously with the EME signal. The time delay between both signals is caused by different propagation velocities of the acoustic and electromagnetic signals in the sample under examination. The AE signal time latency to the EME signal arrival provides information about the distance of the crack from the AE sensor. In case of the AE signal multi-channel measurement, we can get the useful information about the crack position in the stressed material.

The practical application of aforementioned effects may be utilized in the diagnostic of the dielectric solid materials under mechanical stress and particularly for study of the material cracks formation, evolution and localization.

2. EXPERIMENTAL

2.1. INITIAL SET-UP FOR EXPERIMENTAL MEASUREMENT

Figure 1 illustrates our initial fully automated set-up for simultaneous measurement of the EME and AE signals [3]. The FRÖWAG hydraulic press provides the specimen mechanical load in the range of 10 kN to 100 kN. The EME channel consists of a capacitance sensor which dielectric is formed of sample S, a high-pass-filter-type load impedance Z_L, a low-noise preamplifier and an amplifier. A total EME channel gain is 10^3. The AE channel consists of a piezoelectric acoustic sensor (30 kHz – 1 MHz) and a preamplifier with gain of 10^2. Both signals are fed into HP 54645A 4-channel digital sampling oscilloscope. Obtained data are sequentially compiled in Matlab environment.

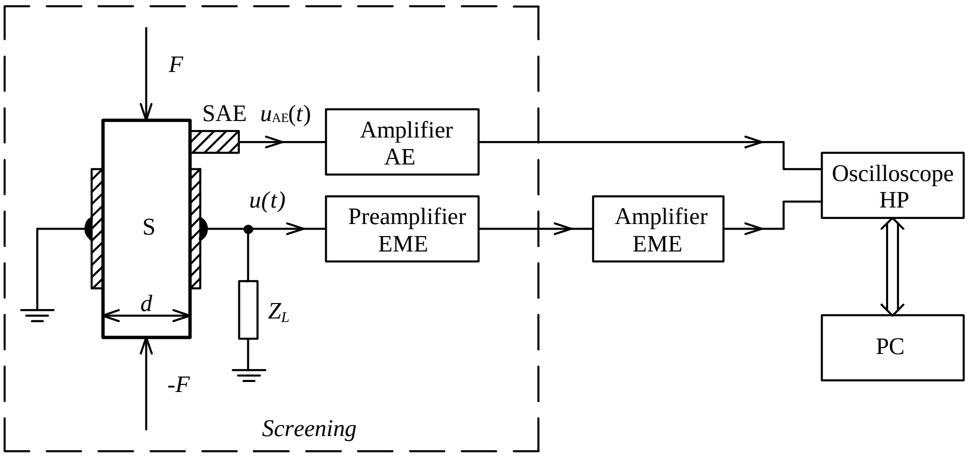

Figure 1: Initial set-up for experimental measurement

2.2. SET-UP FOR CONTINUAL MULTI-CHANNEL MEASUREMENT

In improved set-up, the HP 54645A digital oscilloscope has been replaced by a National Instrument PXI- 5105 8-channel digitizer, features eight 60 MS/s simultaneously sampled input channels with 12-bit resolution, 60 MHz bandwidth, input range of 50 mV_{PP} to 30 V_{PP} and 512 MB onboard memory. The LabVIEW environment code was created to provide continual multi-channel measurement with NI PXI-5105 digitizer.

The experimental results, described in section 3, were measured with the following features. Two channels measurement was used (CH0 for EME and CH1 for AE signal) with 5 MS/s sampled frequency and 1 MS block length on channel. Each sample was saved as 16-bit binary value. Final dataflow was

$$2 \times 5 \text{ MS/s} = 10 \text{ MS/s} = 20 \text{ MB/s}.$$

The data was saved in 2 MB interleaved (2 channels) data blocks. It was necessary to automatically process this huge quantity of data. The special code in MATLAB environment was created for this purpose. It allows finding of the specific events in the individual channels data (Fig. 2), saving these events as separate files and describing their basic parameters (event start / end time, maximal amplitude, RMS value, etc.). Each event is described by a vector of ten values. Therefore many various progresses may be traced during the time period, while the mechanical load is applied (the figures from section 3 for example).

2.3. MATERIAL UNDER STUDY

The measured specimens are prepared from EXTREN 500 composite material based structural profiles. The composite material under study consists of a combination of a fibre glass reinforcement and a resin binder. The binder protects the reinforcement from mechanical damage, maintains the structural profile shape and transfers the tension into the reinforcement. The applied mechanical stress was perpendicular to the reinforcing glass fibre direction [2, 3]. The measured specimens are blocks of dimensions (50-52) mm × (58-61) mm × 10 mm.

3. EXPERIMENTAL RESULTS

Figure 2 shows the examples of typical EME and AE time behavior (referred to specific channel events in this paper).

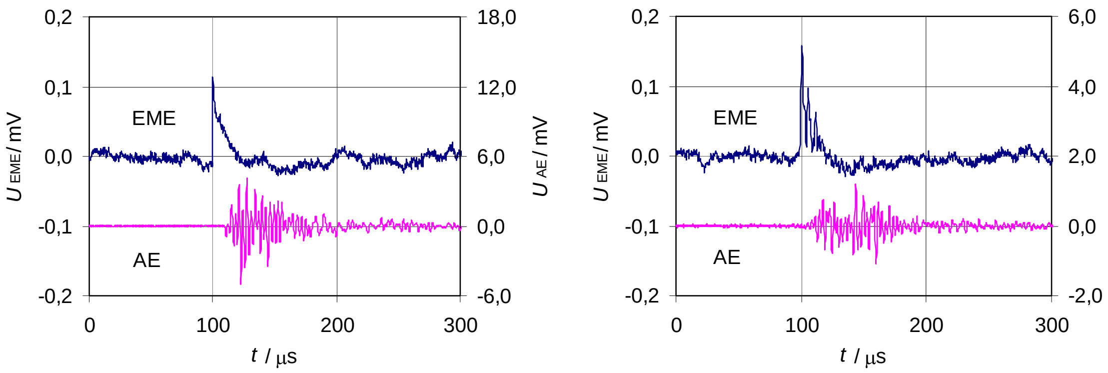

Figure 2: Typical EME and AE time behavior examples

3.1. CONSTANT MECHANICAL LOAD

The experimental results (Fig. 3 and Fig. 4) were measured under constant mechanical load of 41 kN ± 1 kN in the time interval of 180 minutes. The final data file size reached 216 GB (20 MB/s × 60 s × 180). Specific events intensity (event frequency) in AE channel has a downward trend (Fig. 3) as well as events amplitude mean value (Fig. 4).

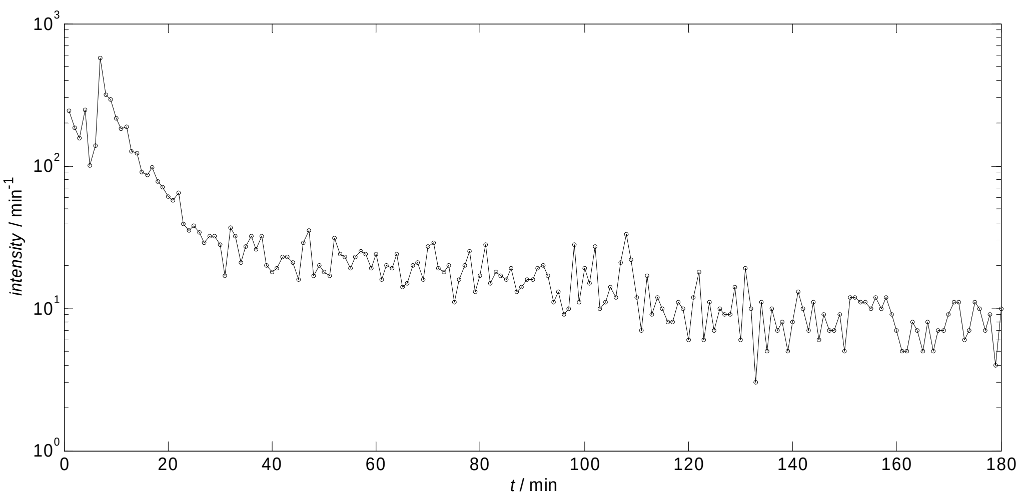

Figure 3: Events intensity in AE channel

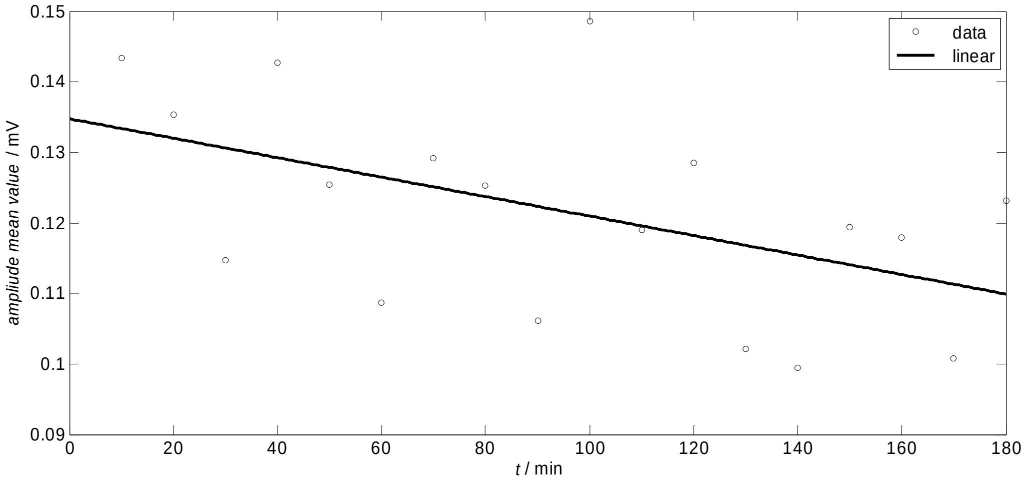

Figure 4: Events amplitude mean value in AE channel.

Forty percent of all events were observed in the first ten minutes of measurement. The weak places inside the material structure cracked after the external pressure was applied. The applied mechanical load was obviously below the critical level specific for material under examination, therefore another significant events intensity or amplitude rising was not observed.

3.2. GRADUAL MECHANICAL LOAD INCREASING

The gradual mechanical load increasing was used in this case. The initial pressure was 40 kN and after each twenty minutes, it was increased in 2 kN. The total measurement time interval was 122 minutes (the stressed sample was destroyed after this period). The events intensity (Fig. 5) and the events amplitude mean value (Fig. 6) has an increasing character, compared to the results from section 3.1. It is possible to observe that the events intensity and amplitude reached the maximum just before the sample destruction. The sample was destroyed after the 114 minutes of measurement and external pressure equals 50 kN. As the figure 5 shows, the events intensity rising starts in twenty minutes periods, which corresponds to the external pressure increase.

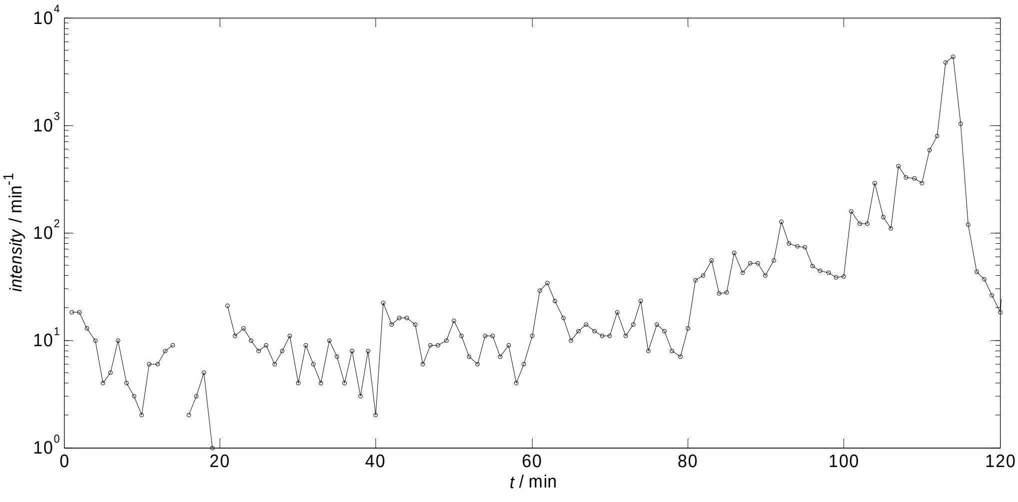

Figure 5: Events intensity in AE channel

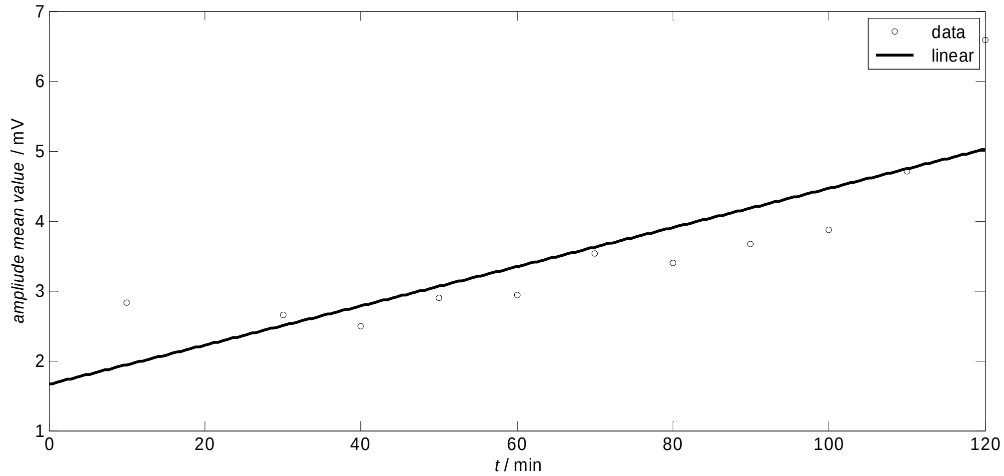

Figure 6: Events amplitude mean value in AE channel

4. CONCLUSION

The continual multi-channel measurements of EME and AE stochastic signals were described in this article. The new NI PXI-5105 digitizer was purchased and the LabVIEW environment code was created for continual multi-channel data acquisition. The sample was measured under the constant mechanical load at first, and under the gradual increasing of mechanical load in the second step. The specific events intensity and amplitude progress was tracked during the measurement. The preliminary experimental results, (AE channel only for now) were presented in section 3. The improved method of EME and AE signals measurement, presented in this paper, offers the possibility to observe the stressed materials response to applied mechanical load continuously.

ACKNOWLEDGEMENTS

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