CHARACTERISTICS OF THE IMPROVED SET-UP FOR ELECTROMAGNETIC AND ACOUSTIC EMISSION SIGNALS CONTINUAL MEASUREMENT

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ABSTRACT

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 formation in stressed materials. This paper describes our new set-up, which was developed for these specific signals measurement. Designed measurement system, based on the modern PXI industry platform, significantly improves the previous set-up in the several ways. The new measurement system offers continual measurement, real-time processing and evaluation of electromagnetic and acoustic signals and it is completely controlled by the National Instruments LabVIEW graphical programming environment.

1. INTRODUCTION

Generally, an application of mechanical stress leads to micro-cracks formation in stressed solid dielectric materials. Cracks generation is accompanied by generation of the electromagnetic (EME) and acoustic (AE) emission signals, which can be measured by appropriate sensors. More information about the EME and AE phenomenon is available in literature [1, 2].

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

Currently, there is no EME and AE problems complex solution commercially available on the market. In contrary, our improved measuring set-up is able to solve whole problem globally (real-time measurement, EME and a AE signals processing and evaluation).

2. PXI INDUSTRY STANDARD

A new, fully automated set-up for measurement EME and AE signals was developed in our department (FEKT UFYZ). The main part is composed by specific PXI system, which offers the maximal flexibility and mobility of whole designed measurement system.

2.1. PXI INDUSTRY STANDARD CHARACTERISTICS

A PCI eXtension for Instrumentation (PXI) is one of the most extended modular platforms for measurement and automation systems [3]. Its characteristic properties are:

- open, multi-vendor industry standard based on the standard PC technologies,
- combination of PCI electrical-bus features and the specialized synchronization,
- easy incorporation of different instruments (oscilloscopes, digital multimeters, switches and sources) into a small modular system,
- connectivity to existing platforms (PCI, GPIB, VXI, MXI, VME, CardBus, PCMCIA, SCSI + Ethernet),
- high data transfer rate (32-bit PCI bus, 33 MHz → 132 MB/s),
- specialized synchronization (timing, triggering and synchronization are defined in PXI standard, which enables easy synchronization of modules from multiple vendors),
- standard Microsoft Windows software architecture support (Visual Basic, Visual C/C++, Measurement Studio, LabWindovs/CVI) or National Instruments LabVIEW graphical programming environment alternatively,
- real-time software architecture support (time-critical applications),
- high-performance and low components costs.

2.2. PXI SYSTEMS COMPOMPONENTS

PXI systems are composed of three basic components [3].

Chassis

- provides modular packaging for the PXI system,
- provides peripheral modules power supply, reciprocal connection and communication,
- available in different slot-number modification.

System Controllers

- remote controllers from a desktop, workstation, server or laptop computer,
- high-performance embedded controllers with the Microsoft OS or a real-time OS.

Peripheral Modules

- National Instruments offers more than 200 different PXI modules at present time,
- more than 1500 other modules are available from more than 70 vendors.

3. EXPERIMENTAL MEASUREMENT SET-UP

Figure 1 illustrates our improved, fully automated set-up for EME and AE signals continual multi-channel measurement. The hydraulic press provides the specimen mechanical load in the range of 10 kN to 200 kN. Actual mechanical load is measured by the very precise tenzometer. It provides actual mechanical load linear convert to the output voltage (1 mV ~ 20 kN) and it must be powered by 5V DC voltage. The EME channel consists of a capacitance sensor which dielectric is formed by the stressed sample, a high-pass-filter-type load impedance Z_L, a low-noise preamplifier and an amplifier (if it's necessary). A total EME channel gain is 40 or 60 dB. The AE channel consists of a piezoelectric acoustic sensor (30 kHz ~ 1 MHz) and an amplifier with gain of 40 dB. In case of the AE signal multi-channel measurement, we can use this redundancy information for the crack localization (EME + 3 up to 8 AE channels). The developed set-up main part is composed by the specific PXI system.

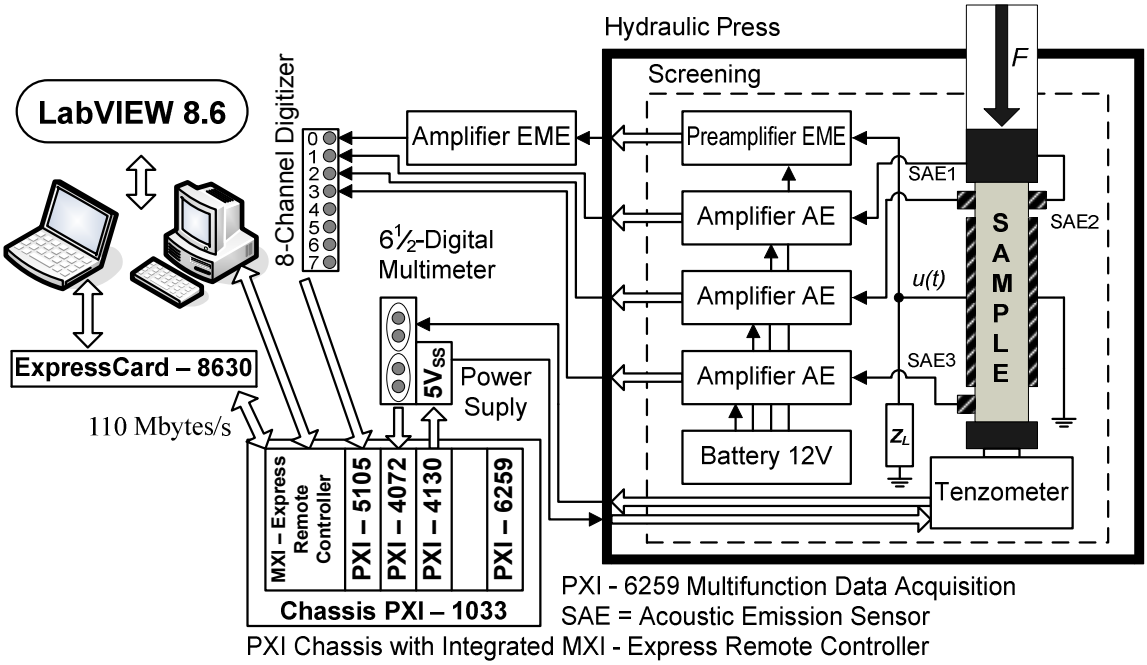

Figure 1: Experimental set-up

EME Preamplifier (3S SEDLAK PA31)

This low-noise EME signal preamplifier offers 20 Hz to 10 MHz bandwidth, high input impedance 2 × 10 MΩ / 20 pF, variable gain 6 / 20 / 40 dB and producer guaranteed noise voltage < 1,8 nV / √Hz.

AE Amplifier (3S SEDLAK PA15)

It is used for AE signal forcing and specific parameters are: 3 Hz to 1 MHz bandwidth (sufficient for AE signals), high input impedance 2 × 10 MΩ / 40 pF, variable gain 0 / 20 / 40 dB and noise voltage < 2 nV / √Hz.

AE sensors

The piezoelectric sensors from different vendors are used for AE signals scanning. These sensors meet the requirements of the AE signal frequency band (at least up to 1 MHz) and to the sample are usually mounted by beeswax. This variant provides good mechanical contact between the sample and the sensor and sensors easy mounting and removing.

EME sensor

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

4. DESIGNED PXI SYSTEM

Efficient modular PXI system must be able to provide continual multi-channel data acquisition, power sourcing of the tenzometer, continual tenzometer output voltage reading and eventually, the hydraulic press mechanical load regulation. The advanced requirement is the possibility of PXI system remote control by the laptop computer. It is useful in the cases, when we want to utilize our set-up out of our laboratory. Finally, the PXI system

must by sufficiently universal for other applications then just EME and AE signals measuring. Designed PXI system consists of the following components:

- NI PXI-1033 Chassis,
- NI PXI-5105 8-Channel Digitizer,
- NI PXI-4072 Digital Multimeter,
- NI PXI-4130 Power Source,
- NI PXI-6259 Multifunction Data Acquisition,
- NI ExpressCard-8630 Laptop control of PXI.

4.1. PXI SYSTEM COMPONENTS CHARACTERISTICS

NI PXI-1033 (Chassis)

The main part of whole PXI system is created by the NI PXI-1033 Chassis with integrated MXI-Express remote controller. Thanks to integrated MXI-Express controller, this chassis provides a transparent remote link with up to 110MB/s data throughput rate. This low-cost chassis can be controlled from either a PCI Express desktop host or an ExpressCard laptop host. It offers five slots for I/O PXI peripheral modules and fully support of the National Instruments LabVIEW graphical programming environment. In the present time our PXI system uses 4 from 5 available PXI slots.

NI PXI-5105 (8-Channel Digitizer)

This module offers 8 simultaneously sampled channels, 12-bit resolution, 60 MHz sampled frequency on channel, 512 MB onboard memory and 50 mV_{PP} to 30 V_{PP} input range. Usage of this digitizer in the designed PXI system is EME and AE channel (or channels) data acquisition.

NI PXI-4072 (Digital Multimeter)

This multifunction device combines the functionality of three common instruments (a $6^1/_2$-digit multimeter, an LCR meter and a 1,8 MS/s isolated digitizer) with 10 to 23-bit flexible resolution. The DC voltage values are continually read from the tenzometer thanks to digital multimeter functions of this PXI module.

NI PXI-4130 (Power Source)

The NI PXI-4130 is a programmable, high-power source measurement unit (SMU). It has a single isolated SMU channel that offers a four-quadrant ±20V, 2A output. It also includes a utility channel (6V, 1A) that can work either current or voltage power supply with 16-bit setpoint and measurement resolution. Both channels can act as a constant voltage/current source with a settable limit for either mode. This PXI module serves for tenzometer DC voltage sourcing.

NI PXI-6259 (Multifunction Data Acquisition)

This multifunction device offers 32 16-bit analog inputs with 1MS/s (multi-channel) or 1,25 MS/s (1-channel), four 16-bit analog outputs (2,8 MS/s), 48 digital I/O and 32-bit counters. It can be used for regulation of the FROWAG hydraulic press at FAST, which enables programmable settings of different mechanical load modes.

NI ExpressCard-8630 (Laptop control of PXI)

It provides the ability to use the laptop computer to PXI systems control. This solution allows using the same cable and the same data throughput rate (110MB/s) as the

MXI-Express. With the laptop control of PXI, our designed PXI system is fully mobile and we can use it in the measurement set-up at FAST or other workplaces.

4.2. PXI SYSTEM MODULES CONTROL SOFTWARE

The complex software package was developed in the LabVIEW environment. It allows PXI system modules control, finding the typical events (Fig. 3) 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.). Each event is finally described by the vector of 10 parameters. Processing and evaluation of these parameters is taking place simultaneously (in real-time) with the process of measurement. It offers the possibility to observe the stressed materials response to applied mechanical load in real-time.

5. CONSLUSION

New improved set-up was developed for EME and AE signals measurement. This new measurement system is based on the PXI platform, which is one of the most extended modular platforms for measurement and automation systems. Designed PXI system can be controlled from the desktop or the laptop computer.

The complex program package in the LabVIEW graphical programming environment was developed for the PXI system modules control. This program further offers the continual multi-channel EME and AE signals measurement, real-time processing and evaluation.

EME and AE signals continual measurement, real-time processing and evaluation can be used for the diagnostics of the mechanically stressed solid dielectric materials and for quantitative sample damage estimation.

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REFERENCES

[1] Koktavý, P.: Experimental study of electromagnetic emission signals generated by crack generation in composite materials. *Measurement Science and Technology*. 2008. 20(1). p. 0 - 7. ISSN 0957-0233.

[2] Koktavý, B., Koktavý, P., Grmela, L.: Study of crack behaviour during mechanical stressing of composite materials. In *New trends in physics.* -. Brno, Z. Novotný, Ing., CSc. 2007. p. 65 - 68. ISBN 978-80-7355-078-3.

[3] *What is PXI?* : *Developer Zone* [online]. 2010 [cit. 2010-03-02]. National Instruments. Dostupné z WWW: <http://zone.ni.com/devzone/cda/tut/p/id/4811>.