# Working title: DAMAGE DIAGNOSTICS USING ACOUSTIC EMISSION (AE)

***Note:*** Work on AE and test-bed development was done in collaboration with Predrag Dukic M. Sc. from Vocational studies department of University of Split (contact: stijena@tapko.de).

A range of mechanical engineering methods for testing and evaluation of materials and structures are based on acoustic wave analysis. Some mechanical and other physical processes, while occurring, generate a number of short acoustic wave pulses. Detecting, measuring, and processing self-generated acoustic pulses (sometimes called events) is recognized as one very promising method of discovering existence of flaws in mechanical engineering structures and elements. These short pulses are result of: -Cracking or breaking the object under observation. -Micro-cracking the object and its parts (crystallites) due to fatigue. -Migration of dislocations during plastic deformation of the metallic object. -Chipping of the surface of the corroding metallic objects. -Friction and other phenomena (including even such as corrosion). -Changing of the orientation of the elementary magnets of any ferromagnetic material after coming under influence of the external magnetic field. Frequency range of acoustic waves of interest is from 20 kHz to approximately 1 MHz. These limits are only extremes, and most of the spectral energy lies between 50 and 300 KHz. Amplitude levels usually encountered are very small, sometimes only slightly above the noise level of the measurement equipment and sensors.

## Examples of AE:

All the three tests performed are commonly used for generation of repeatable AE events similar to those emerging from fatigue cracks, and described in relevant literature.

Superficial layer of epoxy resin present on the specimen (Carbon Fiber Reinforced Polymer - CFRP) was removed using sandpaper to expose electrically conductive graphite fibers. It is necessary, because one electrode of the piezosensor is in the close contact with the specimen. The specimen then serves as one of the electrode contacts, i.e. ground connection. The piezosensor is attached to the specimen using epoxy resin similar to the one used for the specimen itself. Setting of the resin was performed under pressure sufficient to achieve electrical contact of the sensor with the specimen through the resin. After soldering of the coaxial cable to the upper electrode and the ground contact, the whole sensor and surrounding part of the specimen was wrapped in copper tape to reduce electromagnetic interference present in the room (EMI). The EMI was found to be one of the major sources of measuring errors, i.e. non-gaussian noise.

Test No1: "Dropping ball test":

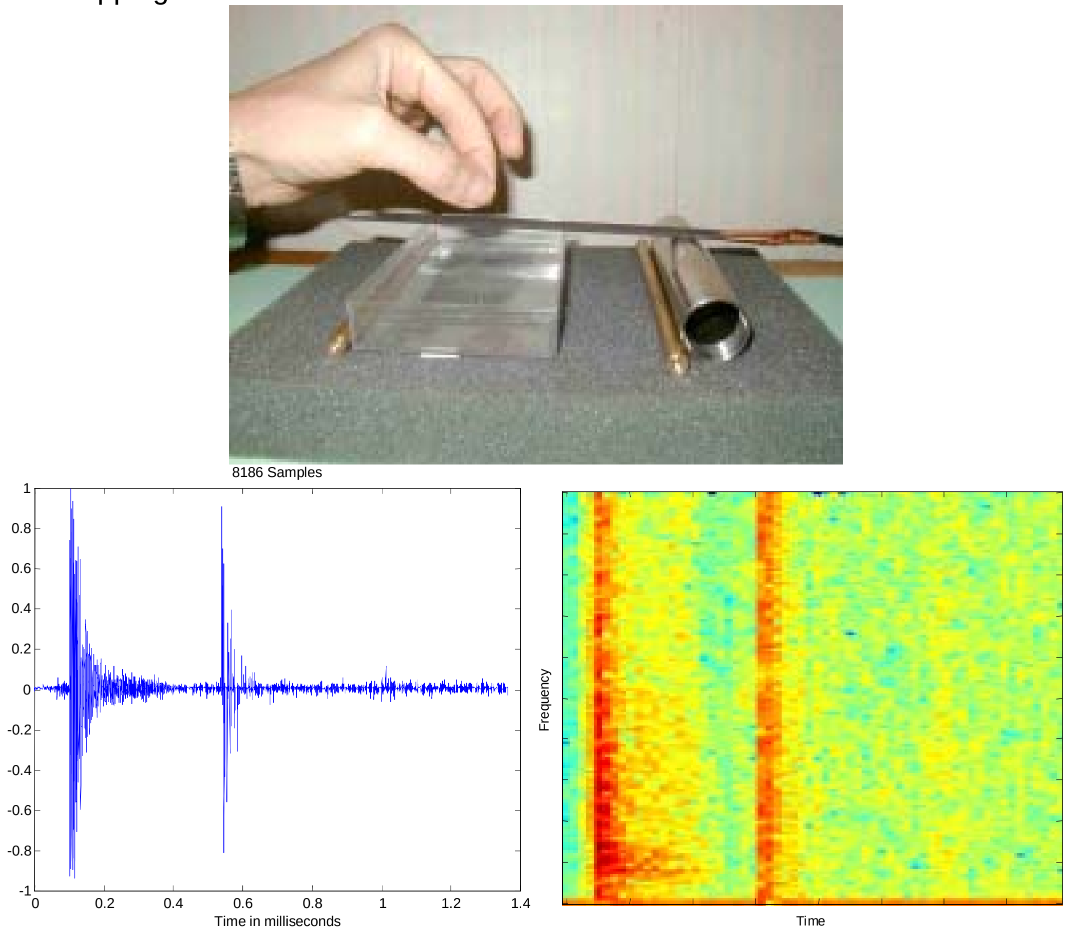



Fig.1a Dropping ball test and (play signal 1000x slower) .

A small ball (pellet used for shot-peening), less than 1mm in diameter was dropped on the surface of the specimen from a height of about 30 mm.

Test No2: "Scratch test":

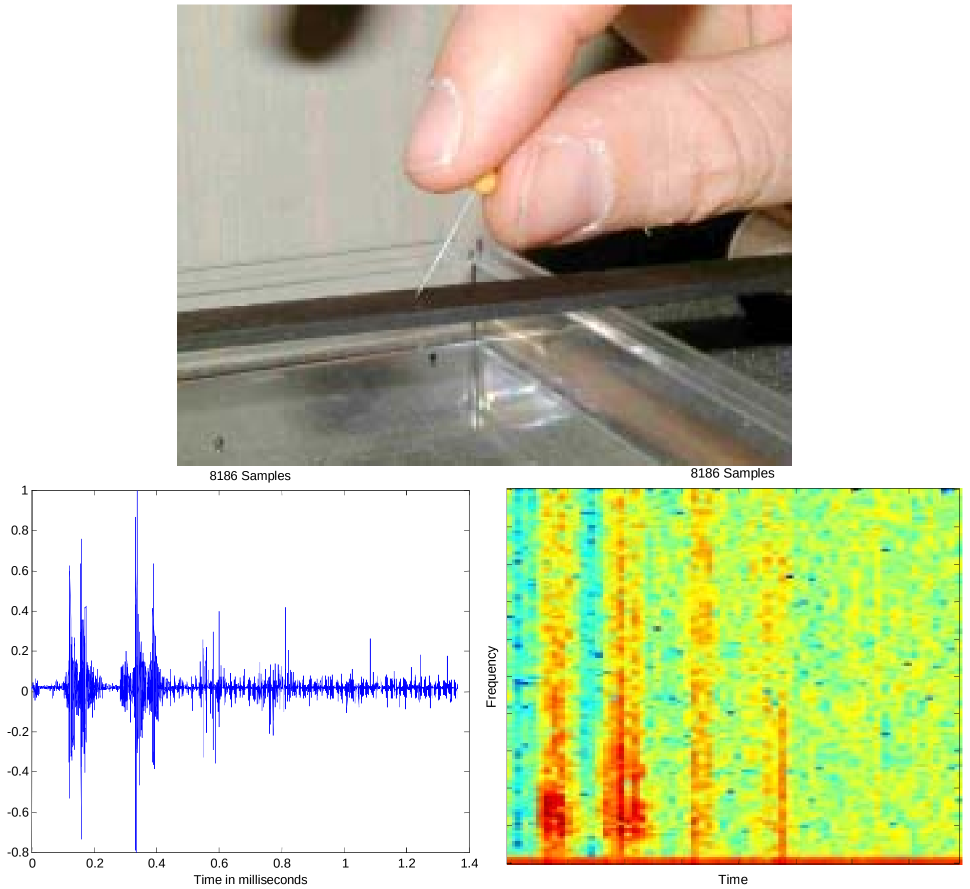



Fig.1b Scratch test (play signal 1000x slower) .

In this test, a series of acoustic events was generated by light scratching of the surface with a needle. Roughening of the surface was not necessary, because the specimen itself already has rough surface. Scratching length was 3-5 mm, and the pressure was as low as possible.

Test No3: "Graphite pen tip break":

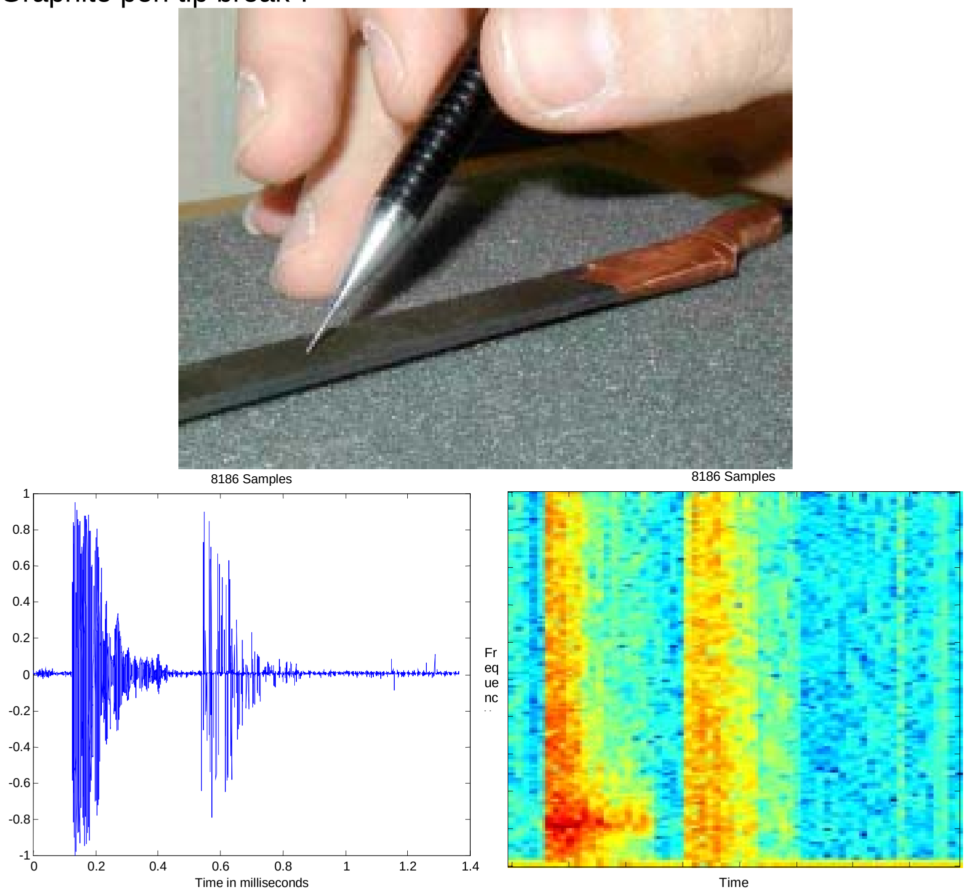
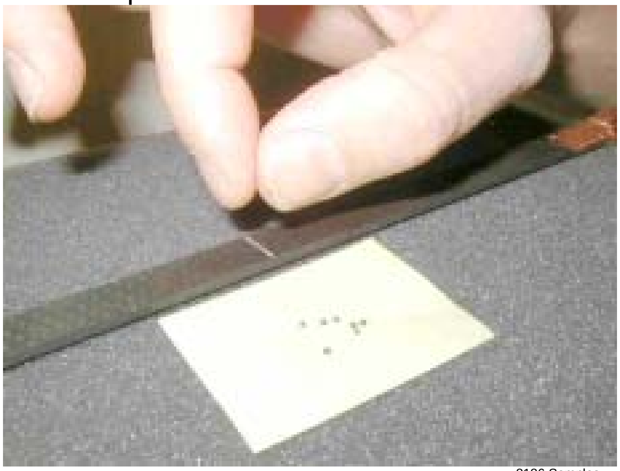



Fig.1c Graphite pen tip break test (play signal 1000x slower) .

In this test an AE event is generated by sudden release of the pressure applied to the surface of the specimen as a result of breaking the graphite pen tip pressed upon it. The graphite core was 0.3 mm diameter, HB type, 2 millimeters protruding from the pen. The tip was pressed at an angle of 30 degrees from the specimen surface.

Test No 4: "Dropping ball test-damped"



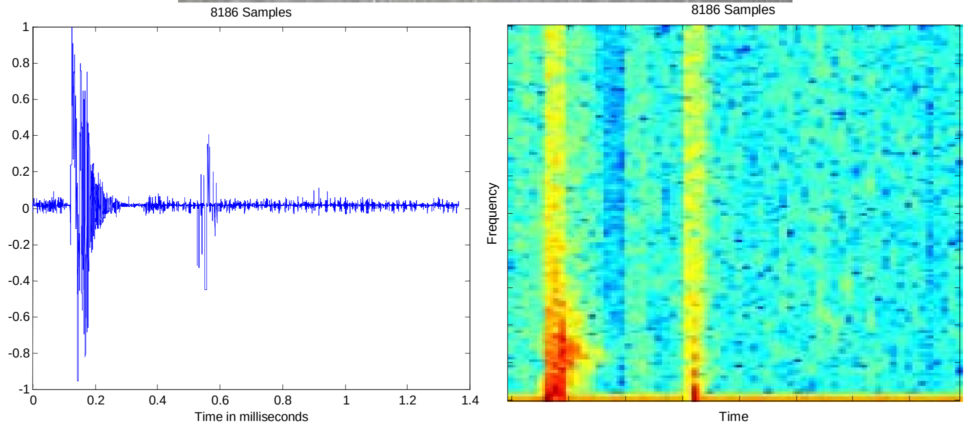



Fig.1d Graphite pen tip break test (play signal 1000x slower).

It was also the "Dropping ball test" but with a piece of polyurethane foam placed under the specimen, to investigate the influence of sound absorbing material

## Problem definition

The ultimate, and only meaningful use of AE methods is through continuous, real time monitoring of structure deterioration. Nature of recordable signals calls for computing power unreachable with «classic» computing. This research is directed towards development of algorithms and devices able to cope with these demands. It will use a high density smart sensor array embedded in the structure, combining AE data with sensors for other physical values affecting the process of structure deterioration. Introduction of reconfigurable hardware, and microprocessors reconfigurable in hardware provided by today's semiconductor devices industry enables computing power mentioned before. However, algorithm development still cannot ignore this issue altogether. Every new step in development has therefore two steps: Computational feasibility analysis, and following that, changes in software and algorithms.

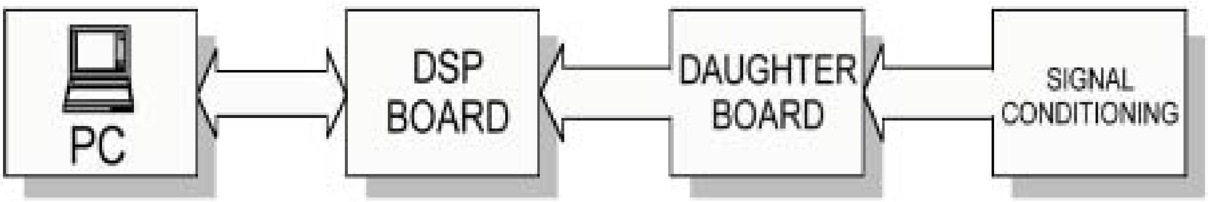



Fig.2 DAQ flow chart.

2000.-2006.

Current version of the test-bed device, shown on Fig.3. uses high density in-house developed FPGA devices to integrate acquisition, filtering, high speed DSP functions, and a standard DSP processor for low speed functions like data storage and transfer. At the moment it is able to localize and classify signals from plate specimens by simultaneous acquisition of four channels, Fig.4. For the ease of further development, all the functions are reachable from Matlab, using proprietary interface software.

Fig.3. AE module under development.

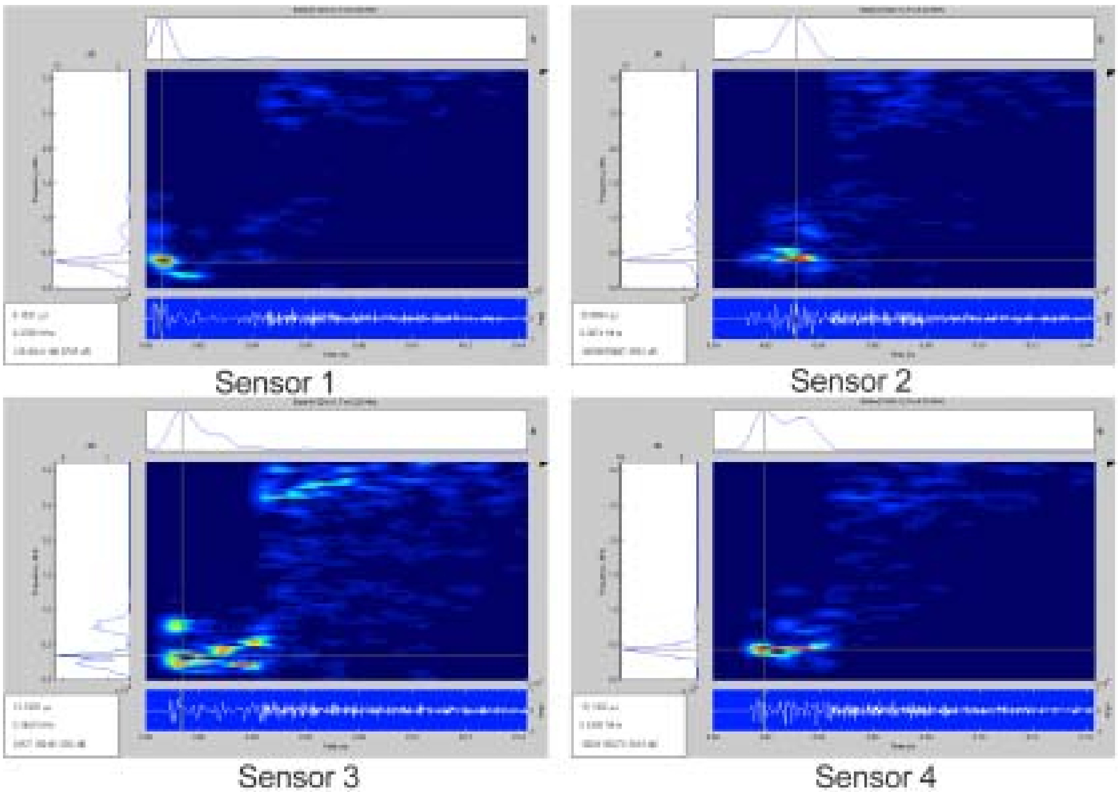



Fig.4. Waveform spectrogram of a representative AE signal on CFRP plate.

Tests were conducted on two types of materials CFRP and aluminum plate.

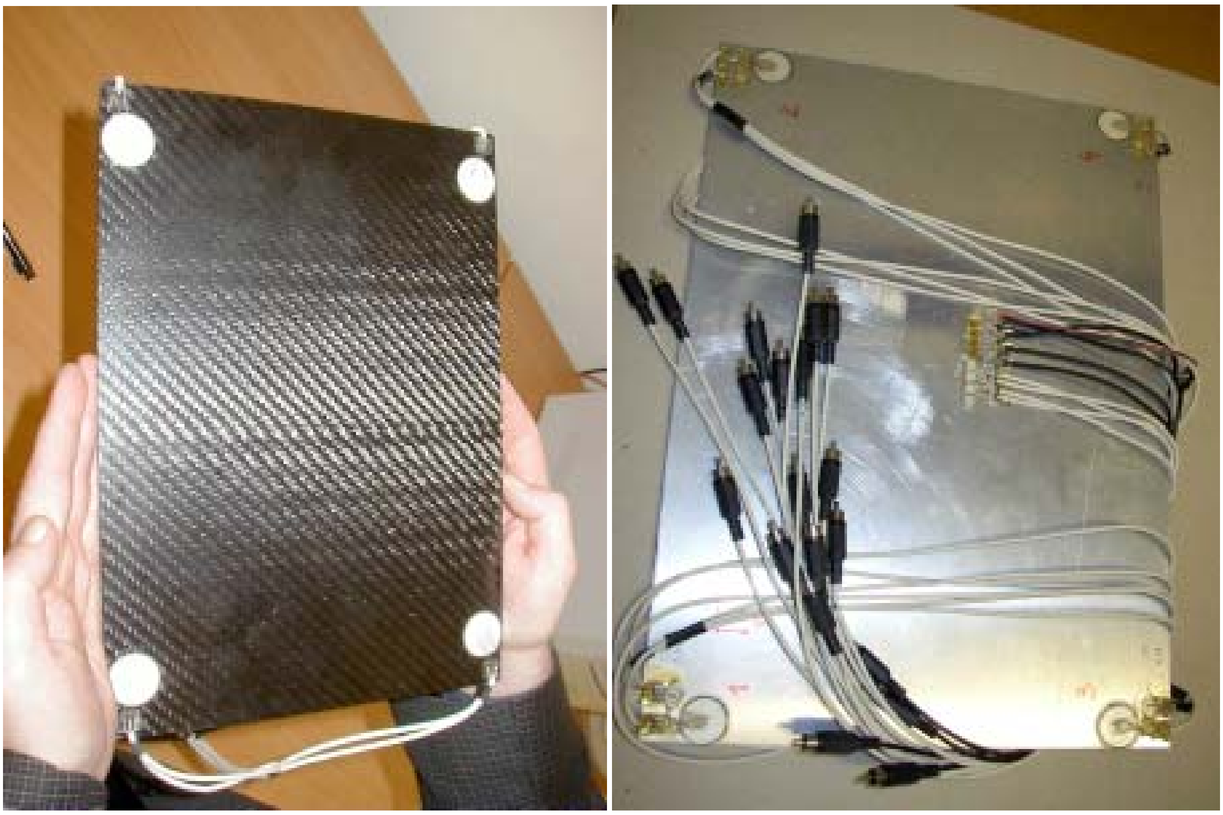


Fig.5. CFRP and Aluminum plates, with sensors

Algorithms implemented till now include digital filtering, using IIR, FIR or Wavelet filters, and standard Time-Of-Flight localization, with hard thresholding as the trigger for capture and analysis. The pictures 5 and 6 show a test sample (bed) with combined corner triangulation detectors, and two four-element phased sensor arrays. They are intended for directional detection and edge reflection suppression. Two types of sensors are used: Strain gages and piezoelectric sensors for the array, and piezoelectric sensors of two sizes and on the both sides of the plate for the corners. They are all applied on the same aluminum plate for comparison and combination purposes.

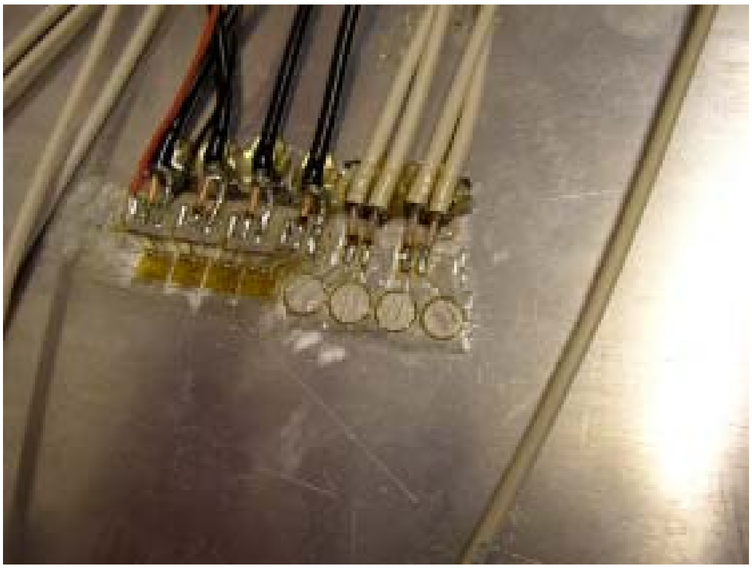


Fig.6. Two four-element phased sensor arrays.