RECIPROCITY AND STEP FUNCTION CALIBRATION OF ACOUSTIC EMISSION SENSORS

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ABSTRACT

The paper reviews the background, the methodology and the standardization of the primary calibration of acoustic emission sensors. Two basic calibration methods, which were practically realized on our test stand, are closely described and explained. It is the method of reciprocity calibration according to NDIS 2109-91 [2] and the step function calibration according to ASTM 1106[1]. As a transfer medium for wave propagation a large steel block was used. The comparison of the results of the both method is presented.

1. INTRODUCTION

Acoustic Emission (AE) is a passive non-destructive testing technique that has been used widely since the 1970s. AE has been defined as the spontaneous release of elastic energy by material when it undergoes deformation.

Good metrology of the AE calibration method is necessary to be able to compare the results of calibration made by other laboratories or to compare the effects of ageing, thermal cycling and so on. ASTM E1106[1] and NDIS 2109[2] outlines a method for primary calibration.

2. AE SENSOR

Transducers used for acoustic emission measurement are in general sensitive to motion normal to the surface to which they are attached. Typically, AE transducers are sensitive to frequencies above 100 kHz. The highest frequencies likely to be of interest to users of AE transducers are in the range from 800 kHz to 1 MHz.

There are several ways how this sensors can be achieved. The piezoelectric effect, capacitance methods and optical interferometry are common techniques used for detection of AE in industry and research. Piezoelectric devices offer the greatest sensitivity and thus they are the most widely used type of transducer in AE applications. Interferometers and capacitance transducers are often used to calibrate piezoelectric transducers.

3. AE SENSOR CALIBRATION

A main problem of the calibration is to find the characteristic of the transducer. A frequency response of a specific sensor in the mechanical input quantity (velocity, displacement) is the most common result of calibration. Output quantity of calibration is output stress relate to unit of mechanical input (displacement, velocity, acceleration). The absolute value of input quantity and its shape has to be known for primary calibration. Each method has its specific limitations.

There are two types of AE sensor calibration:

For *primary calibration* the absolute value of input signal and its shape has to be known. A mechanical source of input signal with standard characteristics (shape of waveform – step or impulse, duration) is important for this. The method of calibration with a step function is described in ASTM E 1106 [1] and reciprocity calibration in NDIS 2109 [2].

Secondary calibration requires a reference sensor with known characteristics. Calibration is done by comparison of the results of the reference and tested transducers. Data from the secondary calibration is of the same type as from the primary, but is more limited (in frequency, absence of shift characteristics, and greater error of calibration).

4. INVESTIGATION OF RECIPROCITY CALIBRATION AT FEEC BUT

The selection of instruments was limited by the capability of the laboratory and by instruments used by Hatano at al. [3]. Here is the list of components used:

- Vector signal analyzer HP 89410A, two channels from DC up to 10 MHz, GPIB interface, sampling rate up to 25,6 MHz
- Arbitrary waveform generator HP 33220A. A waveform can have up to 64000 points, resolution 14 bits, 40 MSa/s, GPIB interface
- Current probe Tektronix P6022 with impedance matching. Sensitivity 1 mA/mV or 10 mA/mV. Bandwidth on range 1 mA/mV is 8,5 kHz up to 100 MHz.
- Personal Computer Pentium 4, 3,2 GHz, 1024 MB RAM, GPIB-USB, OS Windows XP
- AE amplifier with gain 30 dB in range from 35 kHz to 4 MHz for drop 3 dB.
- Steel cylinder with diameter 94,0 cm, height 43,8 cm. Used material is signed 34 MnV (0,34 C). To suppressed interference the block was grounded with HP 89410A.
- Adhesive paste Krautkramer TGT, number 50472.
- GPIB and sensor cables

The duration of the driving signal was 100 μs according to the size of the testing block. The first reflected wave from the bottom surface came after 150 μs. The sampling rate was 25,6 MHz. The source signal was generated from 8000 points. The experiment was controlled by software developed in LabVIEW 8.0. The frequency transmission was probed in the range from 60 kHz to 1 MHz point to point with step size 5 kHz. The resulting characteristic has only 189 frequency points and the experiment took 1,2 hour.

The low frequency is limited by the duration of the input signal and the high frequency is limited by the sensitivity of the transducer.

Figure 1: Test rig

5. INVESTIGATION OF STEP FUNCTION CALIBRATION AT FEEC BUT

The driving signal for the step function is generated by break of glass capillary. A holding fixture was manufactured for it. The basis aparature was used the same as for reciprocity calibration, but it was supplement according to ASTM E 1106 [1]:

- Force sensor LCMFD-100N. Range ±100N, sensitivity 0,180067 mV/N
- Holding fixture for aparature for capillary breaking
- Glass fibre with diameter smaller than 0,2 mm, manufactured from laboratory glass
- Laser interferometer Polytec OFV-5000 with optical head OFV-505 and computing module DD-300 for AE

Analyzer 89410A was drived by trigger 0,05 V and 200 μs of oncoming signal was sampled. Pretrigger 40 μs was used and sampling frequency was 25,6 MHz. Signal of the capillary break was calculated by Matlab with the same length and sampling parameters as real signal. Signal generated from Matlab was recalculated from displacement to velocity and FFT was calculated from both signals. Final characteristic is calculated by the dividing measured spectrum by calculated spectrum.

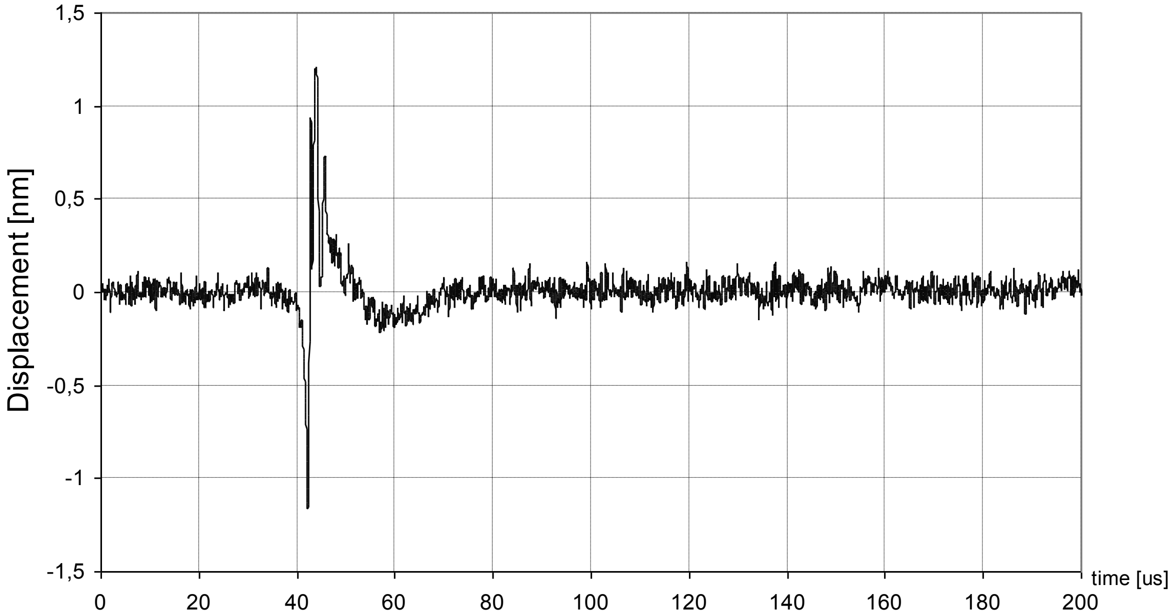

Figure 2: Break of capillary measured by laser interferometer

6. COMPARISION OF RESULTS

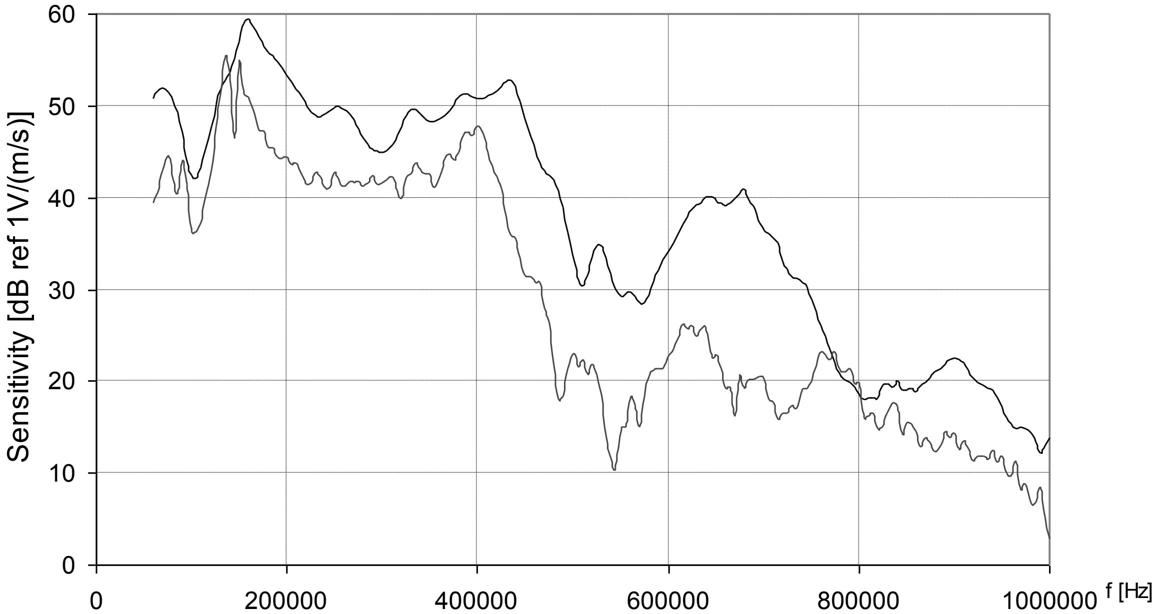

Figure 3: MIDI 06 – 12 - reciprocity and step function calibration

On Figure 3, there are measured characteristics for sensor MIDI 06 – 12 manufactured by Dakel. The shape of measured results corresponds well. Next step is to find the reason of the difference in amplitude and make analysis of uncertainty.

7. CONCLUSIONS

For the realization of step function calibration the holding metal construction was manufactured and suitable capillary had to be obtained. The construction holds the capillary breaker. For controlling of the whole experiment PC was used. Software was programmed in LabVIEW 8.0 and controls measurement by all of the methods. The apparatus enables primary calibration of acoustic emission sensors by reciprocity method according to NDIS 2109 [2] and by step function method according to ASTM 1106 [1] together.

Matrix channel switch was developed to automate of the whole process. It allows increasing count of measurement and decreasing the possibility of error made by change of cables.

Laser interefometer Polytec OFV-5000 with optical head OFV-505 and computing module DD-300 for AE was used for validation of shape of signal generated by capillary break.

Plan for the future is to analyze the uncertainty of the measurement.

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