# CORRELATION ANALYSIS OF ARTIFICIAL ACOUSTIC EMISSION SIGNAL PARAMETERS AND FEATURES


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**Abstract**: This work aims to identify signal features that are correlated with acoustic emission source type by analyzing artificial acoustic emission events. Signals are generated using a piezoelectric transducer and a signal generator that emits signals with various parameters.



**Keywords**: acoustic emission, source type identification, signal features


## 1 INTRODUCTION

Acoustic Emission (AE) is a natural effect whereby elastic waves suddenly appears in a material under mechanical stress. The elastic waves arise from the energy released during displacement in the structure of the material. Acoustic emissions in materials might be generated by several different physical processes. Two major dislocation types occur in stressed crystal lattices: edge and screw (Fig. 1). Edge dislocation is perpendicular to the causing force. The atoms in crystal slips in a way, that an extra half-plane of atoms is missing from the structure (gray color). Screw dislocation is parallel with the causing force, where rows of atoms parallel with the force slip to the next position in crystal structure (gray color). Between the slipped and original parts a small transitional region exist [1].

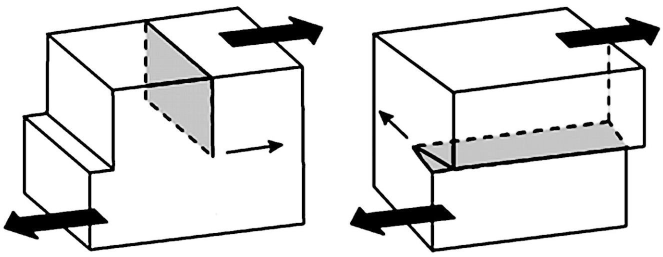

**Figure 1:** Dislocation types: edge (left), screw (right)

Distinction of these processes can be supported by analysis of the recorded signals. An AE signal itself is not directly related to its origin. Signals are affected by many factors such as the tested specimen, waveguide transfer function given by structure and homogeneity of material, transfer function of used sensors, etc. It contains a large amount of information, thus, it is more difficult to extract the required information. Characteristic information, namely features, can be extracted from acquired signals and used to analyze the AE source [2, 3]. The features are related indirectly to physical parameters of the generating mechanical process, such as crack size or dislocation type.

The objective of this paper is motivated by the fact that almost every researcher in acoustic emission try to find suitable features that would distinguish sources in its examined material or construction in these days. The paper tries to discover the influence of signal source parameters on individual signal features.

## 2 EXPERIMENTAL SETUP

In this experiment, the acoustic emission source was emulated by a piezoelectric transducer casted-in in a mortar block. This transducer was excited by a rectangle pulse with variable amplitude and width. Two piezoelectric sensors were used for sensing of elastic waves. Their electric output signals were amplified by low noise amplifiers (LNA, 3S Sedlak PA21) and recorded by a digital acquisition card (TiePie HandyScope HS4) at 5 MHz sampling rate and 12 bit resolution. The sensor, that was closer to the transducer, was connected to input channel 1, the other one to channel 2. Figure 2 represents schematically the experimental setup.

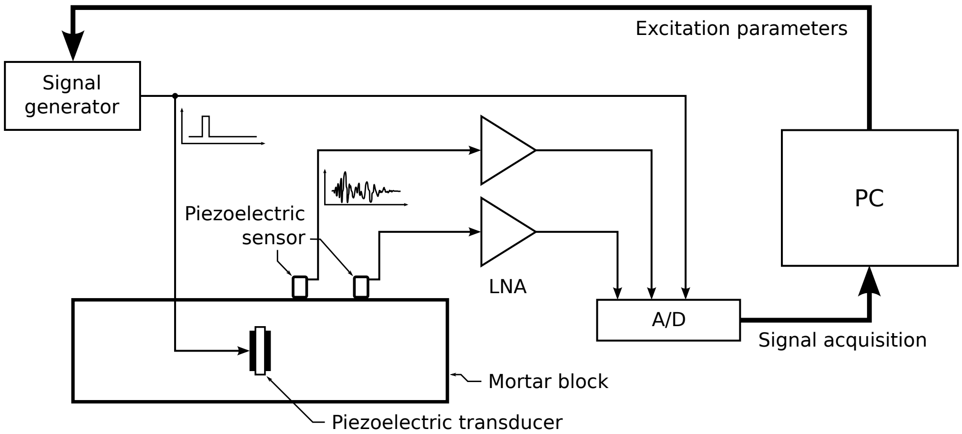


**Figure 2:** Experimental setup

The amplitude of the excitation pulse is intended to reflect the various attenuation depending on the distance between the transducer and sensor. The pulse width variation may represent the different source types. Figure 3 illustrates a sample of recorded signals.

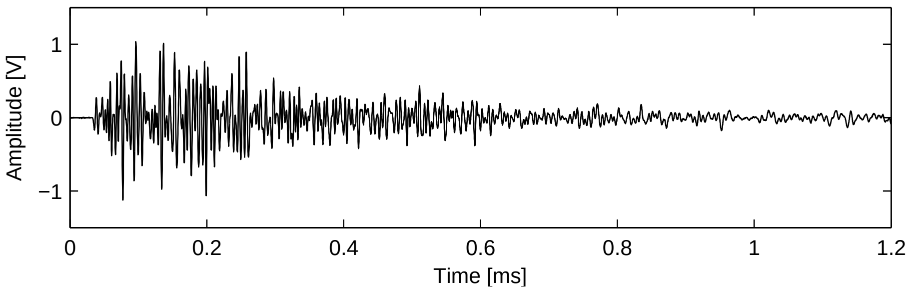


**Figure 3:** A sample of recorded signals

## 3 EVALUATION RESULTS

Various sources exist in acoustic emission. It is difficult to specify precise shape of displacement function. Even though the displacement function of pencil lead break is known, step function is assumed to be suitable for emulation of AE event in material under deformation.

The rectangular pulse of amplitudes 8, 4, 2, 1 and 0.5 V and pulse widths 1, 2, 5, 10, 20, 50 and 100 $\mu$s was used to emulate various types of AE source. Sample signals for these parameters are shown in figures 4 and 5. For each combination 10 events were excited. The features of all recorded signals were calculated, and were used for analysis. Figure 6 shows the result of correlation analysis of excitation pulse amplitude and width with each signal feature for the two input channels.

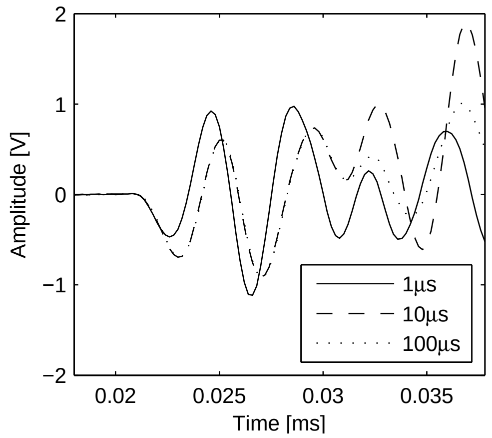


**Figure 4:** Three signals with the same excitation amplitude (8 V) and variable width

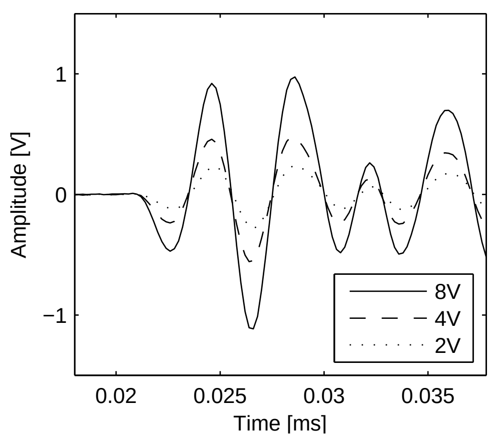


**Figure 5:** Three signals with the same excitation width (1 $\mu$s) and variable amplitude

The excitation voltage has direct connection with features maximal amplitude, first peak amplitude, energy and maximal amplitude in fast Fourier transformation (FFT), their correlation is very high; figure 7 illustrates such dependence in detail. These features are mainly determined in time domain. The duration, count and zero crossings have indirect connection. These features are affected by the ratio of signal amplitude and their own threshold level. The threshold level is constant, thus, these features also correlate with the excitation amplitude. Because the amplitude does not carry information about the source type, we can conclude, that these features are not useful for the purpose of source type identification.

Signal features that have high correlation with pulse width are good candidates for source type identification: rise time, count to max., third moment and the continuous wavelet transformation (CWT) features [4, 5]. This is especially true for features that has simultaneously low correlation with amplitude. From this point of view, the two features relying on wavelet transformation excel: CWT maximal peak frequency and CWT first peak frequency. Features that have correlation with both amplitude and pulse width carry less information about source type, however, they might be used as auxiliary data source. These features include average frequency, FFT max. frequency, centrum of gravity and the powers in spectral bands (P1 - P6). Figure 8 shows the dependence of the first one on the pulse width. This relation is not as clear and straightforward as e.g. the dependence of maximal amplitude.

## 4 CONCLUSIONS

This work analyzed the suitability of common and some uncommon signal features concerning acoustic emission source type identification. Some signal features have high correlation with the excitation signal shape but lower correlation with its amplitude. These features carry the most information regarding the acoustic emission source type.

On the basis of this investigation we can state that rise time, count to max., third moment and the continuous wavelet transformation are the most suitable features for AE source analysis, since those carry the most information about AE source type. Among all, the CWT features appear to have the best properties. Average frequency, FFT max. frequency, centrum of gravity and the powers in spectral bands could serve as auxiliary data source, however, they contain less information than previous ones.

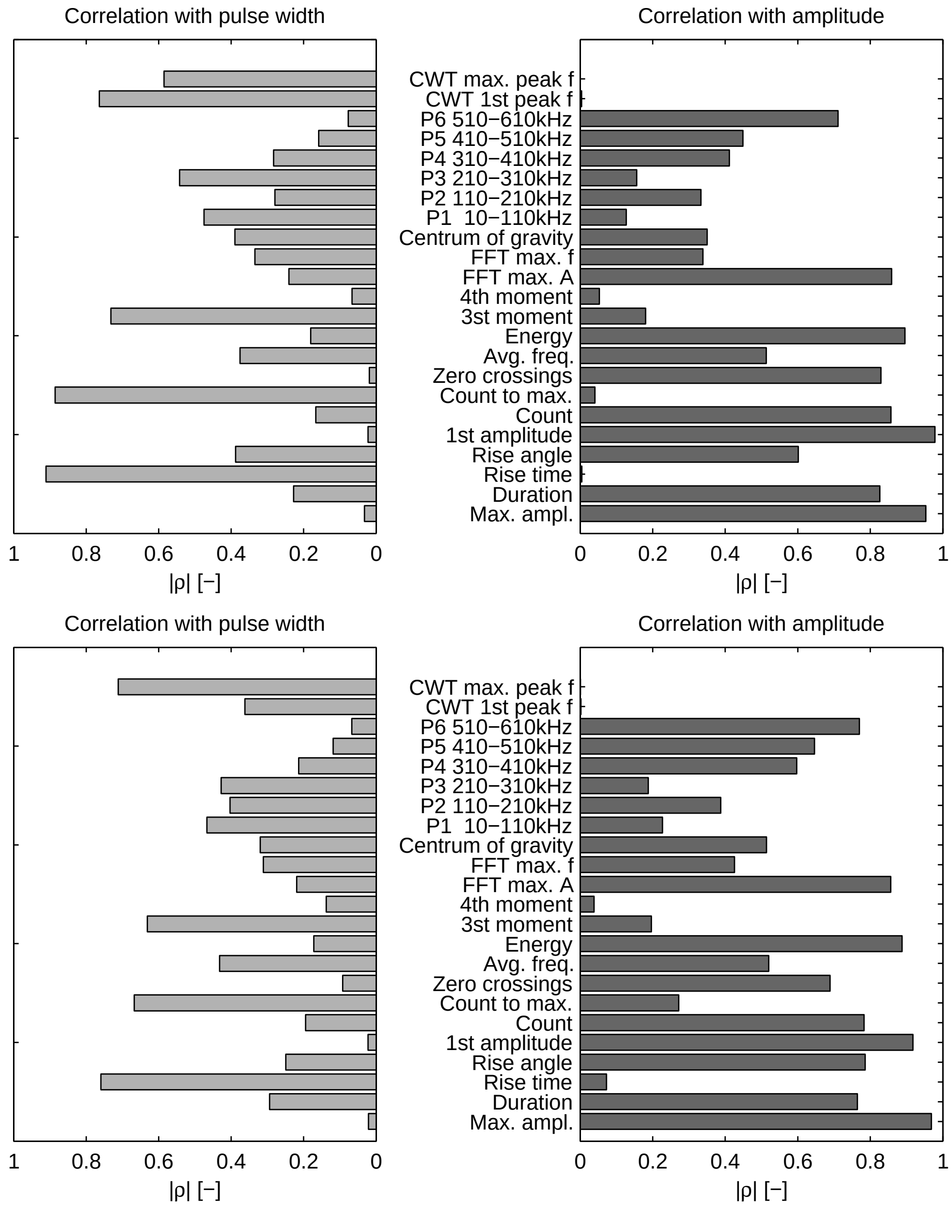


**Figure 6:** Correlation coefficients in absolute values of features for channel 1 (upper) and channel 2 (lower)

## ACKNOWLEDGEMENT

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## REFERENCES

[1] *Materials and Processes*. [online] http://www.ndt-ed.org/EducationResources/CommunityCollege/Materials/cc_mat_index.htm. cit. 1.3.2012

[2] *AE Signal Features*. [online] http://www.ndt-ed.org/EducationResources/CommunityCollege/Other%20Methods/AE/AE_Signal%20Features.htm. cit. 1.3.2012

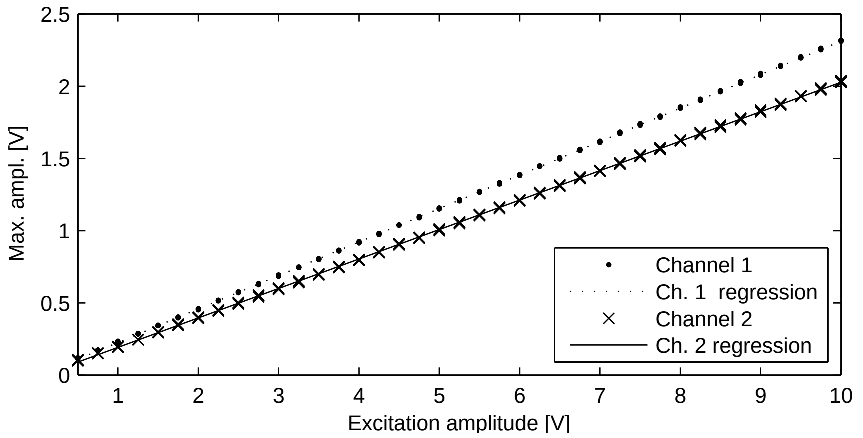


**Figure 7:** Dependence of the feature maximal amplitude on excitation voltage

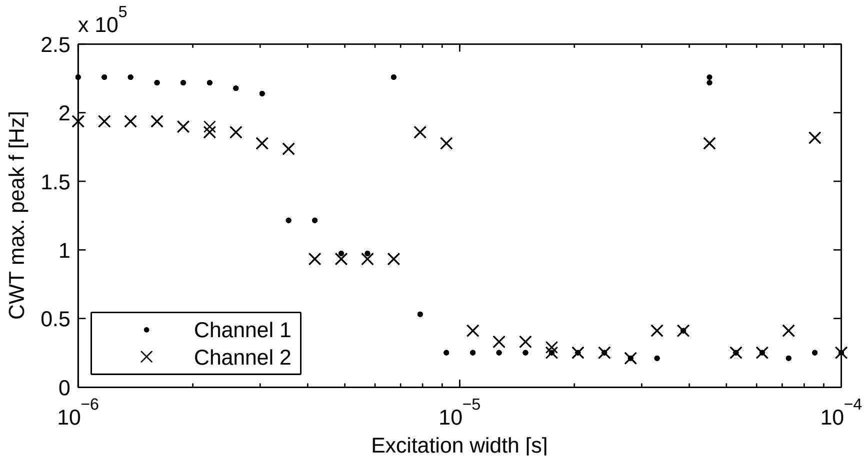


**Figure 8:** Dependence of the feature highest peak frequency of wavelet transformation on excitation pulse width

[3] Muravin, B. *Acoustic Emission Method*. [online] http://www.muravin.com/ae/Muravin%20-%20Acoustic%20Emission%20Method%20-%20short%20presentation%20for%20students.ppt. cit. 1.3.2012

[4] Ito, K. Enoki, M. *Material Transactions 48*. 2007. pp. 1221-1226

[5] Cséfalvay, G. Klampár, M. *Dimensionality Reduction Methods for Classification of Acoustic Emission Sources*. In Proceedings of the 17th conference STUDENT EEICT 2011 Volume 3. 1. Brno: NOVPRESS s.r.o., 2011. pp. 321-325. ISBN: 978-80-214-4273-3.