

# MONITORING OF CHANGES SIGNAL ACOUSTIC EMISSION SIGNALS USING WAVEGUIDES

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## Abstract

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This paper is focused on possibilities of acoustic emission (AE) signal detection from material surface through waveguide for commonly used piezoelectric sensors. It also considers the experimental study of enhanced detection of occurrence of signal guided through waveguide corpus, its changes and deformities. Aim of this work is verification of several waveguide setup possibilities for maximization of AE signal detection in practice. For this purpose, multiple waveguide setups were manufactured from stainless steel and aluminium alloy. Hsu-Nielson pen test was utilized for signal actuation. Results demonstrate the differences between measured AE signal with and without employment of waveguide (changes in signal course through different materials and shapes), as well as magnitude of signal dampening and amplification necessary for veritable signal interpretation. Measurements were conducted on agglomerated composite of medium density fibreboard (MDF).

Keywords: acoustic emission, acoustic waveguide, non-destructive test

## INTRODUCTION

This work deals with experimental verification of detected AE signal, which spreads throughout the entire sample, but detection takes place on the sample surface. Objective is to determine the influence of acoustic waveguide utilisation on signal quality. Comparison of signal detected with utilization of different waveguides contrasting to direct AE signal detection from sample surface is also described. For acquirement of unified impulses in each case of AE event the Hsu-Nielson pen test was utilized. AE waveguide construction (namely its shape, girth, acoustic conductance) significantly affects the output results in AE signal detection. Waveguides also increase the distance of sensor from signal source, which is also considered unfavourable. It is common in practical application, that installation of sensor directly to surface is impossible, e.g. inaccessible location on construction, or high temperature of measured surface (this is a most common cause of waveguide employment). However, there are certain

cases, when employment of waveguide enhances the possibilities of signal detection – typically in structural engineering, namely firm fixing of waveguide into a hole drilled in wood or concrete. Also fixing the waveguide to a plant for transpiration flow measurement in plant stem was conducted (Sriwongras *et al.* 2015).

AE uses the detection of elastic waves generated by sudden deformation of material and detects the microscopic shifts in material structure. AE signal emission is connected to concentration of mechanical tension by ČSN EN 1330–9, 2000. This tension could be observed as a vector field, which shows declination and direction in every random point of material structure. When mechanical tension reaches its threshold value (locally reaching the plastic state of structure), irreversible deformations occur in structure. Both tension values are linked to AE events.

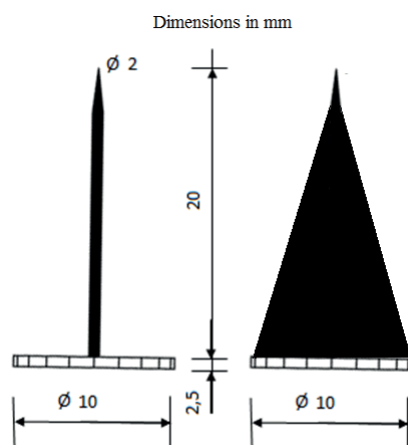
Spherical acoustic wave spreading from the point of origin is modified throughout its course by diffusion, reflection and dampening until it reaches

the material surface, where it is detected with sensor. Further changes in signal shape is determined by transformation of mechanical waves to electric energy inside the sensor. Respective recorded signal is adjusted in terminal phase – amplified, filtered, etc. (Pazdera *et al.* 2004).

Underlying principle of AE measurement method is observation of ripples in material structure. Ripples could be divided regarding its characteristics into lateral undulation and successive transversal undulation. AE signals recorded with sensors adjacent to material surface are mostly impulses of superficial waves (Rayleigh's waves). AE sensors employ the planar oscillation, therefore are usually atoned to resonance corresponding to radial dimensions of inverters. AE sensors are tuned to 20 kHz to 2 MHz frequency band (Miller *et al.* 2008).

## MATERIALS AND METHODS

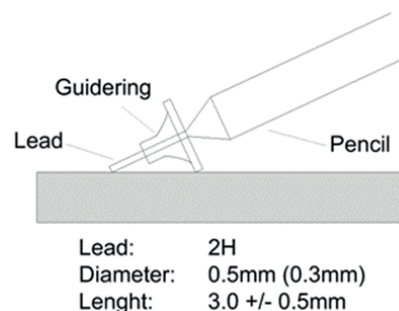
Material for waveguide manufacturing is chosen corresponding to material of measured object. It should represent the same acoustic conductance for minimization of AE signal refraction and improvement of wave transfer from sample to waveguide and subsequently to sensor. For purpose of experiments the selected materials were selected according to effective conductance of AE signal and minimization of unfavourable collateral signal refraction. Attention was focused on construction characteristics – comparison and selection of waveguide shapes with respect to measurement of various materials of samples (Muravin *et al.* 2011). Selected materials were stainless steel X5CrNi 18–10 and aluminium alloy AlMgSi0.5. Length of waveguides was determined to 20 mm with regards on practical use. Optimal detection area was determined as 2 mm diameter circle (Fig. 1). Regarding the IDK 09 Dakel sensor the connective surface area is a 6 mm circle. Transfer from 2 mm to 6 mm area was for experimental reasons chosen in two segments, for first the most commonly used spike with cylindrical head and for second conical transition to cylindrical surface.



1: Waveguides dimension

For stable fixation of waveguides the mechanical lever press with worktable and digital dynamometer was employed. Its purpose was to create optimal contact pressure of waveguide to examined material. Waveguide should be positioned perpendicular to surface, pressed into the material and not further adjusted. The force should be appropriate to prevent the tilt of waveguide with connected sensor and sufficient enough to prevent the sensor movement in course of measurement. It is recommended to use force in order of tens of N. It is obvious that means of sensor installation shows a significant influence on measured data quality (Černý *et al.* 2008).

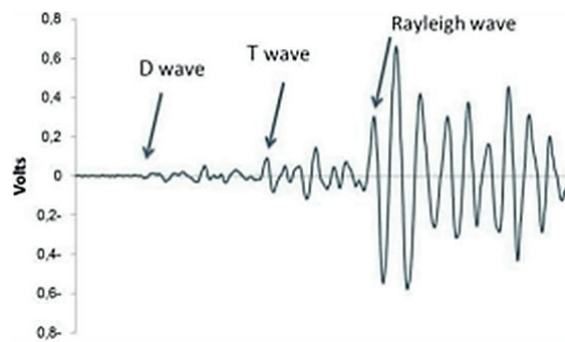
Method of AE source actuation was conducted with use of Hsu-Nielsen test, which is standardised by ČSN EN 13544, 2002. Pen test is considered the basic AE source and is commonly used for sensor calibration (Fig. 2). It represents the sudden quantum lift of force perpendicularly pressing onto the plate surface. Magnitude of this force oscillates between approx. 0.8 and 1.0 N for pen-test pencil leads of 2H hardness and 0.35 mm diameter. Fragmentation occurs through special Teflon support ring, which ensures the precisely defined lead fragmentation. Lead fragmentation took place in 10 cm distance from acoustic sensor to ensure sufficient signal strength for hit recording.



2: Hsu-Nielsen source (pencil lead break)

The essential point of view for AE method on object dynamic tension is an idea, respectively representation of elastic wave spread with *wavefronts* and *rays*. Compared to liquids, where only dilatation waves occur, in solid objects we can observe in most cases two types of waves – dilatation (lateral) “D” and transversal (shearing) “T”. Further could be e.g. Lamb’s (dilatation or transversal flex) wave in thin plate or Rayleigh’s wave on the material surface (Fig. 3).

Signals were recorded and analysed with measuring system Dakel XEDO. Pre-amps were used with piezoelectric sensors. Amplification was necessary also in DaeMon measuring software. Sensitivity was set for direct contact sensor to 30 dB and for sensor with waveguide to 40 dB. Amplification is always preset in AE measurement to prevent the waveguide sensor reporting no signal. Parameters of Dakel XEDO setup are listed in Tab. I.



3: Wave planes of dilatation "D" waves, transversal "T" waves inside the object and Rayleigh's wave on the surface.

I: The AE sensor parameters.

Acoustic Emission Parameter	Value sensor 1	Value sensor 2,3,4
Sampling frequency	8 MHz	8 MHz
Gain (analyzer)	20 dB	40 dB
Gain (pre-amplifier)	35 dB	35 dB
Maximum Range	$\pm 2000$ mV	$\pm 2000$ mV
Acoustic Emission Event Start Threshold	1200 mV	1200 mV
Acoustic Emission Event End Threshold	1200 mV	1200 mV

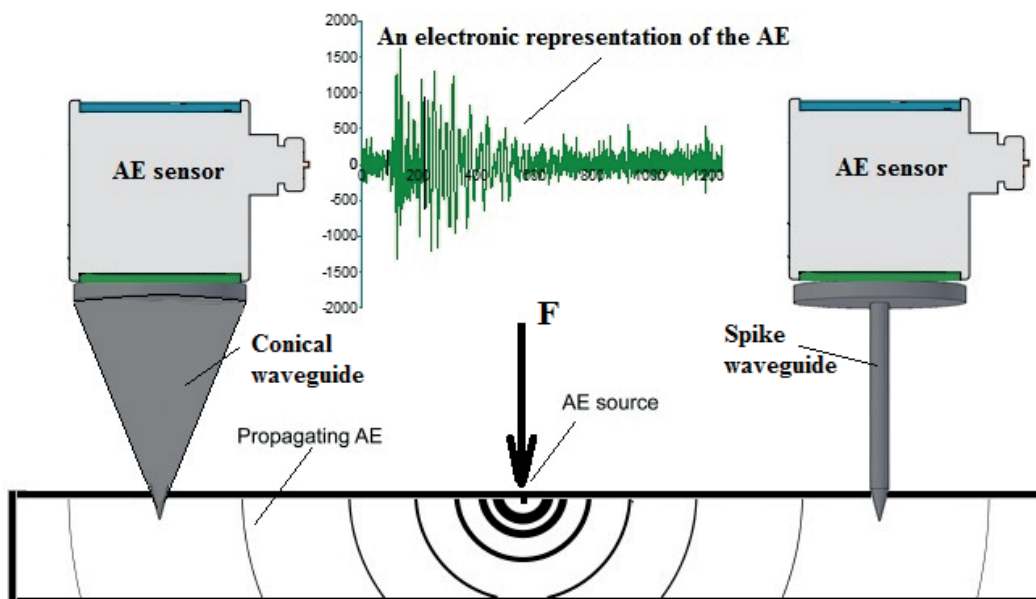
### Measuring setup

Four AE sensors with close frequency ranges were used. Entire setup was then placed perpendicular to tested material samples of 450 mm length and 80×20 mm rectangular cross section. First sensor was equipped with conic waveguide, second with stainless steel spike, third with aluminium spike and fourth was in direct contact with sample. Every contact surface was smeared with ultrasonic adhesive, which is used to minimize the signal dampening in transfer between different environments (Fig. 4).

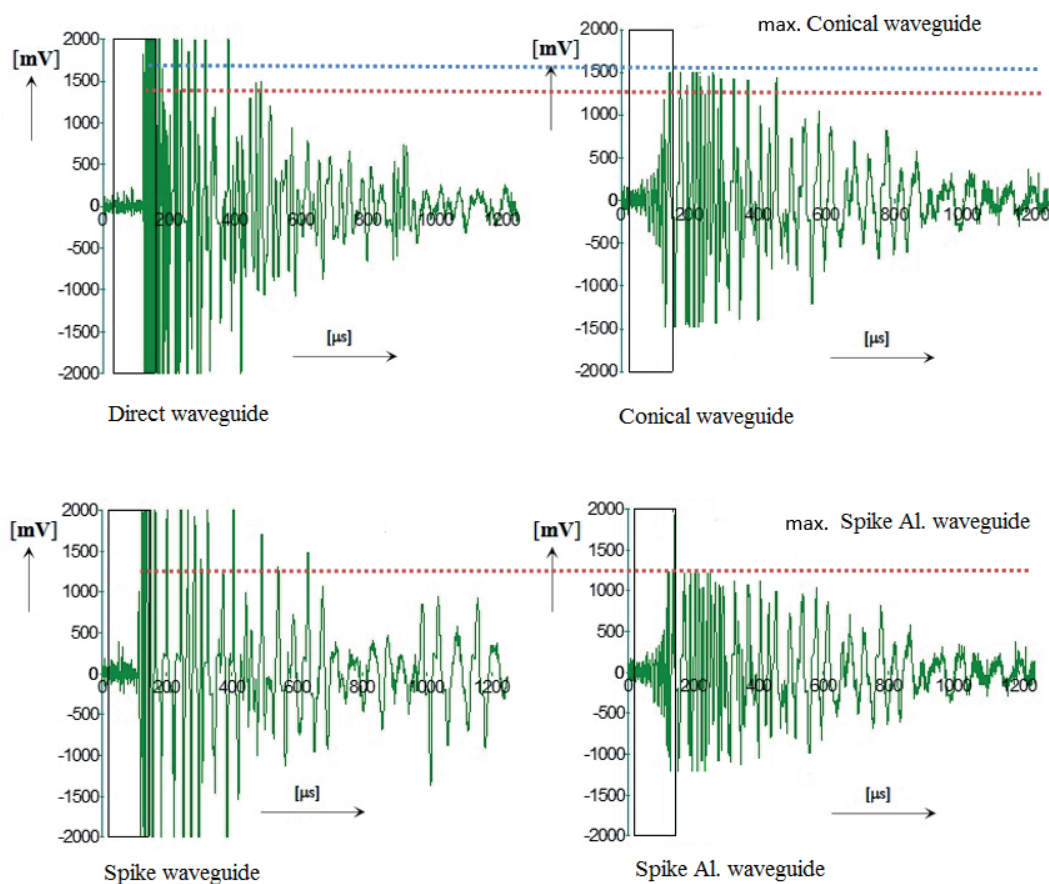
Four control sets of AE events were recorded, every one of them consisted of 10 individual events. Further the sensors were applied to different material, while alignment of sensors and waveguides remained the same. From this setup other 4 sets of 10 separate events were recorded. Described setup was also applied on oriented strand board, plywood, particleboard.

### RESULTS AND DISCUSSION

Values recorded in course of experiment effectively show the differences in signal, namely



4: Involving the measuring system for the measurement AE



5: Typical AE event recorded on material surface

values of signal intensity and comparison of transformed signal courses. According to these parameters the differences in signal dispersion are clearly observable. Based on conducted measurements of AE signal spread velocity, dampening, background noise and experience from previous measurements the adjustment of measuring apparatus is necessary, which consists of calibration of amplification, band width, detection threshold, dead time, sampling speed configuration, etc. Undesirable sources of noise should be removed or neutralized by appropriate measures to ensure the consistency and effectiveness of testing.

Comparison of signal course graphs shows obvious dampening of signal strength with every waveguide setup compared to direct sensor contact with object surface (Fig. 5). Signal intensity dampening with applied waveguide shows increase in time course of experiment and the course of dampening is significantly faster than at sensor in direct contact with object.

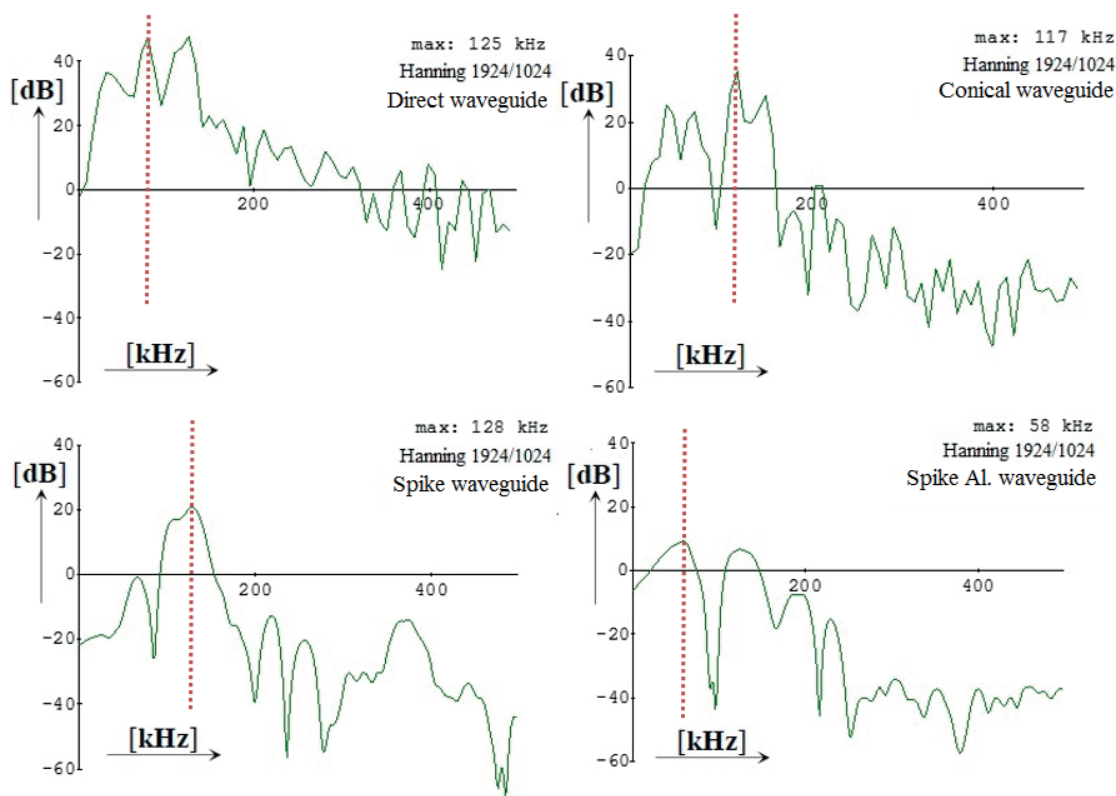
Difference in signal intensity measured with adjacent sensor and through the waveguide is caused by numerous factors, especially by dampening of signal by passage through waveguide and signal dampening on transitory surfaces.

Entire graphs of individual emission occurrences and their transformations were transferred to Excell

software for improved clarity and better orientation in results, where they were merged into time-course graph of emission event and its transformation with Hanning method (Kreidl, Šmíd 2006).

In comparison of transformation course between adjacent sensor and individual waveguides we can observe differences in course of signal measured with application of conical waveguide and adjacent sensor as well as in spike with cylindrical head waveguide respectively (Fig. 6). With use of every waveguide the sensitivity is dampened. Main sensitivity decrease is observed in point of wave transfer from object surface, i.e. in point of waveguide placement. The contact surface is minuscule at this point, which explains the magnitude of dampening.

Comparison of transformations of sequential measured signals with use of adjacent sensor confirms the functionality of Hsu-Nielsen source (pen test) as a normalized AE source. Entire transformed signals bear the same corresponding peak placement and in most of them correspond in value of frequency bearing the maximum signal value.



6: Comparison of the transformed signal sensor – waveguides

## CONCLUSION

From experimental measurement and recording of signal it is possible to assess the significant influence of waveguide employment on signal recording. Based on results we are able to draw following conclusions: It is important to put emphasis not only to appropriate waveguide material selection, but also on appropriate dimensions of waveguide ends in contact with sensor. Construction of waveguides without transition surfaces leads to signal dampening.

Great disadvantage is loss in magnitude of measured signal. Cause of this phenomenon is loss on material interface and signal dispersion in material. With employment of waveguide the interfaces are two – first between tested object surface and waveguide, second between waveguide and sensor. Because in testing the pencil lead is broken off manually, sometimes differences in signal occurrence are observable. Reason for this is different angle of applied force and differences in manual force application. This results in not recording the hit or its significant diversity. This work could be considered the base for further research and development of various sets of waveguides for AE application.

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## REFERENCES

- ČERNÝ, M., MAZAL, P. and FILIPEK, J. 2008. Sensing of the acoustic signal by waveguides. *Acta univ. agric. et silvic. Mendel. Brun.*, 61(1): 43–54.
- KREIDL, M., and ŠMÍD, R. 2006. *Technical diagnostics*. 1st Edition. Prague: BEN technical literature. 408 p.
- MURAVIN, G., MURAVIN, B. and BEILIN, D. 2011. Application of quantitative acoustic emission method for non-destructive inspection of metal and reinforced concrete structures. *J. Sci. Isr.-Technol. Adv.*, 13(2–3): 1–292.
- MILLER, R. K. and HILL, E. K. 2008. *Acoustic emission testing*. 3rd Edition. Columbus: American Society for Nondestructive Testing. 446 p.

- PAZDERA, L., SMUTNY, J. and MAZAL, P. 2004. Utilization of acoustic emission method in endpoint loaded materials and construction. Brno: VUT.
- SRIWONGRAS, P. and DOSTÁL, P. 2015. Monitoring of water stress condition in maize by using acoustic emission technique. In: MendelNet-Proceedings of International PhD Students Conference. November 11 and 12, 2015, Brno, Czech Republic. Brno: Mendel University.
- ÚNMZ. 2000. Nedestruktivní zkoušení – Terminologie. ČSN EN 1330–9. Prague: The office for Standards, Metrology and Testing.
- ÚNMZ. 2002. Nedestruktivní zkoušení – akustické emise – všeobecné zásady. ČSN EN 13554. Prague: The Office for Standards, Metrology and Testing.

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