COOPERATION OF MENDEL UNIVERSITY AND BRNO UNIVERSITY OF TECHNOLOGY IN THE FIELD OF BIOLOGICAL APPLICATIONS OF AE METHOD

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Abstract: This paper gives an overview of the common experiments performed in identifying the possible usage of acoustic emission (AE) in selected areas of monitoring life processes of living organisms. The paper accumulates and partially comments the results of experiments where AE method has been applied to evaluation of response of transpiratory flow responses in various species in different parts of day. The second part is focused on deepening knowledge of diagnostics and evaluation of the influence of natural conditions to the growth of maize. The final part of the paper deals with a continuous monitoring of honey bee (Apis mellifera) colony. Overall colony activity was monitored and data was recorded to describe development of the bee colony.

Keywords: acoustic emission, SAP flow, tree, maize, insects, honey

1. Introduction

Mendel University in Brno focuses in research work on agricultural and forestry sciences. Brno University of Technology is the second largest technical university in the Czech Republic with several workplaces focused on the non-destructive testing of materials and condition monitoring of structures. Both universities are significantly different in its focus, but some workplaces work closely together. This cooperation exists e.g. between the Laboratory of Acoustic Emission of Faculty of Mechanical Engineering BUT and the Department of Technology and Automobile Transport of Faculty of AgriSciences of Mendel University and focuses not only on application of AE method in various technical applications (welding, corrosion), there are implemented also the measurements which are aimed to verify the possibility of unconventional application of AE method in biological sciences.

2. Measurement and overview of results

2.1 Evaluation of transpiration activity of trees

The identification of changes in transpiration activity trees is in the centre of interest of scientists since the mid-60s. Introduction of AE into the investigation of plants (begin. of eighties) meant significant progress in identifying sources of AE \cite{1}. Development and application of AE occurred largely in the end of the 20\textsuperscript{th} century, and the results were published in several papers at conferences and in journals \cite{2}, \cite{3} and \cite{4}.

Our joint research in this area was launched in 2008. We applied the AE method to evaluate acoustic responses of diurnal changes of sap flow rate in maple tree (Acer pseudoplatanus), lime tree (Tilia cordata), Douglas spruce (Pseudotsuga menziesii) etc. Sap flow rate was
measured at breast height by the standard trunk heat balance method for comparison with our results.

Measuring channel units of multi-channel AE systems Dakel Xedo® were fitted with piezoceramic sensors of type MTR-15 and magnetic MDK-13. The information from data files was subsequently processed by software DaeShow®, which enables all basic procedures of evaluation – ring down counts, AE burst rate, summation of AE counts, RMS etc. Sensors MTR-15 were fixed on steel blade and magnetic sensors were mounted on the end of waveguides with conical end (see Fig. 1). Conical wave-conductive sensors appeared to be better than blade-form ones.

![Steel blade and waveguide with magnetic AE sensor](image1)

![Position of sensors on the tree: on steel blade and on waveguide](image2)

![Final situation on the tested tree](image3)

Figure 1. Arrangement of AE tests on the trees [5]

Examples of basic results from tested trees are presented in Fig. 2. Simplest records of AE activity changes in several days are shown there. AE counts — the amount of overshoot of signal over a preset threshold levels during any selected portion of a test. Our measurement could record up to 16 levels (Counts) of AE signal. In figures there are plotted only selected energetic levels and RMS value of the AE signal. The change of AE activity roughly corresponds to the day’s cycle. It is evident that the AE signal is more active in the early-evening and partially in the early morning periods.

For evaluation of AE signal sources it is necessary to use more detailed analysis of the captured signal. It is possible to evaluate changes of rise-time, duration of AE events, peak amplitude, etc. This could provide another view to estimate the sources of AE signal [5] and [6].

Our results of application of AE for monitoring of changes to the SAP flow showed significant changes of selected parameters of the signal in different daily hours on all monitored trees (maple tree, lime tree and Douglas spruce). The regularity of these changes and a comparison of changes of AE signal parameters with results of the other standard methods suggest that they correspond to the daily life cycle of the trees. [7] and [8].

Records of RMS value and individual events in the frequency analysis in measurements of acoustic emission (AE) have different activities (maximum of records) at regular intervals depending on the natural processes occurring during daily biorhythm hydration xylem vessels. A clear correlation can be found between the records of all the curves obtained from available measurements of temperature fields (Fig. 3). Development of acoustic response activities can be found in the areas of increased temperature of differential thermocouple with inverted value (curve 3), which follows its heating and cooling due to sap flow.

The second important activity occurs at the minimum (of the curves 1 and 2) at the differential records both in the vertical and horizontal layout. Minima correspond to the size of the transpiratory current, respectively to dimensional changes of status (change in diameter) in the aboveground part of the trunk.
Figure 2. Examples of typical changes of AE records during a day (maple and lime tree) [5]

Interesting information can be expected from a detailed frequency analysis of AE events in selected time intervals [5] and [6]. Simultaneously a development in the area of acoustic wave conduction by changing the shape of the waveguides is taking place. The specific shape of the waveguides affects the signal intensity obtained.

2.2 The maize

The aim of second type of experiments was to monitor AE signals generated by plant to describe the plant response to various stimuli - being under both water-stressed and well-watered conditions [9]. The maize has been chosen as a test plant and installed with an AE sensor at position of its stem to acquire AE signals. The results indicated that great amounts of AE signals occurred during the daytime whereas small amounts of AE signals appeared during night. As the results, AE signals generated by tested maize are capable of indicating its
stress condition. Therefore, using of AE method is interestingly modern technique, especially in agricultural field [10].

![Figure 4. Schematic plot of test arrangement [10]](image)

To implement the experiment suitably, experiment was operated inside the greenhouse of Mendel University at 9.30 AM from 27th March to 3rd April, 2015. The stress conditions of tested maize were visible using AE device showing the AE signal parameters, which are root mean square and the number of counts values, and environmental factors as following charts.

Similarly to the measurements on trees also the initial measurements in maize indicate a good sensitivity of AE method on changes in plant nutrition process. AE parameters can be used for denoting the stress condition of maize, especially in the number of counts and RMS values. The variation of AE parameter values might occur from the response of transpiration system of plant due to change of environmental parameters.
2.3 Acoustic emission and insects

Acoustic emissions can also be used to evaluate the incidence, activities and status of certain species of insects. It is quite understandably that in focus are mainly wood-destroying insects. The losses caused by pests of wood used in construction and other industries achieve such high values that the need to develop effective diagnostic methods for detecting of pests continues to grow. There are supplied instruments for identifying wood-destroying insects e.g. termites.

Our interest was focused especially on the application of AE for evaluating the condition of useful and economically important insects, e.g. bees.

2.3.1 Wood-destroying insects

The experiments with evaluation of longhorn beetle (Hylotrupes bajulus) activities were performed in the laboratories of Mendel University in the past. The preliminary measurements have shown that damage of wood by beetle larvae is accompanied by the emission of acoustic signals in the audible and ultrasonic spectrum. The character of monitored events was measured in relation to the function of the power spectral density (PSD) and the total activity of larvae in both day and night mode. According to the PSD function, it is possible to distinguish two main types of AE signals. The first type or second type consists primarily of frequencies with a maximum of 8 kHz, respectively 30 kHz. Considering the directional
anisotropy of mechanical characteristics (along and perpendicular to the fibres) caused by the construction of wood, can be expected that AE signal emitted by fracture perpendicular to the fibre will have a higher frequency than the signal emitted by fracture along the fibres.

It was interesting to monitor the activity of the larvae during the 17 daily measurements (Fig. 7). Although terrarium maintain a constant temperature of between 24-26 °C and a relative humidity of 90%, the activity of larvae for unknown reasons, changed significantly after the initial slightly elevated stage came a sharp rise and then a significant drop in the number of measured AE events.

![Figure 7. AE events sum change during the long-term measurements of beetle larvae activities](image)

During the 24-hour cycle was observed cumulative increase of AE events in order to establish preferential time zone for the actual measurements in the field. During the reporting period, there were no typical pattern of distribution of AE events, it was not possible to identify the "active" hours characterized by increased activity of the larvae, or "inactive time" without tracking events AE [11].

2.3.2 Beneficial insects - honey bee (Apis mellifera)

The initial measuring of activity of honeybees was carried out in 2012. One AE sensor was placed on the glass plate, which was stored at the bottom of the hive and the opening of the port. A second sensor was attached to the plate dimensions (30x100 mm), which was inserted between the frames.

Measurements began in late March and early April. Fig. 8 shows the colony activity in different phases on two-channel measuring system (glass and metal).

Sensor on a glass plate (Fig. 9 above) - as shown, thus the RMS correlates with temperature, which determines the activity of the colony. Between days when the temperature was unfavorable for the development of colonies is visible low activity on the glass. After warming activity is increased. When the colony had a chance collecting pollen and nectar (5th day) the activity is even at night. The colony processed brought material. The glass plate most reacted at elevated temperatures when the activity of bees performing work outside the hive was the highest. The activity at night is a result of the cleaning instinct, when the space of hive is cleaned and bee corpses are pulled out of the hive environment.
Sensor on the metal plate - (Fig. 9 below) the sensor on the plate was not influenced by the outside temperature, because in the hive bees can create enough heat to their thermal comfort. This sensor was influenced by its location, so that it was placed on the penultimate a frame where there is no a large accumulation of bees. In the first phase can be observed that bees respond positively when the foreign object (plate with sensor) was placed in its space. In subsequent phases of measuring the colony pulled together into a tight formation to reduce heat loss and activity, thus declined. When the outside temperature increase the colony responded by loosening of clusters into other aisles, where was placed the sensor with metal sheet. The last phase of activity measurement is high hives sheet metal backing, when the bees fill the entire space of the hive.
The vibroacoustic signals are an important part of communication in the honey bees (Apis mellifera L.). The aim of next study was to observe the acoustic emission that varies in a bee colony during different weather phenomena (strong winds and hailstorms) and to estimate the nature and the extent of the reactions of the colony by the analysis of the obtained data. Example of bee colonies response in very bad weather (storms with hail and wind) is shown in Fig.10 [13].

Continuation of these experiments was additional measurements aimed at monitoring the activities of bees exposed to stress factors. There were detected some intensive biological processes, which were deviated from the standard norms. It was the insertion of formic acid into the colony [14]. The method of acoustic emission scans disconcerted colonies in the imminent vicinity. To standard hive assembly was inserted glass plate, on which were placed two sensors. One sensor is placed on top of the glass plate, which intervened to another extension. A second sensor was inserted into the bottom edge of the glass plate that was at the bottom of the first extension. The first part was measured normal activity in the colony and the following day was inserted the carrier Mitegone which weared the formic acid.

The upset of the colony, which was caused when inserted into the evaporator Mitegon environment hive, when this type of acid reacted more experimental bees in the hive, and it subsequently, increased expression of excitement that was recorded. Exclusively acoustic emission, which was used with a suitable methodology for setting and recorded the activity of colonies on a glass plate. Glass plate impulses transmitted from individual colonies that have shown significant differences between both samples. Total RMS samples are very different from each other on the reaction of acid insertion. General view of the insertion of formic acid in the hive environment is an increased activity of the colony, which manifests enhanced cleaning soil and intensive ventilation, which was recorded in the Fig. 11. Finally, it is an effort to encourage the use of application of formic acid, which, when properly handled is beneficial for the treatment of hives.
3. Conclusion

Presented examples of the AE method using in biological applications clearly show a positive reaction of AE signal to the processes occurring in living organisms. The problem is the correct interpretation of experimental data.

Application of acoustic emission method for evaluation of growth parameters of the trees can significantly extend the knowledge of the nutritional status of trees and the status of forest stands in the future. A similar situation occurs when evaluating agricultural crops - mostly tomatoes, corn etc. Also, this application can be useful for assessing the current status of these crops, or when deciding on the necessary intervention of growers. Identification of the precise resources AE signal, of course, requires further detailed studies.

AE method shows its applicability in monitoring the presence or condition of living organisms, particularly insects. Also in this case, the application offers various levels of EA, from the mere registering the presence of wood-destroying insects in design to sophisticated monitoring the status and activity of beneficial insects, which will create optimal living conditions, application of medicaments.

Overview of presented results deals with a continuous monitoring of honey bee colony depending on the activity, hive space and in the hive. Overall colony activity was monitored using acoustic emission (AE) method. Data was recorded to describe development of the bee colony. The information gained will be used to represent a more comprehensive view on the life-cycle and behaviour of honey bees (Apis mellifera).

AE method allows determining, without the immediate presence of the operator both select plants or insects react to external stimuli. AE method for diagnose the condition of monitored objects can also be used at more distant sites. This can be very beneficial, especially for bee colonies when the AE signal line may describe the flight activity and intensity field bees that provide water and pollen. The method can be used if the colony is located at remote sites or to beekeepers, which is time busy.

It is obvious that the main task now is to develop the measurement methodology that allows obtaining comparable results. The collaboration with other professionals is essential to explain the processes that give rise to acoustic emission signals.

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