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THE USAGE OF ACOUSTIC EMISSION IN *APIS MELLIFERA* RESEARCH

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Abstract

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This paper deals with acoustic emission (AE) which was used to monitor group approximately ten pieces of honeybees in a glass jar. Acoustic emission is a part of the non-destructive methods and it is especially used for to monitor and detection defects of material on construction sites and industrial process. In the last time the acoustic emission was tested for very special objects such as to monitor of growth of plants or behaviour of insects. The mission this work was to apply a new experiment on the behaviour of colonies by means of acoustic emission, which it allows to capture waves and vibrations spreading in the material. Vibrations are one of the major parts of communication in the bee communities. Sensing colonies with the support of acoustic emission can be used for understanding of biological behaviour and reaction bees on different kinds of stimuli. During the experiment were used two sensors for to monitor the activities of selected bees diverging from the normal state were observed. The sensor No. 1 was mounted directly on the glass with using a rubber strip. The sensor No. 2 was mounted on the steel sheet by using a clamp. Whole glass jar was isolated with polystyrene against disturbing waves through the environment. The non-destructive method of acoustic emission was scanned activity of the selected bee sample in the immediate vicinity for approximately thirty hours.

Keywords: acoustic emission, AE, bee, *Apis mellifera*, vibration, sensor

INTRODUCTION

The NDT (non-destructive testing) method called acoustic emission (AE) can be used to detect deformations, initiation of micro cracks and location of defects and/or corrosion damage prior to actual material failure. Currently its usage has been extended to include also applications in the field of biology (e.g. termites, bark beetles, house longhorn beetle larvae, etc.). It has been used to understand both external and internal manifestations of the selected biological species. That was an inspiration for the beginning of the AE application in context of honey bee (*Apis mellifera*).

Insects represent an ancient group of animals dating with its origins back to the period between the Devonian and Carboniferous era. It developed before the reptiles in natural and logical process of evolution (Weiss and Vergara, 2002). Researchers suppose that the honey bees had originally come from the area of today's Afghanistan and they spread to surrounding areas including Europe (Preston, 2006). Gymnosperms (lycopodiophyta, equisetaceae, and ferns) had been a source of food but did not provide enough energy. They were later replaced by angiosperms which the bees adapted to (Švamberk, 2003). Accordingly, the bees adapted also their morphological features to collect certain kind of pollen (Michener, 2000). It is estimated that the number of bee species could be as high as thirty thousand (Michener, 2000). Modern bees are classified into a single family which includes five species: common honeybee (*Apis mellifera*), giant honey bee (*Apis dorsata*, *Apis laboriosa*), Indian honey bee (*Apis cerana*), and dwarf honey bee (*Apis florae*) as indicated in recent published works (Winston, 1991). Bees are valued not only for their products, such as honey, propolis, wax, venom, and royal jelly (Viuda-Martos *et al.*, 2008). They are crucial for agriculture as well. Eighty percent of crops pollination is done by honey bees. Pollination share of wild plants is found important as well (Michener, 2000).

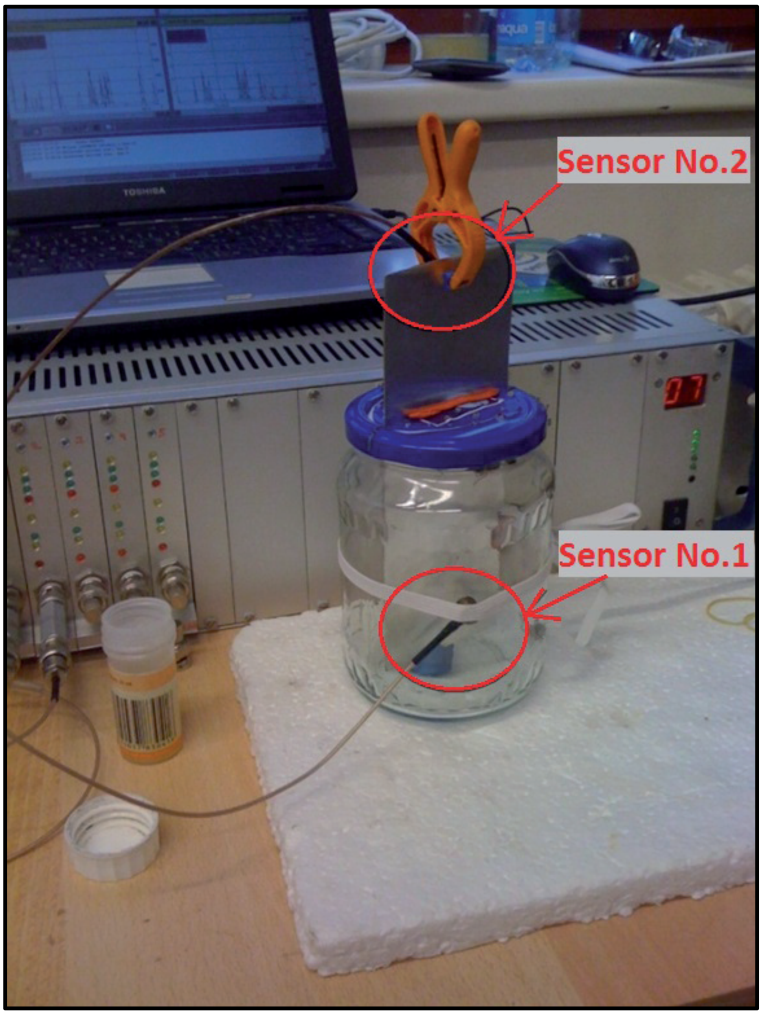
The field of non-destructive testing of materials and structures (NDT) includes methods used for testing of materials, structures, and systems without limiting their future application. This field of technology, which is now quite indispensable for quality management and safe operation, developed gradually during the late 20 century.

The AE method detects and characterizes the process development. It works by "hearing" acoustic activity emitted by processes occurring in the material (plastic deformations, crack initiation/ development/movement, medium leakage, etc.) The AE method detects, locates and evaluates the activities of disturbances and defects in their course and it can be described as passive (Kopec, 2008).

MATERIALS AND METHODS

The experiment was launched after two sensors (see Fig. 1) had been placed. For laboratory measurements was used sensors MIDI from Dakel with stainless steel contact surface with a diameter of 5 mm. The first sensor was located on a round side of the jar. Domed contact point (sensor / glass) was first resurfaced in the plane, then the sensor to the surface secured with glue and fixed using a rubber grip. The sensor was installed in the middle circumferential portion of the jar to ensure effective signal reception.

The second sensor was placed on a special sheet metal plate cut from common steel and inserted into the jar. The plate was selected and adjusted for this experiment. Sensor No. 2 has been fitted to the sheet metal plate by a clamp for more intense acoustic coupling. The sensor was placed outside the jar so that it was not directly in contact with the bees inside. The sheet metal plate is suitable for the transmission of AE signal even for more distant pulses (due to high wave velocity), so the internal placement of sensor was not necessary.



1: *Location of two AE sensors during the experiment. Photo by J. Tlačbaba.*

RESULTS AND DISCUSSION

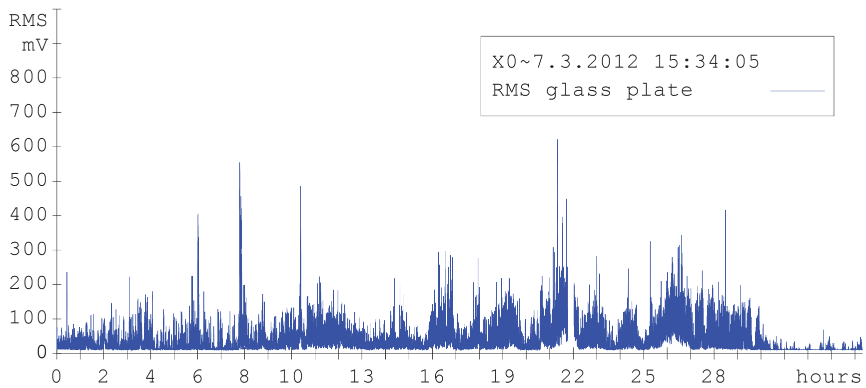
Sensor No. 1 showed higher activity throughout the entire period of the selected bee colony sample measurement. During the first hours of measurement we can see increased values of RMS which indicate that the bees were exploring new situation and location. Twenty-first hour of the experiment corresponds to actual time of 1 p.m. CET. In this period, the bees in our natural environment work for the colony, e.g. they are collecting pollen and/or water or taking care of new generation individuals. Although the bees were detached from their natural environment, the internal mechanism is still functional despite unknown and potentially hostile environment.

The sensor No. 2 (on the sheet metal plate) showed a weaker activity compared to sensor No. 1 (on the glass). Stronger RMS on sheet metal plate was caused by access of air and by bee individuals staying in the upper part of the setup. In the beginning, high peaks of RMS can be observed. They correspond to examination of conditions that the Apis mellifera were exposed to. Signal transmission occurred only in certain part of a sheet metal plate where the sensor has been exposed. Sixteenth hour of the experiment corresponds to 8 a. m. when the bees woke up and began to work in the colony. Total activity was lower than on the measured jar in which the measurement subjects (*Apis mellifera*) stayed more on the circumference or bottom of the jar.

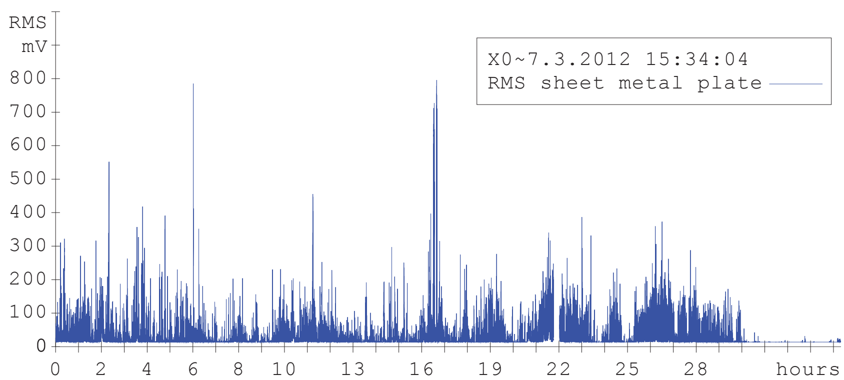
The experiment proved the ability of Dakel Xedo measurement technology to capture bee impulses transferred using an intermediate medium. Results provide basis for future monitoring of a biological group in real life conditions. The experiment has been conducted in laboratory environment; it has been artificially induced to investigate the possibility of wider application of the AE in biological research. Laboratory conditions allowed for adjustment of the technology in a way that activity of *Apis mellifera* individuals in a closed vessel could be actually captured. From several options, a glass jar with metal plate has proven to be the best. Not only for its simplicity and manipulability but also for quality of signal transmission between the bee subject and the sensors placed.

The event numbers captured on the jar are very different from the expected behaviour of bee workers in confined space. It is possible that the sensor placement on the glass jar affected the way the pulses were produced by the bees exploring the space of the jar. The insect individuals probably moved nearer and further from the sensor which caused the step-like development of event signals.

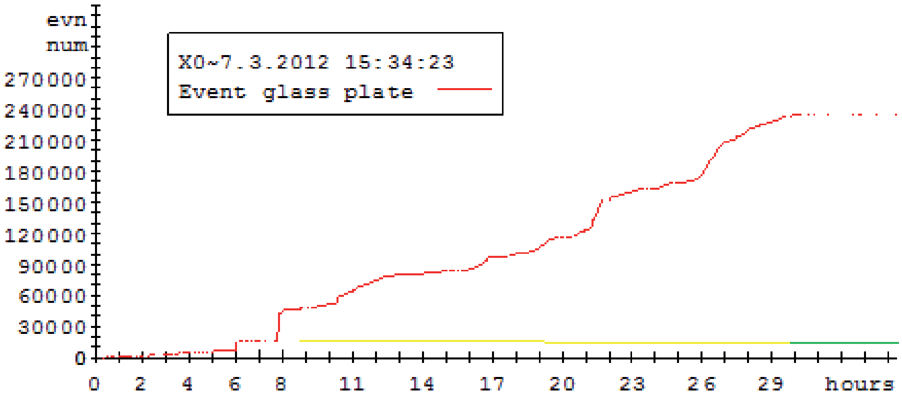
In contrast, relative increase in events captured by the sheet metal plate has almost a linear character. The only step-like change was close to the



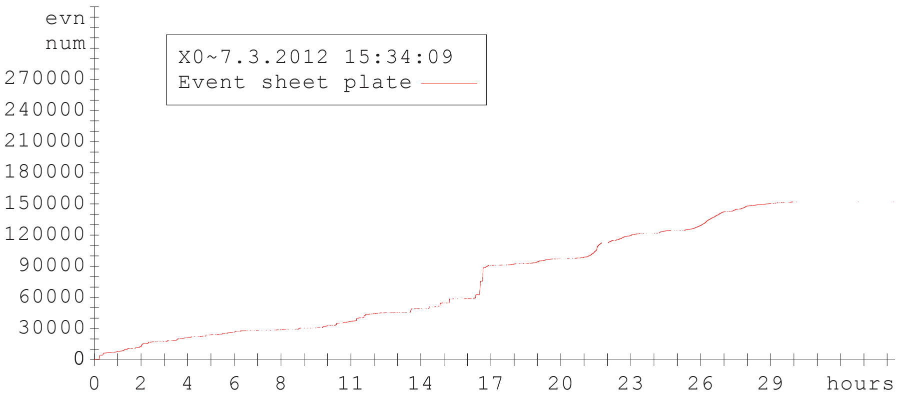
2: *AE RMS plot (the jar surface sensor)*



3: *AE RMS plot (sheet metal plate sensor)*



4: *Cumulative plot of AE events (jar surface sensor)*



5: *Cumulative plot of AE events (sheet metal plate sensor)*

sixteenth hour section of measurement, probably representing the stimulus for work in the colony. The yellow line depicts the activity of bees in the jar and the green line represents the number of deaths of the individuals in the jar.

After 30 of hours in the jar, the bees showed gradual mortality. There was a constant temperature of 25 °C with 40% relative humidity in the laboratory where the sample was stored. At the time of measurement, the sample was placed in natural sunlight. This was due to simulation of daily cycle in which bees live in their natural environment. Acoustic emissions were generated throughout the entire period of measurement and that indicates the active involvement of vibrations occurring probably also in natural environment. Probability of communication between bees using vibrations will be studied in the future. The benefits of the AE in biological research leading to better understanding of honey bee are obvious.

The "vibration signal" of honey bees is a tactile behaviour that has been known by many other names. It occurs in A. mellifera under different circumstances than the waggle dance and is one of the most commonly performed honey bee behaviours (Schneider, 1987; Schneider and Lewis, 2004). Similar behaviour was recorded using acoustic emission on a glass jar and steel plate. Despite the similarity of names, the vibration signal does not generate substrate vibrations nor does it generate high-frequency vibrations by flight muscle contractions while the body remains stationary, thereby making it easily confused with the term 'vibration signal' as used for stingless bees.

During Apis honey bee forager recruitment dances, a dancing bee waggles her gaster and vibrates her wings and in doing so simultaneously generates substrate-borne vibrations, near field sounds, and jets of air (Michelsen *et al.*, 1986; Dreller and Kirchner, 1993; Michelsen, 2003; Hrncir *et al.*, 2006), these impulses are transmitted across the glass and steel surface, which were recorded by the connected sensors. All of which can transmit information from the dancer to the following bees. Waggles enhance the transmission of thoracic vibrations to the substrate (Tautz *et al.*, 1996), with maximum signal transfer when the thorax is fully laterally displaced during a waggle (Storm, 1998; Hrncir *et al.*, 2006).

SUMMARY

The experiment focused on the ability of the bees to communicate with each other, when information is transmitted through the glass jar or through a steel plate which is inserted into the measuring beaker. Bees communicate with each other using pheromones, but also using vibroacoustic signals that spread through the material that is the environment of the colonies. Two sensors were used that were placed on a glass plate and glass surface. The sensors were shielded from the vibration, which could spread in the space of laboratories. A sensor placed in the glass vessel had significantly higher activity than the sensor located on the plate. Sensor placed on a glass jar recorded the intensity of bee grouping which had been exposed to a new environment. RMS recorded activity and response to the group that is formed insertion into the enclosure. The behavior of the group does not differ from the whole colony from which they were withdrawn. Their behaviors were similar, but with the exception that they were in a foreign environment without the presence of the rest of the colony as a bonding element. The sensor on the plate showed lower activity also due to smaller areas to receive upset group. Event records that were registered on the glass surface were visually significantly higher than on a steel plate that was inserted into the center of the container. The relative increase in events that are measured on a steel plate have a nearly linear character. The only jump event in the measurement section, which was an impetus to for the activity in the colony. Group examined the whole space, looking for space to escape from the enclosure. The aim is to record activity and subsequent behavior in laboratory diagnostics space. Writing measuring system Dakel that recorded RMS and events that arose during controlled trial. Pilot measurements create the beginning of the main pillars for measuring biological groups in the practice of using acoustic emission. Laboratory and acoustic emission techniques to align and demonstrate the ability to capture the vibration leg and chest muscles *Apis mellifera* and movement of selected individuals in a closed container. Communication between biological subjects using vibration laboratory will continue to be studied. The application and benefits of AE in biological research is to further understand the species, as important as the honey bee, more than obvious. The information obtained is used to propose a methodology for subsequent measurement, which will further analyze the behavior of bee colonies.

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