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APPLICATION OF THE SELECTED PHYSICAL METHODS IN BIOLOGICAL RESEARCH

Jaromír Tlačbaba, Michal Černý, Antonín Přidal, Petr Dostál

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Abstract

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This paper deals with the application of acoustic emission (AE), which is a part of the non-destructive methods, currently having an extensive application. This method is used for measuring the internal defects of materials. AE has a high potential in further research and development to extend the application of this method even in the field of process engineering. For that matter, it is the most elaborate acoustic emission monitoring in laboratory conditions with regard to external stimuli. The aim of the project is to apply the acoustic emission recording the activity of bees in different seasons. The mission is to apply a new perspective on the behavior of colonies by means of acoustic emission, which collects a sound propagation in the material. Vibration is one of the integral part of communication in the community. Sensing colonies with the support of this method is used for understanding of colonies biological behavior to stimuli clutches, colony development etc. Simulating conditions supported by acoustic emission monitoring system the illustrate colonies activity. Collected information will be used to represent a comprehensive view of the life cycle and behavior of honey bees (Apis mellifera). Use of information about the activities of bees gives a comprehensive perspective on using of acoustic emission in the field of biological research.

honey bee, acoustic emission, monitoring

Honey bees live in communities called colonies. The colony is considered a family made up of fertilization-capable mother and her off springs including worker bees and drones. The colony as a social entity did not evolve by chance. It results from long adaptation of honey bees to acceptable living conditions (probably as long as 80 million years). There have been as much 16 328 species, as indicated by prof. Michener. Each species, genus or family seems to be at different stage of development. Honey bee that lives in colonies represent top of the development tree. By living together, honey bees gain a lot of interesting features and characteristics. This is why a colony acts as an organized system unit (VESELÝ, 2003).

Honey bees are remarkable for keeping relatively very stable temperature, or rather the bee colony keeps the temperature in the foetus which is sensitive to differences in temperature and even slight difference from the optimum, which is 35 °C, causes its damage. Bees have to keep in the foetus constant high temperature which is nearing the temperature of human body, namely in case of the outer temperature dropping very low below zero or on the contrary rising very high and a closed hive which is airtight starts overheating. At that moment bees start ventilating: they increase air circulation and its exchange with the surroundings by intensive whirling of wings in the space of hive entrance. Bees turn into a system of small ventilators which drives overheated air out of the hive.

This measure however does not have to be sufficient and the temperature can still dangerously rise during summer heats. Then bees start bringing water into the hive, they put it in empty cells so that it can create a thin film on their inner surface. If bees have enough water within the reach of the hive, they are able to cool the foetus on necessary temperature for a long time even in extremely high temperatures.

On honeycombs with foetus there are usually many worker bees which look after it and warm it. Only after precise finding out the temperature it was proved that these bees carry out the most important and energetically most demanding job – warming up the closed cells with chrysalises. There are muscles in the thorax which serve for warming up the foetus in the environs of the hive (DETTLI, STEINER, 2011).

Bee colonies are fascinating for their social life and wisely led cooperation. Bees live in mutual harmony; they make intensive contacts and lively communication. The life of bee colonies is based on finely tuned organization. The colony lives in the dark, in a hidden spot, in a tree trunk or in a hive. Bees individually fly out into the light, look for flowers or bring water (STEINER, SINGH, 2001).

Creating suitable climatic conditions within the hive. While the bee as an individual is a poikilothermic animal and has no body reserves to come over inconvenient temperature conditions, even if for a short time, the bee colony behaves as a homeothermic animal. This is made possible by collected reserves stored in the form of honey in honeycombs. The colony is thus able to keep constant temperature 15–29 °C in the tuft and come over the cold period of the year. As only the tuft is warmed up, no bee can leave it – it would go stiff. Every colony is able, if it has enough reserves, to survive even very frosty weather without a greater thermal insulation of the hive (PŘIDAL, 2005).

Breeding efforts should be directed towards achieving fit-and-productive condition of all colonies. Since bees are dependent on natural resources for food and thus the vegetation and weather conditions, colony treatment depends on life cycle of bees and nature during the year.

Individual interventions into colony life should be scheduled according to phenological calendar, current nature status and biological patterns. Such a complex background calendar and biological patterns produce breeding calendar, often referred to as beekeeper's year (BY). As a result, the BY features specific beginning and end terms (PŘIDAL, 2005).

It is desirable to treat bees with respect to their natural habitus including species characteristics, and inter-ecosystem relationships. That is why the beekeeper should always judge his interventions using a critical approach (BENTZIEN, 2008).

Acoustic Emission Method

Acoustic emissions are the stress waves produced by the sudden internal stress redistribution of the materials caused by the changes in the internal structure. Possible causes of the internal-structure changes are crack initiation and growth, crack opening and closure, dislocation movement, twinning, and phase transformation in monolithic materials and fiber breakage and fiber-matrix debonding in composites. Most of the sources of AEs are damage-related; thus, the detection and monitoring of these emissions are commonly used to predict material failure. In technical diagnostics, AE method has been used to monitor rotational part status (friction and cavitation of bearings/gears), detection of micro-cracks, pressure vessel defects, tubing system defects, aircraft structure evaluation/testing, and bridge status diagnostics. Major advantages of AE include continuous monitoring of the object, time savings, and forecast abilities of the concept. On the other hand, AE wave source is not always obvious, as the emitted energy may result from several phenomena inside of the part. Further variable factors include shape of the object, surface area, material structure, and homogeneity level (KREIDL, ŠMÍD, 2006).

Recently, the AE method was used to monitor activity of termites and other pests in various materials as well as biotechnological processes (e.g. beer fermentation).

METHODS AND MATERIALS

For the pilot measurement, a small-size beehive was chosen (designation Q04/11). The hive contained five frames with dimensions of 37 × 15 cm. Two identical sensors (designated Slot01 and Slot02, manufactured by Dakel Company) were placed in the hive: Slot01 and Slot02. This naming scheme corresponds to individual channels (slots) of the Dakel XEDO analyzer.

The Slot01 sensor was placed on a sheet metal plate with dimensions of 3 × 10 cm. The sensor was coupled with a 35 dB preamplifier. Contact area was treated with acoustic paste for improved acoustic coupling. The actual sensor was fixed in place using a rubber band and the entire plate was hung into the hive between the frames. To have enough space, one frame was necessary to be removed from the hive. The plate was specially chosen for the environs of the hive which is highly corrosively aggressive. The sheet metal plate had specific dimensions because of the dimensions of the hive but also for the reason of the size of the carrying medium for the acoustic signal transmission. The sensor in the contact area with the sheet metal plate was treated with coupling medium for balancing unevenness and improved signal transmission. This coupling medium consists mainly of bee wax which was chosen for hygienic reasons.

The Slot02 sensor was placed on a glass plate inserted in the inlet port of the hive. The sensor was connected to a 35 dB preamplifier. The glass plate covered the entire area of the inlet port and captured both the flight activity and cleansing/ventilation movements. The sensor was attached to the glass plate using a clamp. Special silicon sodium-calcium glass was chosen for the experiment as it is the most suitable for emission transmission. The sensor was attached with a clamp which was chosen for its specific qualities for fixing to the glass plate. The clamp made an optimal pressure on the sensor and the plate.

The signals from both sensors were pre-amplified and later processed by the Dakel XEDO AE analyzer. An Ethernet-connected laptop PC with

1: *Row of small hives used in the experiment. Photo by authors.*

2: *Slot01 sensor on the sheet metal plate in the hive interior. Photo by authors.*

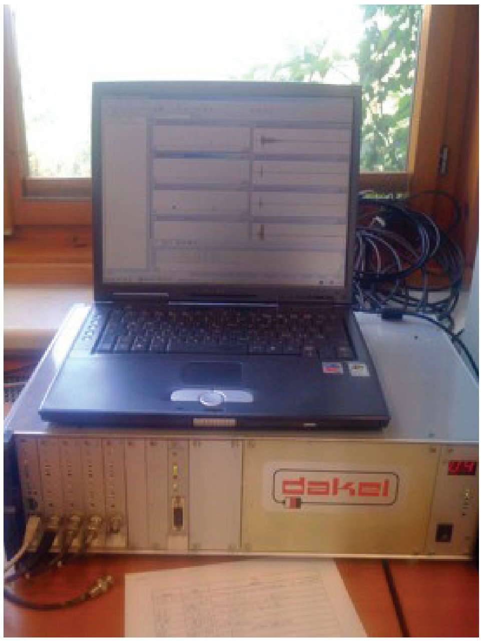
Dakel DaeMon software was used for continuous viewing and storage of the AE data. The data from AE monitoring has been evaluated using Dakel DaeShow software to provide visual representation and statistics. The AE was monitored continuously for a week.

RESULTS AND DISCUSSION

Start of the AE monitoring run was scheduled on the 28th of March 2012 at 15:47:59. (see Fig. 5). This way, we monitor the actual activity of the bee colony at different stages of the day. The chart shows RMS of AE signal for both sensors.

It is clear that the colony activity corresponds to variable temperature. When the temperature was relatively high, there was an increased flight activity of the bees. Later, there was a rapid decrease of the temperature during the day and at night. On the 1st of April, when there was a snowfall, the bees were not leaving the hive at all with an exception of water supply-related flights. To confirm this behavior, bee activity rose stronger as the air got warmer on the following day. Thus, experiment showed a close relationship between temperature and the activity of bees.

3: *Slot02 sensor on the glass plate in the inlet port. Photo by authors.*



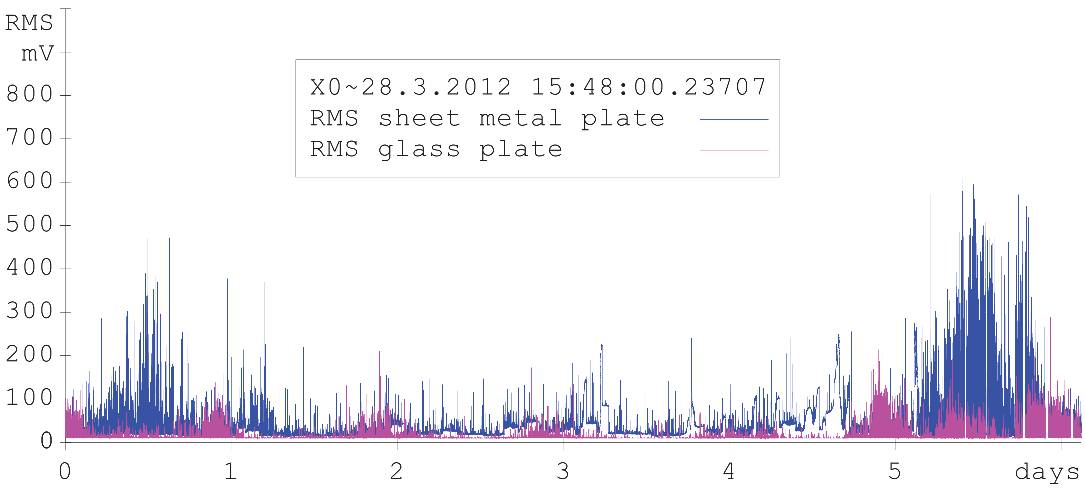
4: *Dakel XEDO AE analyzer used in the experiment. Photo by authors.*

Sheet Metal Plate Sensor

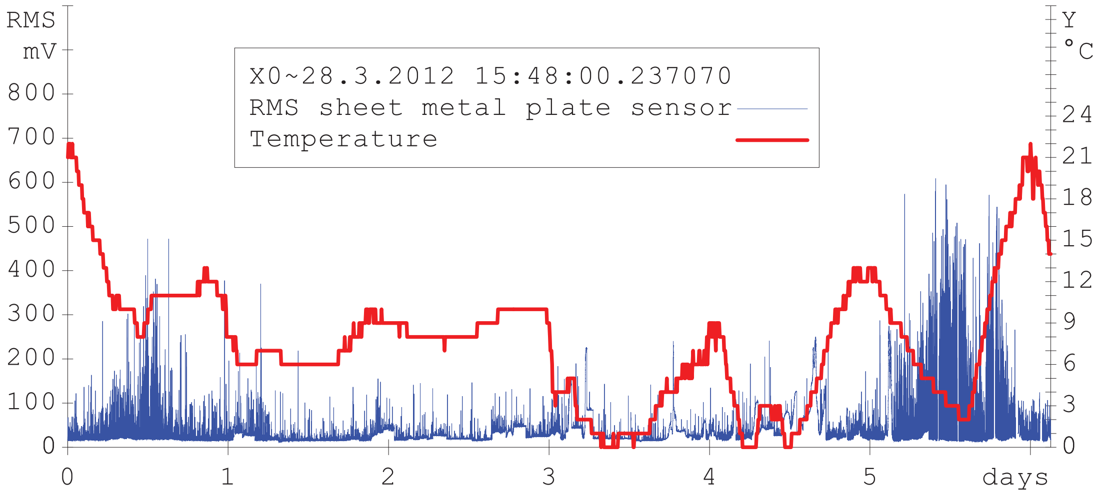
Acoustic emission sensor on the sheet plate was not affected by outside temperature, because the bees in the hive were able to generate sufficient heat for their thermal comfort. However, the sensor was influenced by its location, as it was placed on the penultimate frame where a large accumulation of bees does not usually happen. When it got cold outside, the bees stuck together and left the area where the sensor was located. In the first phase, the sensor was accepted by the bees although it was a stranger object. In later phases of the measurement, the colony concentrated into a tight formation to reduce heat losses. Thus, the overall activity decreased. As the outside temperature rose, the cluster was loosened and extended in multiple inter-frame gaps including the one with the sensor plate. The last phase of the measurement shows high activity of the colony. This was when the bee individuals filled the entire inner space of the hive space.

Glass Plate Sensor

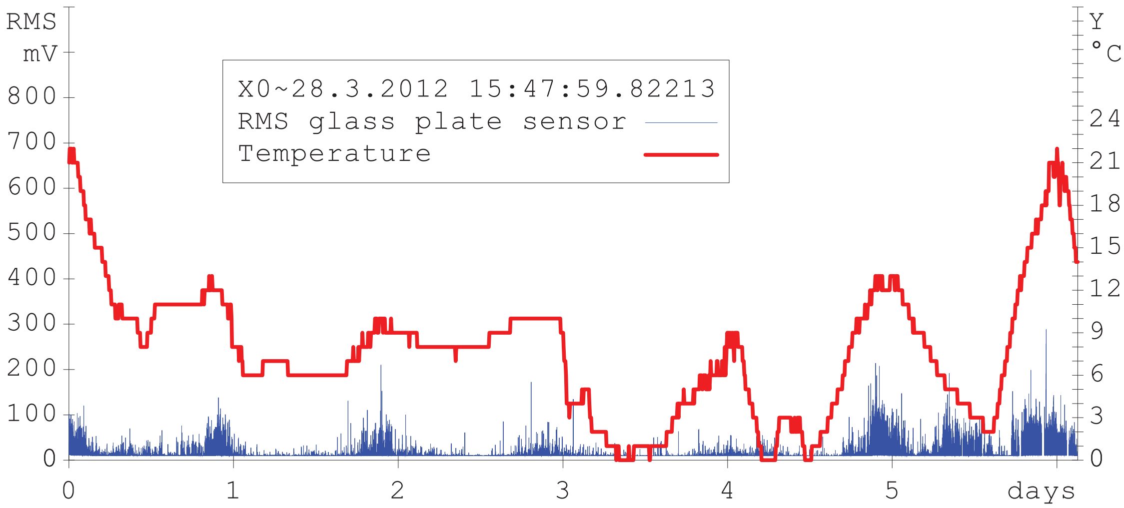
The glass plate sensor showed live activity when there was a temperature rise. This can be explained by simple fact that bees performing tasks outside the hive were flying and landing heavily. The time frame of this activity a few hours, when there was a suitable temperature in the course of the day. Bees flew at lower temperatures as well, but many of them did not survive such hostile environment changes. Night activity probably corresponded to cleaning



5: *RMS for both channels (sheet metal plate, glass plate)*



6: *RMS and temperature curves for sheet metal plate sensor*



7: *RMS and temperature curves for glass plate sensor*

procedures, when the space was cleaned and dead bee corpses were pushed out of the hive space.

The flying activity of the bee colony (the number of bees flying of the hive) is influenced by climatic conditions (outside temperature, intensity of light near the hive entrance) and the motivation of the colony to fly off (collecting pollen, necessity to defecate etc.). In some cases bees were observed flying off at full moon.

So called summer activity the indicator determined by the number of bees flying off the hive or returning there after some time, depends on physiological condition of bee colonies and on climatic conditions. One of the main factors influencing the beginning and finishing of the flights off is lighting. In the time convenient for replenishing feeding stock part of bee colonies become active long before the dawn when the lighting is only 0.05 lx. They approach the flyer but do not fly off. The minimal lighting that allows first flights off depends on the distance from the sources of food that bees visited the day before (Jeskov, Jeskova, 2011).

CONCLUSIONS

The acoustic emission (AE) method was used to remotely monitor bee colony responsiveness to various stimuli. This method describes the measurement of online flight activity and intensity of flying bees that provide water and pollen. The method can be used with colonies located at remote sites or for the beekeepers which are too busy to perform separate inspections. The results indicate rather surprising fact: the bee activity never seized completely, not even during the night. This might be due to ongoing cleaning and/or hive ventilation effort of the bees. At the end of the measurement it can be seen that the RMS curves nearly overlap due to high temperature values (see Fig. 5). The colony is actively involved in its predetermined development. Temperature seems to be the limiting factor controlling the hive organism life cycle. High temperatures allow the colony for active cleaning, picking water and flying off the hive. Using acoustic emission is beneficial for practice as the worker can observe the activity of bee colonies on-line throughout the world. It is possible to follow and predict the development of bee colonies that do not need to be interfered and based on this method the worker's time is saved and the level of stress at bee colonies is reduced. The method can serve for monitoring bee colonies while hibernating when the breed can die, which will show lower level of RMS and can serve for checking the affected colony. At sudden rising of RMS it can serve for inspecting the hives and eliminating the stress factor or revealing diseases or pest.

SUMMARY

This work deals with continuous monitoring of bee colonies, depending on the daily temperature, season and hive body. The project deals with the research of colonies behavior during the year depending on the job operations, hive space, application of pharmaceuticals and cumulatively, on the vitality of the colony at that time. All colonies activities were scanned using acoustic emission. Progress of colonies development is recorded continuously. Obtained information will provide the basis to create a more comprehensive view on problems of the honey bee (Apis mellifera).

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Address

Ing. Jaromír Tlačbaba, doc. Ing. Michal Černý, CSc., Ing. et Ing. Petr Dostál, Ph.D., Department of Engineering and Automobile Transport, Ing. Antonín Přidal, Ph.D., Department of Zoology, Fisheries, Hydrobiology and Apiculture, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: jaromir.tlacbaba@mendelu.cz, michalc@mendelu.cz, apridal@mendelu.cz, petr.dostal@mendelu.cz