MONITORING OF NATURAL STOCHASTIC PROCESSES USING ACOUSTIC EMISSION METHOD

SLEDOVÁNÍ PŘÍRODNÍCH STOCHASTICKÝCH PROCESŮ POMOCÍ METODY AKUSTICKÉ EMISE

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Abstrakt: Předložený příspěvek popisuje použití moderní NDT (nedestruktivní testování) metody měření akustické emise u přírodních nebo pseudo-přírodních systémů. V průběhu výzkumu bylo třeba vyřešit specifické a dosud neřešené problémy související s proměnlivostí a variabilitou stavu a chování živých organismů. Velká pozornost byla věnována správné interpretaci naměřených dat. V popisovaných projektech bylo nutné použít inovativní postupy a metodiku, například vyvinout zcela nový typ vlnovodu nebo integrovat měřicí soustavu do včelího úlu. Článek tak přináší nové informace o kombinaci nedestruktivního testování v netradiční oblasti aplikací.

monitorování, přírodní systémy, akustická emise

Abstract: The paper presents utilization of modern NDT (non-destructive testing) method of acoustic emission in the field of natural or pseudo-natural systems. Specific issues had to be addressed during this research. These were closely connected to variability and behavior of the living organisms. Acquired data was carefully examined to match the research intention. Multiple innovative approaches had to be used in the outlined projects including development o a new waveguide type or integration of acoustic emission monitoring system into a bee hive. As a result, the paper brings on new information about non-destructive testing in non-traditional field.

monitoring, natural systems, acoustic emission

1. INTRODUCTION

Apart from extensive utilization of state-of-art detection and diagnostics in the context of industrial machinery, there have been multiple R&D projects that use a different approach. Monitoring systems are being integrated into natural stochastic processes. Obviously, measurement methods for such applications come as derivations of similar projects in industry environment. However, scientists have to face unexpected challenges as the living or environmental subjects do not behave in a way similar to man-produced (or artificial) ones.

The output data acquired from nature-based sources often provide unique and innovative insight into the behavior of living organisms or natural processes. Most of the research, however, has to be carried out on-site, i.e. in the natural habitat of the subject. The monitoring systems are often required to be power-independent and durable. Specific limitations ought to be taken in account that will never emerge in industrial applications. Imagine questions like the following:

- What if the living organism under inspections dies or leaves the monitoring site?
- Will the signal be strong enough for the entire monitoring run?
- Can the outer environment conditions change and make the measurement impossible?

Major difference between industrial and natural applications lies in complexity or number of parameters. Let us say that even the most sophisticated artificial systems feature limited set of variables that can addressed with more or less success. However, living organism or natural phenomenon exposes vast number of features, most of which remain fuzzy or completely unknown. This paper lists several applications of modern NDT (non-destructive testing) method of acoustic emission (AE) in context of natural processes.

Acoustic Emission Method

Acoustic emissions are stress waves produced by a sudden internal stress redistribution of materials caused by changes in the internal structure. Possible causes of 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 AE are damage-related; thus, the detection and monitoring of these emissions are commonly used to predict material failure. In technical diagnostics, the AE method has been used to monitor the 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. The AE technique has proven useful in fatigue testing and destruction experiments. Major advantages of AE include continuous monitoring of the object, time savings, and forecast abilities of the concept. On the other hand, the AE wave source is not always obvious as the emitted energy may result from several phenomena inside of the part. Further variable factors include the shape of the object, surface area, material structure, and homogeneity level [3].

2. MATERIALS AND METHODS

Wood Pest Activity Detection

Wood pests impose significant losses in the area of building and other industries. Thus, effective methods of non-destructive diagnostics are required to capture wood damaging activity.

We carried out an preliminary study that included measuring of acoustic emission (AE) signals emitted by living old-house borer (Hylotrupes bajulus) larvae feeding in wood samples. Using a small wood sample and an attached AE sensor, the experiment has proven that AE signals can be used to determine presence of feeding larvae. Similar methodology was used in sap flow monitoring experiments [1].

The monitoring run was initially scheduled on a long-term basis. Pilot measurement took place from May 20th to June 6^{th}, 2008. Shortly after the data from this phase was analyzed and evaluated, the larvae's activity weakened. After several days, the AE signals completely vanished and the larvae was found dead for an unknown reason.

This experiment showed practical application of AE method in the context of pest detection research. Acquired data allowed for evaluation of larvae activity in day/night time domains. Although the laboratory site with terrarium featured constant temperature/humidity conditions, the activity of larvae feeding on the wood fiber mass showed significant deviations. So called AE events were counted. These pulses supposedly correspond to wood fiber cutting caused by feeding larvae.

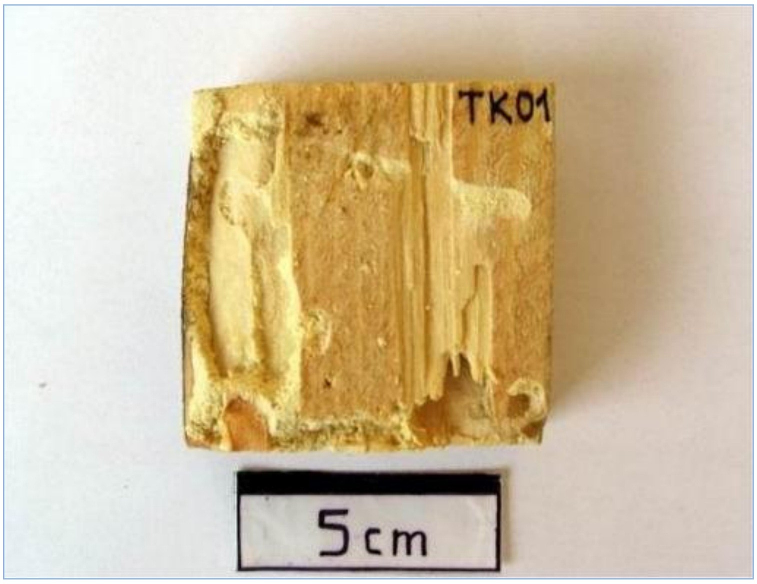

Figure 01: The TK01 sample with pest larvae. Photo by David VARNER

Figure 02: Experiment setup with terrarium and AE analyzer. Photo by David VARNER

Beer Fermentation

Another interesting research was carried out in food production laboratory of the Department of Agriculture, Food and Environmental Engineering at Mendel University. The Destila micro-brewery system serves for model and/or analysis purposes. It allows for amount modifications of malt, hops, yeasts, and other ingredients. Temperature can be streamlined within the actual brewing process as well. The variable configuration features make the micro-brewery an ideal ground for various research projects. The cylindroconical fermenter body that was subject to experiment is made from Cr/Ni stainless steel. [5], [7]

Figure 03: The Destila micro-brewery system. Photo by David VARNER

Figure 04: The new glass-rod waveguide in the tank lid. Photo by David VARNER

The first run of AE monitoring was done with AE sensors attached directly to the fermenter body. However, the results were not satisfactory and the signal showed unknown parasite sources. As the structure of the fermenter body is double-layered dues to cooling purposes, it was very hard to determine wave propagation modes.

To solve this situation, a special glass-rod was designed for capturing of the AE signals from the fermenter. The basic concept was that immersion of the waveguide with a sensor attached to its opposite end will result in closer contact with the liquid inside the tank. After several testing steps related to wave propagation in the glass rod, the glass-rod waveguide was manufactured and integrated into the Destila system. The waveguide was 80 cm long with diameter of 12 mm. A single piezoelectric sensor of appropriate size was fixed on one end of the glass rod to capture waves coming from the fermentation zone liquid.

Several monitoring runs showed that despite the waveguide immersion and direct contact with the liquid in the tank, parasite signals still deformed the acquired data. Further measures will be taken to improve the signal acquisition conditions.

Bee Activity

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. [8]

Figure 05: Slot01 sensor on the sheet metal plate. Photo by David VARNER

Figure 06: Slot02 sensor on the glass plate. Photo by David VARNER

The intention was to monitor bee hive behavior using AE method. For the pilot measurement, a small-size bee-hive was chosen that contained five frames (37 x 15 cm). Two identical sensors were placed in the hive, one on a sheet metal plate and one on a glass plate inserted in the inlet port of the hive. The signals from both sensors were pre-amplified and later processed by the Dakel XEDO AE analyzer. The AE was monitored continuously for a week. [4]

3. RESULTS

Although quite different in scope and AE signal origin, all three experiments proved that monitoring of live organisms represents unique challenges.

The wood pest experiment proved usability of the method and was terminated due to death of the subject larvae. Captured signals indicate that the larvae activity varies with temperature and day/night cycle. Thus, temperature could be used as correlation property for time domain evaluation. Two main signals types were registered. These might correspond to different “biting” mode of the feeding larvae (longitudinal or radial direction of the fibers).

In the beer fermentation experiment are concerned, unwanted parasitic signals needed to be recognized and eliminated. However, as the beer fermentation requires the temperature and environment regulation devices, this might be very complicated issue. The yeasts in the hopped wort do not produce the alcohol in the same way for all the beer types that are being brewed in the micro-brewery. When a single successful measurement plot is obtained, there will be time to produce comparative plots for various beer types.

Bee monitoring research has been limited by time of the year when the bees are active. In other words, the experiment can be carried out in certain months to capture typical life behavior of the insect colony. The movements of the bees causing the sensor to capture signals may be estimated only, as there is no visual clue to distinguish individual modes of activity. Bees probably behave in different ways based on feeding cycle and health conditions in the bee hive. All these circumstances make proper data evaluation a complicated issue.

4. ACKNOWLEDGMENTS

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