Acoustic Emissions Tree Monitoring System

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***Abstract*—Trees play an essential role of providing oxygen and taking in the increasing carbon dioxide in the atmosphere. They can live thousands of years, but their lives can be cut short due to unexplained circumstances. The Morton Arboretum's Center for Tree Science speculates that acoustic emissions (AE) can help resolve these mysteries by detailing and quantifying the stress waves inside a tree to better understand the health and well-being of trees. For this goal, an electrical circuit and accompanying mechanical housings were designed to support an AE sensor. The AE sensor system was tested in Northern Illinois University's Digital Signal Processing Lab's anechoic chamber. During testing, the system recorded three distinct responses from each mode of testing. While the device displayed an ability to serve as a platform to collect AE readings, improvements to the mechanical housing for eventual long-term deployment and expansions to the circuit to support more detailed data collection methods can be made.**

Keywords- Acoustic Emissions; Tree; Tree Health

I. Introduction

Acoustic emission is a phenomenon of radiation of acoustic waves in solids that occurs when materials undergo irreversible changes in its internal structure, be it elastic and plastic deformation [1]. For such irreversible changes to occur, the material must be subjected to external forces. It is this mechanical loading that produces structural changes that generate local sources of acoustic waves [1]. Waves generated as a part of AE are of interest in structural health monitoring and quality control. When monitoring AE during testing, it is possible to detect, locate, and characterize the damage done to the object under study. AE testing has been widely applied and studied in the industrial field, through concrete and metallic structures, metallic pressure vessels, pipelines, and composite aircraft structures, among many others [1].

Despite AE testing being prevalent in a plethora of industries, little research has been done in its application on living structures. Within the scope of this investigation, AE testing is ought to be done in two ways: actively and passively. Active AE testing involves an external force controlled by the system being applied to the tree and then studying its response. Passive AE testing involves listening to the structure and its response to naturally occurring stimuli. As part of passive testing, it is theoretically possible to listen to the tree as it undergoes its phenological processes through the developed AE system.

An AE platform would allow researchers to monitor the structural health of trees and provides an opportunity to study physiological processes, such as growth or sap flow, from a new angle. Doing so could provide better insight on internal structural changes as the tree ages and record data on its change through environmental occurrences. With more information, the client seeks to better monitor their older trees and address any health or structural issues as they arise. Similarly, it has relevance in studying physiological processes within the tree, such as plant-water relations or growth. This information will also assist in the management and development of their trees and their environment. Outside of the inner workings of plant life, the acoustic study of trees at Morton Arboretum presents the opportunity to study and measure trees' effectiveness as sound barriers to mitigate noise pollution from highways, industry, or other sources.

II. Methods and Materials

This client hopes for the device to be deployed on older maple and pine trees as they are the most common for them and are more likely to fail due to structural defects, which could pose a threat to their surroundings [2]. While it is desired to have a modular platform with multiple sensors collecting data simultaneously, only the acoustic emission sensor is utilized in the current design. Despite this shortcoming, the design still has the capability to be modular, where other ecological sensors can be added to the circuit with no little to no loss of function. In a typical usage case, this device would be deployed outdoors during Illinois' springtime for at least one week at a time.

A 3-D printed electrical housing protects the electronics. When deployed on a tree, the electrical housing is secured by an adjustable strap that wraps around the tree trunk. This adjustable strap loops through the rectangular cutout in the bottom half of the housing and holds the device against the testing platform. One strap in the center of the bottom housing is not sufficient to hold the system tight against the testing platform.

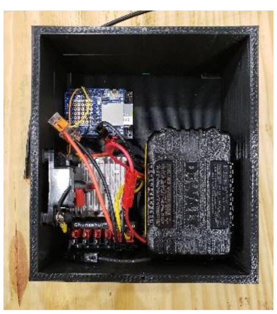

Figure 2. Electrical Housing

Inside the housing contains the circuit for the device. It is made up of a battery, switch, power rail, voltage step down converter, and microcontroller.

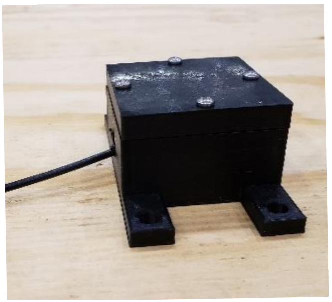

Figure 3. AE Sensor Housing

Connected to the microcontroller is the AE sensor that is external to the electrical housing. It is attached to a nail in the crevasse of the tree in its own separate housing. Because the AE sensor is a sensitive device, sound-dampening insulation lining the walls of the AE housing help insulate it from any unwanted noise coming from the environment.

III. Results and Discussion

Once the microcontroller was set up to take data from the AE sensor, testing began with developing three test cases. It was decided that the AE sensor would be tested with no input response, a knocking input response, and a water flow input response. The primary interest is in the water flow response as this is the client's priority goal. The knocking response and no input response are cases to verify the AE sensor is functional. Next in the process was determining where would be the best location to test. After performing general analyze in an indoor environment and outdoor environment, it was discovered that the AE sensor is quite sensitive to everyday vibrations, like speech. Because of this, further testing was performed in the anechoic chamber. The results of this are shown in Figures 3, 4, and 5.

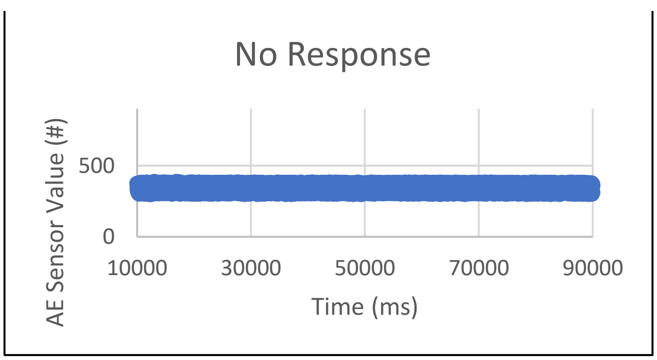

Figure 3. AE Data Collection with No Input Response

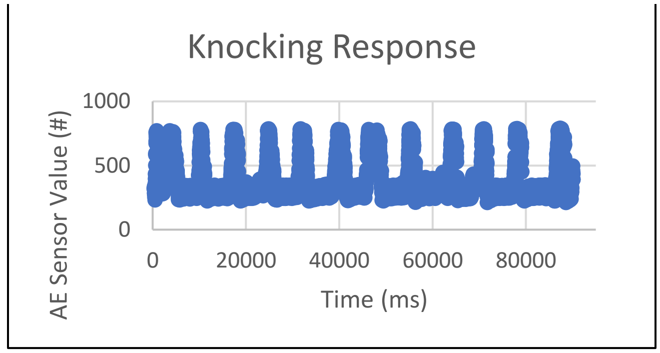

Figure 4. AE Data Collection with Knocking Input Response

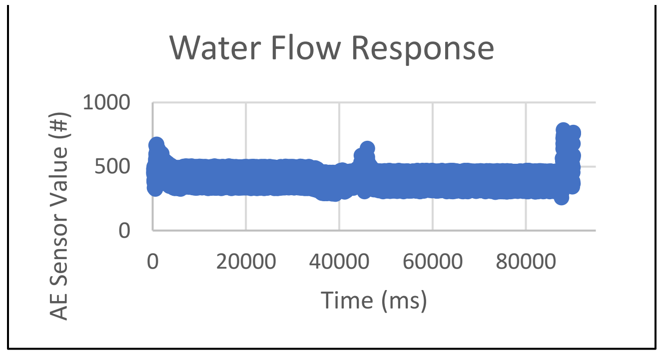

Figure 5. AE Data Collection with Water Flow Input Response

IV. Conclusion

Overall, a baseline acoustic emission platform was built that would be the future gateway to expansions upon the system. There are remaining improvements that could be done before being deployed in the field. With that, a future goal is to improve the modularity and usefulness by adding additional sensors. Another would be to filter out unwanted noise from the AE sensor data when deployed outdoors especially.

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