E-Experiments for condition monitoring of sustainable technologies

Abstract: Several colleges are experiencing overcrowding in their classrooms and laboratories, making it impossible to provide high-quality education, which will have an impact on the quality of engineers graduating. Furthermore, this overcrowding leads for high carbon emissions from the students and from the cars of some of them. It is necessary to include the missing experimental component in the teaching of courses without having to establish additional labs. This is accomplished by making these experiments virtually available over the internet, giving students 24 hours to repeat the experiment as many times as necessary to achieve the experiment's learning objectives. There are several E-learning programs available today in terms of courses and teaching materials, but there are only a handful E-laboratories available globally. Some of the E-laboratories are totally simulated, while others are controlled over the internet using genuine gear from a university lab. This article provides the readers with efforts in converting the condition monitoring experiments from lab-based to virtually based ones within the "Condition Monitoring for Sustainable Technologies and Climate Change Mitigation" which is funded by the British Council's Climate Grant in Going Global Partnership Programme.

Keywords: E-learning, Higher Education, Teaching, British Council Climate Grant, Acoustic Emission, Climate Mitigation

Introduction

No doubts that there are connections between how climate change affects many societal sectors. Human health and food productivity can be harmed by drought. Flooding can cause infrastructural and ecosystem damage as well as the spread of disease. Human health problems can raise mortality, affect the availability of food, and reduce worker productivity. All of these issues, will make it difficult for Higher Education Students to continue their studies pleasantly.Therefore, it becomes necessary to use technology as it is a vital part of our everyday lives to counter the climate change crisis, and it forces professionals, educators, and students to reconsider their fundamental beliefs in order to use advanced technology to re-design or re-engineer the higher education and training system. These technology tools are called electronic learning (e-learning), mobile learning (m-learning), and the digital learning (d-learning). In this paper, we will focus on e-learning means. E-learning is a learning system based on formalised teaching but with the help of electronic resources. While teaching can be based in or out of the classrooms, the use of computers and the Internet forms the major component of E-learning. [1]. According to this study[2], educational systems that rely on E-learning use 90% less energy and generate 85% less CO_2 emissions per student. On the other hand, the laboratory experiments of condition monitoring on the sustainable technologies are too expensive and take long time that could exceed the laboratory period for the students. This result in increasing the percentage of the CO_2 emissions of the students at the lab. Therefore, we thought of innovative way to combine between E-learning technology and condition monitoring and reducing the CO_2 emissions. The project “Condition Monitoring for Sustainable Technologies and Climate Change Mitigation” which is funded by the British Council Grant for Climate Change[3], aims at developing E-learning experiments for condition monitoring. This is the website of the project for further information [4].

The condition monitoring refers to the field of continuous watching of the asset using advanced technologies such as acoustic emission, vibration level, temperature level, and oil viscosity status [5]. Acoustic emission (AE) is the process of detecting elastic waves generated by sudden strain release from cracks, delaminations, matrix cracking, fibre pull-out, etc [6].

The advantage of the AE is that it does not require to inject energy in the wind turbine blade to find out the defect and its location. It is a passive technique as its sensors are piezoelectric ones and they just sense the elastic waves on the surface of the blade[7]. By knowing the time of arrivals of the elastic waves and their velocities and by using three or more sensors, the defect location can be found [8]. However, the elastic wave in a wind blade or solar panel is subject to attenuation due to many factors such as material effects and geometric effects[9], [10].

Because the AE laboratory exercises are done in groups and there is not enough equipment or infrastructure for doing individual practises, students of condition monitoring courses, whether from universities or specialised training courses, find it difficult to implement the various measurement procedures explained in detail within the theory lectures or ASTM standards[11] . These constraints brought on by the large number of students enrolled in each course also exist in other branches of research, such as biology or chemistry, and they have already been partially addressed with the creation and application of virtual laboratories. Despite improvements in prediction and simulation software for room acoustics and the usage of instructional tools created at universities, there are no virtual laboratories in the field of acoustic emission that allow students to put their classroom learning into practice.

In this project, we have simulated the AE experiments to the students to help them recognising the contemporary push for more effective wind blade or solar panel operation and maintenance and recognising some of the environmental problems associated with modern green energy production. The CMST project has the following objectives:

1. Enhancing and modernising the courses ASU offers to undergraduate and graduate students. They will contain the latest expertise and technology required for a professional engineer in the present era.

2. Introducing innovative teaching strategies that are intended to enhance climate change mitigation.

3. Creating E-experiments platform at Ain Shams University. The main aim of these e-experiments is to give all students the opportunity to do measurements themselves to get better feeling of different acoustic emission phenomena.

4. Training the Ain Shams university students on the AE topics, methodologies, and equipment.

5. Attracting students to join the project to get sophisticated trainings on such work.

Acoustic Emission Wave Properties

As aforementioned, the acoustic emission is the elastic wave released from the damage source such as cracks, dislocations, etc. The most important task is to recognise the elastic wave properties in order to propose suitable sensing strategies. The main requirements for wave information definition are wave velocity and attenuation. On the other hand, as the structure under investigation becomes complex as the AE wave information becomes harder to investigate in the laboratories. Therefore, the first E-experiment is designed to help the students to understand the acoustic emission condition monitoring technique for detecting the defect in complex wind turbine blades. Learning the different acoustic properties of materials is an essential part of the course and is currently addressed during lectures and tutorials. However, many students still have a lot of confusion in using this technique. In the Acoustic emission experiment, we try to clarify the AE concepts and how it can be used for damage detection.

Targeted Intended Learning Outcomes (ILOs)

1. To estimate the effect of distance between sensors on acoustic signal.
2. To realize the effect of composite material on acoustic signal.
3. To realize the effect of composite material on acoustic wave velocity.
4. To understand the conversion of the signal amplitude from voltage to dB.

Figure 1 presents schematic drawing of a wind turbine blade with two AE sensors mounted virtually on it. The wave velocity can be computed using Eq.(1).

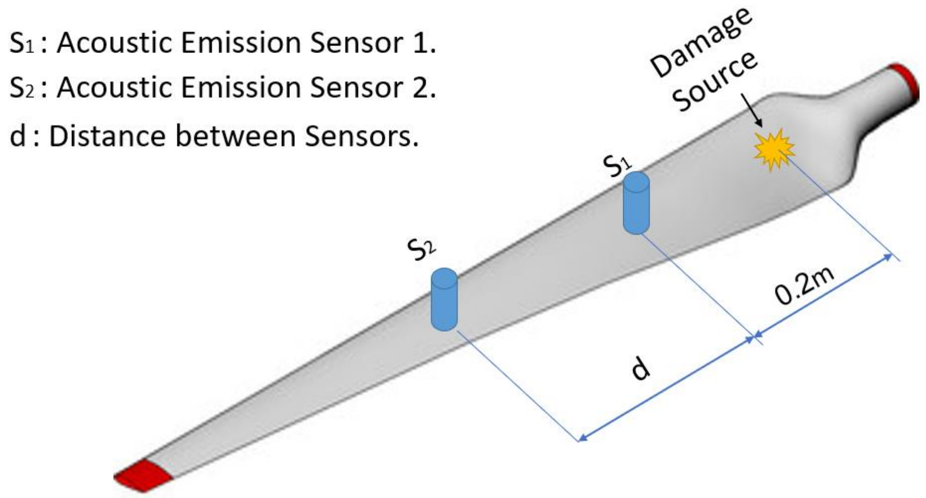


Figure 1. Schematic drawing of wind turbine blade with two sensors.

$$v = \frac{d}{T_1 - T_2} \quad (1)$$

where; v = wave velocity

$(T_1 - T_2)$: Difference in time of arrival of the signals at sensor1 and 2, respectively.

The experiment of determining the AE wave properties were conducted using two piezoelectric sensors (i.e. NANO30 sensors) attached to Mistras's 1283 USB AE Node and then connected to the laptop. Artificial AE sources were generated using the mechanical pencil lead breakage method (i.e. Hsu-Nielsen Method). The results were read using the AEWin^R software.

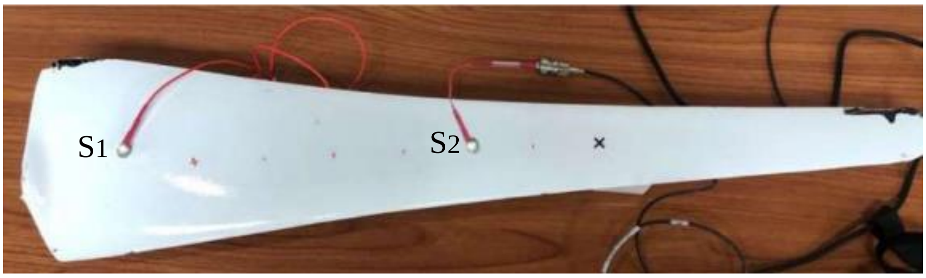


Figure 1. Experimental view of wind turbine blade with two AE sensors.

The wave attenuation is the decay of the AE signal over time. It can be calculated using Eq.(2) as follows;

$$Attenuation\ Rate\ (dB/m) = (dB_1 - dB_2)/\mathrm{d} \qquad (2)$$

where;

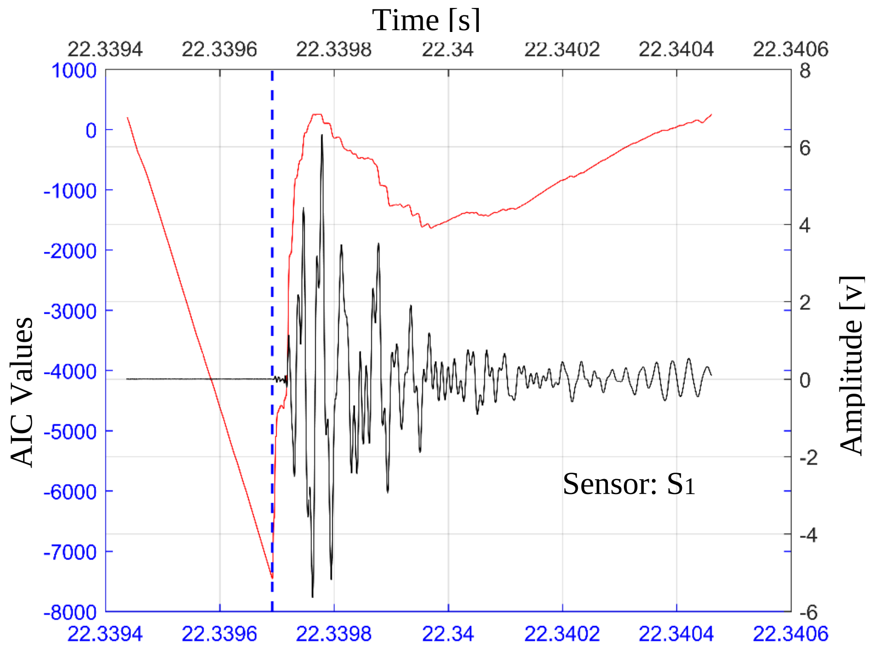
d: Distance between AE sensors.

$(dB_1 - dB_2)$: The difference between peak amplitudes detected by sensors 1 and 2.

Figure 3 presents typical AE signals as detected by first and second sensor. The Akaike Information Criterion (AIC) was implemented in signal processing in order to find out the signal's time of arrival accurately. The AIC compares the similarity between signal parts before and after point (*n*) until it reaches the minimum similarity value (and hence the signal onset is effectively determined. Eq. (3) shows the AIC function.

$$AIC(n) = n\ log(var(y(1{:}n))) + (n_{sample} - n - 1)\ log(var\ (y\ (n+1{:}\ n_{sample}))) \qquad (3)$$

where $y(1, n)$ (for data points starting from 1 to n) and $y\ (n+1{:}\ n_{sample})$ (for data points n + 1 to n_{sample}) are the two segments in the selected time window, and *(var)* stands for the statistical variance of the data. The red line represents the results of the AIC function.



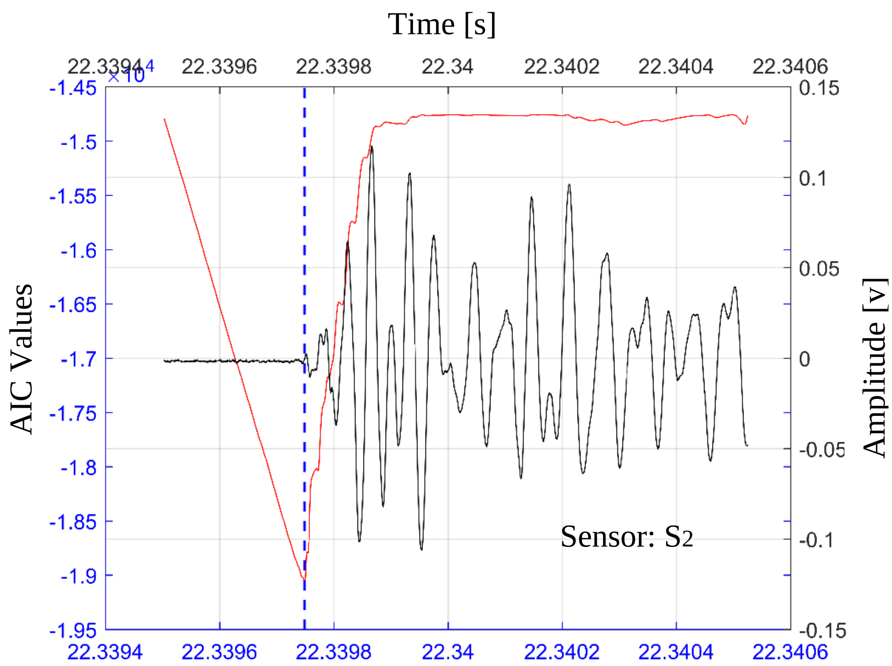


Figure 3. The AE signals detected using the two sensors.

E-Experiment Development

We chose to employ a two-dimensional spatial representation to portray the test blade in order to streamline the E-experiment graphical user interface, as shown in Figure 3. The necessary information has been tabulated as show in Figure 4. The E-experiment is developed in two steps; instruction modelling in which the E-experiment is written on sequential basis from beginning to end on power point slides, and then using Java Scripting to upload the experiment online on the Project's website (cmst-asu-cu.info).

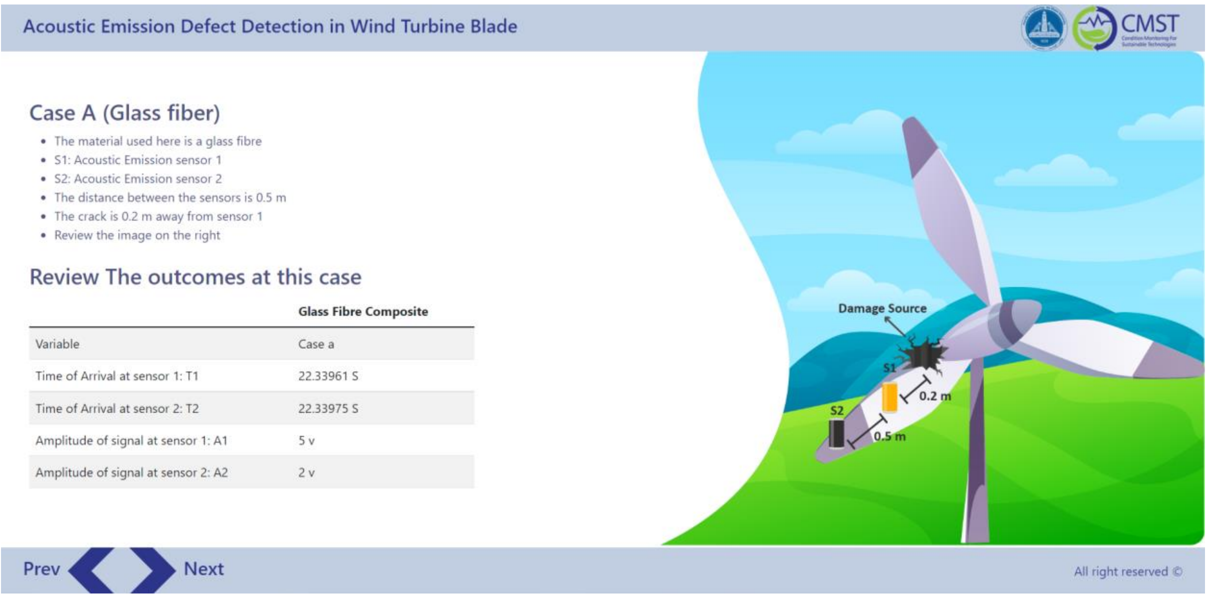


Figure 4. Graphical representation of the E-experiment.

Furthermore, because this type of non-presential laboratory is experimental in nature, we decided against implementing a real instrument appearance and instead chose to concentrate on the development of measurement techniques rather than the usage of acoustic instruments. As a result, the practitioner won't set up any devices; instead, he or she will concentrate solely on measuring techniques on two common types of materials (e.g. carbon fibre and glass fibre) and calculating the wave properties with precise spatial coordinates in metres. Two cases are offered, sensors distant 0.5m and 2m for each material to understand the nature of the AE wave. Once the calculation is finished, the findings will be displayed in a table. Then, the practitioner can see their answers against the correct ones. Figure 5 presents the calculation procedure.

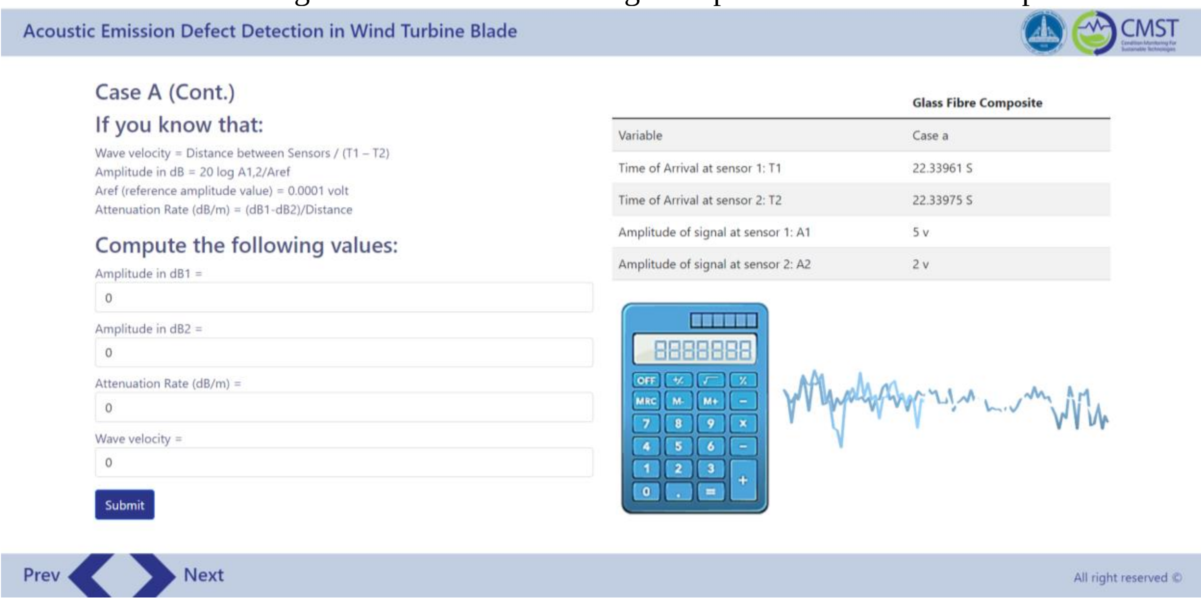


Figure 5. Calculation procedure of the E-experiment.

Conclusions

This work describes E-experiment for acoustic emission used on wind turbine blade. The developers recreate a Virtual Environment using Java scripting to upload the E-experiments online. The results of experimental work were used in developing the E-experiment scenario.

It is anticipated that the scope of these types of E-experiments will be expanded to include additional test scenarios to enhance the educational resources in condition monitoring for sustainable technologies. For example, laboratories will be developed to teach about AE damage location on sustainable technologies using sensor arrays for 1D and 2D cases to improve the student's understanding of this technique.

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Availability of data and materials

- The datasets generated and/or analysed during the current study are available in the [E-Experiments] repository, [https://cmst-asu-cu.info]

Declaration

Competing interest

The Authors are not aware of any competing interest.