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Fiber Bragg Grating Based Sensors for Structural Health & Condition Monitoring of Wind Turbine Blades

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Abstract

Wind turbine reliability is key to support the growth of the wind energy market. To improve reliability, early failure detection on critical components is crucial, as it allows operators to take fast actions and conduct effective maintenance.

More attention has been given to turbine blades as they are responsible for the biggest share of insurance of claims in wind turbines.

Condition monitoring systems are used to detect damage initiation and to monitor failure process. The currently available systems, based on conventional sensors, suffer from operation in harsh environments. In contrast, fiber optic sensors based on Fiber Bragg Gratings (FBG) are immune to electromagnetic interference, possess longer fatigue life, are more compact, highly multiplexable and more cost effective.

The BladeSave project, co-funded by the Horizon 2020 EC Programme [1], addresses the need for a structural health and condition monitoring system capable of providing multi-sensing capability and a blade management software that will link the data from three different types of FBG based fiber optic sensors (acoustic emission, strain and vibration) and generate actionable insights for wind farm operators.

The objective of this poster is to shed light on the performance of the acoustic emission (AE) part of the BladeSave system. The fatigue load measurements based on strain sensors (which will be combined with AE damage detection sensors) are known to the industry.

Objectives

- Demonstrate the performance of FBG based optical sensors in comparison to electrical sensors.
- Validate the detectability of cracks through the AE functionality of the FBG sensor.
- Develop an effective algorithm to detect damage initiation and classification in glass-fiber reinforced polymer (GFRP) materials.
- Develop a novel fiber-optic sensing system for wind turbine blade structural health & condition monitoring.

Methods

A tensile test was carried out on a 1000mm × 100mm × 4mm GFRP panel with both piezoelectric (PZT) and Fiber optic (FO) AE sensors attached, see Figure 1. The PZT sensors were connected to a Vallen AMSY-6 system.

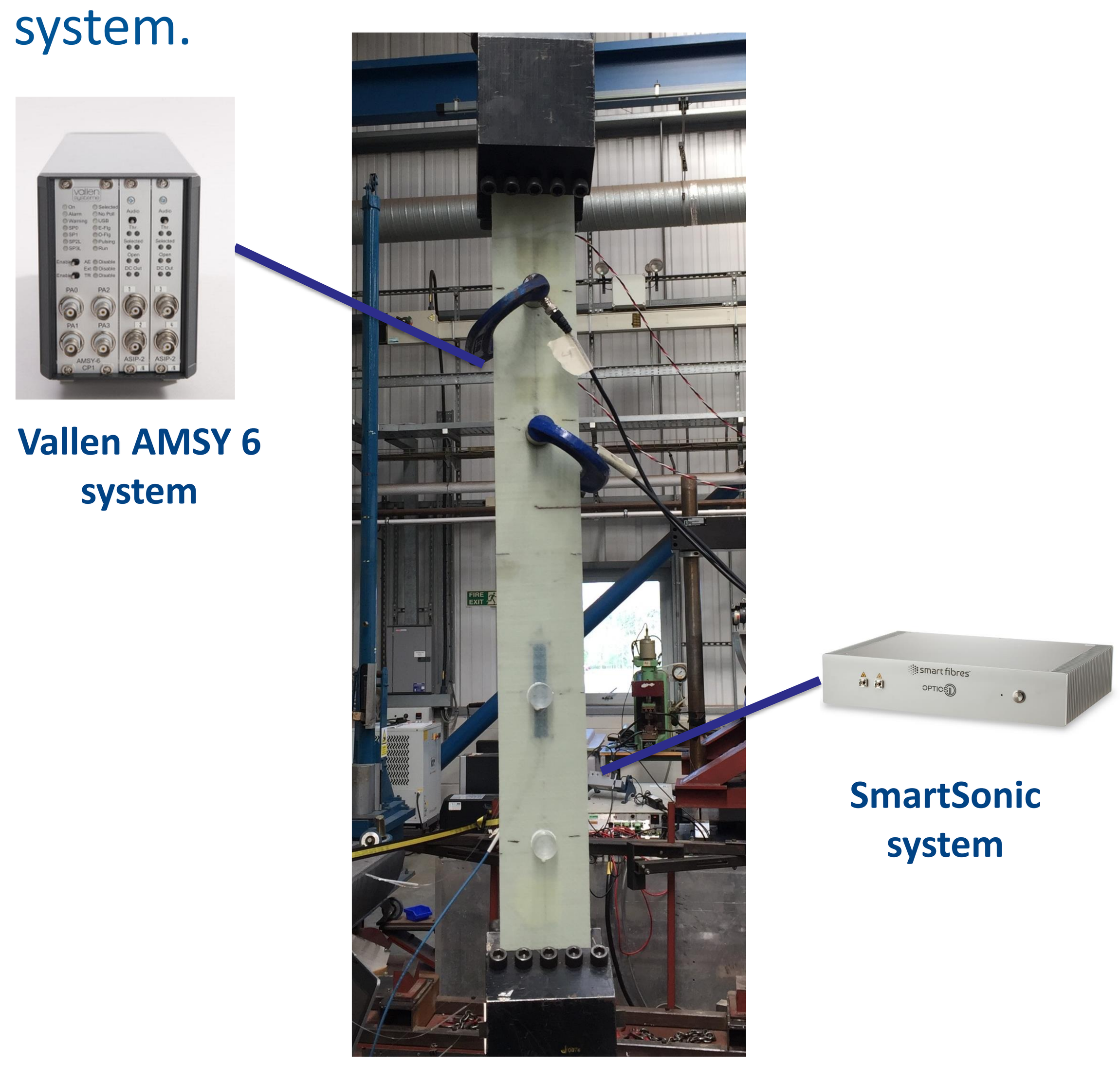

Figure 1. PZT and FO AE sensors attached to the specimen.

Two FO AE sensors were attached to the test specimen 150 mm and 300 mm away from the center of the plate respectively. PZT AE sensors were located symmetrically on the other side. The tensile test was conducted using displacement control with a speed of 0.5 mm/min. A repeated loading was applied to look into the Kaiser effect.

The metrics used to compare the performance were the number of events and selected waveform parameters, such as peak amplitude, duration, rise time, energy and number of counts.

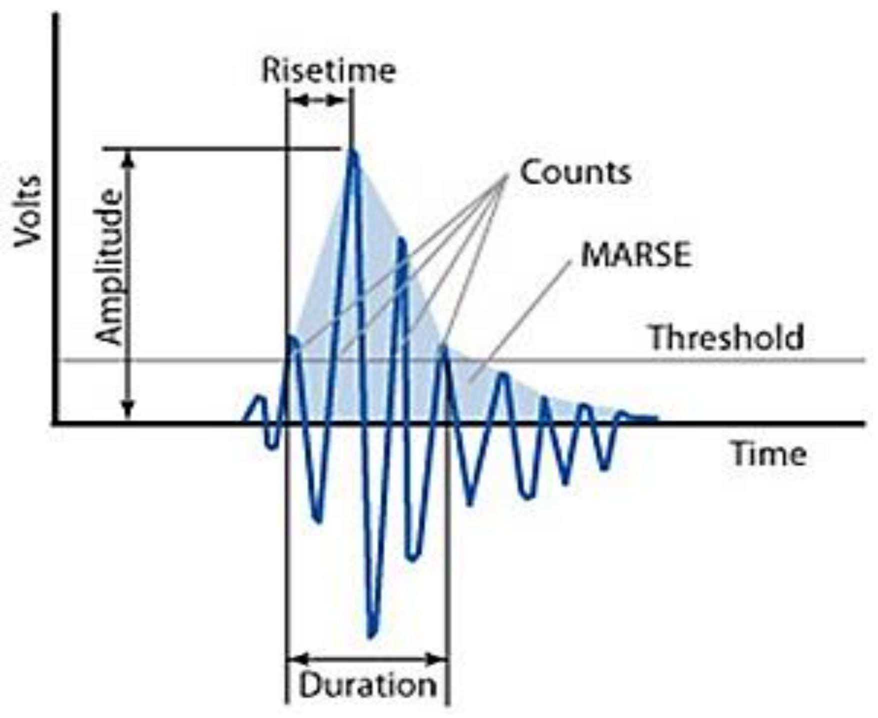

Figure 2.AE waveform parameters [2]

Main failure modes in GFRP materials include fiber failure, matrix cracking, fiber-matrix debonding, and delamination. The identification of damage for a particular type of failure based on AE sensors can be achieved using macroscopic level of parameter distributions.

Results

The waveform parameters such as peak amplitude or energy are extracted from the signals acquired by both types of sensors, see figure 3. In figure 4, AE events with high peak amplitude and energy only occurred in the last phase of the test, which indicates severe damages such as Fiber breakage [3]. Figure 5 shows events with relatively high peak frequency (above 250 kHz for PZT sensors and above 50 kHz for FO sensors), which are also a sign for fiber breakage.

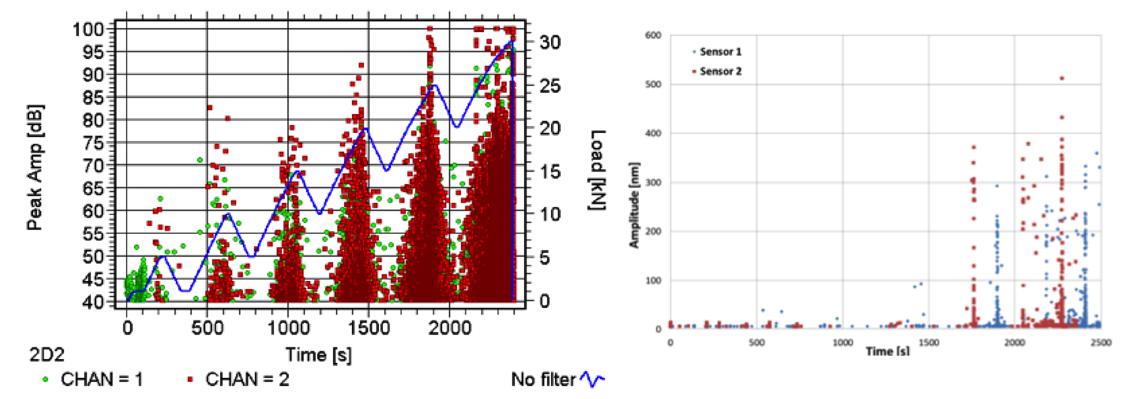

Figure 4 Peak amplitude vs Time for (a) PZT sensor (b) FO sensor.

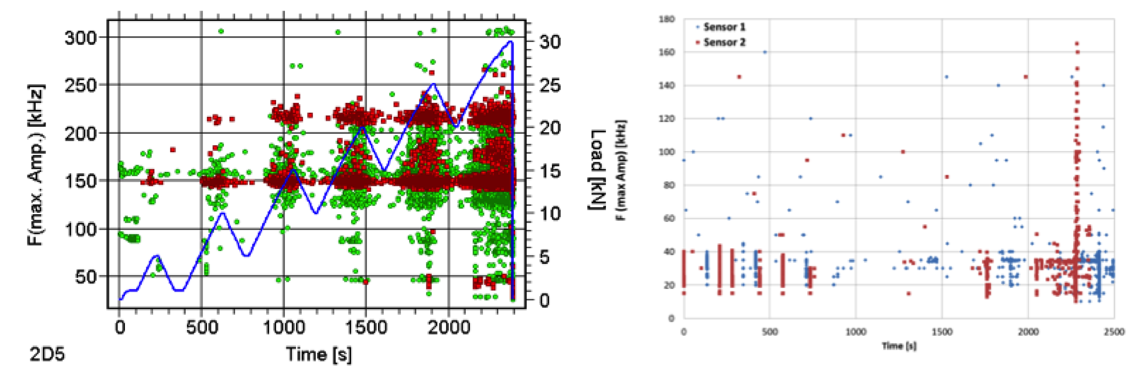

Figure 5 Peak frequency vs Time for (a) PZT sensor (b) FO sensor.

Conclusions

A tensile test has been performed to demonstrate the FBG based fiber optic sensors' performance and compare it to that of PZT sensors. The experiment proved that FBG based fiber optic sensors are able to monitor damages on composite materials as well as standard electrical sensors but with the intrinsic advantages of a fiber optic based technology.

References

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[3] Interfacial properties and microfailure degradation mechanisms of bioabsorbable fibers/poly-L-lactide composites using micromechanical test and nondestructive acoustic emission," Compos. Sci. Technol.

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