International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 3 Issue 12, November 2016

ISSN: 2394-4404

Structural Health Monitoring Using Continuous Sensors And Neutral Network Analysis

Abhishek Bhushan Pandey

Department of Mechanical Engineering,
Ashoka Institute of Technology and Management Varanasi,
Uttar Pradesh

Abstract: In the structural health monitoring using continuous sensors and neutral network analysis, study help in the identify the defect's and problems which are occur in the large bridges, dams, flyovers and many more places. It is also for the uses of the safety of all these things. Smaller damage such as cracks propagation and fibre breaking generate higher- frequency waves called acoustic emissions. There is the researcher who explained that, how flexural and extensional modes are generated in a plate due to crack propagation, that researcher is Gorman. There is another researcher who connected piezo-ceramic sensors serially and electrically to form a continuous sensor that is Sundaresan. Other approaches for passive SHM that use long sensors are a Brillion optical time domain reflect meter (BOTDR). A wave simulation algorithm (WSA) that uses a model superposition solution was used for this study. The WSA use several excitations to generate waves. The response characteristics and advantages of a long continuous sensor were studied by the simulation of wave propagation and compared with those of a short sensor. This simulation was carried out using a MATLAB code, which can simulate wave propagation in a simply supported plate using different type of materials. The long continuous sensor can be formed by connecting in series a plurality of discrete monolithic PZT sensors spaced appropriately to detect the waves of interest. The responses from the sensors were similar if the damage were at the same normal distance to the long sensor. These patterns were utilized in the NN technique for subsequent damage localization and the similar patterns can make it easy to estimate the damage. The neurons can be interconnected to form a neural system, designed as a grid, and attached to the surface of a structure as a sensor layer that acts like the neural system in the human body. This system is called an artificial neural system. A grid type ANS composed of long continuous sensors was developed for effective damage localization in plate structures. It was also found that the damages could be successfully identified with the noisy response data if the NIL was carried out.

I. INTRODUCTION

Preventing maintenance and structural safety information for large and complex structures such as bridge, buildings and aircrafts can be provided by a structural health monitoring system. Smaller damage such as cracks propagation and fibre breaking generate higher- frequency waves called acoustic emissions. Gorman was one of the first researchers who explained how flexural and extensional modes are generated in a plate due to crack propagation. Prosser extended the research of Gorman by testing the damage source at different orientations. Sundaresan connected piezoceramic sensors serially and electrically to form a continuous sensor. These concepts can reduce the required number of data acquisition channels and highly distribute the sensor over the structure. Kerkira further reduced the required number of data acquisition channels by building Structural Neural System Analogue Processor. Other approaches for passive SHM that use long sensors are a Brillion optical time domain reflect meter (BOTDR). The BOTDR can measure continuous strain over several tens of kilo meters. It is an expensive technique and is difficult to use to sense dynamic strain. Carbon nanotube can be fabricated as a long film sensor which can be considered to be a long continuous sensor. A limitation of carbon nanotube neuron is again that the bandwidth is small. The great majority of NN techniques for large structure are based on the simple back propagation algorithm. The BPNN has been applied successfully to solve difficult and diverse problems by training the network in a supervised manner with a popular algorithm known as the error back- propagation algorithm. The response measured by the long continuous sensors are used as the input to NN analysis software mimicking how the sensing signal is transmitted to the brain through a biological neural system.

II. THEORETICAL BACKGROUD

A. LAMB WAVE PROPAGATION

Anti-symmetric bending wave propagation in a simply supported plate 0.4 inches thick is used here for studying the ability of continuous sensors to detect waves generated by damage .A wave simulation algorithm (WSA) that uses a model superposition solution was used for this study. The WSA use several excitations to generate waves. The excitations can represent (a) caustics emissions; (b) foreign object impact (c) an actuator that generate a sinusoidal input . The classical plate theory used in simulation overpredicts the anti-symmetric bending wave speed for higher frequency wave because transverse shear distortion and rotary inertia of the plate are neglected.An example of wave propagation due to an impulse input at the centre of panel (aluminium with thickness of 0.04 inch).

B. THE NEURAL NETWORK ANALYSIS TECHNIQUE

The NN design employed in this study consist of an input layer, two hidden layers, and an output layer. The input layer contains the measured strain responses, and the output layer consists of the damage locations to be identified. The input/output relationship of the NN can be nonlinear as well as linear, and its characteristics are determined by the synaptic weights assigned to the connections between the neurons in two adjacent layers. The training algorithm for BPNN consists of o processes: a forward process and a backward process. In the forward process, an input vector is applied to the input layer of the network, and it is propagated and converted through the network, layer by layer. Finally, an output vector is generated as the result of network computation. An error is determined from the difference between the calculated output and desired output.

III. THE LONG CONTINOUS SENSOR

A. SIMULATION OF WAVE PROPAGATION

The response characteristics and advantages of a long continuous sensor were studied by the simulation of wave propagation and compared with those of a short sensor. This simulation was carried out using a MATLAB code, which can simulate wave propagation in a simply supported plate using different type of materials. A piezoelectric lead zirconium titanate (PZT) sensor was used. The sensor width was 0.05 inch and type of input (damage) was a five cycle tone burst with a frequency of 50KHz . The time step used in computing the response was $2*10^{-7}$s and 70 vibration modes of the panel were used in computing the response solution. The neural frequency of the 70th vibration mode was 157.7KHz. The amplitude for each sensor length become similar after a specific time (about 0.0005 s). The amplitude from the short sensor is larger than that from the long sensor in the early stage of wave propagation because there are smaller-amplitude and higher- frequency waves in the long sensor. The amplitudes for the long sensor are larger if the damage location is not perpendicular to the centre of the sensor. However, the amplitudes for all the sensor lengths become similar as the distance between the damage and the sensor become large when the damage location is not perpendicular to the centre of the sensor.

B. COMPARISON OF CONTINUOUS AND SHORT SENSORS

Some advantages and limitations of the long continuous sensor and the short sensor found from the result of the simulations of wave propagation are summarized as follows-

- ✓ For the short sensors, a large amplitude of the response can be obtained if the damage is located perpendicularly to the centre of the sensor. However, the larger the angle between the short sensor and the damage, the smaller that the response will be, and the short sensor cannot sense the response well in some cases. That is, the short sensor is very sensitive to nearby damage but can miss damage when the sensor is not in the neighbourhood of the damage.
- ✓ The long continuous sensor does not miss damage, even though the response is smaller than that of the short sensor, if damage is located perpendicularly to the centre of the sensor.

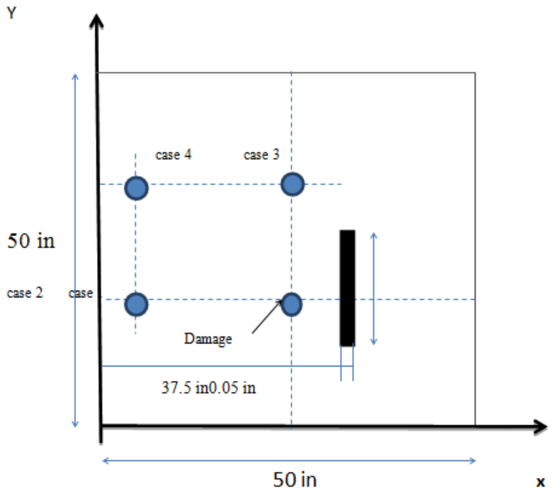

Figure 1: Damage and sensor locations for simulation of wave propagation

C. FABRICATION OF THE LONG CONTINUOUS SENSOR

A feasible method of fabricating the long continuous sensor using piezoceramic ribbon fibres is briefly discussed.

The long continuous sensor can be formed by connecting in series a plurality of discrete monolithic PZT sensors spaced appropriately to detect the waves of interest. The continuous sensor can also be formed by casting PZT ribbon fibres in epoxy. The ribbon fibres can be connected in series or in parallel to form a continuous sensor. The advantage of the ribbon fibres is their small cross- sectional size (80µm thick by 240µm wide).

IV. DAMAGE LOCALIZATION

A. RESPONSE PATTERN FROM THE LONG CONTINUOUS SENSOR

A simulation of wave propagation using three long continuous sensor for 24 damage location cases shown in figure.

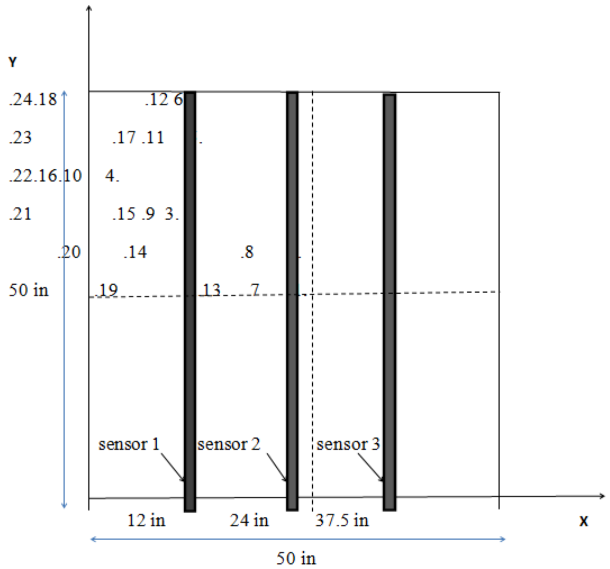

Figure 2: A simulation of wave propagation using three long continuous sensor for 24 damage location.

One cycle sine wave (50 kHz) was used as the input and the sensor length was 50 inch. The strain responses in the x-direction from each of the three long continuous sensors were obtained using the MATLAB code and the absolute values of the responses were calculated. Then the maximum of the absolute values for each sensor were calculated and normalized. The responses from the sensors were similar if the damage were at the same normal distance to the long sensor. These patterns were utilized in the NN technique for subsequent damage localization and the similar patterns can make it easy to estimate the damage.

B. THE ARTIFICIAL NEURAL SYSTEM

An artificial neuron can be formed using a long continuous sensor (a dendrite) and an analogue electronic processor (the cell body). The neurons can be interconnected to form a neural system, designed as a grid, and attached to the surface of a structure as a sensor layer that acts like the neural system in the human body. This system is called an artificial neural system.

C. DAMAGE LOCALIZATION USING THE NEURAL NETWORK TECHNIQUE

A formalized method for damage localization of a plate structure is now presented using strain responses obtained from long continuous sensors. The method is applied to damage detection in the plate described, and the strain responses from eight long continuous sensors. The training patterns can be obtained directly from experiment for a structure to monitored. This experiment should be carried out after setting up a sensor system and before operating the structure in the service condition. The damage can be simulated by a lead break method and it was reported that the multi-layered neural networks can be well trained for practical applications if the number of training ptterns is over 10 times the total number of synapses. A hybrid method can be used if the required number of experiments for the training patterns is too large. For the practical application of an NN technique, noise injection learning (NIL) can be employed to reduce the effects of measurement noise.

The noise level artificially contaminated in the strain responses in the test patterns was 5%, root mean square (RMS). The NN was trained using the NIL, and the prescribed noise level for the NIL was 10 % RMS.

V. CONDUCTING REMARKS

A method for impact and damage detection on a plate using strain responses from long continuous sensors and analysis by a NN technique was presented and verified by numerical simulation. It was found that the long continuous sensor does not miss damage. These patterns were utilized in the NN technique for damage localization, and the similar patterns can be making it easy to detect damage.

A grid type ANS composed of long continuous sensors was developed for effective damage localization in plate structures. It was also found that the damages could be successfully identified with the noisy response data if the NIL was carried out.

Continuing work includes the fabrication of long continuous sensors followed by experimentation to verify the response characteristics of the ANS for practical application of the method in the near future. Also, estimating the size of the damage or impact will be attempted based on the amplitudes of the responses of the neurons.

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[4] Mr. Vibhas Patel, Head of Department, Department of Mechanical Engineering, Ashoka Institute of Technology and Management, Varanasi.

ISSN: 2394-4404

[5] Mr. Rajeev Singh, Assistant Professor, Department of Mechanical Engineering, Ashoka Institute of Technology and Management, Varanasi.

[6] Mr. Sooraj Singh Rawat, Phd Scholar in Tribology, Department of Mechanical Engineering Indian Institute of Technology BHU Varanasi.