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Summary. *This paper presents a structural health monitoring (SHM) method for in-situ damage detection and localization in carbon fibre reinforced plates (CFRP). The detection is achieved using the electromechanical impedance (EMI) technique employing piezoelectric transducers as high-frequency modal sensors. Numerical simulations based on the finite element method are carried out so as to simulate more than a hundred damage scenarios. Damage metrics are then used to quantify and detect changes between the electromechanical impedance spectrum of a pristine and damaged structure. The localization process relies on artificial neural networks (ANN) whose inputs are derived from a principal component analysis of the damage metrics. It is shown that the resulting ANN can be used as a tool to predict the in-plane position of a single damage in a laminated composite plate.*

1 INTRODUCTION

Structural health monitoring employing smart materials is increasingly gaining popularity among engineering communities. In particular, the electromechanical impedance (EMI) based SHM technique possesses distinct advantages such as the ability to detect incipient damage, use of non-intrusive piezoelectric transducers and potentially low-cost applications. That is, the advantage of using piezoelectric sensors for damage detection resides in their high-frequency capability, which exceeds by orders of magnitudes the frequency capability of conventional modal analysis sensors. Thus, they are able to detect changes in the high-frequency structural dynamics at local scale which are directly associated with the presence of incipient damage.

Damage indicators derived from the measured electromechanical impedance are commonly used to either detect the presence of damage in any structure or provide information about damage localization in a one-dimensional structure. However, as soon as a two-dimensional structure is considered such indicators fail to furnish enough information for damage localization. Therefore, in the present paper, artificial neural networks are utilized in order to predict the in-plane damage position in a laminated composite plate.

2 PROPOSED METHOD

The use of neural networks requires a large set of data in order to learn a process as well as to improve their capacity to generalize and predict the process they have been trained for. In the present case, ANNs are trained to predict the position of a single damage in a composite plate. In order to generate a significant dataset relative to different damage localization, a coupled-field finite-element model of the EMI technique is first developed (figure 1). The resulting electrical impedance at the terminal sensors is then utilized as a damage indicator. Finally, damage metrics derived from the impedance spectrum are used as inputs to train, validate and test the ANN.

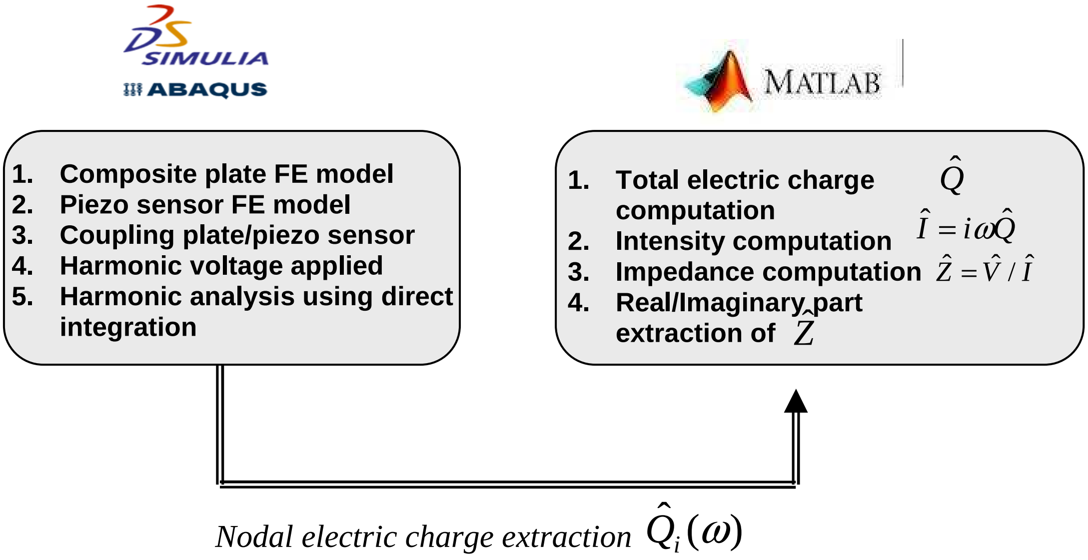

Figure 1: Modeling principle of the EMI technique.

3 FINITE ELEMENT MODELING

The proposed method lies on a harmonic analysis of the structure under study. This structure must be modeled with accuracy since it is well-known that a simple modelling of the structure with perfect boundary conditions and standard material properties gives results far from measurements. The material properties of the model such as damping ratios, Young modulus, dielectric properties of the sensors are thus adjusted so as to match the experimental impedance spectrum of a pristine structure. The FE model is composed of composite shell elements as well as 3D piezoelectric elements.

4 LOCALISATION BY ARTIFICIAL NEURAL NETWORK

The localization process relies on an artificial neural network (ANN) whose inputs are derived from a principal component analysis of the damage metrics. First, the optimal number of neurons to assign to the hidden layer is computed. Second, neural networks are trained and validated using random input vectors taken from the dataset. Finally, the trained neural networks are tested using samples partitioned from the main dataset. The testing data is not used in training in any way and hence provides an “out-of-sample’ dataset to test the network on. This gives a sense of how well the network is doing.

5. CONCLUSION

The damage detection and localization method based on EMI and ANNs is tested on a carbon fibre reinforced plate. The experimental results show that ANNs can be used as a tool to predict the in-plane position of a single damage in a laminated composite plate taking into account an important database of damages scenarios created from finite-element simulations.

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