International Journal of Engineering Research and Technology.
ISSN 0974-3154 Volume 6, Number 6 (2013), pp. 795-800

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Investigation into Metal Wire Based Variant of EMI Technique for Structural Health Monitoring

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Abstract

Electro mechanical impedance method (EMI) is a newly non-destructive evaluation method which is becoming very famous in the field of structural health monitoring. In this article a new approach is being proposed to effectively detect the initiation and progression of structural damage by the global dynamic electro-mechanicalimpedance (EMI) techniques. In this context the PZT patches are being used to determine the natural frequency and the strain mode shapes and the electromechanical admittance signature to facilitate an improved damage assessment. Nowadays the safety issues for the case of composite building materials are getting more importance. The main problem of using EMI method is its brittleness so to overcome from this problem we are using this method by coupling a metal wire with a PZT element. In this method we created progressive damages and deterioration scenarios and we evaluated with the application of the proposed metal wire EMI method.

Keywords: Structural health monitoring, PZT, Electromechanical impedance, compositematerial.

1. Introduction

The process for implementing a damage identification strategy for civil, mechanical and aerospace engineering infrastructure is referred as Structural Health Monitoring. Though the mechanical and aerospace industry started to concentrate on the structural health monitoring aspects earlier, the civil engineering community had a little delayed start in this area. Civil engineers studied vibration-based damage assessment of bridge structures and buildings since the early 1980s. Modal properties and quantities derived from these properties, such as mode shape curvature and dynamic flexibility matrix indices, have been the primary features used to identify damage in civil structures.

Damage in structure is defined as the change of material or its geometric properties of the system, including the changes in boundary conditions and system connectivity, which adversely affect the system's performance [1]. There are so many methods developed so far for damage detection in structures [2-6]. Recently one methodology called Electro-mechanical impedance (EMI) method has been successfully applied for this purpose. EMI method is a relatively new non-destructive evaluation (NDT) technique in which we can use a single piezoelectric material to act as an actuator and a sensor simultaneously. As the piezoelectric materials are very light in weight and we can get in various size and shape so they are being widely use in structural dynamics applications[7-8]. In general very soft type of material (lead-zirconate-titanate which is having a very high piezoelectric constant) is being used as piezoelectric material for the case of EMI method. In the case of brittleness of the structures we have to use this only for the case of flat surfaces.

Piezoelectricity is the ability of the crystals and certain ceramic materials to generate a voltage in response to applied mechanical stress. The piezoelectric effect is reversible in the case of piezoelectric crystals, when subjected to an externally applied voltage, can change shape by a small amount. In the field of physics the piezoelectric effect can be described as the link between electrostatics and mechanics for the infrastructure. A piezoelectric sensor is a device that uses the piezoelectric effect to measure mechanical signals like pressure, acceleration, strain or force by converting them to an electric signal and an actuator just does the opposite of this. Generally we use two main groups for the piezoelectric sensors and actuators and they are piezoelectric ceramics and single crystal materials. One main disadvantage of piezoelectric sensors is that they cannot be used very effectively for true static measurement, however for the dynamic measurements they give a very effective results. Up to date the application of EMI technique for structural health monitoring has been developed by various authors, including damage detection of composite materials, steel and concrete structures, at which place most of the work are being involved by using PZT patch attached to the structures[[9-12]]. As mentioned earlier the brittleness behaviour of the piezoelectric material make the use of electro mechanical impedance method limited and to improve this method we are using above methodology which will be useful for the complex geometry also. To overcome from this problem we will be using metal wire in conjunction with EMI method to monitor composite structures is proposing here. The main advantage of using a metal wire with EMI method is the elimination of the need for attaching the brittle PZT element onto the surface of thehost structure.

In this proposed study we are using metal wire EMI method is using to health monitor composite structures subjected to progressive damage, de-bonding and deterioration of the bonding layer between the composite plates. The satisfactory result proves the effectiveness of the proposed technique on composite structures.

2. Electromechanical Impedance Method

In the EMI technique PZT impedance sensors, in the form of small patches, which do not measure direct physical parameters like stress, strain or temperature. These are very new as impedance sensors, barely two decades old. In this method the PZT patches are usually bonded on the surface or embedded inside the host structure to be monitored. The main basic concept of EMI method based SHM approach is that the presence of damage in the host structure will affect its mechanical impedance and thus the EMI admittance of the PZT patch which can be directly measured by an electrical impedance analyser or LCR meter.

Fig. 1: LCR meter used for damage detection.

The impedance analyser imposes an alternative voltage signal of to the bonded PZT patch over the user specified frequency range and acquires admittance signature of the structure. The changes in the extracted admittance signature are indication of the presence of structural damages, which can be used for damage assessment. The PZT admittance signature is a function of the stiffness, mass and damping of the host structure, and the properties of the PZT patch.

3. Damage Idetification Using Emimethod

Generally when a crack occurs on a composite structure, it may be possibly grows to a point where the structure fails thus this is very important to able to detect any damage that is progressing in any composite structures. The value of conductance at a particular frequency range will have less value in the case of damaged structure due to the presence of cracks, delamination and due to de-bonding.

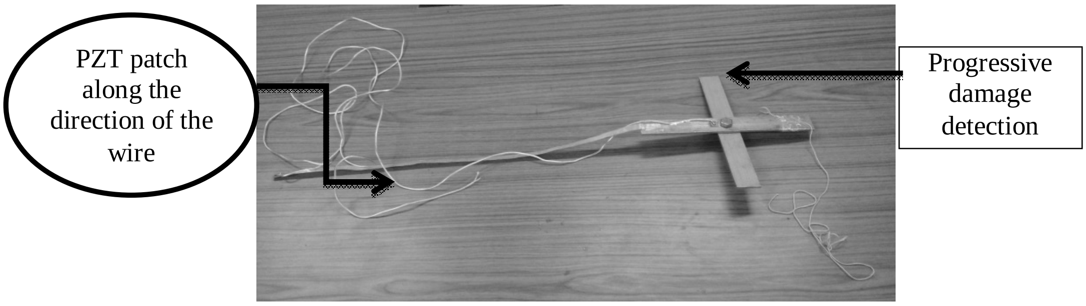

Fig. 2: progressive damage plans for the specimen.

So, by comparing thefrequency vs conductance plots of a structure in its damaged and undamaged condition, we can identify damage in a structure.

4. Results and Discussions

For this experiment , two composite plates of a size 200 mm X 50 mm with 3.0 mm thickness was used at the temperature of 28 degree centigrade with one metal wire and two PZT element. The fig 2 shows the test specimens with the experimental plan subjected to progressive damage. A torque range is using to create artificial damage for this experiment. The progressive damage first created by giving 8 Nm to 20 Nm at the centre of the two aluminium plates and we will be measuring frequency verses conductance through LCR meter. To evaluate the performance of the proposed metal wire EMI method subjected to some artificially created progressive damage, the composite specimen was set as the reference signature and all signature subjected to the damage was compared with the reference signature.

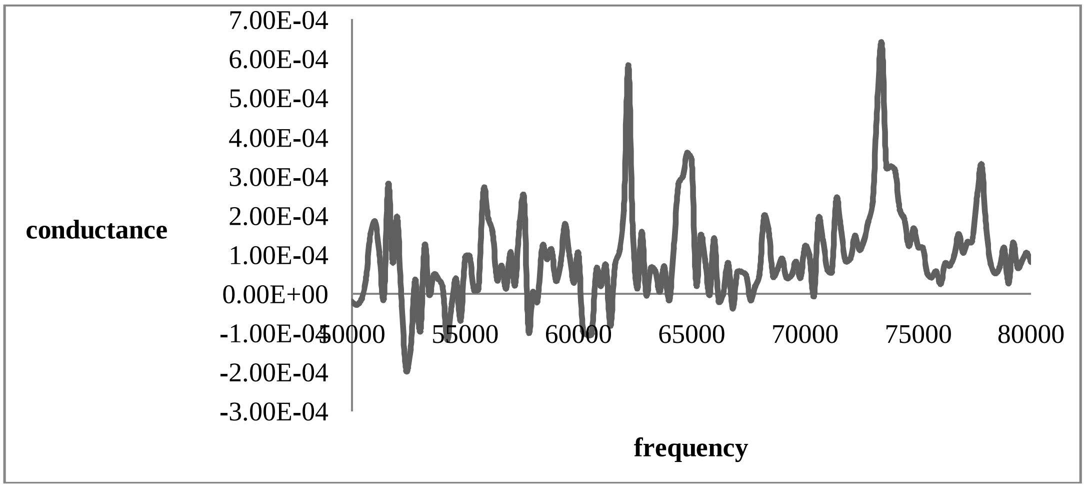

Fig. 3: Damaged condition.

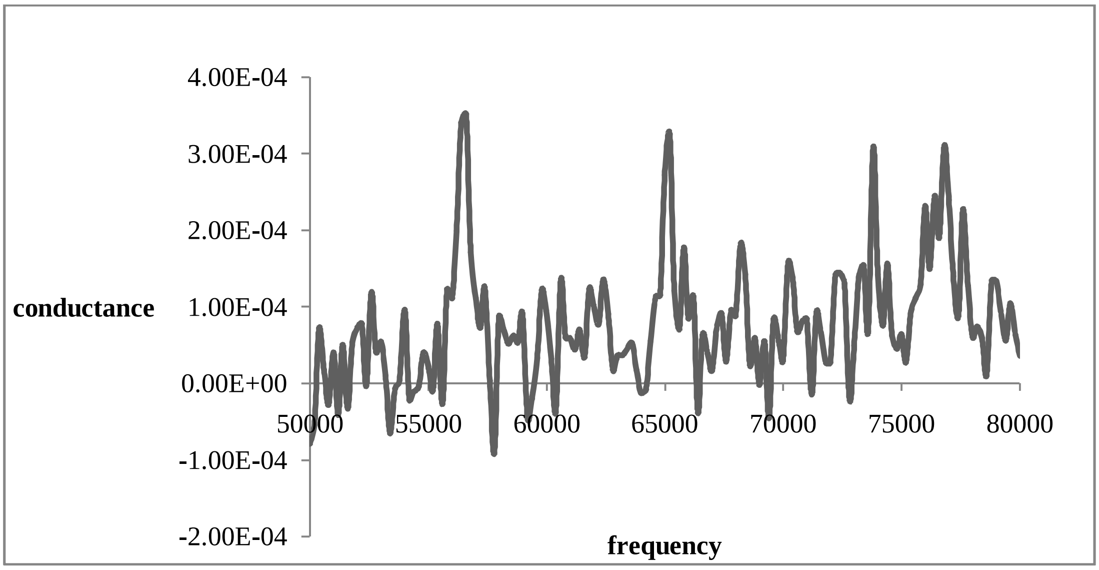

Fig. 4: Undamaged condition.

If we take a close look into figure 3 and figure 4 then it can be noticed that in case of damaged structure the conductance has lower values compared to undamaged structure for a particular frequency indicating the presence of damage in the structure. The proposed metal wire EMI method is showing promising results subjected to progressive damage of composite plates, as the impedance signature mostly dominated by the metal wire, damaging or de-bonding.

5. Conclusion

In this experiment the metal wire based EMI method is being introduced for the case of composite structures subjected to progressive damage, de-bonding and deterioration of adhesive layer. The major advantage of this proposed metal wire is for complex surfaces and surfaces with elevated temperature. The biggest factor which will effect this experiment is the size of PZT patches which has largest effect on temperature.So metal wire based EMI method is showing promising results.

The whole work and the experiment have been done at Smart Structure Laboratory at INDIAN INSTITUTE OF TECHNOLOGY DELHI.

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