International Journal of Engineering Research and Technology.
ISSN 0974-3154 Volume 6, Number 4 (2013), pp. 579-584

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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 technique (EMI) is a newlyinvented non-destructive evaluation technique which is becoming very popular in the field of structural health monitoring.Nowadays the health monitoring issues for the case of composite building materials are getting more importance. In this article a new variant of EMI technique is proposed to effectively detect the initiation and progression of structural damage by the global dynamic electro-mechanicalimpedance (EMI) technique. In this context the PZT patches are used to acquire frequency electromechanical admittance signature to facilitate an improved damage assessment. The main problem of using EMI technique is the brittleness of the PZT patches. So to overcome from this problem this technique is approved by coupling a metal wire with a PZT element. The experiments were conducted on a bolted joint which connected two aluminium bars. In this method we created progressive damages and deterioration scenarios and evaluated with the application of the PZT patch metal wire EMI variant.

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 (SHM).Though the mechanical and aerospace industry started to concentrate on the SHM 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 several methods developed so far for damage detection in structures [2-6]. Recently, one technique called Electro-mechanical impedance (EMI) technique has been successfully applied for this purpose. The EMI technique is a relatively new non-destructive evaluation (NDE) technique in which we can use a single piezoelectric patch to act as an actuator and a sensor simultaneously. As the piezoelectric materials are very light in weight and we can get in various sizes and shapes so they are being widely use in structural dynamics applications[7-8]. In general very hard type of material (lead-zirconate-titanate (PZT) which is having a very high piezoelectric constant) is being used as piezoelectric material for the case of EMI technique. 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 in sense that, 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 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 SHM has been developed by various researchers, including damage detection of composite materials, steel and concrete structures, at which place most of the works are being involve 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,a metal wire was proposed to be used conjunction with the EMI technique to monitor composite structures by Na and Li [13]. 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 study we are using metal based wire EMI techniquehealth monitor for composite of 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 Technique

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 technique 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(shown in fig 1).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 (consisting of conductance and susceptanceare indication of the presence of structural damages, which can be used for damage assessment[14]. The PZT admittance signature is a function of the stiffness, mass and damping of the host structure, and the properties of the PZT patch.

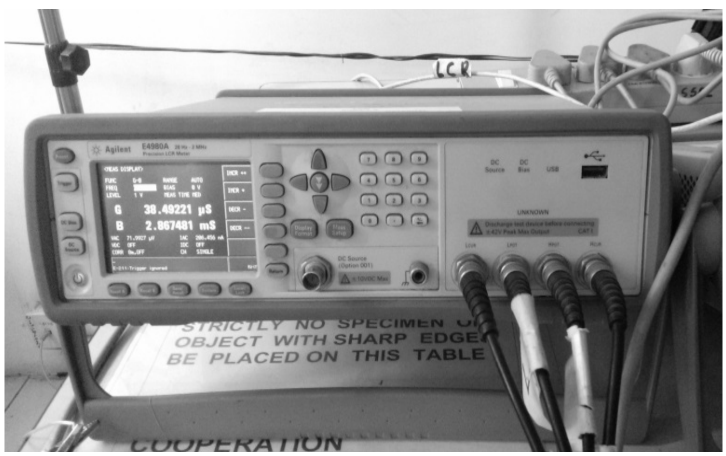


Fig. 1: LCR meter used for damage detection.

3. Damage Idetification Using Emitechnique

Generally, when a crack occurs on a composite structure, it may possibly grows to a point where the structure fails. Thus it is very important to able to detect any damage that is progressing in any composite structure. The value of conductance at a particular frequency range will have different value in the case of damaged structure due to the presence of cracks, delamination and due to de-bonding.So, by comparing thefrequency vs conductance plots of a structure in its damaged and undamaged condition, we can identify damage in a structure.

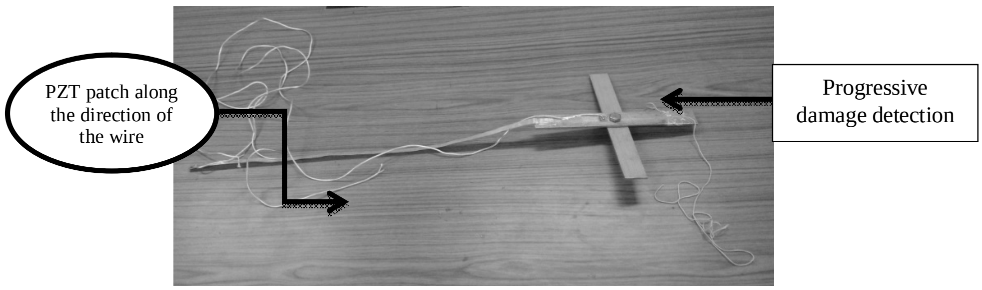
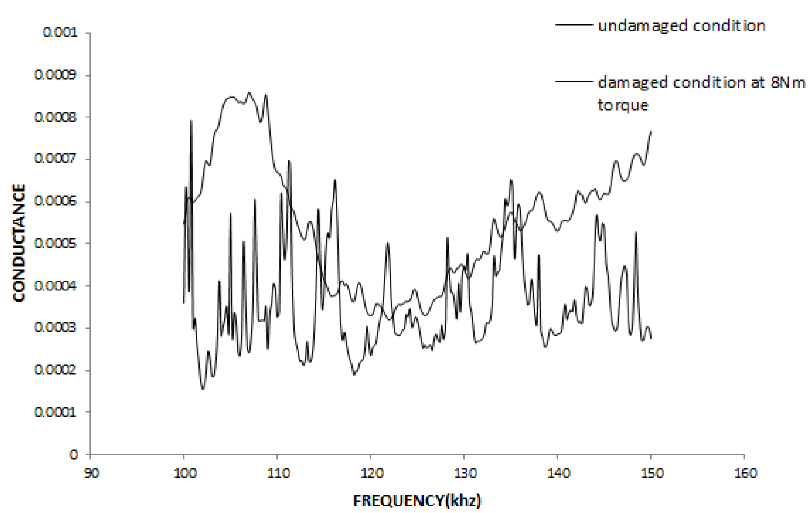


Fig 2: progressive damage plans for the specimen.

4. Experimental Details, Results and Discussions

For this experiment, a connection consisting of two aluminium plates of a size 20 cm X 2.5 cm with 3.25 mm thickness was used at the temperature of 28 °c with one metal wire and two PZT elements. Fig2 shows the test specimen with the experimental plan subjected to progressive damage. 8mm bolt was tightened to a torque of 20Nm. The progressive damage is created by reducing the torque to 8 Nm.To evaluate the performance as the signature 20 Nm was set as the reference signature and the signature after reducing the torque to 8Nm was compared with the reference signature.



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 hasdifferent 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 alluminium plates, as the impedance signature mostly dominated by the metal wire, damaging or de-bonding.

5. Conclusion

In this study the metal wire based EMI technique is introduced for the case of composite structures subjected to progressive damage. The major advantage of this proposed metal wire is for complex surfaces and surfaces with elevated temperature. The metal wire based EMI technique has shown promising results. A very through experimental study is in progress and detailed results will be published very soon elsewhere.

The whole work and the experiment have been done at Smart Structure Laboratory at INDIAN INSTITUTE OF TECHNOLOGY DELHI (http://ssdl.iitd.ac.in).

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