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Finite Element Modelling of Mart Structures

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ABSTRACT

Structural health monitoring is gaining importance day by day. Failure of any infrastructure causes severe loss of life and economy. Therefore, critical structures should be monitored at frequent intervals. This study concentrated on high frequency because of the limitations of low frequency techniques, in locating incipient damages. Unique properties of direct and converse piezoelectric effects enable piezo electrio-ceramic (pzt) patch to act both as an actuator and as a sensor simultaneously. Making use of the sensing capability the of PZT patch, conductance signature of the structure can be obtained against which health monitoring of the structure can be done. Signature of the structure in healthy state is called the base line signature. It is compared with signature obtained after a time lapse, which is called secondary state conductance signature. The characteristic feature of the EMI technique is that it activates higher frequency modes of the structure.

INTRODUCTION

GENERAL

Health monitoring is the continuous measurement of the loading environment and the critical responses of a system or its components. Health monitoring is typically used to track and evaluate performance, symptoms of operational incidents, anomalies due to deterioration and damage as well as health during and after an extreme event (Aktanetal, 2000).Health monitoring has gained considerable attention in civil engineering over the last two decades. Although health monitoring is a maturing concept in the manufacturing, automotive and aerospace industries, there are a number of challenges for effective applications on civil infrastructure systems. While successful real-life studies on a new or an existing structure are critical for transforming health monitoring from research to practice, laboratory benchmark studies are also essential for addressing issues related to the main needs and challenges of structural health monitoring.

NEEDS FOR HEALTH MONITERING

Appropriate maintenance prolongs the life span of a structure and can be used to prevent catastrophic failure. Higher operational loads, greater complexity of design and longer life time periods imposed to civil structures, make it increasingly important to monitor the health of these structures .Economy of a country depends on the transportation infrastructures like bridges ,rails ,roads etc ,Any structural failure of buildings, bridges and roads causes severe damage to the life and economy of the nation. The U.S. economy is supported by a network of transportation infrastructures like highways, railways, bridges etc., amounting to about US$ 2.5 trillion worth (Wang et al.,1998).Every government is spending many crore of rupees every year for their habilitation and maintenance of large civil engineering structures .Failure of civil infrastructure to perform may affect the gross domestic production of the country.

OBJECTIVE AND SCOPE OF PROJECT

The objective of this project was to develop methodologies for finite element analysis of smart structures. In specific, the project attempted to compare experimental results obtained for health monitoring of lab sized Reinforced concrete (RC) frame with of numerical simulations, using finite element analysis .The study made use of high frequency dynamic response technique employing smart piezo ceramic (PZT) actuators and sensors.

MART STRUCTURAL

STRUCTURAL HEALTH MONITORING (SHM):AN OVERVIEW

Increase in population necessitated the more civil infrastructural facilities in every country. Wealth of the nation can be represented by well conditioned infrastructure .Civil engineering structures undergo damage and deterioration with age and due to natural calamities. Nearly all in-service structures require some form of maintenance for monitoring their integrity and health condition. Collapse of civil engineering structures leads to immense loss of life and property .Appropriate maintenance prolongs the lifespan of a structure and can be used to prevent catastrophic failure. Current schedule-driven inspection and maintenance techniques can be time consuming, labor-intensive, and expensive. SHM, on the other hand, involves autonomous in-service inspection of the structures.

PASSIVESENSINGDIAGNOSTICS

For a passive sensing system, only sensors are installed on a structure. Sensor measurements are constantly taken in real time while the structure is in service, and this data is compared with a set of reference (healthy) data .The sensor-based system estimates the condition of a structure based on the data comparison. The system requires either a data base, which has a history of prestored data, or a structural simulator which could generate the required reference data.

ACTIVE SENSING DIAGNOSTICS

Active sensing techniques are based on the localized interrogation of the structures. They are used to localize and determine the magnitude of existing damages. Local or wave propagation-based SHM is therefore advantageous since much smaller defects can be detected .Chang (2000) concentrates his research on wave –propagation –based SHM. He developed Lamb – wave – based techniques for impact localization /quantification and damage detection. Wilcox et al. (2000) examined the potential of specific Lamb modes for detection of discontinuities. They considered large, thick plate structures (e.g. oil tanks) and thin plate structures (e.g. aircraft skins). They showed that the most suitable Lamb mode is strongly dependent on what the plate is in contact with. Bhalla and Soh (2005) presented the technique using wave propagation approach for NDE using surface bonded piezo ceramics.

TECHNIQUES USING SMART MATERIALS AND SMART STRUCTURES CONCEPT

Smart Structures

The terms smart structures, intelligent structures, adaptive structures, active structures, adaptronics , and structronics all belong to the same field of study. All these terms refer to the integration of actuators, sensors in structural components, and the usage of some kind of control unit or enhanced signal processing with a material or structural component. The goal of this integration is the creation of a material system having enhanced structural performance, but without adding too much mass or consuming too much power.

According to Ahmad (1988), A system is termed as ‘smart’ if it is capable of recognizing an external stimulus and responding to it within a given time in predetermined manner. In addition it is supposed to have the capability of identifying its status and may optimally adapt its function to external stimuli or may give appropriate signal to the user. Smart structures that can monitor their own condition, detect impending failure, control, or heal damage and adapt to changing environment.

Components of Smart System

Sensors: A smart system must have embedded in recognize and measures the intensity of stimulus (stress or strain) or its effect on the structure

Actuators: A smart system may additionally have embedded or bonded actuators, which respond to stimulus in predetermined manner.

Control mechanism: A smart system must have a mechanism for integrating and controlling the actions of the sensors and actuators.

Potential Applications of Smart Materials in Civil Engineering

One idea is to place capsules or hollow fibers filled with crack-sealing material into concrete which if cracked would break the fiber releasing the sealant.

Optical fibers which changes in light transmission due to stress are useful sensors. They can be embedded in concrete or attached to existing structures. Brown University and the University of Rhode Island investigated the fundamentals and dynamics of embedded optical fibers in concrete.

Japanese researchers recently developed glass and carbon fiber reinforced concrete which provides the stress data by measuring the changes in electrical resistance in carbon fibers.

SUMMARY

This chapter has described the concepts of structural health monitoring in recent years .Various SHM techniques and their advantages and disadvantages have been discussed. Latest research done in SHM and research needed in future also discussed .In this particular project, conductance & susceptance signatures are obtained using finite element modeling.

PIEZOELECTRICITYANDPIEZOELECTRICMATERIALS

The unique property of piezo electric materials to play the dual roles of actuators and sensors is utilized in this particular application. Piezo electricity is the effect of interaction between electrical and mechanical systems. it occurs in certain type of anisotropic crystals, in which electrical dipoles are generated upon applying mechanical deformations. The same crystals also exhibit the converse effect, that is, they undergo mechanical deformations when subjected to electric fields. This phenomena was discovered by Pierre and Paul-Jacques Curiein 1880.

PRINCIPLE AND METHOD OF APPLICATION

As suggested by Sunetal (1995) by inducing an alternating current source, pzt patch Imposes a dynamic force on the structure it is bonded to. The structural response in turn modulates the current flowing through the PZT i.e. affects the electrical Admittance .The electrical admittance is therefore is a unique function of the mechanical impedance of the structure at the point of attachment. Any variation in mechanical impedance will alter the electrical admittance, which can be used as an indicator of damage. A frequency range is selected for extracting conductance as a function of frequency. This is called conductance signature. This frequency is kept typically high, in the order of kHz using an impedance analyzer. The conductance signature is recorded for the healthy structure as a bench mark. At any subsequent state, when structure health is required to be assessed, the procedure is repeated. If any change in signatures is found, it is an indication of damage.

The surface bonded piezoelectric patches, because of their inherent direct and converse mechatronic coupling, can be effectively utilized as mechatronic impedance transducers (MITs) for SHM. The MlT –based technique has evolved during the last 8years and is commonly called the electro mechanical impedance (EMI) technique in the literature.

FINITE ELEMENT MODELLING OF SMART STRUCTURES

IMPORTANCE OF NUMERICAL SIMULATION

Since the last two decades, the use of smart structures in area of structural monitoring has been increased tremendously. Research in area of smart structures need to be developed to meet the future requirements in civil engineering field. In research it is not preferable to build the structures to undergo damages to study the behavior of smart structures .In the present study, for understanding the conductance signature of the RC frame, a numerical simulation study was carried out, using the finite element method. The frequency range was kept as 100 to 150 kHz, since the experimental study by Bhalla and soh (2004) confined to this range only.

FINITEELEMENTMODELLINGOFRCFRAME

In the present work numerical investigations were conducted on a lab sized RC frame using finite element for which experimental study was done by Bhalla. and Soh (2004).Harmonic analysis of the frame was carried out by applying self equilibrating constant axial harmonic forces at the PZT patch in the frequency range of 100 to 150KHz.Translational displacements in x-direction at the location of PZT patch were obtained at frequency interval of 1 kHz in between 100 to 150 kHz. Structural impedance and electrical admittance were cal culated at 1 kHz frequency interval using the equations 4.5 and3.3 respectively. The process was initially carried with 10mm element size. The entire procedure was repeated with 5mm, 4mm, and 3mm element sizes. It was observed that convergence of the conductance signature attained tan element size of 3mm. Therefore conductance signature with 3mm element size is considered as healthy signature of the numerical study. The conductance signature corresponding to these three sizes. Now a flexural damage in the form of vertical crack was introduced at PZT location and again Harmonic analysis is carried out for the numerical model to obtain conductance signature at the damaged state. It is assumed that vertical crack occurred at the PZT location. For introducing damage Young's modulus of the elements at the location of damage is reduced to 2×10^5 N/M^2. Deviation of this signature with healthy signature indicated the presence of damage. Numerical analysis results are compared with experimental results. The RMSD index with respect to the pristine state signature can determine by equation (3.4)

COMPARATIVE STUDY

Discussions:

It is observed that simulated and experimental signatures are more are less similar in nature. Peak conductance in the both signatures occurs at quite close at same frequencies (117 and 127kHz). Although the magnitudes are different, the results show much improvement than Tseng (2004) and Giurgiutiu & Zagrai (2002) results. In case of Tseng (2004), peak conductance in experimental and simulation curves did not coincide at same frequency. In the case of Giurgiutiu & Zagrai (2002), the conductance varied by nearly 100 times. But in the present study, conductance varied by65 times only. The variation is due to high frequency effects which could not be included in the analysis and variation of damping of concrete. From dynamic analysis point of view, the damping of concrete might varied from 2% to 6%.

DEVIATION IN CONDUCTANCE SIGNATURE WITH FLEXURAL DAMAGE

Healthy conductance signature has been compared with signature obtained by introducing small vertical flexural crack at PZT location. From it can be observed that the conductance signature corresponding to damaged state shifted vertically and laterally from the healthy conductance signature.

STUDY OF CONDUCTANCE SIGNATURE PATTERN BY INDUCING DIFFERENT DAMAGES TO THE NUMERICAL MODEL.

As a second part of the project various damages at various locations were induced for the numerical model, and the resulting conductance signature was studied.

Determination of damping constants:

Before simulating damaged model an attempt was made to further refine the model developed during part-1 by determine the appropriate damping constants.

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TUDY OF EFFECT OF DAMAGE ON CONDUCTANCE SIGNATURE OF NUMERICAL MODEL RC FRAME.

Effect of Flexural Crack

A flexural crack at the location of maximum bending moment on the top beam of the frame was induced by reducing the young's modulus of the elements at that location from 2.74E10 to1E-06. It can be observed that conductance signature of numerical model with flexural damage was shifted laterally right and vertically up. Peak conductance also changed for a considerable amount. Root means quare deviation was found to be 16.82%

CONCLUSIONS AND RECOMMENDATIOS.

CONCLUSIONS

(1) On this project, Finite element model for an RC lab sized frame was developed using ANSYS 9 software, for which experimental results are obtained by Bhalla and Soh (2004). Self equilibrium harmonic forces of 100 kN were applied at PZT location and Harmonic analysis was carried out at a frequency range of 100 kHz to 150kHz.Translational displacements were obtained at PZT patches in the direction of applied forces at an interval of 1 kHz. Electrical admittance was obtained at each 1 kHz interval. Conductance signature for the PZT patch was drawn and compared with experimental signature. The patterns of both signatures were observed as same manner. Both signatures obtained the peak conductance at the identical frequencies. But there is a variation in magnitude. These variations are due to high frequency analysis, boundary effects and uncertainty of concrete damping.

(2).By reducing the young's modulus of elements in some locations the effect of different types of cracks was introduced. And again procedure was repeated and conductance signature of damaged state was obtained .Effect of different types of damages was clearly demarcated by the conductance signatures. Numerically obtained healthy and damaged signatures followed the same pattern as that of experimental results. Both experimental and numerical conductance signatures showed the peak conductance at identical frequencies .It is found that PZT patches can easily detect damages as far as150mm.The results obtained by Giurgiutiu and Zagari(2002) are shown a variation of 100 times with the experimental. But in the present research, the deviation was around 20 times only. Hence, this is the better simulation compared to earlier researches.

(3)This numerical simulation is useful in future researches in smart structures concept. Using these simulations tedious experimental works can be avoided. It leads to saving of time and economic resources .According to T sengand Wang (2004) detection of damage by a PZT patch limited to 500 mm from the PZT patch .Therefore for large

RECOMMENDATIONS

1. Research in area of smart structures can be handled at an ease with this numerical modeling.
2. The conductance signature patterns for various types of damages and for damages which cannot be studied in laboratory can obtained by numerical modeling.
3. Challenging tasks like modeling of piezo electric coupling in shell or plate structures can be performed in this manner.
4. Fracture analysis in the presence of coupled behavior is another critical aspect to be studied with help of numerical modeling
5. The modeling of full material non linearity's and the modeling of full coupling between smart structures and liquids might be mentioned as possible examples for future research.

REMARKS:

1. Numerical results indicate that location of piezoelectric patch have significant influence on efficiency of smart structure.

2. The validity and efficiency of modeling confirmed by comparing numerical results with experimental results.
3. It is feasible to model a efficient smart structure using finite element methods.

LIMITATIONS

1. In numerical modeling material is assumed as elastic ,linear isotropic
2. Temperature was not taken into account. But a property of the PZT patch varies with the temperature.
3. Effect of initial cracks formed during curing and hardening may not accounted with the damping constants used.
4. Coupled behavior of the smart materials cause nonlinear nature. In case of piezo electric material, the encounter inversion of material characteristics in presence of sufficient electric field was not taken into account.

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