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Review on Investigation of Shear Lag Effect for EMI and PZT Technique by Using Analytical Approach

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Abstract: The advent of smart materials such as piezoelectric (PZT) sensors has helped to revolutionize the field of structural health monitoring (SHM) based on NDT techniques. Currently, the effect of the thickness of the adhesive layer (Shear lag Effect) is considered insignificant in the practical application of EMI technology. Although a relatively new NDT method known as the electromechanical (EMI) technique has been studied for more than two decades, there are still a number of issues that must be resolved before it can be applied to real structures. A technique with significant potential to advance one of the most efficient SHM systems involves the use of a single PZT to excite and sense the host structure. This article reviews the research related to EMI technology over the past decade to understand its trend. It also compares new concepts and ideas proposed by other authors and ends the work with a discussion of possible directions for future work.
Keywords: Structure health monitoring; Electro-Mechanical impedance technique; PZT patches; Shear lag effect etc.

I. INTRODUCTION

SGM involves checking the response of a structure to current loads, taking into account environmental conditions. Evaluate any part of the structure [1] for non-uniformity, damage or performance. Continuous monitoring, feedback, and analysis of test data to facilitate decision making are key aspects of SHM [2]. Early detection of localized or premature damage prevents serious damage. The severity of the injuries ranges from local to severe. Moderate to severe damage is clearly visible, and this type of damage significantly alters the structure's vibrational response. Changes in the vibrational response, i.e. changes in mode shapes, modal frequencies, are detected using global methods. Local damage is difficult to detect with global techniques because frequency or shape deformation is not that important for local damage. Thus, local defect detection relies more on local techniques. Local class techniques are ultrasonic pulse velocity methods to detect structural strength, acoustic emissions, echo tests, etc. These are usually massive techniques and result in the extraction of some information, which is the history of the applied load and stress accumulation, which does not provide much information about the initial or local damage.

Investigating the shear gap effect of structure-attached or embedded PZT sensors is a difficult task because the bond layer thickness of a real structure-attached PZT sensor cannot be changed. This article focuses on studying the effect of adhesive layer thickness using a numerical approach. Therefore, a coupled system and tie-layer model were developed using FEM-based numerical models from ANSYS. After numerically extracting the signatures of the coupled system, further analyzes of the changes in the signatures were conducted to study the effect of the thickness of the tie layer on the accurate state prediction of the structure.

II. PROBLEM FORMULATION

Many researchers have studied the effect of the adhesive layer and found that the effect of the adhesive layer is significant. Therefore, the combined system signature must account for errors that occur at the communication layer. Monitoring a structure after it has been erected is just as important as during design or construction. A bad control structure can prevent many accidents. Structural health monitoring (SHM) plays an important role. Experts blindly analyze the old system. Various non-destructive tests (ND) are used for recreation, including hammer rebound and ultrasonic magnetic velocity tests. Another way to evaluate these sensory structures in Piezoelectric has also been discovered. Electromechanical impedance (EMI) technology using Piezoelectric materials is widely used for structural improvement at various stages. EMI hates damage, corrosion and the strength of certain structural parts.

III. OBJECTIVES

The primary objectives of this project can be summarized as follows:

1) Exploring differences in the use of new concepts and ideas in EMI over the past ten years.
2) Structural condition monitoring consists of determining the location and severity of damage and assessing the remaining useful life of major structures.
3) Analyze the PZT technique using MATLAB software.
4) Check the thickness of the adhesive layer.
5) Using the finite element method (FEM), numerically analyze the effect of the thickness of the adhesive layer.

IV. LITERATURE REVIEW

The growth of design activities in piezoelectric transducer development and industrial applications has led to the development of efficient and reliable simulation and design tools. Piezoelectric ceramic (PZT) chips are gaining popularity as sensors and actuators for non-destructive techniques (NDT) and structural health monitoring (SHM) due to their small form factor, cost-effectiveness and dual effect (both sensor and actuator effect).

In the electromechanical impedance (EMI) technique, a bonded PZT chip is electrically excited by applying an alternating voltage using an impedance analyzer/LCR meter. This causes localized deformation of both the chip and the surrounding host structure. The response in this region is returned to the PZT chip in the form of acceptance (electrical response) which includes conductance (real part) and susceptance (imaginary part). Any damage to the structure is shown as a deviation on the insert label for early detection.

1) Spencer et al. 2008 , Structural Health Monitoring (SHM) was used to assess the condition of structures such as bridges, apartment buildings, cable-stayed bridges, trusses, and other infrastructure. In SHM, several techniques are used to predict the condition of a structure.
2) Xu and Liu 2011, Interconnect layer between piezoelectric element and main structure as a spring-mass damper system. Permeability in the Liang model was calculated by including the mechanical impedance (Zb) of the bonding layer. The bond layer impedance was determined "in series" with the structural resistance (Zs) of the structure. The analysis itself is not realistic because it has not been confirmed by experimental results.
3) Bhalla and Soh 2012, Bhalla and Soh12 presented a detailed introduction (semi-analytical with harmonically tuned displacement calculated by FEA) to integrate the shear delay effect into the impedance formulation assuming pure shear deformation of the glutamate. Their parametric study concluded that using a larger shear modulus and small bond layer thickness provides accurate stress conversion.
4) Yang et al. 2013, Simulated PZT structure interaction in the high frequency region (up to 1000 kHz) using the commercially available FEM software ANSYS version 8.1 using directly coupled field elements.
5) Han et al. 2011,It was observed that the dynamic behavior of piezoelectric sensors depends on the bonding conditions at the interface between the sensors and the host structure. Both numerical and analytical comparative studies were performed to simulate the two-dimensional electromechanical behavior of the integrated system. They concluded that the loading frequency should not be too high to ensure the accuracy of the sensor output. In addition, the material combination of the sensor and the host structure must be carefully selected to improve the interaction efficiency.
6) Dugnani et. to 2015, It showed that for a circular PZT patch, the effect of the adhesive layer depends on frequency and the losses due to the shear deformation of the adhesive layer are large near the first radial resonance. In the model, the inertial conditions of the adhesive layer were not taken into account and it was assumed that the piezoelectric sensor was loaded by the host structure at the edge.
7) Huang et al., 2016, reviewed the development of analytical, numerical, and hybrid methods for modeling coupled piezo-elastodynamic behavior, including the buckling effect. They highlighted several issues related to the precise characterization of the coupled piezo-elastodynamic behavior between the actuator and the host medium.
8) Tinoco et al. 2017, a numerical study was performed to understand the effect of the adhesive layer on the electromechanical coupling of piezoelectric sensors attached to structures. They found that the deformations along the interface connected to the sensor structure represent a non-linear distribution of strain and displacement. The electrical potential emitted by PZT sensors when a known force is applied to the structure depends on the thickness of the adhesive layer. The mechanical effects of the adhesive thickness are reflected in the voltages and the electrical effects in the electric potential generated by the PZT sensor. They also performed a parametric study of the bond stress-strain profile and found that the probe length affects the shear

stresses. The transferred shear forces act on the tip of the PZT sensor, where the shear stress is higher. On the other hand, when the PZT sensors are of shorter length, the force transfer mechanism is entirely through the shear stress across the interface.

9) Kaur et al. In 2017, the EMI technique is one of the SHM techniques that have been used by several researchers. Piezoelectric properties are used in EMI technology to assess the condition of a structure. Several experimental and analytical studies have been reported in the application field of SHM PZT sensors. PZT sensors are used to assess the condition of structures. In EMI technology, PZT sensors are attached to the structure with an adhesive material. These bits are used as sensors or actuators in structures.

10) Yang et al. 2018, derived the governing equation relating the surface stresses of the piezoelectric site and host structures, including the electromechanical coupling effect of piezoelectric materials for both static and dynamic cases. They numerically simulated the strain ratio (ratio of piezo to structure) (Sp/Sb) and that it matches the theoretical solution reasonably well. They found that the voltage at the ends of the chip changes suddenly due to the singularity, which cannot be simulated by FE multiphysics, and also investigated the effect of the circuit resistance on the compensation delay.

11) Moreno-Gomez et al., 2018, Electromechanical behavior of PZT actuators in the bonding layer is one of the key issues in EMI technology. Accurate estimation of the shear stress and stress distribution around the interface bond plays a dominant role in transferring the actuator effect from the actuator to the main structure. The effectiveness of piezolamination depends largely on the ability of the adhesive layer to transfer stress and strain between the active and passive components. Therefore, it is important to study the coupled electromechanical behavior of sensors in these bond layers to reliably assess the relationship between the measured signal and the local mechanical strain.

12) Jin and Wang 2019, predicted through their numerical simulation that increasing the thickness of the adhesive layer increases the level of shear stress distribution within the actuator and reduces the stress concentration at the ends of the actuator. In addition, the material combination of the actuator and the main structure must be carefully selected to improve the performance of the actuator.

13) Sumedha Moharana and others. to 2019, Electromechanical impedance (EMI)-based structural health monitoring (SHM) uses adhesively bonded piezoceramic chips to evaluate and diagnose the monitored host structure. The adhesive bond forms a defined layer to transfer force between the patch and the underlying structure. The mechanical and geometric properties of the adhesive layer significantly affect the overall interaction of the PZT structure. This article presents the geometric deformation of the connection region in the coupled reception through mathematical modeling.

14) Maurya et al, 2020, Investigating the shear-delay effect of a structure-bonded or embedded PZT sensor is a difficult task because the bonding layer thickness of a bonded PZT sensor cannot be varied for a real structure. This paper focuses on investigating the effect of bonding layer thickness using a numerical approach. Therefore, a model of the bonded system and bond layer was developed using a FEM-based numerical model in ANSYS.

15) Junjie Zhang et al. to 2020, This paper combines an advanced global search algorithm, a quantum particle swarm optimization algorithm, first with a finite element method to accurately detect structural damage through the electromechanical impedance method based on conductivity and frequency spectrum.

16) Xin Zhang et al. to 2020, this paper introduced an advanced structural sound tracking method using dual piezoelectric transducers. Two piezoelectric transducers, one as an actuator and the other as a sensor, were used to extract the electrical impedance of the measured structure. A Convolution Neural Network (CNN) model was used to classify the response signals of different structures with high accuracy.

Several researchers have studied the effect of the bonding layer and found that the effect of the adhesive layer is significant. Therefore, it is important to calculate the error due to the coupling layer in the signature of the coupled system. Monitoring a structure after it is built is just as important as during its design or construction. A properly controlled structure can prevent many catastrophic accidents. Structural health monitoring (SHM) has an important role. A preliminary analysis of expert systems was performed visually.

Investigating the shear delay effect of a structure-bonded or embedded PZT sensor is a difficult task because the bonding layer thickness of a bonded PZT sensor cannot be varied for a real structure. This project focuses on investigating the effect of bonding layer thickness using a numerical approach. Therefore, a model of the bonded system and bond layer was developed using a FEM-based numerical model in ANSYS. The signature of the coupled system was numerically extracted, and further analysis of the signature change was analyzed to investigate the effect of the bond layer thickness on the accurate prediction of the structural state.

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V. PROJECT METHODOLOGY

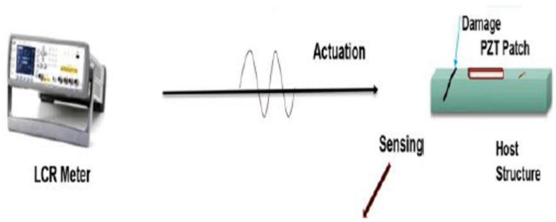

Fig. 1 EMI technique

EMF surface waves are generated by vibration or excitation of the PZT chip. These waves propagate radially outward. Waves Play detects any bugs or corruptions that prevent you from progressing. This technology uses PZTs connected or embedded in the main structure. Or heat the patch.

1) The patch is tuned using an impedance analyzer or LCR meter and an alternating electric field. The analyzer then measures the electromechanical response of the chip when it is penetrated. The analyzer plots the real and imaginary parts of the penetration in the frequency domain, called signatures.
2) In the picture. Figure 1 shows the mechanism of EMI technology using an LCR meter. Ancient signatures are considered key indicators. Flaws in the structure change the signature and defects are detected.
3) Projects dedicated to EMI technology and its various functions. Links to several studies conducted over the years allow readers to see how the technology has evolved so far.

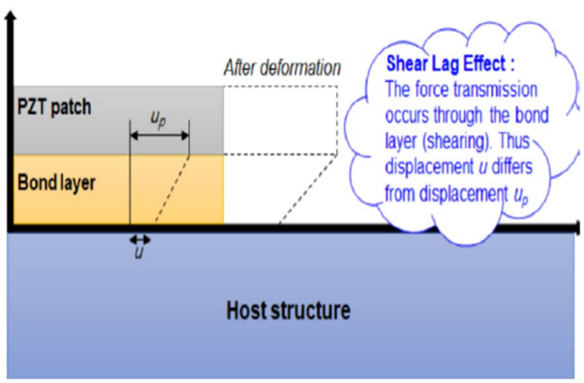

Fig.2. Shear Lag Phenomena

4) Construction of an analytically accurate analysis solution taking cleavage lag into account. Figure 2 presents the mean shift phenomenon. In the previous model, the inertial PZT effect was ignored, but it was considered when constructing the displacement gap model here.
5) The new model simultaneously considers potential differences and inertial effects. The new model's predictions fit the test more closely.

VI. CONCLUSIONS

All countries spend a lot of money on construction. All social structures play an important role in the life and development of the people living in the country. Damage to such structures and systems affects the country's GDP, loses many lives and hinders the growing development of the country and its people. Structural strength is weakened by constant loads and environmental influences. Therefore, you should evaluate the performance of your design to see whether the performance is satisfactory. Structural damage can be prevented with proper monitoring.

This review discusses electromagnetic interference techniques and focuses on the latest research in this field. Implementations still have many challenges to overcome, such as the limited sensing range of PZTs, selection of appropriate frequency ranges, temperature changes to be overcome to monitor damage, and accurate statistics to be accounted for.

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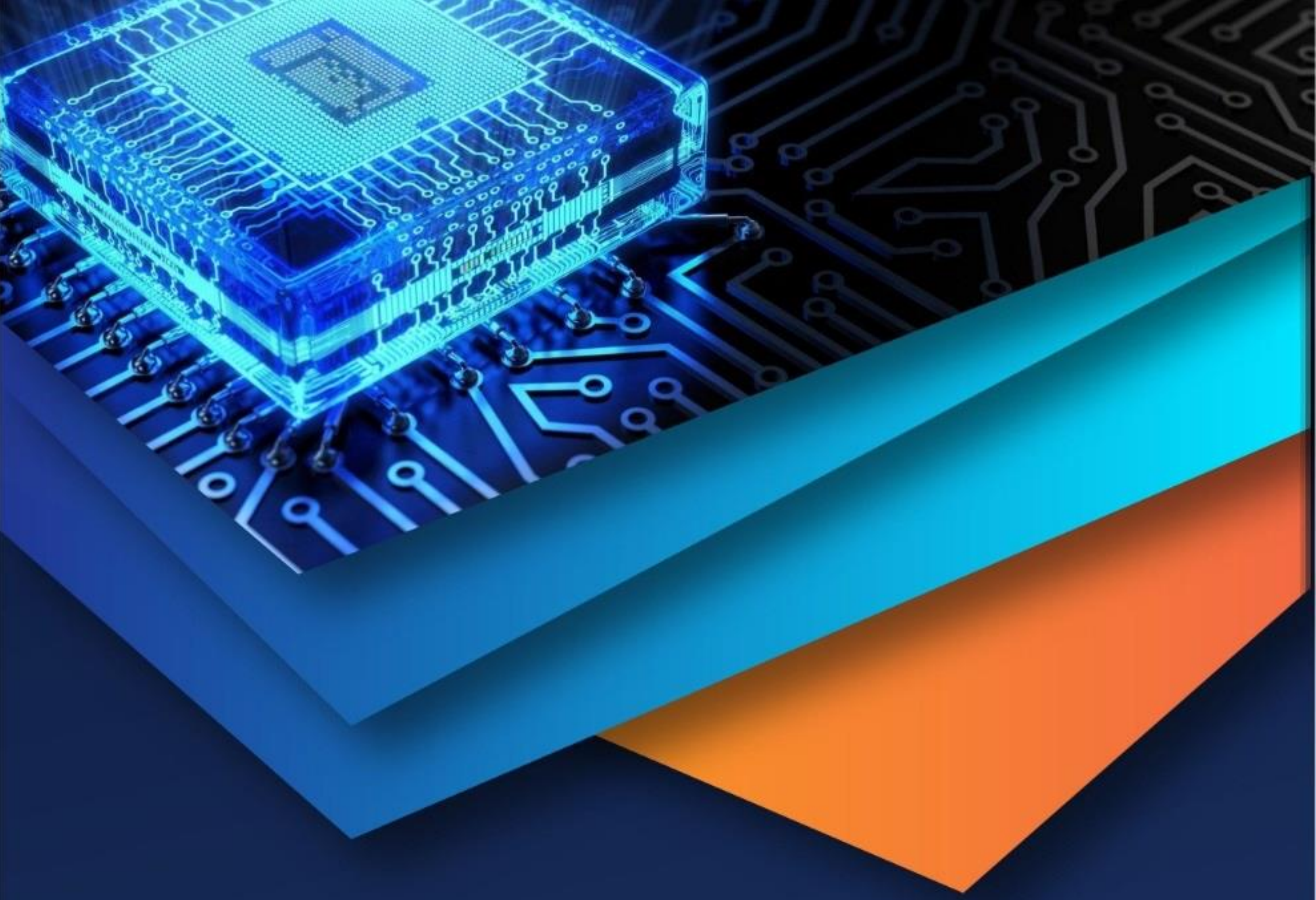

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