Review on Active Vibration Control of Beam using PZT Patches

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Abstract— Piezoelectric materials have the ability to produce a contraction or extension when an electrical charge is applied to them. By integrating piezoelectric elements into slender structures, structural vibration and oscillations can be reduced by measuring them and controlling the actuators in real time. Such a structure is referred to as smart-structure. This review paper presents the study of previous researchers on active vibration control.
Key words: PZT Patches, Active Vibration Control

I. Introduction

The motivation for this work checks the possibility of using induced strain actuation for vibration suppression, stability accretion, and noise deduction in beam-like aerodynamic surfaces. While building the beam, it is taken into consideration that piezoelectric materials must be bonded to the beam in a uniform fashion along with the fact that both materials must have electrical contact on each side of the material. For piezoelectric actuators surface bonding is advantageous as there is better access for fabrication, easier access for inspection, and less maintenance cost.

However, as these materials are exposed, they are more susceptible and more prone to be damaged. But, in this type of experiment, it is peremptory for the piezoelectric components to be on the surface because it was the only way it could be easily manufactured.

A smart structure has the following components:

- Sensor(s): It generates signal proportional to the changing property that can be measured according to environmental changes.
- Actuator(s): in order to achieve the desired response, actuators are used to change the properties of the smart structure
- Control System(s): In order to determine if any action is required, control systems incessantly monitor the sensor's signal, process the information and in case if action is required, then a signal is applied to the appropriate actuator(s).

If the set of actuators and sensors can be treated separately in case they are located at discrete points of the structure. From a mechanical point of view, for classical structural materials as elastic constants relating stress and strain, and their thermal expansion coefficient relating the strain to the temperature describes their properties. While in case of smart materials, strain can also be generated by different mechanisms involving electric field, magnetic field, temperature, etc. as a result of some coupling in their constitutive equations.

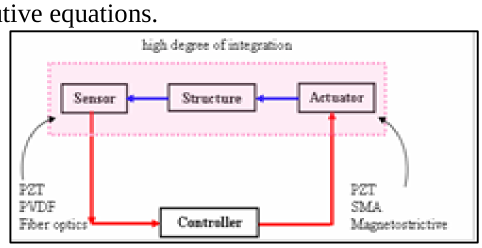

Fig. 1: Components of Smart Structure.

II. Literature Survey

There are many authors who have worked on suppressing the vibrations actively of cantilever beam. Omer Faruk Kirkali et al. [1] presented mathematical modeling of the smart beam conducted by using the assumed-modes method. This resulted in a higher order model including a large number of resonant modes of the beam. By including only the first two flexural vibrational modes of the smart beam the higher order model was truncated to a lower model. By employing a model correction technique which considered the addition of a correction term that consequently minimized the weighted spatial 2 H norm of the truncation error the possible error due to that model truncation was compensated. Hence, the effect of out-of range modes on the dynamics of the system was included by the correction term.

A class of resonant controllers for minimizing vibrations of flexible structures using collocated piezoelectric actuator-sensor pairs was introduced by Dunant Halim et al. [2]. The resonant responses of a chosen number of vibration modes are minimized by the controller. The controller structure should be such that the closed loop stability is guaranteed.

Paolo Gaudenzi et al. [3] the problem on the attenuation of the vibration effects in cantilever beams. They simulated the problem numerically and analyzed experimentally. A finite element approach based on an Euler-Bernoulli model and subsequent modal factorization is used for the numerical simulation. The results of the numerical simulation have been compared to those ones obtained with the experimental tests and a good correspondence has been obtained in the three cases. Besides, the analysis has demonstrated the better effectiveness of the position control respect to the velocity control as strategy to reduce the vibration levels in a cantilever beam.

Balamurugan et al. [4] presented a paper which dealt with the active vibration control of beam like structures with distributed piezoelectric sensor and actuator layers bonded on top and bottom surfaces of the beam. They developed a finite element model which is based on Euler-Bernoulli beam theory. Here, they considered the contribution of the piezoelectric sensor and actuator layers on the mass and stiffness of the beam. Direct promotional feedback, constant-gain negative velocity feedback and Lyapunov feedback these three types of classical control strategies and an optimal control strategy, linear quadratic regulator (LQR) scheme are applied to study their control effectiveness. Also, the control performance with different types of loading, such as impulse loading, step loading, harmonic and random loading is studied.

In the paper of Yavuz Yaman et al. [5] the smart plate consists of a rectangular aluminum plate modeled in cantilever configuration with surface bonded piezoelectric patches. The patches were symmetrically bonded on top and bottom surfaces. ANSYS (v.5.6) software was used to

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derive the finite element model of the smart plate. The study first gave the influences of the actuator placement and size on the response of the smart plate and determined the maximum admissible piezoelectric actuation voltage. The optimal sensor locations are found and actual smart plate is produced. These experimental results of the smart plate are then used to determine a single input single output system model.

Melin Sahin et al. [6] presented the theoretical and experimental studies conducted in Aerospace Engineering Department of Middle East Technical University on smart structures. They gave particular attention to the structural modeling characteristics and active suppression of in-vacuo vibrations. The smart structures considered in these analyses are flat aluminium cantilever beam-like and plate-like structures with surface bonded PZT patches. Finite element models of smart beam and smart fin are obtained. The experimental readings are taken to study regarding open loop behavior of the structures performed by using strain gauges and laser displacement sensor to determine the system models.

A. Benjeddou et al. [7] presented a paper on finite element model for adaptive sandwich beams to deal with either extension or shear actuation mechanism. Based on Bernoulli-Euler theory for the surface layers and Timoshenko beam theory for the core the mechanical model was developed. Three variables, through-thickness constant deflection, the mean and relative axial displacements of the core's upper and lower surfaces were used. The piezoelectric effect is handled through modification of the constitutive equation, when induced electric potential is taken into account.

M. Yaqoob Yasina et al. [8] worked on the active vibration control of smart plate which was equipped with patched piezoelectric sensors and actuators. To model the kinematics of the plate and to obtain the shear strains, an equivalent single layer third order shear deformation theory is employed. They considered the linear variation of electric potential across the piezoelectric layers in thickness direction. Undamped natural frequencies and the corresponding mode shapes are obtained. The finite element model in nodal variables are transformed into modal model and then recast into state space. The dynamic model is reduced for further analysis using Hankel norm for designing the controller. To control the vibration of the plate the optimal control technique is used.

Chang Zheng et al. [9] used impedance method and FEM to simulate beams with piezoelectric actuators. Very first, to describe the dynamic of one piezoelectric stretch actuator one impedance matrix equation is used and each impedance equation is equivalent to one (M-C-K) mass-damping-spring system. Secondly, to build FE model of beams driven by piezoelectric bending actuators the equivalent system is used.

How to obtain optimal location and size of PZT actuators is studied by Jingjun Zhang et al [10]. According to the method of model reduction based on the truncation criterion of modal cost, the model of a piezoelectric smart structure is built by the application of ANSYS software which extracts the required modes, then, both the optimal location and the size of piezoelectric actuators can be ascertained by these extracted modes.

K. B. Waghulde et al. [11] made a setup comprised of actuators and sensors placed at the root of a cantilever beam. Vibrations were given by various sources including human activity and nearby motorized equipment. With help of white noise signal actuator disturbance is produced. Feedback controller sends correction information to the actuator that minimizes the vibration. To optimize results, controllers were designed using Linear Quadratic Gaussian (LQG) theory.

C. van Gemert et al. [12] and Serge study is concerned with nature conservation by auto- matically monitoring animal distribution and animal abundance. The camera mounted on it is uses passive vibration control like by using foam. But still some images taken with this type of arrangement are not clear. For this purpose smart structure pizo-laminated beams are used to control the vibrations of camera.

III. EXPERIMENTAL SETUP

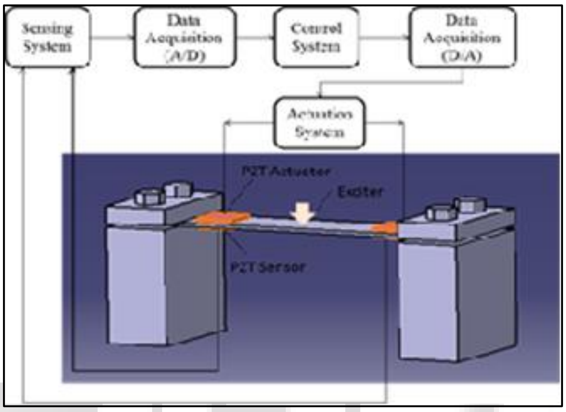

Fig. 2: Experimental Set up

A smart beam is produced as a test specimen to be used in the experiments for the comparison with simulation results. The smart beam consists of an aluminum beam, piezoelectric patches as an actuator, and a sensor. The piezoelectric actuator and sensor is bonded onto beam using conductive epoxy. A wire is soldered on the piezoelectric actuator.

The dimensions of the smart beam are given in Table. The material properties of the smart beam are given in Table

	Beam (mm)	Sensor (mm)	Actuator (mm)
Length	300	25	30
Width	50	25	25
Thickness	3	1	1

Table 1: Dimensions of Different Elements

A fixed beam as shown in Figure is manufactured to provide boundary and initial conditions at both ends of the smart beam. A schematic view of the experimental setup is shown in Figure. In the experimental setup, a PZT sensor, a signal conditioning unit, microcontroller and analog output data acquisition (DAQ) system are utilized for data acquisition and control action. The strain data is acquired with the analog input system through the input module and the signal conditioning unit.

Exciter is used to generate vibration. It produces the vibration which is sensed by the sensor and produces proportional electric signals which is fed to the computer

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through data acquisition system. Then from computer signals are fed to actuator and it produces opposite strain in the beam due to this beam is balanced.

IV. Conclusion

From the references used in this paper, we got the application where active vibration control can be used i.e. the camera of drone which is supposed to face vibration. So the arrangement of experimental setup is done in this way so that it will replicate the actual model. Future scope is to optimize the size and shape of the PZT patches with effective controller.

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