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Active Vibration Control of Plate Structure

Shubham R. Patil
Student of M. E. [CAAD]
Department of Mechanical Engineering,
SSVPS BSD COE
Dhule, Maharashtra,India

Prof. Santosh V. Patil
Assistant Professor
Department of Mechanical Engineering,
SSVPS BSD COE
Dhule, Maharashtra,India

Abstract:- **Vibration control and/or reduction can significantly improve the performance and operation of systems and machines in various industries. As technology advances, the methods of vibration control also become more involved and therefore allow for control of more complex structures. This paper focuses on vibration control of a flexible plate system. An experimental setup is designed to demonstrate reduction of flexible modes of the plate system. Actuators, accelerometers, and force sensors are specified to apply appropriate disturbance forces of varying complexity and to measure and record data necessary to update the theoretical model and design an effective controller. The experimental setup is initially made up of Aluminum plate of 3mm thickness. The control scheme involves non-collocation control of a location to which the piezo-patch is mounted. Software and experimental results of the modeling of a smart plate are presented for active vibration control. The smart plate consists of a rectangular aluminum plate modeled in cantilever configuration with surface bonded piezoelectric patches. The patches are symmetrically bonded on top and bottom surfaces. The study uses ANSYS 16.0 software to derive the finite element model of the smart plate. By using this model, the study first gives the influences of the actuator placement and size on the response of the smart plate and determines the maximum admissible piezoelectric actuation voltage.**

INTRODUCTION

As piezoelectric technology advances, dynamic systems present more complex problems with less conclusive solutions. One common application for these advanced controllers is vibration reduction. In high precision systems, vibrations can decrease accuracies and efficiencies, and cause potentially disastrous damage. The ability to control these vibrations and minimize amplitude response to disturbances is valuable to many different industries across the board [1].

This paper focuses on vibration control of a flexible plate system. Advanced piezo-controllers make up a broad category within the controls field. These controllers are capable of achieving control as well as being robust and adaptive to variances in system parameters. Advanced controllers can be made effective when the system is modeled accurately. With the goal of more effective controllers, the dynamic system model pays an important role in the controller design. A state space representation of the system is used to create a full state feedback controller that will perform based on the desired pole placement. A more ideal approach involves a complete and accurate reference model that essentially contains frequency response functions between all inputs and the output to be controlled. With this method, if the disturbance input can be measured at the source, the non-collocated output can be estimated using the reference model and the output can be controlled appropriately with a control input [2].

The main methods that are explored in this system involve flexible control with a patch actuator and control. To implement each of these, separate experimental setups must be designed, built, characterized, and tested. The focus is on the systems response within a defined frequency range. The smart structure can be defined as the structure that can sense external disturbance and respond to that with active control in real time to maintain the mission requirements.

Smart structures consist of highly distributed active devices and processor networks. The active devices are primarily sensors and actuators either embedded or attached to an existing passive structure. The active vibration control of simple cantilever plates is studied in piezoelectric patches as actuators are mounted on the plates. Another piezoelectric patch or a strain gauge can be used to sense the vibration level. The system identification and pole placement control method is used. The plate and piezo-patches finite element model of the structure is constructed and the closed loop control is applied.

Active vibration control is defined as a technique in which the vibration of a structure is reduced or controlled by applying counter force to the structure that is appropriately out of phase but equal in amplitude to the original vibration. As a result two opposite force cancel each other and structure stops vibrating. Techniques like use of springs, pads, dampers, etc. have been used previously to control vibration. These techniques are known as “Passive vibration control technique”. They have limitations of versatility and can control the frequencies only within a particular rage of bandwidth hence there is a requirement for active vibration control.

Active vibration control is a modern approach towards vibration control at various places; classic control techniques are becoming too big for modern machines where space is limited and regular maintenance is not possible and if possible, it is too expensive, at such conditions AVC techniques comes handy, it is very cheap requires no manual maintenance and the life expectancy is also much more than the passive controllers [3]. Active vibration control makes use of smart structure. The system mainly requires actuators, sensors, source of power and a compensator that performs well when vibration occurs. Smart structure are used in the bridges, trusses, buildings, mechanical systems etc. analysis of a basic structure can help in improving the performance of structure under poor working conditions involving plate vibrations.

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The Major components are

1. Sensor patch- It is bonded to the host structure (plate). It is generally made up of piezoelectric crystals. It senses the disturbance of the plate and generates a charge which is directly proportionally to the strain. Direct piezoelectric is used.
2. Controller- The charge developed by the sensor is given to the controller, the controller lines are charged according to the suitable control gain and charge is fed to the actuator. Controller also forms the feedback functions for the system.
3. Actuator patch- The lined up charge from the controller is fed to the actuator causes pinching action (Or generates shear force) along the surface of the host which acts as a damping forces and helps in the alternating vibration motion of the plate. Converse piezoelectric is used. [1]

The plate is clamped at one end using the set table hence making it a cantilever plate, the excitation is given from the other end, the free end using an exciter, excitation of which can be controlled using a function generator (producing a wave form of sinusoidal, triangle, square) and an amplifier.

In this work a smart plate (aluminum plate) with one pair of piezoelectric lamination is used to study the active vibration control. The smart plate consists of rectangular aluminum plate modeled in cantilever configuration with surface bonded piezoelectric patches. The study uses ANSYS-16 software to derive the finite element model of the smart plate. Based on this model, the optimal sensor locations are found and actual smart plate is produced. In this experiment we find a suitable control methodology by which we optimize the controller gain to get more effective vibration control with minimum control input.

The main methods that are explored in this system involve flexible control with a patch actuator and control with an inertial actuator. To implement each of these, separate experimental setups must be designed, built, characterized, and tested. The focus is on the systems response within a defined frequency range. The smart structure can be defined as the structure that can sense external disturbance and respond to that with active control in real time to maintain the mission requirements. Smart structures consist of highly distributed active devices and processor networks.

1. *Smart Materials and Structures*

An active structure consists of a structure provided with a set of actuators and sensors coupled by a controller; if the bandwidth of the controller considered. If the set of actuators and sensors are located at discrete points of the structure, they can be treated separately. The distinctive feature of smart structures is that the actuators and sensors are often distributed, and have a high degree of integration inside the structure, which makes a separate modeling impossible [3].

From a mechanical point of view, classical structural materials are entirely described by their elastic constants relating stress and strain, and their thermal expansion coefficient relating the strain to the temperature. Smart materials are materials where strain can also be generated by different mechanisms involving temperature, electric field or magnetic field, etc. as a result of some coupling in their constitutive equations. The most celebrated smart materials are briefly described below:

Shape Memory Alloys (SMA) allows one to recover up to 5 % strain from the phase change induced by temperature. Although two-way applications are possible after education, SMA is best suited to one-way tasks such as deployment. In any case, they can be used only at low frequency and for low precision applications, mainly because of the difficulty of cooling.

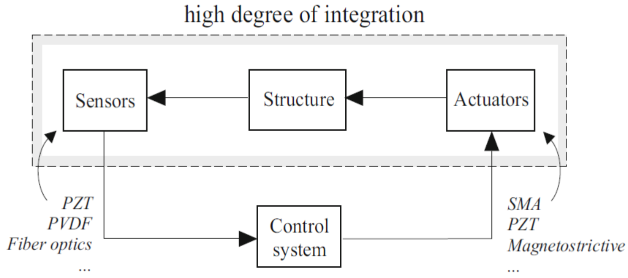

Fig. 1. Smart Structure

Piezoelectric materials have a recoverable strain of 0.1 % under electric field; they can be used as actuators as well as sensors. There are two broad classes of piezoelectric materials used in vibration control: ceramics and polymers. The piezopolymers are used mostly as sensors, because they require extremely high voltages and they have a limited control authority; the best known is the Polyvinylidene Fluoride (PVDF or PV F2). Piezoceramics are used extensively as actuators and sensors, for a wide range of frequency including ultrasonic applications; they are well suited for high precision in the nanometer range (1nm = 10−9m). The best known piezoceramic is the Lead Zirconate Titanate (PZT); PZT patches can be glued or co-fired on the supporting structure.

Magnetostrictive materials have a recoverable strain of 0.15% under magnetic field; the maximum response is obtained when the material is subjected to compressive loads. Magnetostrictive actuators can be used as load carrying elements (in compression alone) and they have a long lifetime. They can also be used in high precision applications. The best known is the TERFENOL-D; it can be an alternative to PZT in some applications (sonar).

Magneto-Rheological (MR) fluids consist of viscous fluids containing micronized particles of magnetic material. When the fluid is subjected to a magnetic field, the particles create columnar structures requiring a minimum shear stress to initiate the flow. This effect is reversible and very fast (response time of the order of millisecond). Some fluids exhibit the same behavior under electrical field; they are called Electro-Rheological (ER) fluids; however, their performances (limited by the electric field breakdown) are currently inferior to MR fluids. MR and ER fluids are used in semi-active devices.

3. OBJECTIVE OF WORK

1. To study damping characteristics of Piezo Materials
2. To find out the optimum effective positions of actuator and Control in Al & Composite Plates.
3. To study the effect of Piezo materials on Composite plate (Glass Fiber).
4. To detect the damages such as debonding between substrate and piezo-patches delamination between the interfaces of substrate.
5. To validate the Software results with experimental work for Cantilever Plate.

4. Methodology

Methodology includes mostly trial and error strategy.
First the results are obtained in ANSYS for:

1. Measure the vibration at different locations of the plate.
2. Patch the piezoelectric actuators at different locations to find out the optimum locations where we get proper vibrations.
3. Control the vibrations at different locations by using piezoelectric sensor.
4. Find out the optimum place from where we can damp maximum vibrations.
5. Also the voltage and frequencies are varies from 200Hz to 400Hz.

The same has to be done in Experimental Analysis.

5. SOFTWARE WORK

For the software work the Plate is modeled in ANSYS. Element Used are 20 nodded SOLID 186.

1. The Piezo patch is modeled at 30mm increasing distances from the free end , the voltage is applied at another points placed at equidistance's from the fixed end. The vibrations are measured at varying voltage of actuator & the response is recorded.
2. In this phase the piezo patches also actuated in reverse direction so as to produce the reverse Vibrations to damp the vibrations created by actuator.
3. The graphs are plotted for comparing controlled and uncontrolled deflections.

6. EXPERIMENTAL SETUP

The standard experimental setup for the active vibration control consists of several parts described below:-
Aluminum Plate- This is the object on which the experiments are done and our findings will be based. It is a simple beam with a certain density and strength and dimension (300×200×2) mm.

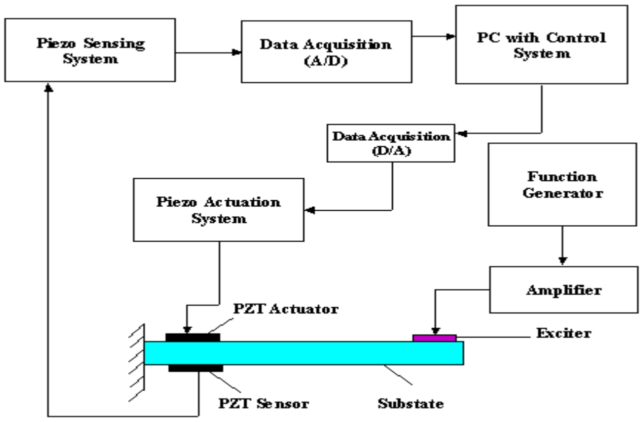

Fig. 2. Experimental setup

The aluminum and Glass fiber Plate (substrate) is fixed at one end on the set table and other end is hanging freely hence is a cantilever beam, from the end we will give under control vibration and this is accomplished by using a exciter the function of the exciter is to produce under control vibration on the beam and the nature of the vibration will depend upon the input signal form the function generator, Vibration produces deflection in the Plate which is maximum at the free end, and to measure this deflection at different Locations of Plate Sensors are used to sense the vibration, it is very accurate and can record even the smallest deflection which is produced in the plate.

7. CONCLUSION

The simulation of active control of forced vibration in composite cantilever beam is done using ANSYS 16.0 FEM tool. The Piezoelectric material can be a good Damping material for Plates applications. They produce a good control over the vibrations. The high frequency can be harmful for Piezo patches as we go from the fixed end the amplitude of vibrations vibrations goes on increasing, and so as the Control of Piezo Materials.

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