Analysis and Study of Active Vibration Control of Piezoelectric Smart Beam

Jincy J S¹, Ance Mathew²

Department of Civil Engineering, St Joseph’s College of Engineering and Technology
Palai, Kerala, India

Abstract Numerous attempts have been made to reduce the unwanted vibration in structures as vibration may cause damage to a structure or degradation of a system’s performance. Such reduction of vibration can be accomplished by using either active or passive methods. Active methods need an actuator. Piezoelectric materials are used in active damping as well as in passive damping. In this study, vibration control of structures using piezoelectric materials where only active vibration control techniques have been considered. The vibration control of beam is considered as an important engineering problem because it will enhance the stability of the system. In this paper conducted on the active vibration control method of beam using smart material. As piezoelectric materials are low cost, light weight and easy to implement materials so control the vibration of structures using piezoelectric smart materials used. Introduction of analytical software package (Ansys) is also discussed here for the modeling of smart beam structure. Also comparative study of Ansys results and experimental results.

Keywords — Piezoelectric materials, Actuator, Ansys

I. INTRODUCTION

Vibrations in structures are inherent in nature. But, these vibrations are not always desirable. Especially, in rockets, aircrafts, medical field etc. In such cases it is necessary to control these vibrations as they may cause large variations in the output and also it may cause disturbance to the users. A smart structure involves distributed actuators, sensors and one or more micro -processors that analyse the responses from the sensors and use integrated control to command the actuators to apply localized strains or displacements to alter system response. A smart structure involves four key elements: actuators, sensors, control strategies and power conditioning electronics. The vibration control of beam is considered as an important engineering problem because it will enhance the stability of the system. The smart plate consists of rectangular aluminium beam modelled in cantilever configuration with surface bonded piezoelectric patches. In this case, disturbance is produced using exciter. The piezoelectric sensors are used to detect the vibration. Simultaneously, feedback controller sends correction information to the actuator that minimizes the vibration. The study uses ANSYS software to derive the finite element model of the smart plate.

II. SCOPE AND OBJECTIVES

The purpose of this study is to focus on the application of piezoelectric material to control the vibration of the structures. The study presents an active vibration control technique applied to a smart beam. Objectives of the research are as follows:

- Introduction of analytical software package (Ansys) is also discussed for the modeling of smart beam structure.
- Analysis of smart beam bonded with piezoelectric materials using ANSYS software.
- Comparative study of Ansys results and experimental results.

III. LITERATURE REVIEW

A. Kumar, et al, (2007): The linear quadratic optimal control algorithm is proposed here to design active control system for buildings against earthquake excitations. Full-state feedback system has been adopted. Active Tuned Mass Damper is used as the control mechanism. The efficiency of the designed system has been verified against El-Centro earthquake. Active control gives 35% more reduction in vibration of the structure than passive control.

Deepak Chhabra, et al, (2011): The present work considers the active vibration control of beam like structures with laminated piezoelectric sensor and actuator layers bonded on top and bottom surfaces of the beam. A finite element model based on Euler-Bernoulli beam theory has been developed. The contribution of the piezoelectric sensor and actuator layers on the mass and stiffness of the beam has been considered with modelling of entire structure in a state space form.

Hojjat Adeli (2008): In this paper next big step in building automation will be development of smart structures and its integration with an automated building environment. Here, strategically placed sensors monitor the health of the smart structure under different loading conditions such as winds and earthquakes and properly designed actuators apply internal forces to compensate for the destructive forces of the nature. Juntao Fei (2005): This paper presents results on active control schemes for
vibration suppression of flexible steel cantilever beam with bonded piezoelectric actuators. The PZT patches are surface bonded near the fixed end of flexible steel cantilever beam. The dynamic model of the flexible steel cantilever beam is derived.

K.B.Waghulde et al, (2011): The objective of this project was to find the optimal location of sensor/actuator pairs and design optimal controller for beam, plate and stiffened plate to suppress mechanical vibrations theoretically and experimentally. The finite element method will be use to model the structure with piezoelectric material.

IV. MODEL DESCRIPTION

The following are the specifications of a model Ansys analysis.

Young’s modulus for the passive portion (Aluminium beam)
is (E) =69GPa. The poison’s ratio of the beam is taken (μ) =0.33 and the density of the aluminium beam is 2710 Kg/m³. The damping coefficient of the aluminium was taken as 0.0004. The dimension of the passive part (aluminium beam) is (300×25×2.5) mm x mm x mm and dimensions of the Piezoelectric patch is (15×15×0.5) mm x mm x mm.

V. ANALYSIS OF PIEZOELECTRIC SMART BEAM

Software analysis of smart beam is carried out using ANSYS to determine position and size of the actuator and sensor. In the modeling first the passive block was created and then the two patches were placed over it. The block is made of the material-1(SOLID45) and the two patches are of same material-2(SOLID5). Meshing is the process to divide the whole matrix in small-small parts which is done on the two types of materials. As a result we can get the exact amount of force, displacement etc. for each small part and the result become more accurate. At fixed portion of the beam degree of freedom was made to be zero. Then frequency in 100 sub-steps (0.0 Hz to 100.0 Hz) would be given. The damping constant ratio for aluminium is 0.0004. A constant force of 10 N on the middle node of the cantilever edge was applied. The direction of the force is positive Z direction. The maximum displacement value is 0.0027 m. The value of maximum shear stress is 0.26×10⁸ N/ m².

Based on the different values of stiffness different vibration patterns are available in Ansys. Stiffness value increases vibration control also increases.
From the finite element analysis the location where the maximum value of shear stress is obtained was determined. From this, the optimal location of the sensor and actuator was found by taking into consideration the clamping area.

VI. COMPARATIVE STUDY OF ANSYS RESULTS AND EXPERIMENTAL RESULTS

The cantilever smarty beam will be under control vibration at its free end. The nature of the vibration will depend upon the input signal form the function generator, whatever will be the nature of the waveform similar kind of vibration will be produced in the beam. The exciter has set the frequency between 1Hz to 1KHz the frequency is high but the amplitude of the wave form is very low to produce any noticeable vibration in the beam hence an amplifier is used to amplify the signal.

On doing the modelling of this experiment in ANSYS we computed the area of stress formation an interesting observation which was made was that the maximum stress which was developed in the beam was not where it was clamped, it was little away from it. Therefore the sensor and actuator are attached little away from the fixed end. The set up is as shown in figure 5. The sensor will produce the correct voltage only here as the current developed is directly proportional to stress hence we will get the maximum current here. The actuator which is responsible to produce opposite stress in the beam is also located at the location of maximum stress formation so that it may control the vibration more efficiently. An oscilloscope can be attached to the sensor and the actuator to monitor in the oscilloscope and the pattern of wave formation can be noted down.
Active vibration control of a cantilever smart beam is considered both experimentally and numerically in this study. A contactless moving load mechanism and contactless vibration measurement system are used in the experimental study. The simulation of the closed loop vibration control with displacement feedback is achieved by using a commercial finite element package. The piezoelectric elements that actuate the beam to suppress the dynamic response are used in the experimental system and are modelled by a commercial finite element package for the numerical analyses. Residual vibrations of the smart beam are suppressed successfully by proportional control. The simulated and experimental results are in very good agreement. The design of active vibration control of more complex structures can be achieved with the programmable finite element packages, which enable us to use active elements. The finite element analysis package ANSYS is used successfully to design a suitable vibration control strategy. The simulation results agree well with the experimental results.

VIII. CONCLUSIONS

- Introduction of analytical software package (Ansys) is also discussed here for the modeling of smart beam structure. This survey will give an introduction to a new researcher in this field to different published papers at a single glance.
- Piezoelectric materials have major role in active vibration control and ANSYS software provides a means for FE modelling of smart structures, coupled field analysis and closed loop control actions can be simulated by integrating control laws into the ANSYS.
- The vibration control of beam is considered as an important engineering problem because it will enhance the stability of the system.
- In this paper a review on the active vibration controls method of beam using smart material as piezoelectric materials are low cost, light weight and easy to implement materials

REFERENCES