Active Vibration Control of Cantilever Beam Using Piezoelectric Patches

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Abstract- *These 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 composite structure is referred to as smart-structure. In this paper the way in which piezoelectric actuators couple into, and excite a beam are briefly reviewed. The position of the PZT sensor and actuator is found out by using ANSYS. The Active Vibration control of cantilever beam is done by using PZT patches as sensor and actuator. Firstly the readings are taken when sensor position is at top and actuator position is at bottom of beam and then vice versa. PID and Strain rate feedback controller is used to suppress the vibration which will give the effectiveness of controller. After experimentation it was found that SRF has good effectiveness and sensor at top position gives better results than at bottom.*

Keywords- Active Vibration Control, PZT, Piezoelectric Effect, Piezoelectric Sensor, Piezoelectric Actuator, PID, SRF controllers

I. INTRODUCTION

The control over the mechanical and structural vibrations is important in most of the fields. In manufacturing, where mechanical vibration degrades both the production rate and the quality of the end products; in civil engineering, where structural vibration affect human comfort; in automotive and aerospace field, where vibrations reduce component life and generate annoying noise.

A. Passive vibration control

Different approaches have been applied to suppress or reduce unwanted vibrations in the engineering field. Traditionally, isolators and passive dampers are used to attenuate mechanical vibration, leading to so called passive vibration control. Recent advances in digital signal processing and sensor and actuators technology have prompted interest in active vibration control.

One of the basic methods of vibration isolation is stopping the waves coming from the source to the object. As per the practical perspective, two methods are used: force vibration isolation and displacement vibration isolation. The main motive of the former is the isolation of the dynamic force generated by the object and transmits it to the ground. In displacement vibration isolation, the vibration suppressing system has to isolate the object from the source of the undesired dynamic displacement which is coming from the ground. From the other views of energy supply, the control mechanisms and technical measures applied in any specific implementation, the two groups of vibration reducing systems are induced like: passive methods group and active methods group. In passive methods which suppress the vibration uses the following:

- Prevention of vibration occurrence,
- Modification in different parameters,
- Modification in structural design,
- Vibration isolation.

In case of these methods energy scattering or periodical storage and producing energy occur. Passive methods have low capacity for reducing vibration in the range of low frequencies, sensibility to operating condition changes etc.

B. Active vibration control

Better results can be obtained using the active vibration control methods, which amount to structural changes or parametric changes using external source of power supply. These methods solve the problem such as high machine efficiency, low vibration level, dynamic stability and rigidity. In active methods properly controlled source of external power can take or give energy, in a specific way, from different parts of the machine. The drive (hydraulic, pneumatic, and electric) added to the vibration isolated object generates opposite force to the unwanted dynamic displacement. The control strategy of the force generator set by controller is based on information about the system coming from the sensor. The measurement system which gives the system the specified force to damp the vibration includes transducers, amplifiers and pre-equalization elements. The energy supply in active methods, a number of vibration reducing systems are additionally differentiated, like passive, semi active, hybrid and adaptive systems. From the point of view of the drive, hydraulic, electromagnetic pneumatic, and hybrid active vibration isolation systems are differentiated.

A typical active vibration control system is integration of mechanical and electronic components with computer controlled. The main components of active vibration control system are mechanical structure introduced by the disturbance (creating unwanted vibrations), the sensors (to perceive the vibration), the controller (to intelligently make use of signal from the sensor and to generate the appropriate control signal, and the actuator (to damp the disturbance of the structure). Destructive interference, from the influence of actuator, suppresses or attenuates the unwanted disturbance on the structure. Different methods of active vibration control system are developed and which are classified in the following two categories:-

1- Feedback active vibration control
2- Feed forward active vibration control

Amongst these two main categories, variation exists, each have their different advantages, disadvantages and applications.

C. Vibration measuring technique

a) Time domain analysis

Time domain analysis uses the history of the signal or the wave form. The signal which is stored in an oscilloscope real time analyzer and any non-steady or transient impulse is noted. For example the damage such as broken teethes in gear cracks in outer or inner races of the bearing can be identified easily from the waveform of the casting of gear box using time domain analysis.

b) Frequency domain analysis

Most rotating machine train failures result at or near the frequency component associated with the running speed. So the ability to display and analyze the acoustical spectrum as components of frequency is far important.

Using frequency domain analysis, the average spectrum for a machine train signs can be obtained. Recurring picks can be normalized to present an accurate representation of the machine train condition. The real advantage of frequency domain analysis is the ability to normalize each acoustic component. This ability simplifies isolation and analysis of mechanical damping within machine train.

II. LITERATURE SURVEY

In “Spacecraft vibration suppression is done using the variable structure output feedback control and smart materials” Qinglei Hu and Guangfu Ma had studied that the vibration reduction is critical problem related to manufacture of floatable spacecraft which employs large flexible structures which are light in weight and have relatively low damping for the fundamental and initial models. Also, the frequency related with these models are low, the vibration controls of nodes becomes an important issue in satellites and other large spacecraft structure.

Active vibration control has been used as a solution for flexible spacecraft’s to achieve the degradation of vibration or suppression for required precision and accuracy. Negative feedback control system is the effective method for active damping which is the greatest power against the destabilizing effects of spillovers. A second critical problem arises that model uncertainties of the flexible spacecraft is governed by partial differential equation as a system of distributed parameters and therefore possesses an infinite number of dimensions , which make it difficult to control. The paper explores the availability of the variable structure output feedback control (VSOFC) approach to flexible spacecraft for large angle rotational moments with active vibration control using piezo-ceramics. There are three control algorithm viz. constant gain negative velocity feedback controls, positive position feedback, linear quadratic Gaussian control. The goal of design is to achieve good robustness and distribution rejection, which can be achieved during sliding phase. Therefore, the sliding surface should be large as possible, the reaching time should be small and the boundary should also be small. A generalized scheme bound or variable structure output feedback control and altitude controller VSOFC acting on hub and design of independent flexible control system using piezo-ceramics. Three different algorithms namely GNUF, PPF & LOG control are designed acting on flexible appendage and both simple and multimode vibrations are studied.(1)

Jaques Lottin et.al. studied the work deals with the problem of efficient location of sensors and actuators encountered in the domain of active vibration of flexible structure. The optimum solution depends on the control scheme. Usage of the “optimal” before the word location means that there is a criterion that allows the comparison between several situations in order to determine the best choice. Complications occur in the problem like several criteria must be considered simultaneously, one for the sensors, one for actuator and one for the quality of rejection along the beam and models are complex because of their large size and it is not always possible to get an optimized solution. To illustrate the influence of actuator and sensor location, we consider particular criteria called deg5, computed by stimulation experiments were carried out on a fixed-free steel beam where the input was a force and output was position. Dynamic behavior was found to be changing according to the sensor and actuator position as their mass was taken account into while building a model. [2]

Deepak Chhabra et.al. studied the Active Vibration control of beam like structures with distributed piezoelectric actuator and sensor layers bonded on top and bottom surfaces of the beam. The patches are located at the different positions to determine the better control effect. The piezoelectric patches are placed on the free end, middle end and fixed end. The study is demonstrated through simulation in MATLAB for various controllers like Proportional Controller by Output Feedback, Proportional Integral Derivative controller (PID) and Pole Placement technique. A smart cantilever beam is modeled with SISO system. The entire structure is modeled using the concept of piezoelectric theory, Euler-Bernoulli beam theory, Finite Element Method (FEM) and the State Space techniques. By using pro-posed method numerical simulation showed that the sufficient vibration control can be achieved. The present work which deals with the mathematical formulation and the computational model for the active vibration control of a beam with piezoelectric material. The basic scheme of analyzing and designing piezoelectric insolent structures with the control laws was positively developed by the study. It has been observed that without control the fleeting response is prime and with control laws, sufficient vibrations reduction can be achieved. Numerical simulation showed that exhibiting a smart structure by including the sensor / actuator mass and stiffness and by varying its position on the beam from the free end to the fixed end presented a considerable change in the system’s mechanical vibration characteristics. From the responses of the various locations of sensor/actuator on beam, it has been observed that best enactment of control is obtained, when the piezoelectric component is placed at fixed end position.(3)

Yavuz Yaman etal. studied the smart plate which consists of a rectangular aluminum plate modeled in cantilever shape with surface bonded piezoelectric sensor and electric patches. The patches are proportionally bonded on the top and bottom surface now using ANSYS, a model is prepared and experiments are conducted with it to find out the effects of actuator location and size on the response of smart plate and determine the maximum allowable piezoelectric voltage. Now the various parameters are discussed which will be affecting the response of the smart plate. The actuators was BM 500 and HS having dimensions as (25*25*0.5), it was used on aluminum plate, the actuators are placed using modal analysis and same divided patches are expected to be bonded correspondingly on top and bottom. Now to find the effect two cases were considered, the placing of the patches is in x-y co-ordinate system and they are changed while keeping the distance between them constant. As the patches are placed near the root (y=0), retort increases. But when the patches are moved in x-direction then there is no palpable change in response. The effect of increase in size of actuator on the response are examined in terms of change in convergent ratio, which is defined by the ratio of the area converged by piezoelectric sensors. The piezoelectric actuator of 300 V is provided and it is found that increase in size increases the energy transmitted to the smart plate giving rise to the retort for the specified piezoelectric actuation value. It causes to increases the stiffness of the plate. Maximum allowable piezoelectric actuation-Piezoelectric materials are malicious and have tensile strength in order of 63 MPa. Therefore the stress in the actuators can be critical in contrary applications. In order to determine the maximum possible piezoelectric actuation valve, the von mises stresses developed in the actuator should be inspected previous to the operation. It was found to be of the order of 1 MPa. For normal operation (200-300 V), the piezoelectric is not expected to fail. (4)

S.Raja et. al. searched the shear actuator induce distributed force/moments in the sandwich beam in contrast to the extension-bending actuators, which develop only concentrated force/moment and is found more efficient in actively controlling vibration. Actuator thickness & position play an important role in deciding the performance. The leeway-bending actuator yields more oblique deflection than the shear actuator. So the author had observed that soberly thin shear actuators was found to be more effective and also the face covered thickness has a significant effect on the efficiency of the shear actuator. (5)

R. Setola (Italy) studied the reconstructs uses a spline shaped function to intercalate the obtainable measurements and to take into account the boundary condition. The spline functions announce a kind of 3-D filtering on the high frequency mode and thus increase the sturdiness of the control scheme against spillover. Reconstruct to a suitable controller is able to reduce vibration of beam exposed to tenacious multi-frequency trouble acting at unknown beam abscissa. Thus by using this we can reduce the noise created by the flexible structure when they are excited by some external pseudo-periodic cause.(6)

Te“o Lenquist da Rocha studied the active Vibration control by smart material technology is increasing day by day. To obtain enhanced control enactment, actuator and sensor must be placed at positions to excite the favorite mode more excellently. It may be demonstrated by finite element method using MATLAB, ANSYS etc. H norm each sensor and actuator location is determined for selected modes of plate and calculated using linear matrix disparities technique. PZT elements are positioned at the optimal location using two first mode of structure. (7)

Zeki KIRAL et.al. studied the dynamic response of the beam is calculated by using the finite element method in order to design a suitable control method and numerical results are verified by vibration measurements.Two laser displacement sensors are used to ration the active response of the beam The poignant load is obtained by stressed air directed to the beam vi nozzle. In this case the suppression of the remaining vibration that occurs after the moving load has left the beam is measured as main subject. Active vibration control of a cantilever smart beam is considered both experimentally and numerically. The simulation of closed loop vibration control with displacement feedback is achieved by using a commercial finite element package. (8)

C Mei searched that due to demand for mechanical structures to be lighter and faster, there has been increasing attention in Active vibration control in recent years. In this paper, a hybrid approach consisting of balancing wave and mode-based control was described on Timoshenko theory. In modal Active Vibration Control, the aim was to control the features of modes of vibration like their damping factors, natural frequency or mode shapes. Active wave control purposes to control the delivery of energy in structure by whichever reducing the transmission of waves from one part of the structure to another or by gripping the energy carried by other waves. In proposed hybrid approach, wave control was first designed and is embattled at higher frequencies. Two control plans, one optimally absorbs the vibrational energy and the other adds optimal damping to structure. Modal control is then designed for the lower modes of structure based on adapted equation of motion of structure-plus-wave-controller. After the application of wave control, the equation of motion of the system is improved. Hybrid method displays better broadband active vibration control act than the cases with either modal or wave control alone. While control design based on the classical Euler-Bernoulli model theory is only appropriate to slim beams, the present design created on the advanced Timoshenko model is suitable for deep as well as slim beam elements.(9)

Chih-Liang Chu et. al. investigated the Active vibration control of a flexible beam mounted on an elastic base. Beam system is analyzed using a finite element method. The study uses the independent modal space control (IMSC) method for active control of a flexible beam maintained on elastic base. Basic principle of IMSC method is that it converts the coupled system dynamic equations into the decoupled modal space and thereafter smears a process of response control to each decoupled mode. In order to improve analysis accuracy the study reflects Timoshenko beam theory for system examined. The system equation were first uttered as state-space equations then decoupled. The IMSC method uses the characteristics of left/right modal conditions, R & L, to decouple a coupled system. The modal control force were found from control design in modal space. The analysis using the Timoshenko beam theory is inspected with a total of 32 finite elements being used. Numerical results are likened with those obtained using ANSYS. The proposed control strategy is not only proficient of controlling a single vibration mode, but also two modes while using one actuator.(10)

Juntao Fei told that the considerable attention has been devoted recently to active vibration control using intelligent resources as actuators. His paper presents results on active control systems for vibration conquest of flexible steel cantilever beam with attached piezoelectric actuators. The PZT patches are surface attached near the fixed end of flexible steel cantilever beam. The dynamic model of the flexible steel cantilever beam was consequent. Active vibration control methods, such as enhanced parameter PID compensator, strain rate feedback control were examined and implemented using xPC Mark real time system. Experimental results prove that the proposed methods attain active vibration suppression results of steel cantilever beam.(11)

Yavuz Yaman et. al. has studied presents an active vibration control technique applied to a smart beam. The smart beam consists of an aluminum beam modeled in cantilevered shape with surface bonded piezoelectric (PZT) patches. The study used was ANSYS (v5.6) bundle program. The study first examines the effects of element selection in finite element modeling. The effects of the piezoelectric patches on the timbre frequencies of the smart structure were also shown. The developed finite element model was reduced to a state-space form appropriate for a controller design. The work then, by using this abridged model, presents the design of an active vibration controller which effectively suppresses the vibrations of the smart beam due to its first two flexural modes. The vibration suppression is achieved by the application of H∞ managers. The efficacy of the technique in the modeling of the uncertainties is also presented.(12)

K. B. Waghulde et. al. studied the vibration of a smart beam is being controlled. This smart beam setup is included of actuators and sensors located at the origin of a cantilever beam. Vibrations can be caused by numerous sources including human activity and nearby motorized tackle. In this case, disturbance was produced using a white noise signal to the actuator. The piezoelectric sensors were used to notice the vibration. Concurrently, feedback controller sends correction information to the actuator that reduces the vibration. To optimize results, controllers were intended using Linear Quadratic Gaussian (LQG) theory. This theory usually results in high-order controllers. Moreover, optimal control theory is being used to straight optimize low-order controllers. A smart beam was built using a Lucite beam, PZT actuator, and PVDF sensor. A dSPACE controller card was installed and combined with related electronics to generate an active control setup. Experiments were conducted to control the Vibration response to broadband trouble. A 30% reduction in 1st -mode vibration response was attained. Added focus onto the first mode is one way to advance results. Further focus on the first mode will allow the creation of improved controllers over more accurate models of best fit. This research has affected just the tip of the iceberg in vibration control. As this experiment has come to an end, various chances for expansion have been identified. This experiment hints well into many applications of aerospace and structural engineering. Whether used in airplane wings, helicopter propellers, or any type of slim beam where vibration is an obstacle that has to be overcome active vibration control using smart material is everywhere.(13)

Pradeep Kumar Sharma and Sankha Bhaduri told that the purpose of this study is to focus on the application of piezoelectric material to control the vibration of the structures. Piezoceramics are low cost, light weight and easy to implement materials which can be applied to minimize the amplitude of structural vibration. The basic principle of piezoelectric actuation is also discussed in this study. Piezoceramics are applied as sensor or actuators or in both form of sensor and actuators by different authors. It is available in various forms such as rigid patch, flexible patch, stack etc. In this study an attempt has been taken to discuss the application of various form of piezoceramics for active control of structural vibration. The vibration control of beam is considered as an important engineering problem because it will enhance the stability of the system. In his paper a review is 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 therefore many authors attempted to control the vibration of structures using piezoelectric smart materials. They studied the behavior of piezoelectric materials under the influence of externally applied forces and electric current as well. Different methods of active vibration control using piezoelectric patches are discussed in his paper. 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.(14)

III. METHODOLOGY

The methodology used in the presented work is explained in in steps as below:

A) *Objectives:*

1. To control the Vibrations of cantilever beam by using PZT patches.
2. To find-out the suitable controller for effective vibration control of cantilever beam with minimum control input.
3. To find out the effectiveness of system when sensor placed at top and actuator at bottom and vice versa.

B) *Problem Statement:*

The control of mechanical and structural vibrations is important in many fields. In manufacturing, where mechanical vibration degrades both the production rate and the quality of the end products; in civil engineering, where structural vibration affect human comfort; in automotive and aerospace field, where vibrations reduce component life and generate annoying noise.

An Active vibration control system is to be used as smart beam. For the effective vibration control with minimum control input and optimized size of PZT patches is to be finding out. To find out the effective controller system by using PZT patches.

C) *Analysis of Cantilever Beam:*

For the theoretical analysis I used ANSYS software. In this analysis vibration analysis of cantilever beam with and without PZT patches is took place. By changing the thickness of PZT patch I have selected the optimum size of PZT patch.

a) *Dimensions of the Beam*

i. Dimensions of the Beam

	Beam (mm)	**Sensor (mm)**	**Actuator (mm)**
Length	300	20	20
Width	25	20	20
Thickness	5	1	1

b) *ANSYS Elements Used*

The complete assembly is model using ANSYS Element Types as follows:

ii. Elements types used

Element Type No	Element	ANSYS Element	Part Modeled
1	3-D Solid	8 Node 185	Cantilever Beam
2	3-D Solid	8 Node 185	PZT patch

c) *System of Units:*

The following system of units is followed for consistence throughout this analysis and results evaluation.

iii. System of units

Sr. No.	Parameter	Units	Conversion Factor used in Analysis
1.	Length	Millimeters	1.0
2.	Force	Newton	1.0
3.	Moment	N-mm	1.0
4.	Mass	Kg	1.0
5.	Pressure, Modulus of Elasticity, Stress	N / mm ^{2}	1.0

d) *Material Properties*

The Material Properties used for all parts are as follows.

Material: Aluminum

Young’s Modulus = 70000 N / mm2.

Poisson’s Ratio = 0.34

Material: Piezoelectric (PbZrTiO3)

Young’s Modulus = 63000 N / mm2.

Poisson’s Ratio = 0.31

e) Loading (Design Condition)

The Model has been analyzed for combinations one or more of the following loads

Force Acting at the free end of beam = 10 N.

Frequency Range: 1Hz to 100Hz

f) Boundary Conditions

The boundary conditions applied on the model are as shown in the enclosed Fig.1

The model is fixed in all three directions at one end (Fx=0, Fz=0, Fy =0).

The vertical downward force at another end. (F = 10N.)

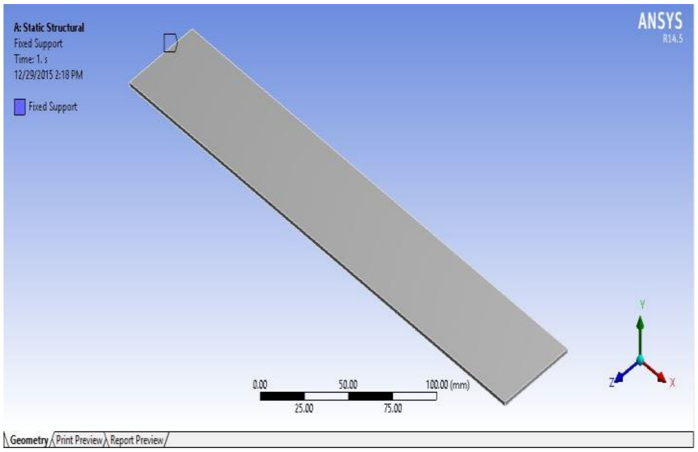
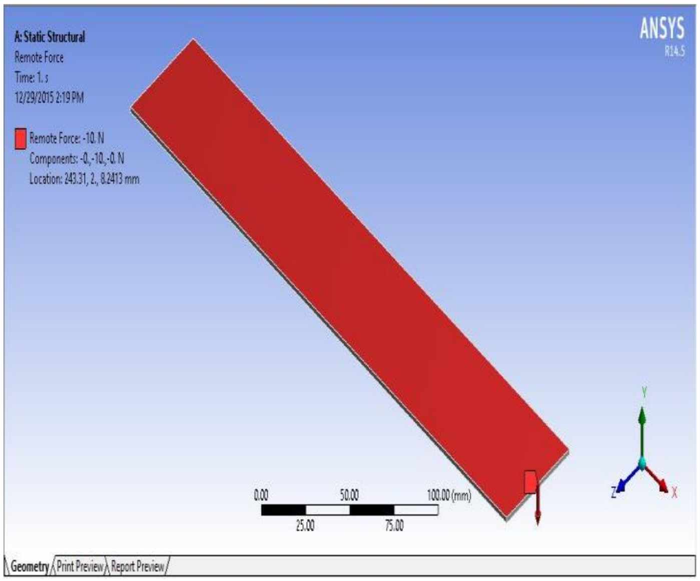

A: Static Structural
Fixed Support
Time: 1. s
12/29/2015 2:18 PM
Fixed Support

Fig.1 Cantilever model with one end Fixed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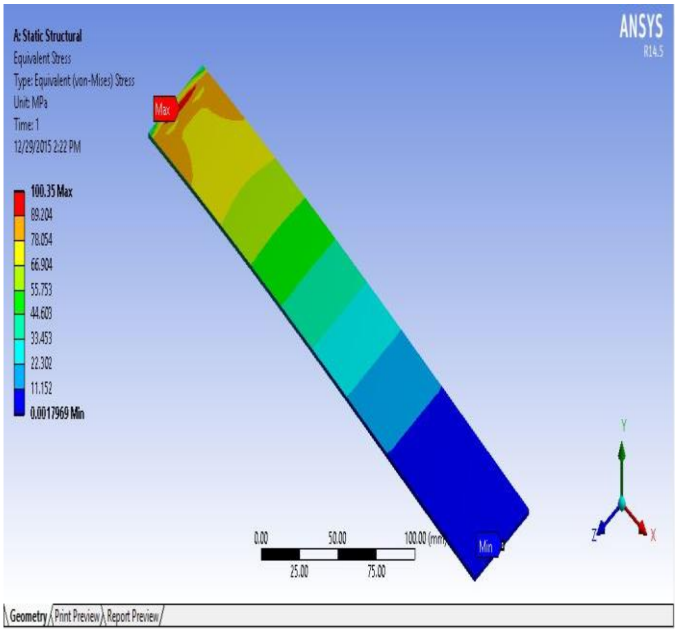
Remote Force
Time: 1. s
12/29/2015 2:19 PM
Remote Force: -10. N
Components: -0.,-10.,-0. N
Location: 243.31, 2., 8.2413 mm

Fig.2 Cantilever model with Force acting at the end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Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
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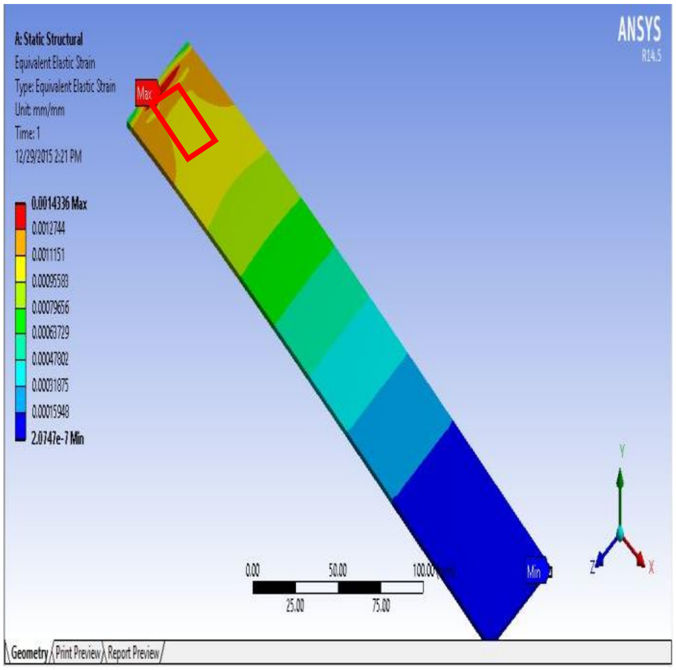
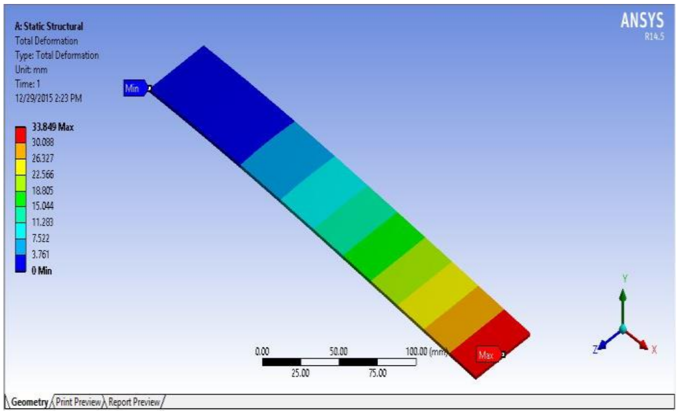
12/29/2015 2:22 PM

Fig.3 Stresses developed in the Cantilever beam model



1) Fig.4 Strain plot in the Cantilever beam model



2) Fig.5 Deflection in the Cantilever beam model

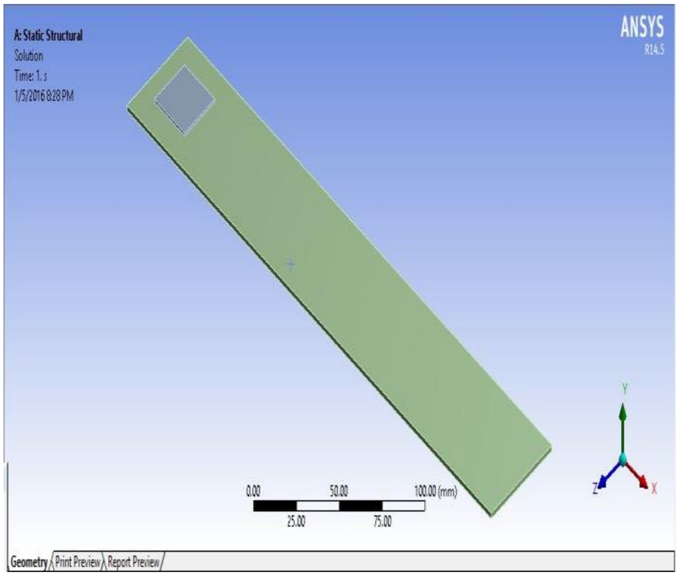


Fig.6 Cantilever beam model with PZT Patches and one end Fixed

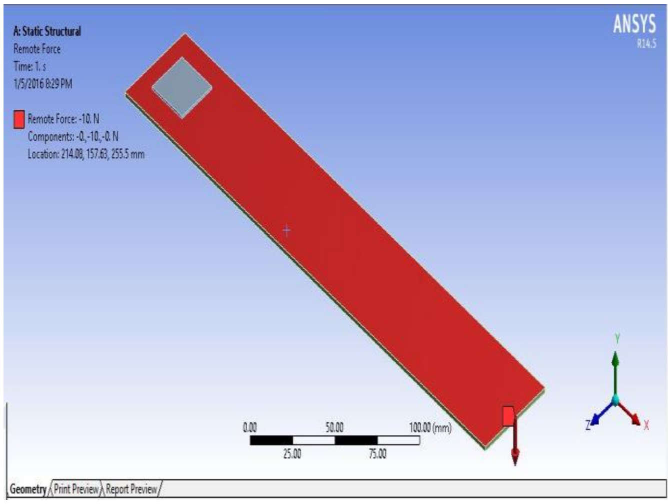


FIG.7 CANTILEVER MODEL WITH PZT PATCHES AND FORCE ACTING AT THE END

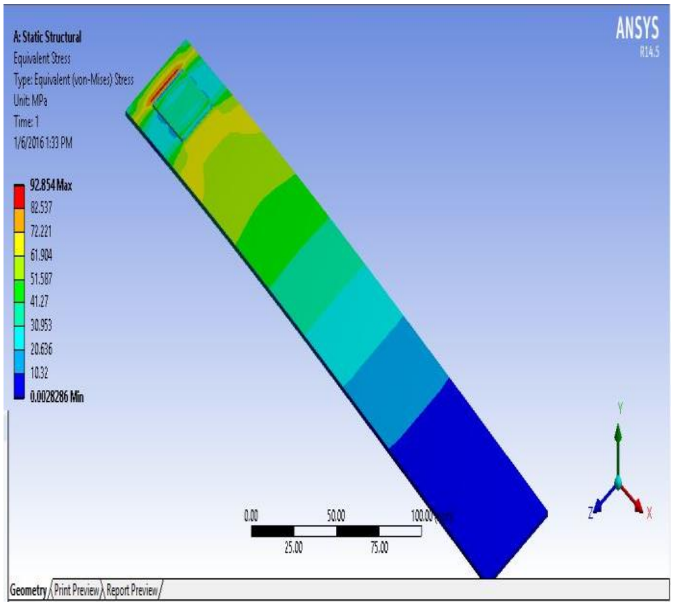


Fig.8 Stresses developed in the Cantilever beam model with PZT Patches

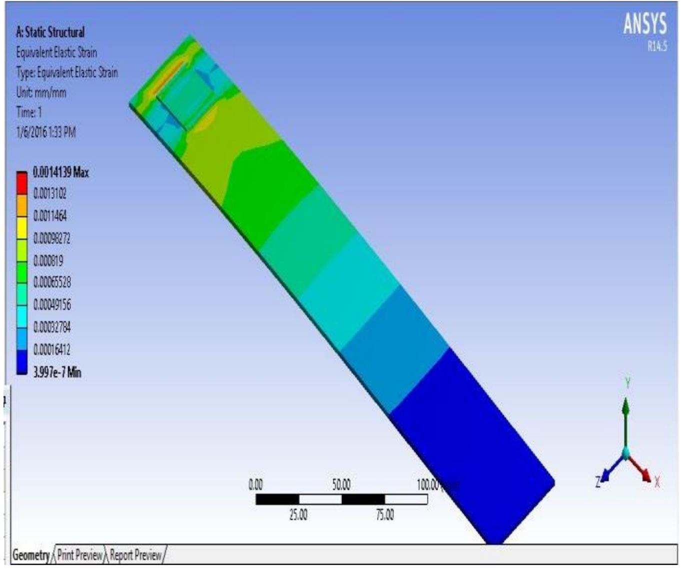


FIG.9 STRAIN PLOT OF THE CANTILEVER BEAM WITH PZT PATCHES MODEL

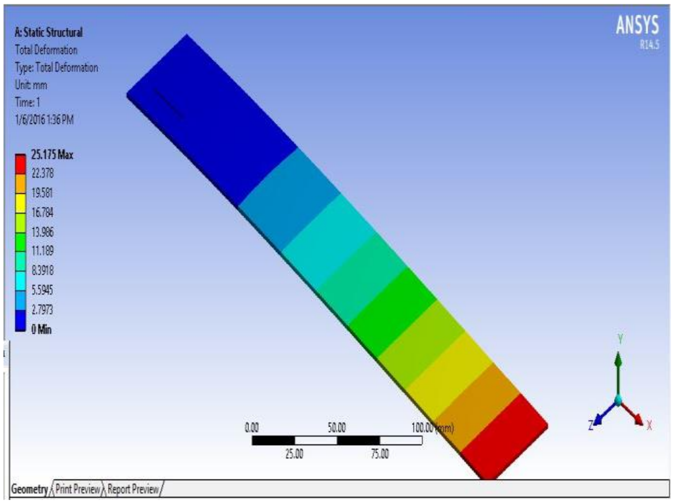


Fig.10 Deflection in the Cantilever beam model with PZT patches

g) Analysis Result

Fig. 2 shows the Cantilever beam model. One end of the beam is fixed and the load is applied at other end. The stress developed in the beam is as shown in the fig. 3. Strain in the beam is shown in the fig. 4. The maximum strain is near to the fixed end. The location where the strain is maximum is more effective area for the actuation. The patches are attached at the location shown in fig. 6. The deflection plot is shown in fig. 10.

Fig. 7 shows the cantilever beam with Patched attached to it. The same magnitude of force is applied for this model to check the effect of the patches. Fig. 8 shows the stresses developed in the beam. Strain plot is shown in the fig. 9. It is reduced at the patch area.

IV. EXPERIMENTAL SET UP

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’s 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. 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 beam vibrations.

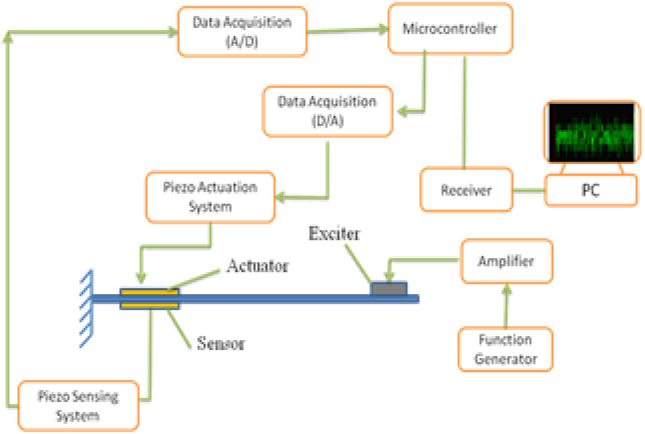


Fig. 11: Experimental Setup

The Major components are:

1. Sensor patch- It is bonded to the host structure (beam). It is generally made up of piezoelectric crystals. It senses the disturbance of the beam 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 beam. Converse piezoelectric is used.

The beam is clamped at one end using the set table hence making it a cantilever beam, 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. The excitation produces vibrations in the beam which results in the formation of shear stress in the beam, the sensor patch present at the fixed end acts to this shear stress and produces proportional electrical signals which is fed to the computer through the D/A system and finally from the computer the signal is fed to the actuator and it produces opposite shear in the beam and the entire beam is balanced. Active vibration control finds its application in all the modern day machines, Engineering structures, automobiles, gadgets, sports equipment, ceramics, electronics etc. As it needs only a little actuation voltage hence it does not requires any external power source, the power can be directly derived from the host machine itself. As the electronics is also developing at a very fast rate hence the size of a processor is also reducing, which is very useful in the design of the control system. 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 beam modeled in cantilever configuration with surface bonded piezoelectric patches. The study uses ANSYS-12 software to derive the finite element model of the smart plate. Based on this model, the optimal sensor locations are found and actual smart beam 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. Also we have taken some readings by changing the sensor position and actuator positions.

V. EXPERIMENTATION:

I. PID Controller:

PID controller is the kind of controller of which proportional gain and derivative gain can be determined based on desired specifications and dynamics of a plant. The optimized parameter adjusted PID controller is widely used in vibration suppression. The turning process can be obtained from an optimal PID control procedure. PID factors play important roles in the control effect in this experiment setting. For a given Kd = 0, the best Kp is 75. However, Kd also plays an important role, once Kd ≥ 0.02, the control effect becomes worse even the Kp is taken as 75. Therefore, the optimal combinations of PID factors are required to obtain the best vibration control result.

II. SRF Controller:

The strain rate feedback control was implemented in real time on the beam using the xPC Target system. The same low pass filter is used as in PID experiment. The mode targeted for control was the dominant frequency of 11.1Hz. The SRF-controller-damping ratio ζc was set at 0.5, controller frequency ωc was set at 11.1Hz which was set to the vibration frequency of the normal specimen, and the effectiveness of the SRF-controller at various gains was tested. The controller gain K was adjusted to be 1.1 for the consideration of maximum applicable voltage and optimal vibration suppression result.

The experiment is conducted for the PID and SRF controllers. The aluminum cantilever beam is used for vibration suppression. PZT patches are attached to the positions where maximum stress has occurred using epoxy resin adhesive. Using PID controller the beam was displaced at its tip end by 1mm downward when sensor placed at top of beam and actuator below the beam and readings were taken. Then the tip end of beam was displaced upward by 1mm with similar arrangement of sensor (up) and actuator(down) and readings were taken. Similarly the sensor and actuator positions were exchanged and readings were taken for down and up displacement of beam at tip. The same procedure was carried out using SRF controller. The graph was plotted using the arduino 1.6.7 software with serial plotter and also the graph can be saved with the help of the serial oscilloscope software with baud rate of 9600. It is tested for the effectiveness of the sensor and actuator positions on the upside and downside of the beam. For both controllers sensor and actuators are interchanged for taking results. Results are recorded for taking actuation time. The time is considered for 70 % of the suppression.

Fig 12 shows the vibrations induced in the beam due to displacement of the free end and the suppression of the vibrations due to the controlling action of PID controller. While fig13 shows controlling action of the SRF controller.

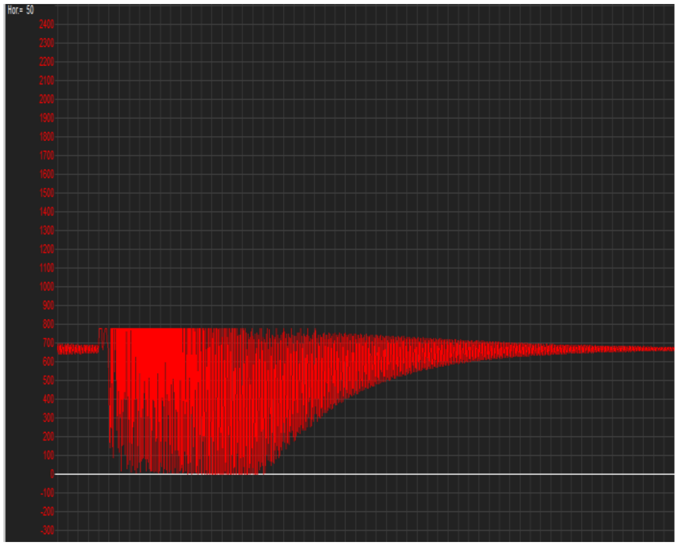


FIG. 12 VIBRATION PLOT OF THE BEAM WITH PID CONTROLLER

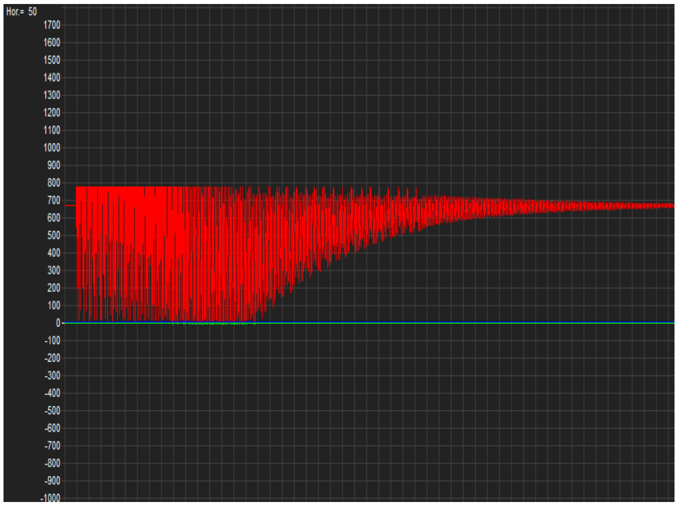


FIG. 13 VIBRATION PLOT OF THE BEAM WITH SRF CONTROLLER

iv. Result Table

Readings	PID		SRF	
Displacement By 1mm	Top Sensor	Bottom Sensor	Top Sensor	Bottom Sensor
Push Up	21sec	21 SEC	20 SEC	20 sec
Push Down	16sec	17 sec	15 sec	15 sec

Result table shows that the Time taken for the 70 % of suppression of the vibration. The sensors at top and the sensors at bottom are tested for optimized position. The sensor at top and actuators at bottom gives better results. The SRF control method is more effective than the PID control method.

VI. CONCLUSION

The active vibration control of cantilever beam is done by using PZT patches in this paper. It is concluded that the SRF control method is more effective than the PID control method. The sensors placed at top and sensors placed at bottom are tested for optimized position. The sensor at top and actuators at bottom gives better performance.

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