RESEARCH ARTICLE OPEN ACCESS

Finite Elelment Analysis of A Cantilever Beam Using Piezoelctric Actualtors

Kamini P. Bhavsar[1], Dr. Prashant Deshmukh[2]
[1]P.G. Student, [2]Professor
Datta Meghe College of Engineering, Sector-3, Airoli,Navi Mumbai

ABSTRACT
In this present scenario deformation is the major problem in structural design. In Aerospace and satellite objects, faces a major problem of static deformation due to many parameter uncertainties and environmental disturbances. Many researchers have studied and found that active control is frequently being used in aircraft, submarine, automobile, helicopter blade, naval vessel. The study uses ANSYS software to derive the finite element model of the beam. Analytical and Numerical results are presented to show the static and dynamic behavior of aluminum beams with piezoelectric actuators. Experimentation was also conducted to verify the analytical and numerical results. Experimentation was also conducted to verify the analytical and numerical results. The effect of the number and locations of the actuators on the control system are also investigated

Date of Submission: 27-11-2017 Date of acceptance: 14-12-2017

I. INTRODUCTION

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. Thus, two opposite forces 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 techniques”. 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 makes use of elegant structure. The system mainly requires actuators, sensors, source of power and a compensator that performs well when vibration occurs. Elegant 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.

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 proportional to the strain.
2. **Controller**- The charge developed by the sensor is given to the controller, the controller lines are charged per 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 i.e. generation of shear force along the surface of the host which acts as a damping force and helps in the alternating vibration motion of the beam.

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 require 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, the size of a processor is also reducing, which is very useful in the design of the control system.

1.1 Study on optimal location and optimal

Studies on active vibration controlling capabilities of these plates have been done. K.B.Waghulde, Dr. Bimlesh Kumar, Prof. T.D. Garse and Prof. M.M. Patil studied vibrations induced in flexible structures such as beam. They focused on various optimization functions and control theories to optimize transient response dynamic characteristics. Piezoelectric materials sensors/actuators have been used to reduce and control these vibrations [1]. J.J. Liu and B.M. Liaw have aimed to explore efficiency problems of using PZT actuators in active vibration control of beams the PZT actuators are surface-bonded as actuators and strain gages are used as sensors [2]. Waleed Khalid and Al Ashtari, describes the governing equation of the thin smart beam transverse deflection was derived by the same procedure that the Bernoulli-Euler equation derived but with some additional mathematical terms to be valid for describing the smart beam [3]. K. Venkata Rao, S. Raja and T. Munikenche Gowda studied partially debonded actuators affect stiffness and vibration characteristics of the piezoelectric beam and thus leading to degradation in actuation authority and active vibration control system [5]

II. MODEL AND HARMONIC ANALYSIS OF CANTILEVER PLATE BY USING ANSYS

The natural frequency of the aluminum beam is found by the well-known Finite Element (FEM) Software ANSYS. Modal analysis is carried out using the Block Lanczos method for finding the natural frequencies. The fixed free boundary condition was applied by constraining the nodal displacement in both x and y direction. The beam in Fig. 1, have length L, width b, thickness h and cantilever end conditions with the fixed end at x = 0 and free at x = L. It is assumed that the beam is homogeneous and constructed from a material, which essentially satisfies the Euler-Bernoulli theory for displacement. After that it is assumed that a pair of identical piezoelectric actuator is bonded to opposite sides of the beam. The Young's modulus, density for the beam and the piezoelectric are given in Table 1. The bonding layer is taken to be negligible.

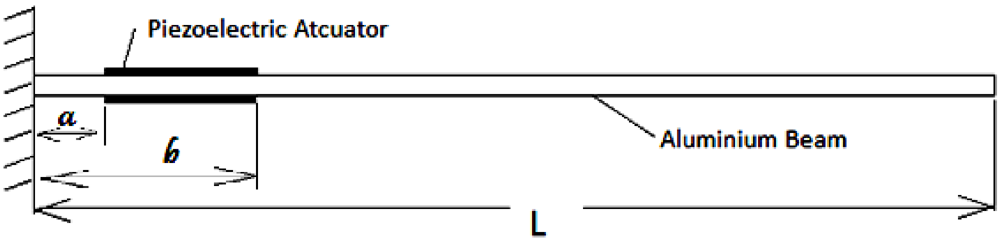


Fig.1 Schematic of Cantilever Beam With Piezoelectric Actuators

Table 1 Material Properties and Dimensions of Aluminium Beam and Piezoelectric Actuator

Dimensions/Properties	Aluminium	Piezoelectric actuator
Length	0.4 m	0.0762 m
Width	0.03 m	0.0254 m
Thickness	0.005 m	0.5x10-3 m
Density	2700 kg/m3	7600 kg/m3
Young modulus	70 Gpa	76 GPa
Poisson's ratio	0.3	0.25
Piezoelectric Stain Constant	---------	-247 x 10-12 m/V

To obtain frequencies of different modes. For the first two modes the values of are calculated as 1.875, 4.694.

$$\omega = (\beta l)^2 \sqrt{EI/\rho A L^4}$$

Finite Element Analysis for First Two Natural Frequencies of Aluminum Beam without Piezoelectric Actuators

Mode	**f_n Analytical(Hz)**
1	25.651
2	162.887

Finite Element Analysis for First Two Natural Frequencies of Aluminum Beam with Piezoelectric Actuators

Mode	**f_n Analytical (Hz)**
1	26.13
2	163.85

We calculate deflection of the beam at different piezoelectric loading and the results are listed in Table 2.

Table 2 Deflection of the Beam for Different Piezoelectric Actuators Loading When 10 N Point Load is applied at Tip of the Beam.

Applied Voltage (V)	One Pair placed near fixed end (m)	One Pair placed at middle of the beam (m)	One actuator placed near fixed end and middle of the beam (m)	One actuator placed near fixed end and free end of the beam (m)
0	$-9.75x10^{-3}$	$-9.75x10^{-3}$	$-9.75x10^{-3}$	$-9.75x10^{-3}$
25	$-9.43x10^{-3}$	$-6.05x10^{-3}$	$-7.76x10^{-3}$	$-4.87x10^{-3}$
50	$-9.12x10^{-3}$	$-2.37x10^{-3}$	$-6.07x10^{-3}$	$1.02x10^{-4}$
75	$-8.82x10^{-3}$	$1.30x10^{-3}$	$-3.80x10^{-3}$	---------
100	$-8.50x10^{-3}$	---------	$-1.72x10^{-3}$	---------
125	$-8.10x10^{-3}$	---------	---------	---------
150	$-7.71x10^{-3}$	---------	---------	---------
175	$-7.35x10^{-3}$	---------	---------	---------
200	$-7.00x10^{-3}$	---------	---------	---------

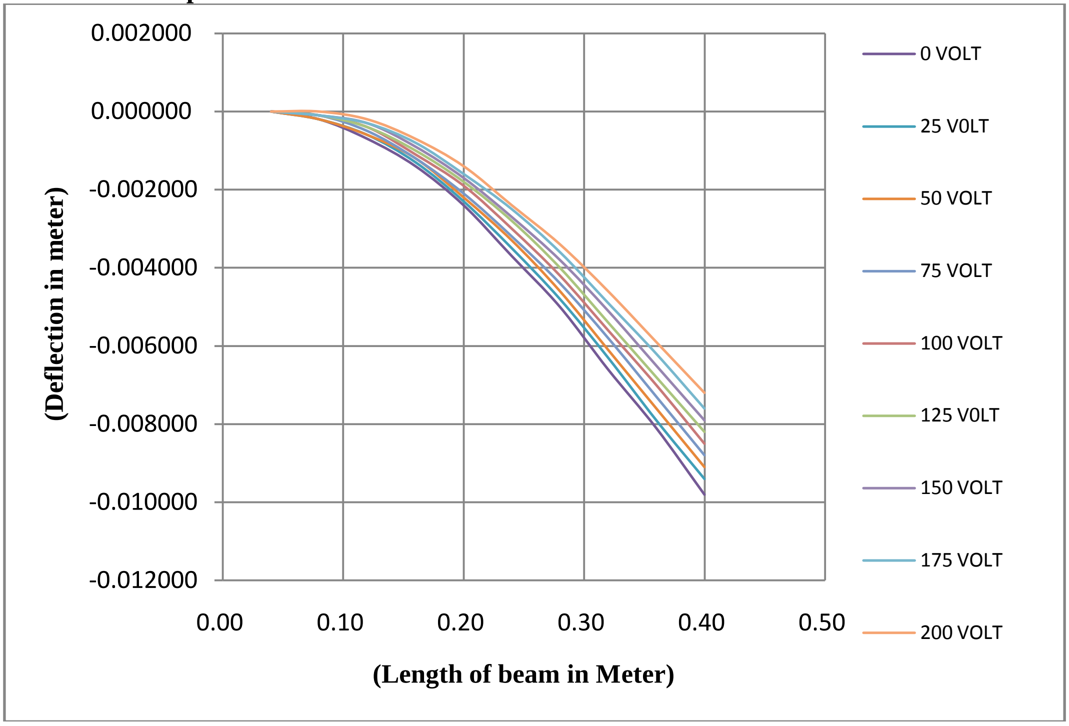
The natural frequencies and mode shapes of a cantilever beam bonded with piezoelectric actuator can be predicted analytically and numerically (FEA). Experimental modal analysis has been conducted to verify the analytical and numerical (FEA) approaches.

Among piezoelectric materials, lead zirconate titanate has high coupling coefficients and piezoelectric charge coefficients. PZT-5H of Sparkler Ceramics Company is used for actuators. They are thin, unobtrusive, self-powered, adaptable to complex contours, and available in a variety of configurations.

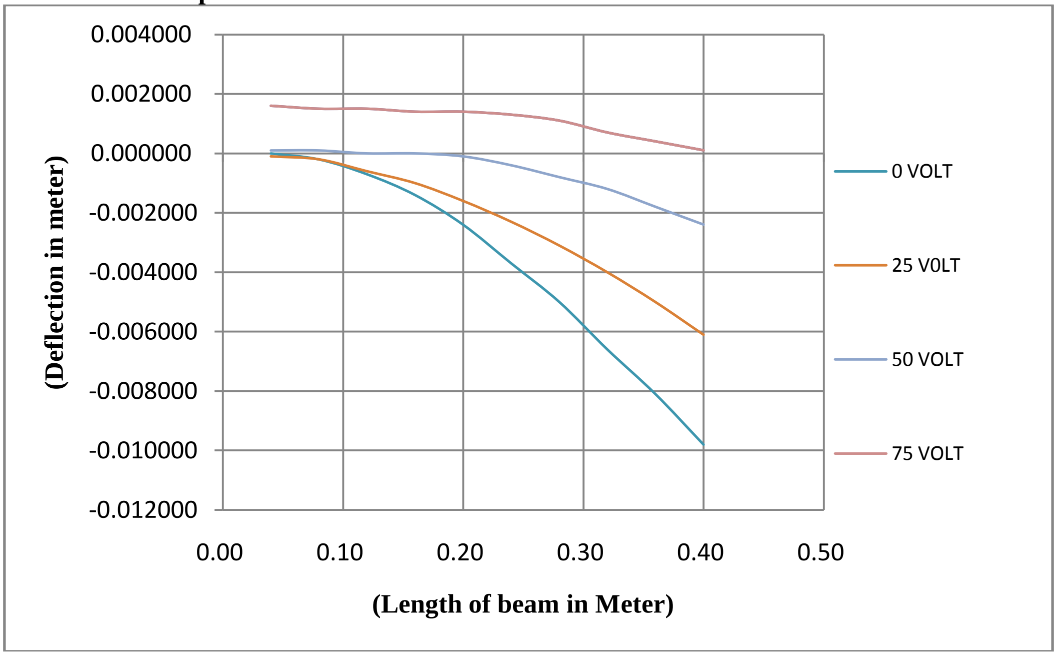
Fig. 2 represents the experimental setup. The experimental setup consists of a cantilever aluminium beam with piezoelectric actuators. A sensor, it was used to measure the displacement at the tip. A control panel instrument (Controller) and a personal computer, acquired the output data from the sensor at the same time. A function generator was used to provide a harmonic signal to an amplifier which supplied voltage to the piezoelectric actuator. In next a constant voltage with an opposite sign was applied to the piezoelectric on each side of the beam. Due to the converse piezoelectric effect, the distributed piezoelectric actuators contract or expand depending on negative or positive active voltage. A 10 N load applied on tip of the beam and voltage is supplied to piezoelectric actuator. When we use one actuator pair then we applied 0 volt to 200 volt to piezoelectric actuator. In next for two piezoelectric actuators, we divide the supplied voltage (means if we have to supply 25 volts to piezoelectric actuator then we supplied 12.5 volts to one actuator and 12.5 volts to another actuator). After that the maximum peak values are considered and we plot graph. The results are shown in Graph 1 to Graph 4 respectively. The comparison of Graph 1 reflects the fact that a lower voltage is needed to reduce the deflection caused by the external load when more actuators are used (Graph 3 to Graph 4).

Fig. 2 Experimental Setup

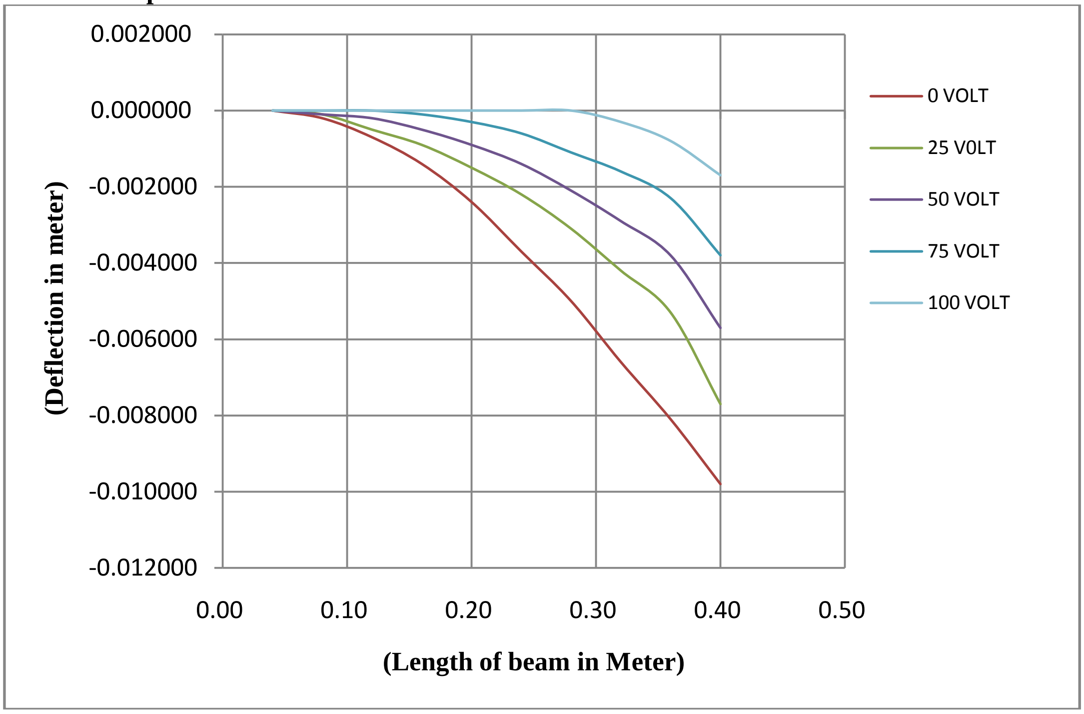
Graph 1 Controller Piezoelectric Actuators at the Fixed End of Beam



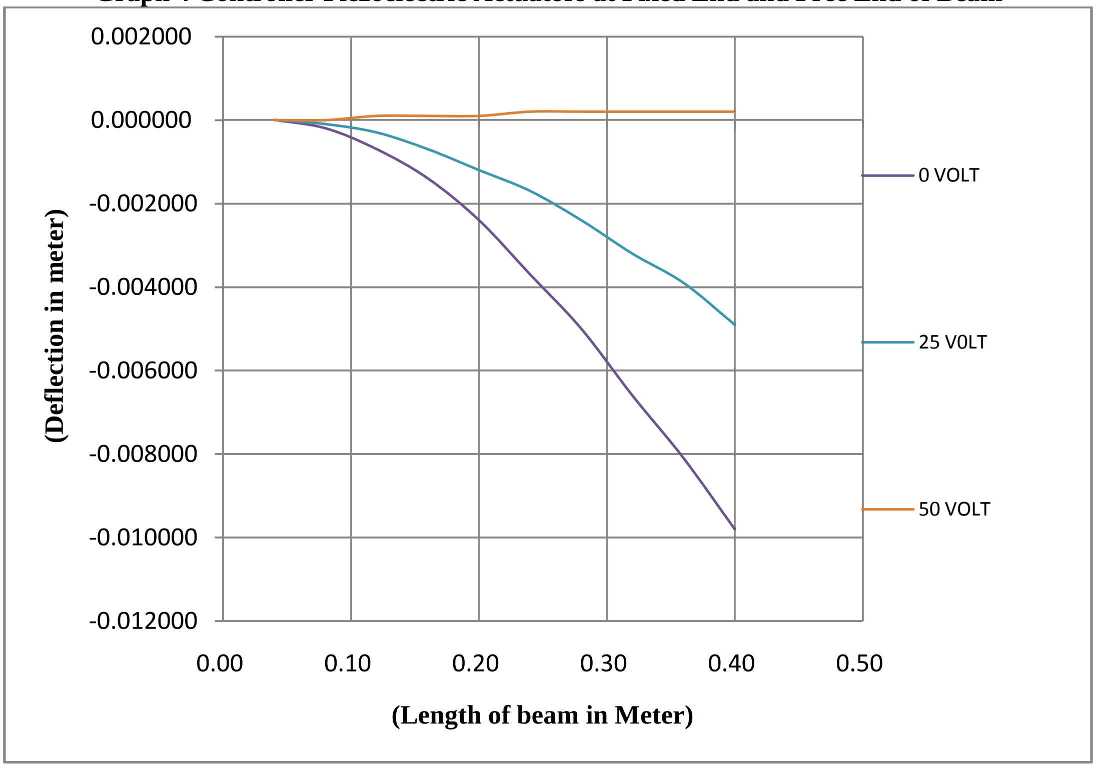
Graph 2 Controller Piezoelectric Actuators at the Middle of Beam



Graph 3 Controller Piezoelectric Actuators at Fixed End and Middle of Beam



Graph 4 Controller Piezoelectric Actuators at Fixed End and Free End of Beam



III. RESULT AND DISCUSSION

Numerical and analytical results are presented to show the static and dynamic behavior of aluminium beams with piezoelectric actuators. In order to verify the proposed numerical calculations were generated from a cantilevered aluminium beam with piezoelectric actuators. The adhesive layers are neglected. A constant voltage with an opposite sign was applied to the piezoelectric on each side of the beam. Due to the converse piezoelectric effect, the distributed piezoelectric actuators contract or expand depending on negative or positive active voltage. In general, for an upward displacement, the upper actuators need a negative voltage and the lower actuators need a positive one. The control of static deflection and modal analysis of the beam under the distribution piezoelectric are analyzed. The natural frequencies for aluminium beam without piezoelectric and with piezoelectric actuator are presented in Table 3 and 4 respectively. After that a 10 N load is applied to the tip of the beam. It is clear that the structure reverts as the specified voltages are increased.

Table 3 Natural Frequencies of Aluminium Beam without Piezoelectric Actuators

Mode	f_n Analytical (Hz)	f_n ANSYS (Hz)	f_n Experimental (Hz)
1	25.65	26.063	26.10
2	161.34	163.218	159.60
3	452.02	457.401	445.70
4	885.96	897.912	914.80

Table 4 First Two Natural Frequencies of Aluminium Beam With Piezoelectric Actuators

Mode	f_n Analytical (Hz)	f_n ANSYS (Hz)	f_n Experimental (Hz)
1	26.13	27.076	27.10
2	162.85	163.87	157.22
3	454.54	450.688	467.45
4	881.42	877.345	892.68

IV. CONCLUSION

Using derived deflection solution, the deflection control in a beam subjected to static external action can be achieved. Experimentation was also conducted to verify the analytical and numerical results. Finally, the effect of the number and locations of the actuators on the control system are also investigated. When we placed one pair of actuator near fixed end then the deflection of the beam is controlled as about 28% also it required more voltage. When we paced near one pair of actuator near fixed end and at middle of the beam then the deflection of the beam controlled as about 82% also it required less voltage and we observed that beam flattened quite smoothly.

REFERENCES

[1]. K. B. Waghulde, Dr. Bimlesh Kumar, “ Vibration Analysis of Cantilever Smart Structure by using Piezoelectric Smart Material”, International Journal on Smart Sensing and Intelligent Systems, Vol. 4, No. 3, Sept. 2011, pp. 353-375

[2]. K.B.Waghulde, Dr. Bimlesh Kumar, Prof. T.D. Garase and Prof. M.M. Patil, “Smart Materials and Structure used for Vibration Control”, Journal of Information, Knowledge and Research in Mechanical Engineering, Nov. 10 to Oct. 11, Vol. 1, pp. 26-30

[3]. J.J. Liu and B.M. Liaw, “Efficiency of Active Control of Beam Vibration Using PZT Patches”International Congress & Exposition on Experimental and Applied MechanicsCosta Mesa, CA, June 7-10, 2004

[4]. Waleed Khalid and Al Ashtari, “The Deflection Control of a Thin Cantilever Beam by Using a Piezoelectric Actuator / Sensor” 1st Regional Conference of Eng. Sci. NUCEJ Special Issue Vol.11,No.1, 2008, pp. 43-51

[5]. K. Venkata Rao, S. Raja and T. Munikenche Gowda, “Bending Behavior and Vibration of Piezoelectric Beam with Debonded Actuators: Coupled Finite Element Analysis”, International Journal of Applied Engineering Research, (2012), ISSN 0973-4562, Vol.7, No.11

[6]. Yuvaraja .M, Senthilkumar.M and I. Balaguru, “Study on Vibration Characteristics of PZT Actuated Mild steel and Aluminium Cantilever Beams”, Annals of Faculty Engineering Hunedoara, International Journal of Engineering, (2011), pp. 177-182

[7]. Action Nechibvute, Albert Chawanda, and Pearson Luhanga, “Finite Element Modeling of a Piezoelectric Composite Beam and Comparative Performance Study of Piezoelectric Materials for Voltage

Generation", International Scholarly Research Network,(2012), pp. 1-11

[8]. Dongchang Sun, Liyong Tong and Satya N. Atluri, " Effects of Piezoelectric Sensor/Actuator Debonding on Vibration Control of Smart Beam" International journal of Solid and Structures, (2001) pp. 9033-9051

[9]. Haichang Gu and Gangbing Song, "Active Vibration Suppression of a Flexible Plate With Piezoceramic Patches Using Robust Model Reference Control", Smart Material Structure, 16 (2007) pp. 1453–1459.

International Journal of Engineering Research and Applications (IJERA) is **UGC approved** Journal with Sl. No. 4525, Journal no. 47088. Indexed in Cross Ref, Index Copernicus (ICV 80.82), NASA, Ads, Researcher Id Thomson Reuters, DOAJ.

Kamini P. Bhavsar "Finite Elelment Analysis of A Cantilever Beam Using Piezoelctric Actualtors." International Journal of Engineering Research and Applications (IJERA) , vol. 7, no. 12, 2017, pp. 23-29.