Experimental and Computational Analysis of Smart cantilever beam

Tushar Choudhary[1] Mukesh Kumar Sahu[2]
National Institute of Technolgy Jamshedpur

Abstract--- This paper Concerns with an Experimental and Computational vibration analysis of piezo-laminated cantilever beam. Since vibration is an important parameter is need to consider will design an structural component specially in turbo machinery and automobile sector where main structure such as wings of aircraft, naval vessel etc are subjected to static as well as dynamic loads if these loads are not counter balance this may leads to catastrophic failure. In this analysis a rectangular aluminum beam and there surface is bounded with piezoelectric patches. The bean is subjected to CFFF boundary condition because the cantilever position governs this B.C is modeled with the help of ANSYS 14.5. The obtained result shows good agreement with the experimental result.

Key Words: - Vibration, Voltage, Ansys 14.5.

I. INTRODUCTION

The process of counter balancing the vibration is known as AVS i.e. Active vibration control in this technique 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.

In past passive techniques are used to counteract the vibration of component of structure such techniques are traditional vibration dampers, base isolation and Shock absorbers. But now a day enormous research and development in the field of vibration control modern techniques are implemented such as piezo-electric, pneumatics, voice coils.

In 1987 brace give a method for active control of disturbances propagating along a waveguide in thin beams two active control systems are incorporated in his method. First C.S measure displacement and rotation and other evaluate displacement measurements at two points.

In 1990 Rashidi proposed an computation strategy for undesirable vibration control. In this strategy consist of an black-box is coupled with dynamic system. Response of vibration system is computed and the decision variables of the formulated optimization problem are taken in consideration to control vibration of rotor system

In 1995 prakash and Kevin use total energy absorption (TEA) in wave type energy-field measurement system. In their method TEA formulation considers vibration energy fields in the structure are sensed by piezoelectric materials.

Eung et. al 1998 applied Filtered-X LMS algorithm and piezo ceramic actuator in flexible cantilever beam vibration control. They revealed that the reduction in vibration can be achieved in a few seconds with this integration.

Yonga and Zimcik in 2003 use Individual Blade Control (IBC) technique for controlling vibration of Helicopter. In this technique Smart Spring are used which is an active tunable vibration absorber. A closed loop test is performed to check its harmonic response and the obtained response shows good agreement on suppress multiple harmonic of blade.

Daley et. al 2004 present the problem encountered in marine application also with new hybrid active/passive mounting system for vibration control and gives a new method for active vibration control in their method is fully developed for damping flexural modes of vibration in the receiving structure

Belouettar et. al 2008 gives an simplified approach for analysis non liner vibration of sandwich piezoelectric beams. Their approach consist of galerkin and harmonic balance method. And amplitude loss factor and nonlinear frequency relationship are derived and discussed.

Chunchuan et.al 2010 studied AVC of a finite L-shaped beam by the travelling wave approach and conclude that the power flow method get affected by changing location of sensor and due to some small error occurred in control forces

Shirazi et. Al 2011 use fuzzy logic control in ACV of a simply supported rectangular plate. The obtained result are show good agreement with the PID control result and use double Fourier series to obtained natural frequency of a plate.

In 2013 Ram and Mottershead states the problem occurred during AVC and gives a new methodology which is valid to to both single-input and multiple-input-multiple-output vibration control of practical engineering structures. Rajiv [10] suggests systematic design for PPF controller. The controller is designed in such a way that it can provide uniform damping to all the modes, even in instrumental phase lead and lag, and he also revealed that the time delay in control loop will be fully eliminated.

Xianglong et. al 2014 present an analytical approach for ACV of a cylindrical shell. His model consist of two-stage isolation system, in order to validate the approach obtained result are compared with other optical control forces and the effect of number, location of actuator are well discussed

Kecik et. al 2014 present an numerical study on the application of magneto-rheological (MR) damper for semi-active control. And proposed two closed loop algorithm for dynamic control based on velocity and amplitude of pendulum and impulse on-off commencement of MR damper.

II. METHODOLOGY

In order to validate Ansys model experimental step is done and the different mode shapes are generated and the frequency of the beam is measure with oscilloscope and the beam which is subject to CFFF condition. Fig1 shows the experimental setup which all instrument and fig 2 shows the symmetric layout of the experimental setup. During experiment different frequency are measured and there mode shapes are shown in figure 3 and the frequency related wave pattern in oscilloscope is shown in fig 4.

Fig. 1: Experiment Setup

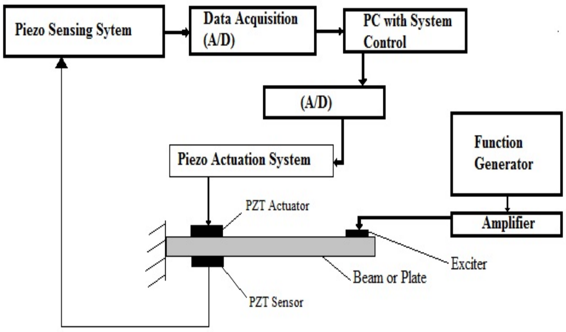
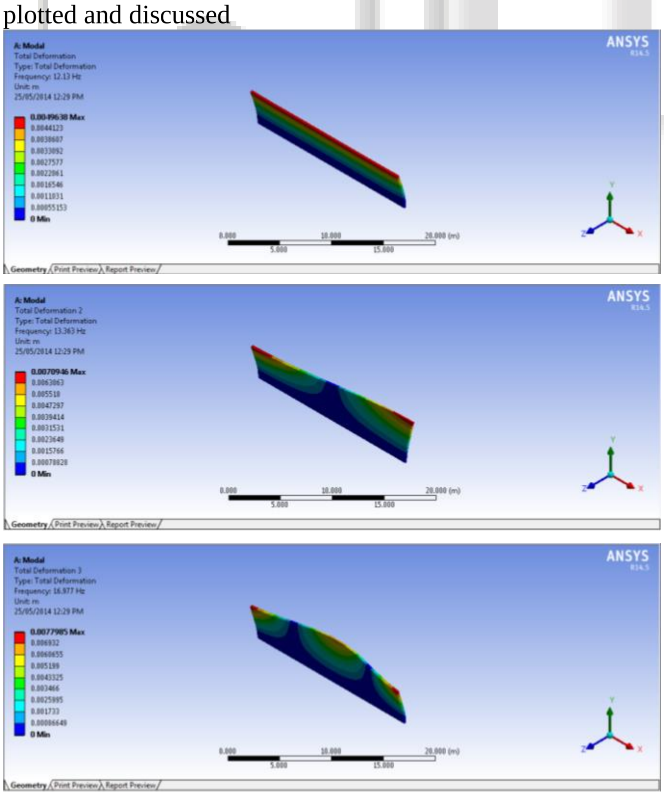


Fig. 2: Experimental Layout

Due to vibration electrical signal is generated by piezo electric patch and it is coupled with oscilloscope and all essential parameters are recorded, since maximum voltage is taken under consideration during this complete experiment. Five observation are taken during experimentation and with the help of that several graphs are plotted and discussed



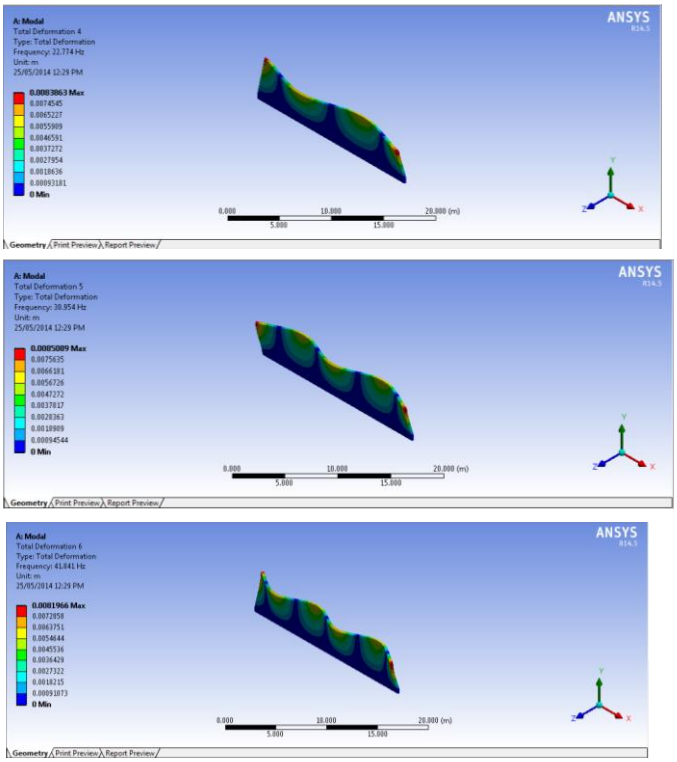
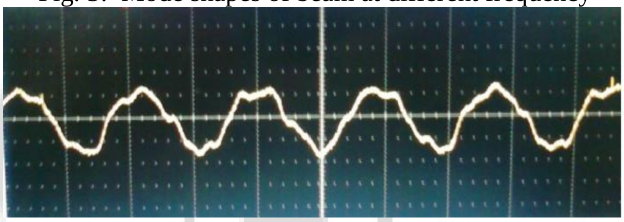
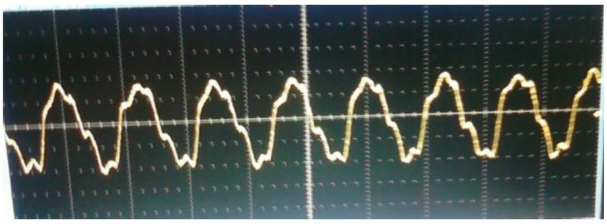


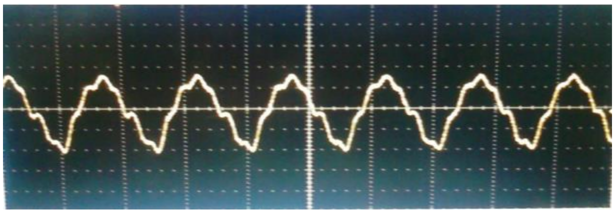
Fig. 3: Mode shapes of beam at different frequency



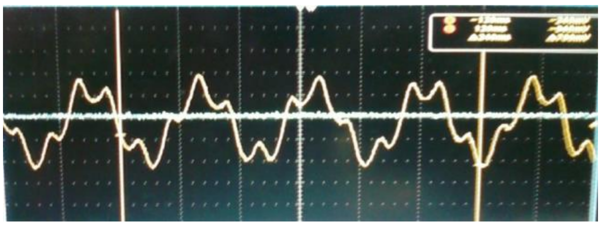
At 12 Hz



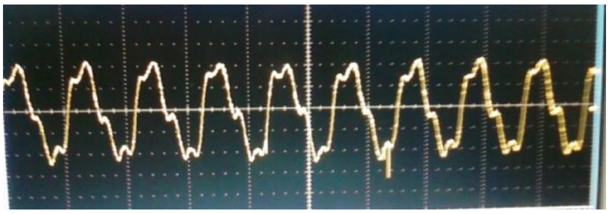
At 15Hz



At 17.5



At 20Hz



At 22.5 Hz

Fig. 4: Signal pattern due to vibration at different frequency in oscilloscope

At 12.5 Hz the maximum voltage is rerecorded with P.E material of 1.760V with amplitude of 2.210V at a peak voltage of 79.94mV and RMS value of 1.122mv.Similarly at 15Hz 0.02% increase in maximum voltage along with 0.196 % increase in maximum voltage is recorded at peak value of 3.72mV and RMS value of 0.01258% increase in voltage is measured.

At 20 Hz the maximum voltage is rerecorded with P.E material of 2.56V with amplitude of 2.440V at a peak voltage of 5.4mV and RMS value of 1.611mv.Similarly at 22.5Hz 0.5187% increase in maximum voltage along with 0.4052 % increase in maximum voltage is recorded at peak value of 9.08mV and RMS value of 0.1543% increase in voltage is measured.

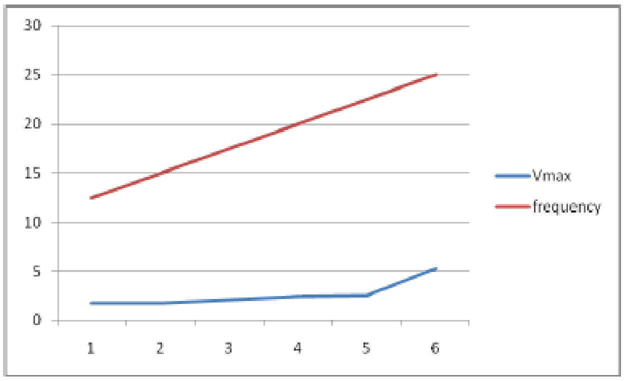


Fig. 5: the curve formed between the maximum voltage and frequency

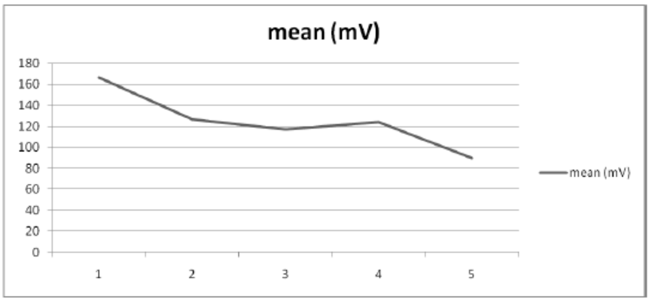


Fig. 6: variation of Mean with respect to input frequency

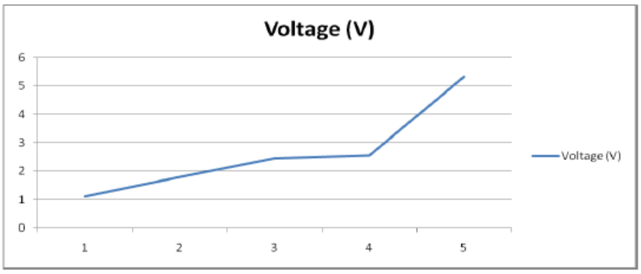


Fig. 7: variation of Voltage with respect to input frequency

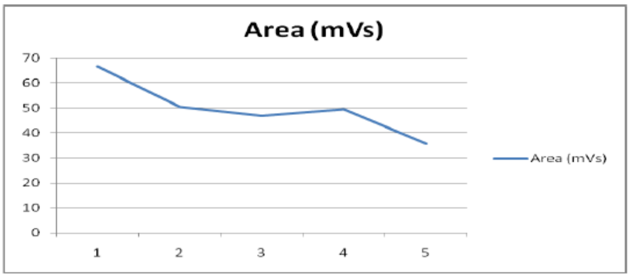


Fig. 8: variation of Area of the Voltage signal with respect to input frequency

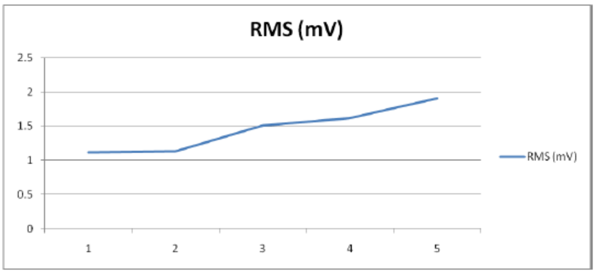


Fig. 9: variation of RMS value of the Voltage signal with respect to input frequency

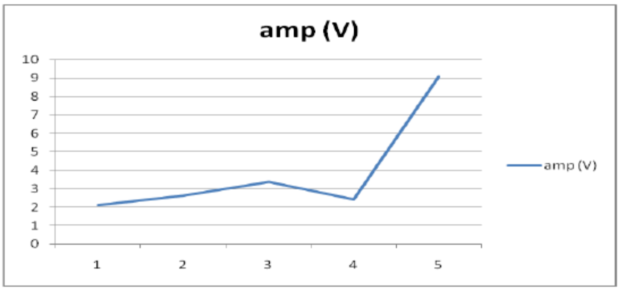


Fig. 10: variation of Amplitude of the Voltage signal with respect to input frequency

In the present study, we control the vibration in an alumunium beam element by applying counterforce. In finite element modelling using ANSYS, the location of piezo sensor was first determined. In the modelling, cantilever aluminum beam was subjected to a constant force of 9 N at the free end. The beam was divided into 1320 nodes. On a frequency variation of 0-100 Hz in 100 sub-steps, the readings of shear stress and displacement at each node was recorded. For 100 Hz frequency, it was found that the minimum value of shear stress was minimum at node 49. The maximum deflection was 0.0273 m. At different frequencies the voltage generated by piezo-electric patch was observed and noted down. Figure 5 is a plot between the maximum voltage generated and frequency input for the set of observation. Frequencies used were 12.5 Hz, 15 Hz, 17.5 Hz, 20 Hz, 22.5 Hz and 25 Hz. The voltages generated were in the reange of 1.7 V to 5.3 V. The graph obtained signifies that for increase in frequency input the maximum voltage value generated by the piezo-patch increases. Figure 6 is a plot between the mean voltage and frequency. For the same set of frequencies the mean voltage ranges were found to be between 90 to 170 mV. Here we obtain a decreasing trend. Figure 8 is a plot between the area of Voltage signal and input frequency where we find a decreasing trend. With decrease in frequency the area of voltage signal increased and the range was between 30 to 70 for the same set of frequency values. Figure 10 is a plot between the amplitude of voltage signal generated by piezo-electric patch and frequency input. The graph shows an increasing trend. As frequency increases, amplitude of vibration obtained is greater.

III. CONCLUSION

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. From the experimental process, the volatage generated by the piezo-electric patch was obtained in variation with frequency input. It was found that if a sinusoidal waveform is provided, with increase in frequency the voltage generated by the piezo-electric patch increased. The plot between voltage generated and frequency input was almost an exponential curve. When we feed the voltage response of sensor into a control system, we generate a controlled output through the actuator that can be used to control beam vibration actively.

REFERENCES

[1] B.R. Mace, "Active Control Of Flexural Vibrations, Journal Of Sound And Vibration, Volume 114, Issue 2, 22 April 1987, Pages 253-270
[2] Majid Rashidi, "A Computational Strategy For Active Control Of Dynamic Systems Via Minimizing The Displacement Magnitudes Of Dominent Harmonics Of Vibration , Mathematical And Computer Modelling, Volume 14, 1990, Pages 410-412
[3] Kwaku O. Prakah-Asante, Kevin C. Craig, "Active Control Of Wave-Type Vibration Energy For Improved Structural Reliability, Applied Acoustics, Volume 46, Issue 2, 1995, Pages 175-195
[4] Jac-Eung Oh, Soo-Hong Park, Jin-Seok Hong, Jun Shin, "Active Vibration Control Of Flexible Cantilever Beam Using Piezo Actuator And Filtered-X Lms Algorithm, Ksme International Journal, July 1998, Volume 12, Issue 4, Pp 665-671
[5] Chen Yong, David G. Zimcik, Viresh K. Wickramasinghe, Fred Nitzsche, "Research Of An Active Tunable Vibration Absorber For Helicopter Vibration Control , Chinese Journal Of Aeronautics, Volume 16, Issue 4, November 2003, Pages 203-211
[6] S. Daley, F.A. Johnson, J.B. Pearson, R. Dixon, "Active Vibration Control For Marine Applications, Control Engineering Practice, Volume 12, Issue 4, April 2004, Pages 465-474
[7] S. Belouettar, L. Azrar, E.M. Daya, V. Laptev, M. Potier-Ferry, "Active Control Of Nonlinear Vibration Of Sandwich Piezoelectric Beams: A Simplified Approach, Computers & Structures, Volume 86, Issues 3–5, February 2008, Pages 386-397
[8] Chunchuan Liu, Fengming Li, Wenhu Huang, "Active Vibration Control Of Finite L-Shaped Beam With Travelling Wave Approach, Acta Mechanica Solida Sinica, Volume 23, Issue 5, October 2010, Pages 377-385
[9] A. Hossain Nezhad Shirazi, H.R. Owji, M. Rafeeyan, "Active Vibration Control Of An Fgm Rectangular Plate Using Fuzzy Logic Controllers, Procedia Engineering, Volume 14, 2011, Pages 3019-3026
[10] Rajiv Kumar, "Efficient Active Vibration Control Of Smart Structures With Modified Positive Position Feedback Control Using Pattern Search Methods In The Presence Of Instrumentation Phase Lead And Lag" Journal Of Dynamic Systems, Measurement, And Control, Volume 135,2013, Issue 6
[11] Y.M. Ram, J.E. Mottershead, "Multiple-Input Active Vibration Control By Partial Pole Placement Using The Method Of Receptances, Mechanical Systems And Signal Processing, Volume 40, Issue 2, November 2013, Pages 727-735
[12] Xianglong Ma, Guoyong Jin, Zhigang Liu, "Active Structural Acoustic Control Of An Elastic Cylindrical Shell Coupled To A Two-Stage Vibration Isolation System, International Journal Of Mechanical Sciences, Volume 79, February 2014, Pages 182-194
[13] Krzysztof Kecik, Andrzej Mitura, Danuta Sado, Jerzy Warminski, "Magnetorheological Damping And Semi-Active Control Of An Autoparametric Vibration Absorber", February 2014, Meccanica