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Active Vibration Control of A Cantilever Beam Using PZT PATCH (SP-5H)

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***Abstract*— Research on Active Vibration Control System (AVCS) is being carried out to reduce structural vibrations caused by unwanted vibrations in many application areas such as in space, aircraft structures, satellites, automobiles and civil structures (bridges), particularly at low frequencies. In this paper; we have discussed Active Vibration Control technique by using piezoelectric patch (SP-5H) as an actuator. Result from ANSYS and experimental results were compared. We also studied effectiveness of AVC technique, particularly an open loop control system. The experimental results are presented for the cantilever beam excited at one of its natural frequency using active vibration control system. For open loop control system, less reduction were observed and the reasons were discussed for it.**

***Index Terms*— Piezoelectric (PZT), Active Vibration Control (AVC), Actuator, ANSYS.**

I. INTRODUCTION

Vibration control of flexible structures is an important issue in many engineering applications, especially for the precise operation performances in aerospace systems, satellites, flexible manipulators, etc. When a structure is undergoing some form of vibrations, there are number of ways in which this vibration can be controlled. Passive control involves some form of structural augmentation or redesign, often including the use of springs and dampers, which leads to a reduction in the vibration. Active control augments the structure with sensors, actuators and some form of electronic control system, which specifically aim to reduce the measured vibration levels. Among the many materials, piezoelectric and shape memory alloys are most suitable for active control of the development of smart composite structures. They are able to generate a relatively large deformation. Piezoelectric materials like (lead-Zirconium-Titanate) can be used effectively in the development of smart systems. The proposed work is to study the irrational characteristics of PZT patch (SP-5H) which is surface bonded PZT, particularly to control the vibration.

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II. CONCEPT OF ACTIVE VIBRATION CONTROL

In AVC technique we are providing a 180^0 out of phase vibration signals to the beam by using actuators to cancel out the excitation vibration signals as shown in Fig.1

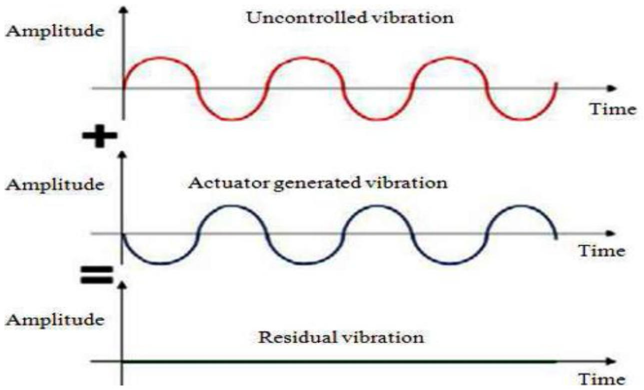

Fig.1. Principle of active vibration control [9]

III. MODAL AND HARMONIC ANALYSIS OF BEAM

For a simple elastic beam with uniform cross-sectional area, the known natural frequency can be calculated by using Euler Bernoulli's beam theory [8].

$$f_n = \frac{(\beta_n L)^2}{\ } \sqrt{\frac{EI}{\ }}$$

Where,

f_n = Natural frequency of beam

L = Length of beam

A= Area of cross-section of beam

ρ = Density of material of beam

E= Young's modulus of material of beam

I= Moment of inertia

$$\beta_n L = \frac{(2n-1)\Pi}{2}$$

Where,

n=1, 2, 3, 4……∞

$\beta_1 L$= 1.875

$\beta_2 L$ = 4.690

$\beta_3 L$ = 7.855

Here $\beta_n L$ is a constant. The constant $\beta_n L$ for first three modes of a cantilever beam are 1.87504, 4.690491 and 7.854757 respectively.

Table- 1 First three modal frequencies

n	$\beta_1 L$	ω_n	f_n
1	1.875	40.86	6.503 Hz
2	4.690	367.769	58.532 Hz
3	7.854	1021.582	162.589 Hz

$f_n = 6.503\ Hz$ is nothing but the fundamental frequency of a beam.

IV. EXPERIMENTAL WORK

In order to verify the effectiveness of vibration control, the real time experimental setup shown in Fig. 3 is designed and built. The setup consists of the following main parts:

1. The beam under test with the surface bonded piezoelectric patch (SP-5H)
2. Function Generator
3. Exciter (Shaker) system

The electrodynamic shaker has magnetic displacement core body with coils placed around it. As the current is passed through the coil it leads to the formation of magnetic field. This magnetic field assists to accelerate the body.

The positions of actuators have a critical influence on the natural frequencies of smart structures. For maximum effectiveness, the actuators must be placed in high strain regions and away from areas of low strains [5].

Firstly, the PZT patch is glued to the surface of the beam at a distance of 25 mm from the fixed end using araldite [5]. The beam is then bolted in the fixture at a desired height, and then beam is excited with fundamental frequency with the help of electrodynamic shaker. After that the actuation system is brought into picture, Fig.3.

The dimensions and material properties of the steel beams, PZT are listed in Table 2 and Table 3 respectively. PZT (Lead Zirconate Titanate) of type SP-5H from Sparkler Ceramics Pvt. Ltd is used in this study

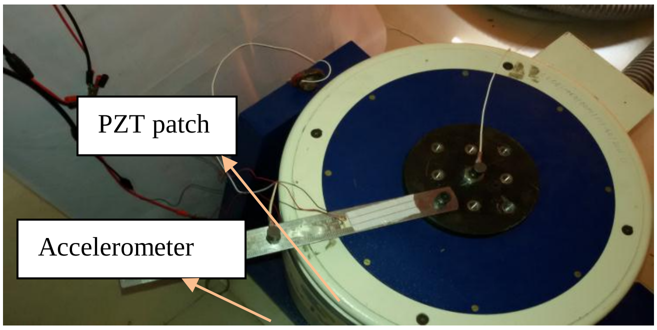

Fig. 2 mounting of beam on shaker

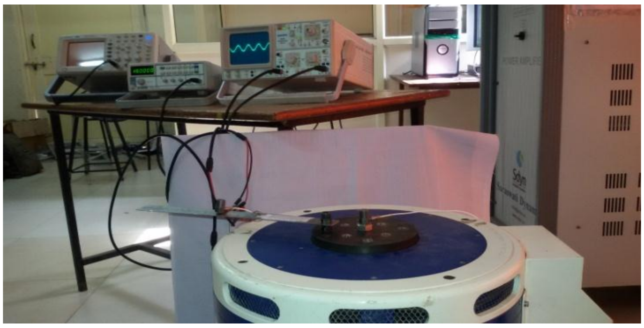

Fig.3 Experimental setup

Table- 2 Material Properties and Dimensions of beam

Dimensions/Properties		Stainless steel
Length (m)	l	0.34
Width (m)	b	0.029
Thickness (m)	t	0.002
Young's modulus (GPa)	E	200
Density (kg/m^3)	ρ	8000

Table- 3Material Properties and Dimensions of PZT [12]

Material Properties	Piezoelectric Coupling Co-efficient	K_p	0.63
		K33	0.73
	Piezoelectric Charge Constant (X10-12 C/N)	D33	550
		D31	-247
	Piezoelectric Voltage Constant (X10-12 C/N)	G33	20
		G31	-9
	Relative Dielectric Constant, (Low Signal)	K^t_3	3100
	Dissipation Factor	tan δ	0.02
	Density (kg/m^3)	ρ	7500
	Curie Temp. (°C)	T_C	190
	Mechanical Quality Factor	Q_m	65
	Frequency Constants (Hz-m)	N_p	1950
		N_t	2000
Dimensions	Patch length (mm)	P_l	76.2
	Patch width (mm)	P_w	25.4
	Patch thickness (mm)	Pt	0.5

The Function Generator connected to PZT patch is switched on. It is then set to the desired frequency level. From the graph obtained by testing PZT patch (SP-5H), it is found that patch shows the resonance at 18 kHz[12], thus the frequency of 18 kHz is supplied to the patch using function generator and the response (mechanical deflection) is observed.

The beam is analyzed in ANSYS for its deformation [4]. Beam has given excitation at one end to get the deformation and stresses near the fixed end of the beam. Fig.4

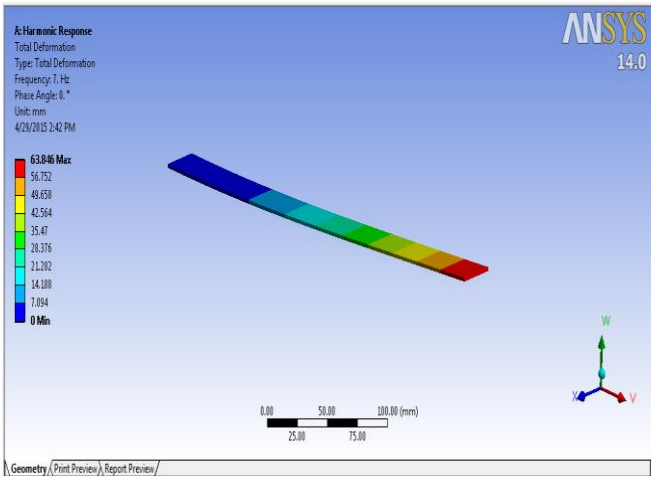

Fig.4 BEFORE CONTROL DEFORMATION IN BEAM

Now the actuating force is given to the beam from opposite direction and again deformation and stresses near the fixed end in the beam is observed. Fig.5

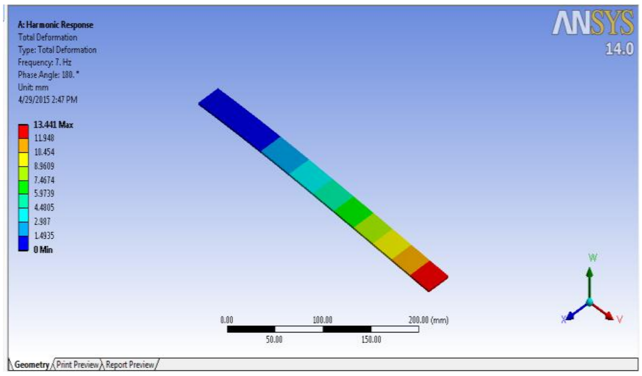

Fig.5 AFTER CONTROL DEFORMATION IN BEAM

ANSYS results show the deformation of 0.007 m before control and 0.0015 m after control near the fixed end.
No. of readings of displacement were observed for before control and after control through accelerometer in shaker system as shown in fig.2

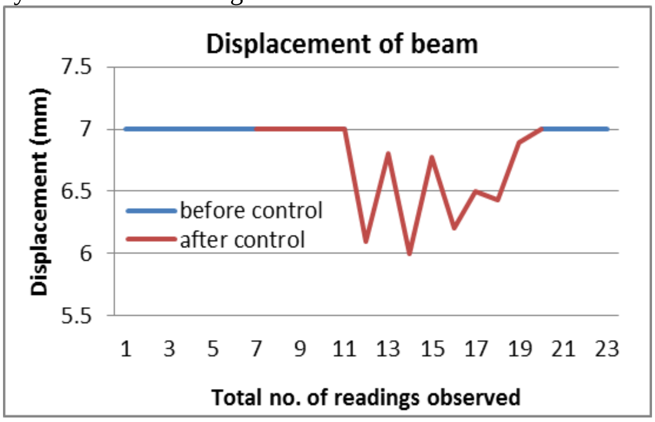

Fig.6 Graph plot on basis of experimental results

V. RESULTS

Table-4 Theoretical vs. Practical Reduction in amplitude

	CONTROL OF AMPLITUDE NEAR FIXED END	
	THEORETICAL	PRACTICAL
RESPONSE WITHOUT CONTROL	0.007 m	0.007 m
RESPONSE WITH CONTROL	0.0015 m	0.006 m
% REDUCTION IN VIBRATION	78.00 %	15.00 %

As per table 4, predefined results using ANSYS shows 78% reduction in amplitude and practically we got 15% reduction in amplitude.

VI. CONCLUSION

The characterization and testing of PZT actuator for AVC has been discussed in this paper and it has been found that the PZT actuators can be used for AVC.PZT patch is able to control the vibration i.e. reducing the vibration's amplitude so as to induce the damping effect .

As we got less reduction which is not significant to prove effectiveness of an AVC system. As a part of the discussion various reasons behind it, may be that The PZT patch which we are using in this experiment is comparably of low operating range that may affect the results. In our system, we have directly used the open loop system i.e. we are directly feeding the signals to the actuators and not using the close loop or feedback systems. Amplitude of signal given to actuator has severe effect on results .

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