Vibration Analysis of Smart Beam

J. R. Chaudhari[1], Dr. C. R. Patil[2]

[1]S.S.G.B. COT & T Bhusawal, North Maharashtra University,
Jalgaon, Maharashtra, India.
jitendra_rc@rediffmail.com

[2]PRMIR&T Badnera, Amaravati University,
Amaravati, Maharashtra, India.
crpatil333@rediffmail.com

Abstract: These instructions Vibration of a smart beam is being controlled by using opposite directional force to the structure. Now a day's active vibration control is frequently being used in aircraft, submarine, automobile, helicopter blade, naval vessel. In this a smart plate with one pair of piezoelectric lamination is used to study the active vibration control. 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-11 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 a suitable control methodology is find by which the controller gain optimizes to get more effective vibration control with minimum control input.

Keywords: Smart Beam, PZT Patch, Vibration suppression, FEA Analysis**.**

1. Introduction

A smart structure involves distributed actuators and sensors along the structure and some type of processor that can analyze the response from the sensor and use control theory to output commands to the actuator. 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. Therefore, a smart structure has four major components: the structure, sensor, actuator, and controller. Actuators and sensors are widely used in various applications and are generally integrated with main structures via surface bonding or embedding. 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. By experimentally a suitable control methodology is obtained to optimize the controller gain to get more effective vibration control with minimum control input.

A. Pizoelectric Material

All Piezoelectric materials are active materials generally with high bandwidths. Two properties that piezoelectric materials have are the direct effect and the converse effect. The direct effect of a piezoelectric material is electric polarization that occurs as the material is stressed producing an electrical charge at the surface of the material. The converse piezoelectric effect results in a strain in the material when placed within an electric field. These properties make piezoelectric materials the most popular smart materials.

Lead zirconium titanate (PZT) and polyvinylidene fluoride (PVDF) are two piezoelectric materials that are most widely used in applications of actuation and sensing.

B. Sensor

Piezoelectric sensors operate using the direct effect, i.e., electric charge is generated when a piezoelectric material is stressed causing deformation. Piezo patches are approximately ten times as sensitive as semi-conducting gauges and over 300 times as sensitive as resistance gauges. Peizo patches can be bonded to another material, which causes to deform with the base structure. The deformation can be measured by measuring the voltage across its electrodes. The Patches are bonded to the bottom surface of the beam using a strong adhesive material.

C. Actuator

Piezoelectric actuators operate using the converse effect of piezoelectric materials which states that when a piezoelectric material is placed into an electric field i.e., a voltage is applied across its electrodes; a strain is induced in the material. PZT is ideal because of its respectable maximum actuation strain, reasonable cost, and high accessibility.

2. Model Description

The following are the specifications of a model for FEA and experimental 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 (310×26×2.6) mm*mm*mm and dimensions of the PZT is (15×15×0.5) mm*mm*mm.

3. Finite Element Analysis of Beam

Theoretical analysis of smart beam is carried out using ANSYS-11 to determine optimal 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 aluminum is 0.0004. A constant force of 9 N on the middle node of the cantilever edge was applied. The direction of the force is positive Z direction. At the solution we find the result that the maximum displacement value 0.00273 m. The value of maximum shear stress is 0.260×108 N/ M2 and it is acting on the node number 49.

4. Experimental Analysis

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 notable vibration in the beam hence an amplifier is used to amplify the signal.
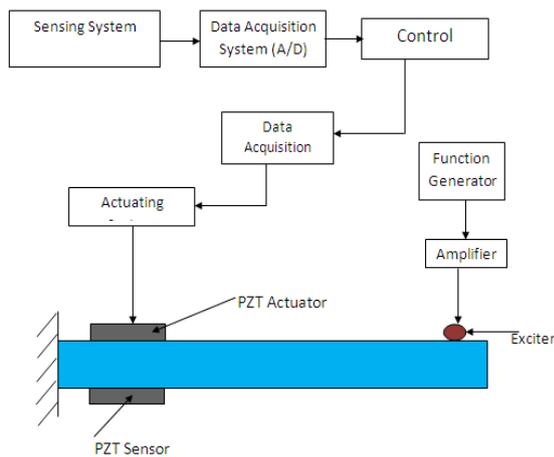
Figure 1: Experimental Set up

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 1. 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.

5. Result and Discussions

The various parameters were monitored and recorded through oscilloscope due to the electrical signal generated by the piezo electric patch.

TABLE I

Frequency (Hz)	Maximum Voltage (V)	Maximum Amplitude (V)	Peak to Peak Voltage (V)
12.5	1.77	2.14	3.35
15.0	1.80	2.65	3.70
17.5	2.44	3.35	5.55
20.0	2.58	2.45	5.40
22.5	5.33	9.08	9.06

The maximum value of voltage, amplitude recorded with frequency as a variant (As shown in Table I). The graph was plotted with the gathered data against the frequency.

The following figure shows an increasing trend. As frequency increases; voltage, amplitude and peak to peak voltage of vibration obtained is greater.
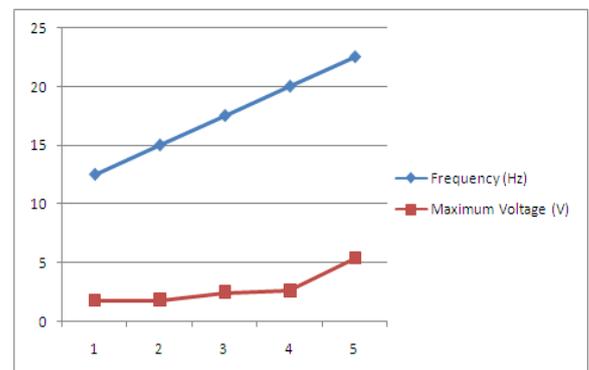
Fig. 2 A graph of V_{max} and corresponding Frequency
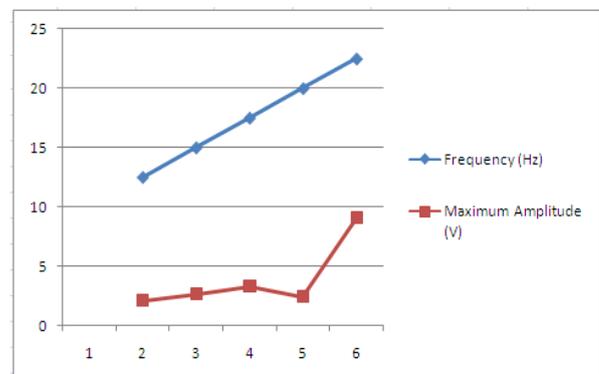
Fig. 3 A graph of Maximum Amplitude and corresponding Frequency
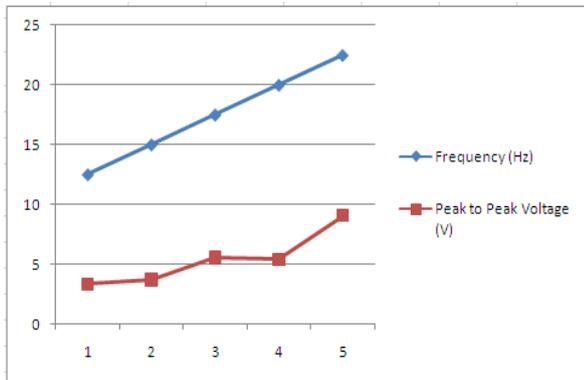
Fig. 4 A graph of Peak to Peak Voltage and corresponding Frequency

6. Conclusion

The location of maximum value of shear stress was determined from finite element analysis. Using finite element analysis optimum position of sensor and actuator was found out. Experimentally the voltage generated by the piezo-electric patch was obtained in variation with frequency input and compared with that in finite element analysis.

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.

By proper feeding the voltage response of sensor into control system, controlled output was generated through actuator that can be used to control beam vibration actively.

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