EXPERIMENT 1
VIBRATION CHARACTERISTICS OF ALUMINIUM CANTILEVER BEAM USING PIEZOELECTRIC SENSORS

OBJECTIVES

This experiment aims to study the vibration characteristics of an aluminium cantilever beam using piezoelectric-ceramic (PZT) sensor. The first natural frequency and the corresponding damping ratio is determined through vibration analysis in measurement cum simulation mode.

EXPERIMENTAL METHODOLOGY

The experimental setup is as shown in Fig. 1. It consists of an aluminium cantilever beam of dimensions 300×18.2×2.15 mm with a PZT sensor bonded on the top surface near the point of fixity. The wires from the patch are connected to a digital multi meter (DMM) for acquisition of voltage signal data from across the PZT patch.

The cantilever beam is excited into free-damped vibrations through an automatic mechanical exciter at regular intervals. As the beam vibrates, the surface strain fluctuates between compression and tension, thereby developing sinusoidally varying charge (and hence voltage) across the electrodes of the PZT sensor through the direct piezoelectric effect (visit http://ssdl.iitd.ac.in/vssdl/piezo.pdf to learn more about piezoelectricity). The instantaneous voltage developed across the piezoelectric sensor is measured using the DMM. The voltage data can be downloaded by the user.

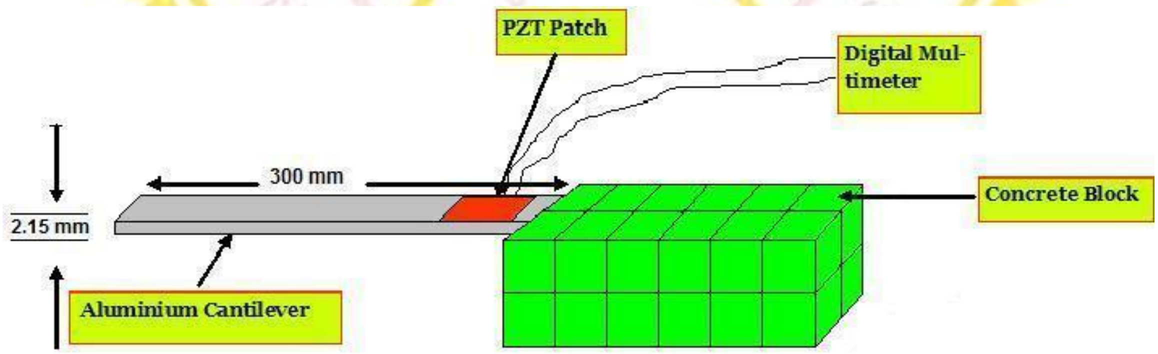

Fig. 1 Experimental set up

The user may plot the time domain data in excel to visualize the free damped oscillations more minutely. At the same time, through fast Fourier transform, the user can convert the time domain data (as an array of voltage output, *V_time*) in the frequency domain. If using MATLAB, following commands can be used:

$$V\_fft = abs(fft(V\_time)) \quad (1)$$

This command will produce an array of voltage values in the frequency domain. The corresponding matrix of frequencies can be obtained by using following command

$$f = (0{:}N\text{-}1)/(N*T) \tag{2}$$

where N is the total number of samples in the time domain and T the sampling interval. Fig. 2 shows typical time and frequency domain responses expected if the experiment is correctly performed.

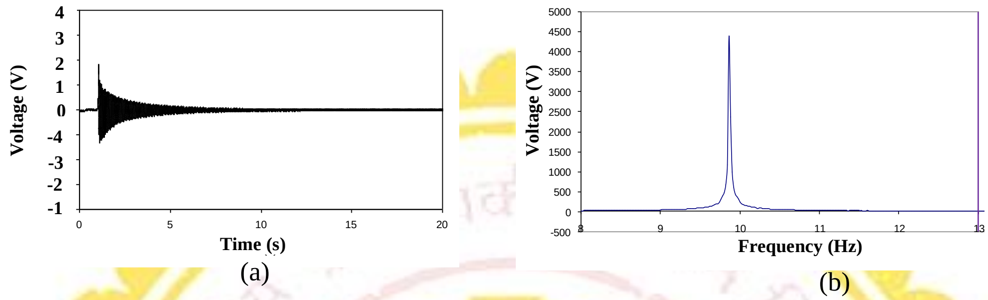

Fig. 2 Expected sensor response (a) Time domain (b) Frequency domain

From the frequency plot, the user can identify the natural frequency of the beam as the frequency corresponding to which peak voltage response is observed. The damping ratio can be calculated using the half power band method (Paz, 2004) as

$$\xi = \frac{f_2 - f_1}{2 f_n} \tag{3}$$

where f_n is the frequency corresponding to peak response and f_1 and f_2 represent the frequencies corresponding to 0.707 of the peak response ($f_2 > f_n > f_1$). The user may compare the values obtained through this virtual experiment with damping ratio available from the literature and the theoretical frequency given below (Paz, 2004).

$$f_1 = \frac{3.516}{2\pi L^2}\sqrt{\frac{EI}{\rho A}} \tag{4}$$

where E denotes the Young's modulus of elasticity of the beam, I the moment of inertia, ρ the material density and L the length of the beam.

REFERENCES

1. Chopra, A. (2001), Dynamics of Structures, Prentice Hall of India limited, New Delhi.

2. Paz, M. (2004), Structural Dynamics: Theory and Computations, 2nd ed., CBS Publishers and Distributors, New Delhi.

3. Sirohi, J. and Chopra, I. (2000), "Fundamental Understanding of Piezoelectric Strain Sensors", Journal of Intelligent Material Systems and Structures, Vol. 11, No. 4, pp. 246-257.

4. Literature on piezoelectric sensors: **http://ssdl.iitd.ac.in/vssdl/piezo.pdf**