DEPARTMENT OF CIVIL ENGINEERING
IIT DELHI

VIRTUAL SMART STRUCTURES AND DYNAMICS LAB

EXPERIMENT 1

VIBRATION CHARACTERISTIC 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. Through the free vibration analysis of the beam, first natural frequency and damping ratios are obtained.

EXPERIMENTAL METHODOLOGY

This experimental setup is as shown in Fig. 1. It consists of a cantilevered aluminium beam of dimensions 300x18.2x2.15mm with a PZT sensor bonded on the surface. The wires from the patch are connected to Agilent 34411A digital multi meter (DMM) which is in turn connected to the LAN port and thus accessible to the user through the World Wide Web.

The cantilever beam is excited into free-damped vibrations through a mechanical exciter. As the beam vibrates, the surface strain fluctuates between compressive and tensile strains, thereby developing sinusoidally varying charge (and hence voltage) across the electrodes of the PZT sensor through the direct piezoelectric effect (click http://ssdl.iitd.ac.in/vssdl/piezo.pdf). The instantaneous voltage developed across the piezoelectric sensor can be measured at the user specified time interval using the DMM. The VEE PRO based interactive dialog box available in the main page of the experiment (http://ssdl.iitd.ac.in/vssdl/exp1.html) can be used for this purpose. A sampling rate of 1 milli second and a total sampling time of 5s (total 5, 000 measurements) is recommended for best results. The dialog box stores the time and the frequency domain data in the computer of the user. Plots are also available in the VEE PRO dialog box.
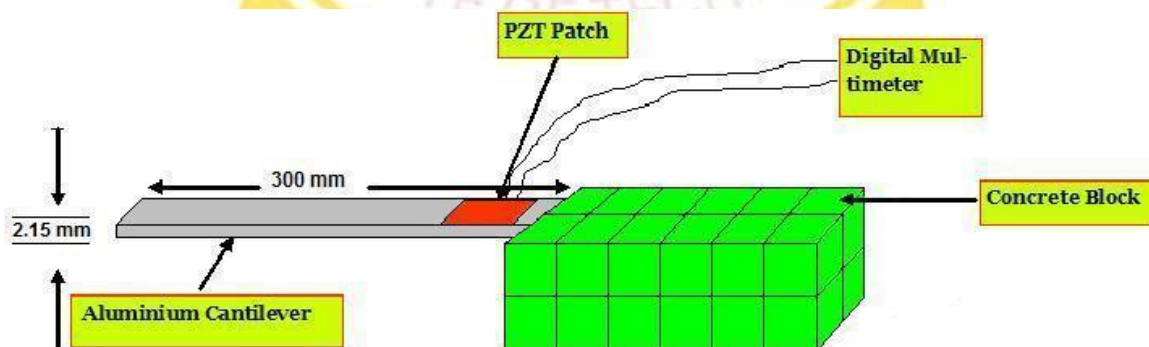

Fig. 1 Experimental set up

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

$$V\_fft = abs(fft(V\_time)) \tag{1}$$

This command will produce a matrix of voltage values in the frequency domain. The corresponding matrix of frequencies can be obtained from

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

where *N* is the total number of samples in the time domain (here 10, 000) and T the sampling interval (here 0.001 second). It may be noted that the VEE PRO dialog box also provides the matrix *V_fft*. The user may use it directly if MATLAB is not available. Fig. 2 shows typical time and frequency domain responses expected if the experiment is correctly performed.
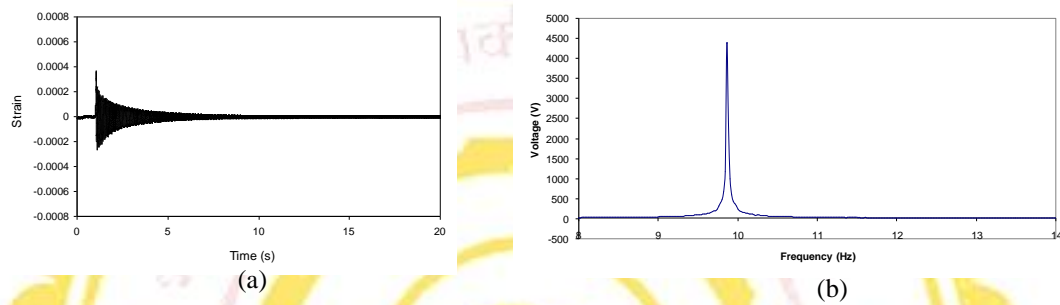

(a)   (b)

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

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

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 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, ρ the material density and *L* the length of the beam.

REFERENCES

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

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

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

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