VIRTUAL SMART STRUCTURES AND DYNAMICS LAB

DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY DELHI

An MoE Govt of India Initiative

EXPERIMENT 3

FORCED EXCITATION OF STEEL BEAM USING PORTALE SHAKER

OBJECTIVES

This experiment aims to obtain the vibration response of a steel beam using a portable dynamic shaker in measurement cum simulation mode. Unlike experiment 1 (which deals with free vibration response), this experiment deals with forced vibration response. Using an external shaker, the excitation can be effectively controlled. Modes otherwise missed out during impact excitation may be specifically excited.

EXPERIMENTAL METHODOLOGY

The experimental setup is as shown in Fig. 1. It consists of a standard beam ISMB 150 of 3 m to 5.5 m length, with a PZT sensor patch bonded on the top surface. The wires from the patch are connected to Agilent 34411A digital multi meter (DMM). The beam is excited using a portable dynamic shaker. The input to the shaker is in the form of the sinusoidal signal generated by a function generator.

The beam is excited into forced vibrations using a harmonic sweep signal. 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 can be measured using the DMM.

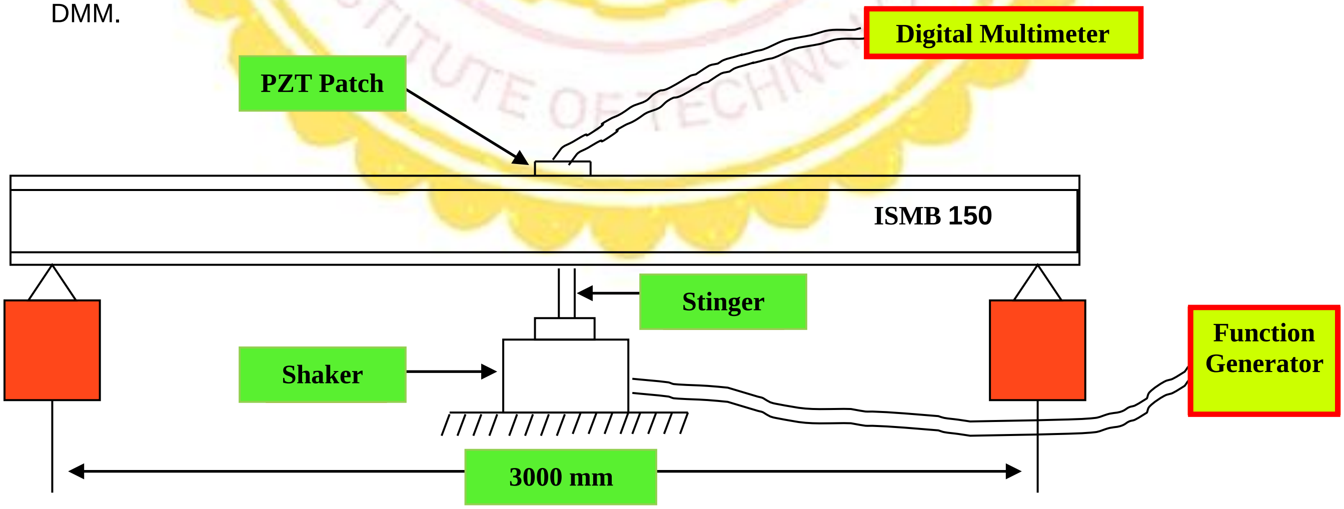


Fig. 1 Experimental set up

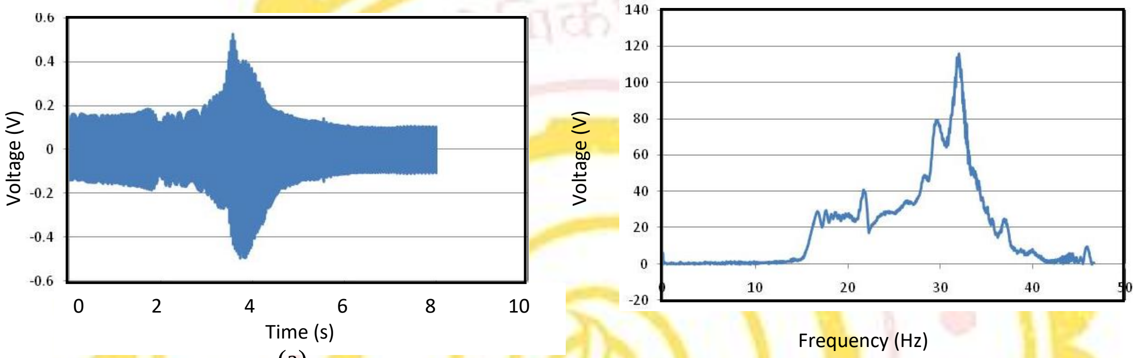
The user may plot the time domain data in excel to visualize the oscillations more minutely. At the same time, through Fast Fourier Transform (FFT), the user can convert the time domain data (as an array of voltage output, *V_time*) in the frequency domain. If using MATLAB, following commands can be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

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

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

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

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



(a)

(b)

Fig. 2 Typical 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 (for example 32 Hz in Fig. 2b). 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 the 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 the damping ratio available from the literature and also the theoretical n^{th} frequency given by (Paz, 2004).

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

where E denotes the Young's modulus of elasticity of the beam, ρ the material density, A the cross sectional area, I the moment of inertia 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**