An experimental approach to free vibration analysis of smart composite beam

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Abstract. Experimental vibration analysis is a main concern of this study. In designing any structural component the important parameter that has to be considered is vibration. The present work involves the experimental investigation of free vibration analysis of a smart beam. Smart beam consists of glass/epoxy composite as a main substrate and two PZT patches. The PZT patches are glued above and below the main beam. By experimentation the natural frequencies and mode shapes are obtained for both with and without PZT patches of a beam. Finally through experimentation the response of the smart beam is recorded.

1. Introduction

Different types of composite material analysis are focused in literature review. By combining two or more materials a composite can be developed in order to take the advantage of desirable properties of the components. In present study a glass/epoxy composite is considered for its better strength and stiffness properties. For these composites more precisely we can control the strength and stiffness properties within the plane. Now a days the development of piezoelectric materials in the field of smart structures motivated many researchers. A structure which can sense the external disturbance and responds to it in a controlled manner is termed as smart structures. The operational efficiency of these structures due to mechanical vibrations is affected to a greater extent. It necessitates the knowledge of dynamic characteristics of a system in the field of demanding areas namely design of vibration control devices and structural health monitoring. In this paper an attempt has been made to determine the free vibrational characteristics of a smart beam experimentally.

2. Methodology

In the present work first a fixture is developed for holding the beam in a cantilever configuration. In this study a Glass/Epoxy laminated composite beam is used. It consists of 3 layers of thickness 0.5mm in which fibers are oriented at an angle of 0\degree in all layers as shown in figure 1. The configuration of the beam considered in this study is fixed-free condition. The dimensions of the beam and the piezo patches are as shown in table 1.
The properties of PZT patches and laminated composite beam are listed in below table 2.

**Table2. Properties of composite beam and PZT patches.**

| Particulars | Properties |
|-------------|------------|
| Composite beam | $E_x = 40.59 \text{GPa}$  
$E_y = 13.96 \text{GPa}$  
$E_z = 13.96 \text{GPa}$  
$\mu_{xy} = 0.22$  
$\mu_{yz} = 0.11$  
$\mu_{xz} = 0.11$  
$G_{xy} = 3.1 \text{GPa}$  
$G_{yz} = 1.55 \text{GPa}$  
$G_{xz} = 3.1 \text{GPa}$  
$\rho = 1830 \text{ kg/m}^3$ |
| PZT-5H | $E = 139 \text{GPa}$  
$\mu = 0.3$  
$\rho = 7350 \text{ kg/m}^3$ |

The beam is marked with 20 nodes for the proper place for mounting the accelerometer and also to get the mode shapes. The connections of data acquisition system, laptop, accelerometer (model 3032A),
FFT analyzer (Data Physics, model-QUATRO), modal hammer (ENDEVCO model-2031) and cables to the system are done as per the guidance manual. Below figure 2 shows an experimental setup.

![Figure 2: Vibration testing of a smart beam with cantilever configuration](image)

The beam was excited in a selected point by means of a small impact hammer (Model 2031), preferably at the free end. The input signals captured by a force transducer, fixed on the hammer. The resulting vibrations of the plate in selected points are measured by an accelerometer. The accelerometer (DYTRAN, TYPE 3032A) was mounted on the plate to the free end by using bees wax. The signal was then subsequently input to the second channel of the analyzer, where its frequency spectrum was also obtained. The response point was kept fixed at a particular point and the location of excitation was varied throughout the beam. Both input and output signals are investigated by means of spectrum-analyzer and resulting frequency response functions are transmitted to a computer for modal parameter extraction. The output from the analyzer was displayed on the analyzer screen by using ME-scope software. The present work represented the natural frequencies and mode shape of beam. The spectrum analyzer provided facilities to record all the data displayed on the screen to a personal computer’s hard disk and the necessary software.

3. Results and discussions

A free vibration analysis is carried out for the smart beam and it can be taken as a basis for other dynamic analyses namely transient analysis, harmonic analysis or even spectrum analysis based on the modal superposition technique. The natural frequencies for a beam with and without PZT patches are tabulated in below table 3.

| Modes | Frequencies (Hz) without PZT | Frequencies (Hz) with PZT | Damping |
|-------|------------------------------|---------------------------|---------|
| 1st   | 14.8                         | 15.6                      | 0.498   |
| 2nd   | 93                           | 94.5                      | 2.82    |
| 3rd   | 271                          | 274                       | 2.53    |
4. Conclusion

Modal testing is done for a smart beam with a cantilever configuration using data acquisition system. Through FFT frequency response functions are obtained. Quantitative results are presented in order to show the effect of PZT patches on modal parameters. It is found that the natural frequency of a smart beam changes slightly mainly because of the smaller size of the PZT patches compared to the size of the main beam. It has been observed that the natural frequency increases with increase in mode number. Also, the damping ratio change from mode to mode.

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