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Vibration Control of Smart Cantilever Beam using Strain Rate Feedback

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Abstract

In this paper simulation and experimental results of Strain rate feedback for active vibration control of a cantilever beam are presented. The piezoelectric patches are fixed on the surface of the host beam based on the Harmonic and Modal analysis done in a Finite Element tool (ANSYS). The dynamic model of the smart beam for the first two modes is obtained using a System Identification technique. The feedback control algorithm is analyzed and is implemented in real-time using National Instruments cRIO 9022 controller. It is observed that with this feedback law 49.29% and 52.84% reduction are obtained for first and second modes of vibration respectively. The result verifies the effectiveness of the controller to suppress the vibration of the smart beam.

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Keywords: Smart beam; system identification; active vibration control; strain rate feedback.

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1. Introduction

Piezoelectric materials have received much attention in vibration control of structures in recent years, because piezoelectric ceramic materials have mechanical simplicity, small volume, light weight, large useful bandwidth, efficient conversion between electrical energy and mechanical energy, and easy integration with various metallic and composite structures. Most vibration existing in machines and flexible structures are undesirable because it

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causes unpleasant noises, unwanted stress in structures, and malfunction or failure of systems. **(**E. F. Crawley and J. de Luis, 1987) initially investigated both analytically as well as experimentally that piezoelectric materials can be used as sensor and actuator for predicting the behavior of flexible smart structures for the first time. Research results indicates that the maximum order of magnitude of vibration response can be measured and optimal control effect can be achieved by the sensor and actuator allocated at the position with maximum curvature of vibration mode **(**K Ramesh Kumar et al., 2008**)**. Most research work on active vibration control are based models developed using Finite Element method. (S. M. Khot et al., 2011) presented PID based output feedback for active vibration control of cantilever beam using a reduced model extracted from a full (ANSYS) Finite Element model. **(**T. C. Manjunath et al., 2005**)** presented a robust decentralized controller for a multimode smart flexible system using a periodic output feedback control technique when there is a failure of one of the piezoelectric actuator. (Manning et al. 2000) presented vibration control scheme of a smart structure using system identification and pole placement technique. (Halim, D. et al., 2002) demonstrated H_∞ feedback controller to suppress the vibration of simple-supported PZT laminate beam. The mathematical model of the system is very crucial for controller design as any control system design procedure. However, due to incomplete knowledge of the system dynamics especially the behavior of the piezoelectric material bonded on the structure at any instant of time, it has been difficult to develop an accurate model of the system that describes the entire dynamics of the system in the case of smart structures. Therefore, the system model uncertainty resulted from the modeling process when it is modeled using Finite Element Method can be minimized using System Identification techniques. **(**Xiongzhu Bu et al., 2003**)** implemented System Identification ARMAX model and pole placement method to achieve the desired closed loop control for vibration suppression of flexible beam. (Xing-Jian Dong et al., 2006) presented a System Identification technique based on measured input and output data of the smart plate using observer/ Kalman filter identification technique in numerical simulation and experimental study based on Linear Quadratic Gaussian (LQG) control algorithm. (Fanson et al., 1990) demonstrated active vibration control of a beam with piezoelectric patches using positive position feedback (Fei, J., 2005) investigated both strain feedback and optimized PID compensator methods for active vibration control of cantilever beam bonded piezoelectric actuators. Moreover, the experimental robustness of PPF is studied for active vibration suppression of flexible smart structure by (G. Song et al., 2002). Since the states of the system are not usually measurable, state feedback based control laws require the total knowledge of the states of the system or a state estimator. However, the output of any system is always readily available for measurement. Therefore, the objective of this study is to evaluate the performance of Strain rate feedback control law as applied to a smart beam to suppress vibration.

2. Mathematical Modeling

The frequency equation of beam structure is a unique equation that yields an infinite number of natural frequencies and normal modes. However, in this paper the dominant modes of the beam vibration are identified experimentally using an Impact hammer test as shown in Figure1. The result shows that the first two modes are significantly dominant over the rest higher mode frequencies in terms of amplitude. Hence, these two dominant frequency modes are considered in the analysis. Developing a mathematical model of a system is an important component for control system design. Here in this study, the system model is derived using MATLAB System Identification Toolbox. The dynamics of the smart beam for the first two dominant bending frequencies is the main interest of present study as stated above. Hence, the stimulus signal used to identify the smart beam governing equation is made to include the first two natural frequencies of interest in the form of sweep signal. The sweep signal used is of frequency from 5 Hz to 200 Hz for 10 seconds and sampled at the rate of at 2K sample/s. The generated sweep signal was made to pass through the PZT voltage amplifier unit for amplifying the signal to the desired level mainly 120 volts and then was applied to the PZT to set the beam into vibration. The smart beam response to the sweep stimulus was recorded simultaneously at the same sampling rate. The response indicates that the beam responds significantly to those excitation frequencies corresponding to the its natural frequencies (resonance frequencies) as it shown in Figure 2. The samples are collected at a frequency of 2 KHz for 20 seconds so as to collect substantial data for model estimation and validation. In this paper, the system identification algorithm used to identify the system is based upon MATLAB System Identification Toolbox ARX method.