Acceleration Sensor-based First Resonance Vibration Suppression of a Double-clamped Piezoelectric Beam

Zhi-cheng Qiu

School of Mechanical and Automotive Engineering, South China University of Technology, Guangzhou 510641, PR China
State Key Laboratory of Robotics, Shenyang Institute of Automation, Chinese Academy of Sciences, Shenyang 110016, PR China

Fan-kong Meng

School of Mechanical and Automotive Engineering, South China University of Technology, Guangzhou 510641, PR China

Jian-da Han and Jin-guo Liu

State Key Laboratory of Robotics, Shenyang Institute of Automation, Chinese Academy of Sciences, Shenyang 110016, PR China

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This paper investigates resonance vibration suppression under persistent excitation near the first structural resonant frequency of a clamped-clamped (doubly-clamped) piezoelectric flexible beam. In this study, an acceleration sensor is used to measure the resonant vibration. Firstly, the finite element method (FEM) is utilized to derive the dynamics model of the system, and modal analysis is carried out. Secondly, an acceleration feedback-based proportional-integral control algorithm and variable structure control algorithms are designed, and a numerical simulation is performed. Finally, a doubly-clamped piezoelectric flexible beam experimental setup is constructed. Experiments are conducted on resonant vibration suppression using the designed control algorithms. The numerical simulation and experimental results demonstrate that the resonant vibration can be suppressed by using the designed control methods, and the improved variable structure control method shows better control performance in suppressing the resonant vibration.

1. INTRODUCTION

Flexible beam structures are characterized by light weight, low structural damping, and low modal frequencies, and they are one of the main structure types used in the engineering field and aerospace structures.[1] Vibrations are easily caused when flexible beams are subjected to heavy loads or affected by a variety of unexpected external factors in the course of their work. Furthermore, these vibrations will last for a long time. If the vibrations are not suppressed effectively, the prolonged vibrations will reduce the working accuracy and working life of large and complex structures, such as space crafts and space robot manipulators. Moreover, if the structure is excited at its resonance frequencies, it will be seriously damaged.[2] Therefore, active vibration control of flexible structures is an important concern.

During the past few decades, a considerable amount of study in the area of active vibration control of flexible structures has been conducted by many researchers. In their investigations, piezoelectric materials (such as PZT, PVDF) are widely used in active vibration control for flexible structures. They provide inexpensive, reliable, and non-intrusive means of actuating and sensing vibrations in flexible structures.[4] Wang, et al.,[5] conducted a study on the vibration control of smart piezoelectric composite plates; they investigated the effect of the stretching-bending coupling of the piezoelectric sensor and actuator pairs on the system stability of smart composite plates. The classical negative velocity feedback control method was adopted for the active vibration control analysis of smart composite plates with bonded distributed piezoelectric sensors and actuators in their study. Sabatini, et al.,[6] studied active damping strategies and relevant devices that could be used to reduce the structural vibrations of a space manipulator with flexible links during its in orbit operations. They proposed an optimized adaptive vibration control via piezoelectric devices. Carlos, et al.,[7] conducted an experimental study into the control of a cantilever beam, which had a PZT patch bonded to it as an actuator and a collocated PVDF patch which was used as the sensor. Their experimental results demonstrated the effectiveness of the active vibration control method. Direct output feedback-based active vibration control has been implemented on a smart cantilever beam at its resonant frequency using PZT sensors and actuators by Parameswaran, et al.,[8] They compared the performance of the conventional PC-based control and a dedicated real-time control at resonance, and their experimental results demonstrated that the implementation of real-time control provides a much more controlled response of the system with an excellent transient response, as well as a highly reliable steady state response.