Active vibration suppression of a flexible structure using smart material and a modular control patch

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Abstract: This paper presents experimental results of vibration suppression of a flexible structure using smart materials and a miniaturized digital controller, called the modular control patch (MCP). The MCP employs a TI-C30 digital signal processor and was developed by TRW for the United States Air Force for future space vibration control. In this research, the MCP is used to implement different control algorithms for vibration suppression of a cantilevered aluminium beam. The beam is equipped with smart sensors and actuators, and both are made of piezoceramics. Positive position feedback (PPF) control, strain rate feedback (SRF) control and their combinations were implemented. Experiments found that PPF control is most effective for single-mode vibration suppression, and two PPF filters in parallel are most effective for multimode vibration suppression. Experiments also demonstrated the capacity of smart material being used as sensors and actuators for vibration suppression. The MCP was shown to be capable of implementing various real-time control laws.

Keywords: miniaturized digital controller, positive position feedback control, strain rate feedback control, vibration suppression, multimode vibration suppression, smart sensors and actuators

NOTATION

A	constant
d_{31}	lateral strain coefficient of the PZT
E_b	Young's modulus of the beam
E_p	Young's modulus of the PZT
G	feedback gain
L	beam length
L_a	length of PZT actuators
L_s	length of PZT sensor
t	time
t_b	beam thickness
t_p	PZT actuator and sensor thickness
w_b	beam width
w_p	PZT actuator and sensor width
α	magnitude of the assumed single degree-of-freedom vibration of the beam
ε_3^T	absolute permittivity of the PZT
ζ	damping ratio of the structure
ζ_c	damping ratio of the compensator
η	coordinate of the compensator
ξ	modal coordinate describing the displacement of the structure
ρ_b	beam density
ρ_p	PZT density
ϕ	phase angle
ω	natural frequency of the structure
ω_c	natural frequency of the compensator

The MS was received on 25 August 1999 and was accepted after revision for publication on 28 July 2000.
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1 INTRODUCTION

The current trend of spacecraft design is to use large, complex and lightweight space structures to achieve increased functionality at a reduced launch cost. The combination of a large and lightweight design results in these space structures being extremely flexible and having low fundamental vibration modes. Active vibration control has been increasingly used as a solution for spacecraft structures to achieve the degree of vibration suppression required for precision pointing