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Positive Position Feedback Control for Active Suppression of Impact-induced Vibrations Using a Point-wise Fiber Bragg Grating Displacement Sensing System

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Summary

Smart flexible structures involve four key elements: actuators, sensors, control strategies, and power conditioning electronics, which makes the structures being capable of realizing specific functions. Recently, fiber Bragg grating (FBG) strain sensors are being considered to be integrated into smart structures since they possess many excellent properties such as low density, small size, simplicity of fabrication, and immunity to electromagnetic fields. In this paper, unlike traditional FBG strain sensors, a fiber Bragg grating (FBG) sensing system which has the ability to detect point-wise out-of-plane displacement responses is set up on a smart cantilever beam to perform active vibration control. The FBG displacement sensor is set up with a piezoelectric actuator on the beam in a collocated way. Responses of the FBG displacement sensor are demodulated by an FBG filter to enhance the signal to noise ratio. The sensing performance as well as the feasibility of integrating the proposed FBG displacement sensing system in an active structural control are investigated. Impact-induced vibrations due to a steel ball are considered. The measurement results of the FBG displacement sensing system are compared simultaneously with a non-contact Fotonic sensor to demonstrate its dynamic feedback sensing ability.

Despite demonstrating the sensing performance, this paper also investigates the influence of the loading effect of the FBG displacement sensor on the responses of the smart cantilever beam in a feedback system. First, to investigate the ability of the proposed FBG displacement sensing system for performing system identification, random inputs are applied to the smart cantilever beam before performing active vibration suppression. Then a positive position feedback (PPF) controller is designed to suppress the first three bending modes of the smart cantilever beam subjected to impact loadings. Based on the resonant frequencies obtained by the system identification of the smart cantilever beam, the PPF controller is designed and implemented. It employs a set of second-order compensators in the feedback path to suppress the vibration. By performing the fast Fourier transform (FFT) of the transient responses with or without the PPF controller, performance of the controller is demonstrated.

Experimental results indicate that the proposed FBG displacement sensing system is capable of integrating into a smart structure to perform active vibration control.

The experimental results also indicate that the loading effect of the FBG displacement sensor will not affect the design and the control performance of the PPF controller.