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Semiactive nonlinear control of a building with a magnetorheological damper system

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ABSTRACT

This paper proposes a linear matrix inequality (LMI)-based systematic design methodology for nonlinear control of building structures equipped with a magnetorheological (MR) damper. This approach considers stability performance as well as transient characteristics in a unified framework. First, multiple Lyapunov-based controllers are designed via LMIs such that global asymptotical stability of the building structure is guaranteed and the performance on transient responses is also satisfied. Such Lyapunov-based state feedback controllers are converted into output feedback regulators using a set of Kalman estimators. Then, these Lyapunov-based controllers and Kalman observers are integrated into a global nonlinear control system via fuzzy logic. To demonstrate the effectiveness of the proposed approach, a three-story building structure employing an MR damper is studied. The performance of the nonlinear control system is compared with that of a traditional linear optimal controller, i.e., H_2/linear quadratic Gaussian (LQG), while the uncontrolled system response is used as the baseline. It is demonstrated from comparison of the uncontrolled and semiactive controlled responses that the proposed nonlinear control system design framework is effective in reducing the vibration of a seismically excited building structure equipped with an MR damper. Furthermore, the newly developed controller is more effective in mitigating responses of the structure than the H_2/LQG controller.

1. Introduction

In recent years, fuzzy logic has attracted great attention to control system design [1–6]. A number of design methodologies for fuzzy logic controllers have been successively applied to a variety of large-scale civil building structures. They include trial-and-errors-based methodologies [7–12]; a self-organizing approach [13]; training using linear quadratic Gaussian (LQG) data [14]; neural networks-based learning [15–18]; adaptive fuzzy [19]; genetic algorithms-based training [20–24]; fuzzy sliding mode [25–27]; etc. However, no study on systematic design framework has been conducted to design a semiactive nonlinear fuzzy controller (SNFC) for building structures equipped with a nonlinear semiactive control device.

From a practical point of view, research related to a systematic design framework is still required for a large building control system for mitigation of natural hazards, e.g., earthquake or strong wind. An active nonlinear fuzzy control (ANFC) system design can be carried out in a systematic way via the so called parallel distributed compensation (PDC) approach,

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