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Hierarchical semi-active control of base-isolated structures using a new inverse model of magnetorheological dampers ☆

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ABSTRACT

Magnetorheological (MR) dampers have received special attention as semi-active devices for mitigation of structural vibrations. Because of the inherent nonlinearity of these devices, it is difficult to obtain a reasonable mathematical inverse model. This paper is concerned with two related concepts. On one hand, it presents a new inverse model of MR dampers based on the normalized Bouc–Wen model. On the other hand, it considers a hybrid seismic control system for building structures, which combines a class of passive nonlinear base isolator with a semi-active control system. In this application, the MR damper is used as a semi-active device in which the voltage is updated by a feedback control loop. The management of MR dampers is performed in a hierarchical way according to the desired control force, the actual force of the dampers and its capacity to react. The control is applied to a numerical three-dimensional benchmark problem which is used by the structural control community as a state-of-the-art model for numerical experiments of seismic control attenuation. The performance indices show that the proposed semi-active controller behaves satisfactorily.

1. Introduction

Base isolation is one of the most well accepted methods to protect moderate hight and weight structures from earthquake hazard because of its simplicity, reliability, and effectiveness [17]. This system by itself can reduce the interstory drift and the absolute acceleration of the structure, but the absolute base displacement of the structure may be large and hard to accommodate. Passive high-damping devices incorporated within the isolation system can control large bearing displacements associated with pulse-like earthquake ground motions, but the beneficial effects of the base isolation system may be significantly reduced for both moderate and strong earthquakes due to the transfer of energy into higher modes which can result in increased interstory drift and floor acceleration responses [10,14]. Semi-active controllers in hybrid base-isolation systems can achieve almost the same performance as an active base isolation system in protecting the safety of buildings against strong earthquakes [8]. Therefore, a hybrid base isolation system with semi-active devices, like MR dampers, in parallel to isolation bearings, can significantly overcome this problem by means of the application of a single force at the base [14].

A variety of semi-active control algorithms have been proposed for control of MR dampers (see for example [7]). However, one of the most important and challenging tasks in control design is the development of an accurate mathematical model of the structural system under consideration. This model must include both the structure and the control devices.

Many works have been done to model the hysteretic behavior of MR dampers statically or dynamically. For example, various modifications on the Bouc–Wen model have been investigated [2,12]. In these models the input–output relation are expressed by a set of nonlinear differential equations. Although the models can simulate the nonlinear behavior of MR dampers, they have complex structures which make the inverse process hard and time consuming. The inverse model of an MR damper is an efficient way to compute the necessary command voltage which has to be applied according to a desired control force.

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