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Application of semi-active control strategies for seismic protection of buildings with MR dampers

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ABSTRACT

Magnetorheological (MR) dampers are semi-active devices that can be used to control the response of civil structures during seismic loads. They are capable of offering the adaptability of active devices and stability and reliability of passive devices. One of the challenges in the application of the MR dampers is to develop an effective control strategy that can fully exploit the capabilities of the MR dampers. This study proposes two semi-active control methods for seismic protection of structures using MR dampers. The first method is the Simple Adaptive Control method which is classified as a direct adaptive control method. By using this method, the controlled system is forced to track the response of the system with desired behavior. The controller developed using this method can deal with the changes that occur in the characteristics of the structure because it can modify its parameters during the control procedure. The second controller is developed using a genetic-based fuzzy control method. In particular, a fuzzy logic controller whose rule base determined by a multi-objective genetic algorithm is designed to determine the command voltage of MR dampers. In order to evaluate the effectiveness of the proposed methods, the performances of semi-active controllers are compared with some other control algorithms in a numerical example. Results reveal that the developed controllers can effectively control both displacement and acceleration response of the considered structure.

1. Introduction

One of the challenging tasks for civil engineers is to mitigate the response of a structure subjected to dynamic loads in order to prevent possible damage that may cause human tragedies and enormous economic repercussions [1]. Structural control methods show great potential to reduce the damaging effects of seismic excitations on civil structures. Over the past decades, many control devices and algorithms have been proposed to mitigate dynamic response of a structure during extreme events such as earthquakes and strong winds [2]. There are mainly three classes of control devices. Passive devices, which require no external power, are reliable and never destabilize the structure [3]. However, they have low adaptability to change of external loading conditions or usage patterns used in their design. On the other hand, active control devices [4] are adaptive to varying usage patterns and loading conditions but their stability problems, reliability and large power consumptions are still major concerns to engineers.

Semi-active devices which are the third class of structural control systems have attracted considerable attention for the seismic protection of structures in recent years [5]. These devices only absorb or store the vibratory energy and they do not input the energy to the system. Therefore, they do not induce adverse effects on the stability of the system. The versatility and adaptability of the active devices and the reliability of the passive devices are offered by semi-active devices. A variety of semi-active devices such as variable orifice dampers, variable friction devices, adjustable tuned liquid dampers, variable stiffness dampers and controllable fluid dampers have been proposed for vibration control of structures [6,7].

One of the most promising semi-active devices is the magnetorheological (MR) damper. MR dampers are controllable fluid devices that employ MR fluids whose rheological properties may be rapidly varied by an applied magnetic field. They can provide large force capacity, high stability, robustness and reliability. Furthermore, they are relatively inexpensive to manufacture and maintain and are insensitive to temperature so that they may be used for indoor and outdoor applications. Because of their mechanical simplicity, high dynamic range and low power requirements, they are considered as good candidates for reducing the structural vibrations and they have been studied by a number of researchers for seismic protection of civil structures [8–12].

One of the challenges in the application of the MR dampers is using an appropriate control algorithm to determine the command voltage of the MR damper. Many control algorithms have been

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