Engineering Structures 33 (2011) 3143–3154

Contents lists available at SciVerse ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Adaptive control of base-isolated structures against near-field earthquakes using variable friction dampers

Osman E. Ozbulut *, Maryam Bitaraf, Stefan Hurlebaus

Zachry Department of Civil Engineering, Texas A&M University, 3136 TAMU College Station, TX 77843-3136, United States

ARTICLE INFO

Article history:
Received 5 March 2011
Received in revised form
31 May 2011
Accepted 11 August 2011
Available online 23 September 2011

Keywords:
Variable friction damper
Semi-active control
Adaptive control
Base isolation
Near-field earthquake

ABSTRACT

This paper investigates the effectiveness of two adaptive control strategies for modulating the control force of variable friction dampers (VFDs) that are employed as semi-active devices in combination with laminated rubber bearings for the seismic protection of buildings. The first controller developed in this study is an adaptive fuzzy neural controller (AFNC). It consists of a direct fuzzy controller with self-tuning scaling factors based on neural networks. A simple neural network is implemented to adjust the input and output scaling factors such that the fuzzy controller effectively determines the command voltage of the damper according to current level of ground motion. A multi-objective genetic algorithm is used to learn the shape of the activation functions of the network. The second controller is based on the simple adaptive control (SAC) method, which is a type of direct adaptive control approach. The objective of the SAC method is to make the plant, the controlled system, track the behavior of the structure with the optimum performance. Here, SAC methodology is employed to obtain the required control force which results in the optimum performance of the structure. For comparison purposes, an optimal linear quadratic Gaussian (LQG) controller is also developed and considered in the simulations together with maximum passive operation of the friction damper. The results reveal that the developed adaptive controllers can successfully improve the seismic response of base-isolated buildings against various types of earthquake.

1. Introduction

One of the main considerations of civil engineers when designing a structure is to reduce the risks of damage and injuries caused by dynamic loads such as earthquakes and strong winds. Over past decades, base isolation has been found to be an effective means to protect structures and their contents from the destructive effects of dynamic excitations. However, recent studies have shown that near-field earthquakes characterized by long-duration pulses with peak velocities result in significant relative displacements at the isolation level of a seismically isolated structure [1–3]. As a result of large isolator displacements, the size of the isolation device significantly increases. This may require very large seismic gaps between buildings or large bridge expansion joints. Therefore, these requirements, in return, increase the cost of the construction, which contradicts the primary goal of seismic isolation to design structures more efficiently and economically by reducing the earthquake forces transferred to the superstructure.

In order to enhance the performance of base-isolated structures against near-field excitations, passive, active, and semi-active control devices have been proposed [4–10]. Passive systems can reduce the deformations of the isolation bearings during strong ground motions; however, they can cause an increase in superstructure response due to large damper forces applied to the structure [11–13]. Furthermore, in the case of a moderate or weak excitation, passive devices can have detrimental effects on an isolated structure since the desired isolation characteristics may be different for these ground motions and passive devices cannot be adapted online. On the other hand, active devices are generally able to control the seismic response of the isolation system for a wide range of loading conditions. However, active devices use an external energy source to produce the control forces imparted on the structure and they require a considerable size of power source, which makes them vulnerable to power failure. Also, an active control system has the potential to destabilize the structural system.

Semi-active control devices have received considerable attention in recent years because of their great adaptability with low power requirements [14–17]. These devices only absorb or store the vibratory energy and they do not input the energy to the system. Several researchers have studied the use of a semi-active device in a base isolation system in order to reduce the displacement response of an isolation system without an increase in superstructure response. Yoshioka et al. [18] performed experimental tests to demonstrate the effectiveness of a base isolation system that employs a magnetorheological (MR) damper. Symans and Kelly [19] investigated the performance of a variable viscous damper modulated by a fuzzy

* Corresponding author. Tel.: +1 979 458 1222.
E-mail addresses: ozbulute@tamu.edu (O.E. Ozbulut), mbitaraf@tamu.edu (M. Bitaraf), shurlebaus@civil.tamu.edu (S. Hurlebaus).

0141-0296/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2011.08.022