Chapter 11
Nonlinear Structural Control Using Magnetorheological Damper

Shaikh Faruque Ali
Swansea University, UK

Ananth Ramaswamy
Indian Institute of Science, India

ABSTRACT

This chapter provides an introduction to semi active control of base isolated buildings using magnetorheological (MR) dampers. Recently developed nonlinear control algorithms are discussed. First a fuzzy logic control (FLC) is designed to decide how much voltage is required to be supplied to the MR damper for a desired structural response. The FLC is optimized using micro genetic algorithm. A novel geometric approach is developed to optimize the FLC rule base. Experiments are undertaken to access the efficacy of the optimal FLC. Secondly the chapter develops two model based control algorithms based on dynamic inversion and integrator backstepping approaches. A three storey base isolated building is used for experimental and numerical studies. A numerical comparison is shown with clipped optimal control.

INTRODUCTION

Civil engineering structures, e.g., tall buildings, long span bridges, deep water offshore platforms, nuclear power plants, etc., have become more costly, complex and serve more critical functions. The consequences of their failure are catastrophic. Devastations in the past and recent earthquakes have shown that the understanding of building physics under seismic motion has increased which has improved the design of building and international building codes too. But we are still at the mercy of the nature as one concern that still remains is that no structure can be built to with stand all possible loads. The uncertainty in future loadings and few fold increase in cost of construction never allow the engineers to design and built a structure that can withstand all possible loading conditions. The best alternative is to supplement structures with added devices such that they can take care of any unforeseen events and loadings. For an example, recent earthquake followed by a

DOI: 10.4018/978-1-4666-7456-1.ch011

tsunami in Japan (11th March 2011) has not only devastated but wiped out cities. Strict building codes and added damping to the structures have saved Japan from wider destructions as noted in various international newspapers worldwide (Glanz and Onishi, 2011; Ross, 2011).

Seismic base isolation is an old, widely accepted and implemented structural mechanism due to its robustness and ease in deployment. Following the Northridge earthquake (1994), and Kobe earthquake (1995), the interest of structural engineers in understanding near-source ground motions has enhanced (Soong and Spencer, 2002). Documents published after these earthquakes emphasized the issue of large base displacements because of the use of none or little isolation damping (of viscous type only) prior to these events. More recent studies have investigated analytically and experimentally, the efficiency of various dissipative mechanisms to protect seismic isolated structures from recorded near source long period, pulse-type, high-velocity ground motions. Consequently, hybrid isolation systems, seismic base isolation supplemented with active/semi-active damping mechanisms, have become the focus of current research trend in structural vibration control.

The recent focus on hybrid mechanism is to augment base isolation devices with semi-active magnetorheological (MR) dampers for efficient structural vibration control. MR dampers provide hysteretic damping and can operate with battery power (Dyke et al., 1996; Ali and Ramaswamy, 2008a).

The use of MR damper as a semi-active device involves two steps:

1. Development of a model to describe the MR damper hysteretic behaviour
2. Development of a proper nonlinear control algorithm to monitor MR damper current/voltage supply

The present chapter deals with the development of nonlinear control strategies to use with MR damper for base isolated buildings. The chapter unfolds in two interlinked areas. First an intelligent fuzzy logic control (FLC) scheme is developed to monitor the MR damper voltage input. The FLC is optimized using micro genetic algorithm. An experimental study is undertaken to access the efficacy of the optimal FLC in real time and to verify the numerical studies. Next the chapter provides insight to two newly developed model based nonlinear control techniques, viz, a dynamic inversion based MR damper monitoring and an integrator backstepping based MR damper monitoring. These two control algorithms are studied through numerical simulations.

The chapter is organized as follows: the next section provides a comprehensive review of literature on nonlinear control schemes to monitor MR damper for structural applications. Next, development of an optimal FLC using micro genetic algorithm is shown in details. A novel geometric scheme is developed to optimize the FLC such that a few optimization variables are required. Experimental study carried out to access the efficiency of the FLC is detailed next. The chapter then introduces the nonlinear control schemes. The mostly used clipped optimal control scheme is discussed. Emphasis is given to recently developed backstepping and dynamic inversion based control schemes. Results of numerical simulations of the nonlinear algorithms are provided and discussed thereafter. Finally the chapter concludes with a future direction of research.

BACKGROUND AND LITERATURE REVIEW

A control system can be classified as passive, active, hybrid, or semi-active based on the level of energy required and the type of control devices employed. Among these systems, the semi-active approach has recently received considerable attention because of its significant adaptability without large power requirements like active