

Chapter 35

Multi-Objective Optimization Design of Control Devices to Suppress Tall Buildings Vibrations against Earthquake Excitations Using Fuzzy Logic and Genetic Algorithms

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ABSTRACT

The main objective of this chapter is to find the optimal values of the parameters of the base isolation systems and that of the semi-active viscous dampers using genetic algorithms (GAs) and fuzzy logic in order to simultaneously minimize the buildings' selected responses such as displacement of the top story, base shear, and so on. In this study, performance of base isolation systems, and semi-active viscous dampers are studied separately as different vibration control strategies. In order to simultaneously minimize the objective functions, a fast and elitist non-dominated sorting genetic algorithm (NSGA-II) approach is used to find a set of Pareto-optimal solution. To study the performance of semi-active viscous dampers, the torsional effects exist in the building due to irregularities, and unsymmetrical placement of the dampers is taken into account through 3D modeling of the building.

INTRODUCTION

One of the most important tasks in structural engineering is to reasonably minimize the undesired vibrations of the structures due to the

environmental dynamic loads such as earthquake excitations. Various strategies and theories have been investigated and developed to approach this goal over the years. Use of the control systems is one of these methods to enhance the structural

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performance against vibration excitations. The main purpose of these methods is to reduce the structural responses such as displacement, velocity and acceleration. Control systems are divided to four groups of passive, semi active, active and hybrid systems based on the performance and rate of the energy consumption and the kind of their installation to the main structure.

The passive systems dissipate the vibration excitations without using any external power source for operation and utilize the motion of the structure to develop the control force. Since the properties of these types of control systems cannot be modified after installation, these systems are regarded as passive. These systems add no energy to the structure, and therefore are not able to make the structure unstable. These systems are undoubtedly simple, inexpensive, and reliable to suppress the undesired vibrations of the structures. Another advantage of these systems is low cost of repairing and maintenance. Passive tuned mass dampers (TMDs) and base isolations are two kinds of these systems (Pinkaew & Fujino 2001; Yang & Agrawal 2002; Cao et al. 1998; Soong & Constantinou 1994; Soong & Dargush 1997). Although TMD control systems may be considered a hybrid of a tuned dynamic absorber, including a mass block and spring, combined with a viscous damper, however, in engineering is known as a passive control system (Pinkaew & Fujino 2001; Soong & Dargush 1997).

An active control system may be defined as a system which typically requires a large power source for operation of electrohydraulic or electro-mechanical actuators which supply control forces to the structure. Control forces are developed based on feedback from sensors that measure the excitation and/or the response of the structure (Symans & Constantinou 1999). Active tuned mass damper (ATMD) or hybrid mass damper is a kind of these control systems, which is considered when the required response reduction exceeds the capacity of the TMD. ATMD systems are more costly, complex, needs careful maintenance, as

well needs huge source of energy difficult to provide in severe earthquakes. Moreover, the control forces which these systems apply to the structure may cause unforeseen behavior of the structure. These disadvantages made them to be less reliable than TMDs and are being used only for certain cases (Chey et al., 2009).

The limitation of passive and active control systems result in developing semi active control systems. Semi-active control systems maintain the reliability of passive control systems while taking advantage of the adjustable parameter characteristics of an active control system (Symans & Constantinou 1999). The semi-active tuned mass damper (STMD) with variable damping is a kind of these systems. Various studies confirm the efficiency of STMDs and show that the application of TMDs is much better when they behave as STMDs, especially in wind and earthquake excitations. In these systems, the stiffness or the damping ratio of the control device changes proportional to the relative displacement or relative velocity, by receiving information from sensors in every second (Mulligan, 2007). Therefore, they do not require large power supply, and they do not add additional energy to the main structure and guarantee stability of the system. In order to regulate the stiffness or the damping ratio of the STMDs, fuzzy systems can be utilized.

Hybrid control systems are the combination of some passive systems with active or semi active systems, resulting to better performance of the control device in reducing the structural responses. One of the most popular systems of them is smart isolator. Another example of hybrid control system is a combination of passive isolation bearings with some passive energy dissipating devices. Additional damping in these systems enhances control performance of them particularly in near field earthquakes.

The main objective of this chapter is to find the optimal values of the base isolation system as a kind of passive control device, and that of the STMD system as a kind of semi-active control

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