Chapter 74
Nonlinear Vibration Control of 3D Irregular Structures Subjected to Seismic Loads

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ABSTRACT

For the active control of three dimensional (3D) irregular structures subjected to seismic load, a new nonlinear model is discussed in this chapter. As well as geometric nonlinearity, material nonlinearity is also considered with a neuro-controller training algorithm, which is applied to a structure of multi degrees of freedom. For the control model, a dynamic assembly of two different motions is considered such as coupling between torsional and lateral responses of the structure and interaction between the structural system and the actuator. The training algorithm and the proposed control system of the structure are evaluated by the response simulation of the structure under the excitation of El-Centro 1940 earthquake. With linear and nonlinear stiffness, a 3D three story building structure is controlled by a trained neural network as an example. As additional parameters for the simulation control time delay, the incident angle of earthquakes is considered. The results show that the proposed control algorithm is efficient in the control of the structural vibration.

INTRODUCTION

Vibrations are the most undesirable events that happens to any engineering system, like structure. These vibrations may happen for many reasons, such as wind force, earthquake force, explosion force and so many more. Damages due to vibration is much more severe. As a matter of fact, preventing the civil structure from the vibration induced damage is one of the main challenges in structural engineering. Earthquake plays significant role in causing heavy structural vibration.

Seismic Vibration control can be defined as a set of technical means that is optimized in reducing the impacts due to earthquake induced forces. Vibration control system can be categorized as active, passive and hybrid control. Passive control devices can be classified as the devices that have

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no feedback capacity between structural elements and the device itself. With a real-time incorporation the active control devices works with the input processing equipment and actuators. Combining features from active and passive controller hybrid control devices works in a more efficient way.

Among the passive control methods are Tuned mass damper (TMD), Tuned liquid damper (TLD) and Tuned liquid column damper (TLCD), and so on. Tuned liquid column damper, proposed by Sakai et al;, combines the liquid mass and orifice damping effect to minimize the vibration. Using the similar concept Tuned liquid damper (TLD) also works fine. The main advantages of TLCD and TLD is that they can be used as both controller and reservoir for daily water supply. But more dangerous thing that probably can be happed with TLCD and TLD is if the lateral loading happened during the empty condition of the devices. Moreover, it is much more difficult to tune the water level to control the vibration effectively. Tuned Mass Damper (TMD) is a reliable solution in such situations. An auxiliary mass attached to the top of the structure by a spring and a dash-pot. TMD system became quite popular worldwide since 1971. Crystal Tower Building in Osaka, the Citicorp Center in New York City, Taipei 101 in Taiwan and Sydney tower in Sydney are the successful examples of TMD. Many paper have been published on the performance investigation of theses controlling systems.

A structure, subjected to heavy dynamic loading, may face severe change in stiffness because of the damages along the structure. But in most case the numerical modeling is conducted over the assumption of linear behavior of the structural system. Therefore, these numerical models fail to predict the accurate final response of the system. To get relatively linear behavior from a larger structure it will be needed to install actuators in an illogical large scale. Many researchers also agreed in the matter that in controlling the structural response linear control system will not be effective (Bani-Hani and Ghaboussi 1998).Therefore, the linear control algorithms are not so effective in controlling the tall structures subjected to the severe ground motion. Because of strong winds or earthquake the tall structures may face yielding and nonlinear action both on geometry and materials behavior in consideration of displacement and torsional responses. In such cases the control system that behaves linearly would not be adequate to find out the actual dynamic characteristics of a structure because the structural stiffens can be changed in a tremendous way due to the damages during dynamic loading. In such cases, a controlling system that consider the changes of geometric and material behavior will be much effective. This chapters deals with a neural-network controlling system that is optimized as a nonlinear vibration controller.

Response reduction of the structure is one of the popular ways to reduce the damages. But the significant issue is that torsional coupled response of the three dimension (3D) irregular full scale structures considering the arbitrary direction of earthquake has been rarely studied. For the development and implementation of active, semi-active, passive and hybrid control, a lot of researches were conducted over the years and published a lot of papers.

Two dimensional structures were the major concern of most of the researches and some other researchers also conducted the 3D effect of the structure (Masri et al. 1982, Kim et al. 1988). Some other researchers also considered the vertical and plan irregularity (Jiang and Adeli 2008). Including the genetic algorithm, fuzzy neural network, magneto rheological (MR) damper, optimal control, sliding mode control, equivalent passive structural control, and optimal polynomial control, a lot of other control strategies have been proposed and used in real structures to reduce the structural response (Ahmadizadeh 2007, Chu et al. 2002, Wang et al. 2009). Structural active control techniques using artificial neural networks (ANN) were started in the middle of the 1990s.