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Seismic Vibration Control of Nonlinear Structures Using Semi- Active Tuned Mass Dampers

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ABSTRACT

In this paper, designing semi-active tuned mass damper (SATMD) for reducing the response of nonlinear frame structures under earthquake excitations has been studied. To determine the appropriate damping coefficient of SATMD, a semi-active control algorithm based on nonlinear instantaneous optimal control and clipped optimal control concept has been developed. Also for optimal design of the control system, the design parameters have been determined by solving an optimization problem that minimizes the maximum response of the structure. As numerical example, for an eight-story nonlinear shear frame with bilinear hysteresis behavior, SATMD has been designed. The results of numerical simulations show the capability of the proposed method for determination of control signal as well as the effectiveness of the SATMD mechanism in reducing the response of the nonlinear structures under earthquake excitation.

KEYWORDS

Semi-Active Tuned Mass Damper, Nonlinear Structures, Semi-Active Control, Instantaneous Optimal Control, Clipped Optimal Control.

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1- INTRODUCTION

The application of structural control systems to reduce the structural response has become an innovative approach to protect the structures against the damaging effects of the natural hazards such as strong winds or earthquakes [1]. Among these control systems, semi-active control strategies appear to combine the best features of passive and active control, making semi-active control a much more promising approach. A significant amount of research and development has recently been conducted on semi-active devices because of their relatively high performance, inherent stability and low power requirements. Most research on semi-active control systems has been limited to the linear structures. However, in practice, structures may undergo large deformation and thus exhibit nonlinear behavior when subjected to strong ground accelerations. Therefore, in order to carry out a more thorough and practical study, in this paper, the simulations have been performed taking the nonlinear characteristics of the structures into consideration.

Among various control mechanisms, tuned mass damper (TMD) is one of the simplest passive control systems proposed to improve the performance of structures against the environmental loads for linear and nonlinear structures [2]. TMD suffers from some shortcomings such as sensitivity to the tuned frequency ratio and hence limited operating band and rather poor robustness. To overcome these drawbacks of TMD and improve its performance, using semi-active control strategies has gained much attention in recent years, and therefore semi-active tuned mass dampers (SATMD) have been proposed accordingly [3-4] and different strategies have been developed as semi-active control algorithms [5-6].

In this paper, the effectiveness of SATMD as a semi-active control mechanism ,in reducing the response of nonlinear frame structures under earthquake excitations, has been studied.

2- METHODOLOGY

The semi- active characteristic of the system is achieved by modifying the damping in each time step in order to allow adjustments in the mechanical properties of the device and therefore to help reduce the response of the main structure [7-9]. A semi-active control algorithm based on instantaneous optimal control using the nonlinear Newmark integration method [10] and clipped optimal control [11-12] concept has been developed to determine the appropriate command signals for selecting the damping coefficient of SATMD. In addition, for optimization of the control system and improving the performance of SATMD, a method based on defining an optimization problem to minimize the maximum response of the structure has been proposed where the genetic algorithm (GA) has been used for solving the optimization problem. In this method, the parameters of the semi-active algorithm, as well as the parameters of SATMD, could be considered as variables and the best values of these parameters are determined through solving the optimization problem. Different objective functions could be selected for the optimization problem, where in this research, minimizing the maximum drift of the main structure has been selected as the objective function.

3- CONCLUSIONS

As a numerical example, an eight-story nonlinear shear-building frame with bilinear hysteresis behavior equipped with a SATMD attached to the top floor has been investigated. The results of numerical simulations show the capability of the proposed method for determination of control signal as well as the effectiveness of the SATMD mechanism in reducing the response of the nonlinear structures under earthquake excitation. Figure 1 shows the time history of maximum drift of uncontrolled and controlled structures.

In order to evaluate the performance of the SATMD for improving the seismic behavior of the nonlinear frames, passive and active tuned mass dampers have also been investigated and the results are then compared. The maximum drift of uncontrolled and controlled structures using different mechanisms has been shown in Figure 2. In addition, it has been found that the performance of SATMD, designed by the proposed method in reducing the seismic response of nonlinear structures, depends on its damping characteristics and control system parameters and for the optimal design of SATMD, these parameters need to be properly chosen.

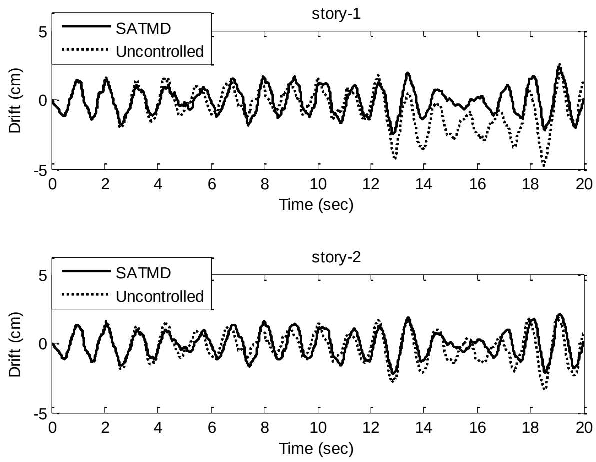

FIG 1. TIME HISTORY OF UNCONTROLLED AND CONTROLLED STRUCTURES DRIFT FOR FIRST AND SECOND STORIES.

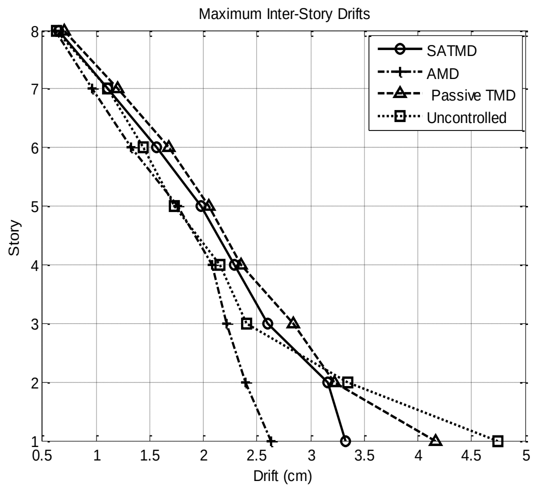

FIG 2. MAXIMUM DRIFT OF UNCONTROLLED AND CONTROLLED STRUCTURES FOR DIFFERENT CONTROL MECHANISM.

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