Vibration control of structures equipped with semi-active tuned mass damper with fuzzy controller optimized by CSS algorithm

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Abstract

This paper presents an optimized fuzzy controller to adjust the damping of semi-active tuned mass damper used to decrease the vibration of building structures due to the earthquake excitations. The fuzzy controller is designed to apply the appropriate voltage of semi-active magneto-rheological (MR) damper working as the tuned mass damper actuator. The fuzzy rules is planned based on the expert operator view of the physical behavior of the system. In this study, fuzzy controller is optimized by CSS algorithm to enhance the performance of the fuzzy controller in reducing the responses of the structure in seismic-induced vibrations. The optimized fuzzy controller is employed to modify the damping of a semi-active tuned mass damper attached on the top floor of a ten story building structure. The results of the proposed fuzzy controller are compared with those of the non-optimized fuzzy controller and passive tuned mass damper in two El-Centro and Tabas earthquake excitations. The outcomes demonstrate a good performance of the optimized fuzzy controller in reducing the responses of the structure.

Keywords: Semi-active Tuned Mass Damper, Fuzzy Controller, MR damper, CSS Optimization Algorithm.

1. Introduction

In recent years, using passive, active and semi-active devices to control the structural responses due to external excitations has been attracted many attentions of researchers. Active control devices require a significant amount of external power to work while semi-active devices need only a small amount of external power resource to adjust its mechanical properties and do not add energy to structures [1]. In this paper, a proposed fuzzy controller optimized by charged system search (CSS) algorithm with a semi-active tuned mass damper is used to reduce the vibration responses of building structures due to earthquake excitations.

For the first time Frahm [2] used tuned mass dampers to reduce the rolling motion of ships. Later, Ormondroyd and Den Hartog [3], Brock [4] and Den Hartog [5] investigated the use of tuned mass dampers for the reduction of the amplitude of vibration of single degree-of-freedom systems. Active tuned mass dampers' (ATMD) operation based on applying additional forces on the primary system to reduce the vibrations [6-8]. Despite the better performance of the ATMD than TMD, they need actuators, pumps, etc., high operational costs and high power requirements. In order to overcome these disadvantages, semi-active tuned mass dampers (STMD) have been introduced with variable damping or stiffness properties. Hrovat et al. [9] used STMDs to control the wind-induced vibrations in tall buildings. Abe [10] studied on some different types of STMDs for the seismic protection of civil structures.

The fuzzy set theory introduced by Zadeh [11] in 1965. Mamdani [12] applied Zadeh's theories of linguistic approach and fuzzy inference to control a steam generator. Because of the independency of the fuzzy controller from the analysis of the mathematical model of the system, the uncertainties of input data from the external loads and structural responses are treated in a much easier way in the fuzzy controller compared with common controllers. Also, by incorporating human expertise, the fuzzy IF–THEN rules can be designed to control complex structural systems.

In the last decade, many new natural evolutionary algorithms have been developed for optimization of engineering problems, such as genetic algorithms (GAs), particle swarm optimizer (PSO), ant colony optimization (ACO) and harmony search (HS), charged system search (CSS) [13-14]. These methods have attracted a great deal of attention, because of their high potential for modeling engineering problems in environments which have been resistant to solution by classic techniques. They do not require gradient information and possess better global search abilities than the conventional optimization algorithms. Having