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Estimating optimum parameters of tuned mass dampers using harmony search

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ABSTRACT

In this paper, the optimum parameters of tuned mass dampers (TMD) are proposed under seismic excitations. Harmony search (HS), a metaheurestic optimization method, which has been successfully applied for several engineering problems, is revised for tuning passive mass dampers. A Matlab program is developed for numerical optimization and time domain simulation. Optimization criteria are the peak values of first storey displacement and acceleration transfer function. In order to find best results, all properties of TMD are searched. For a fast and general optimization, a harmonic loading is utilized for numerical iterations. Also, final TMD parameters are checked under earthquake excitations. This new approach is compared with several other documented methods. Comparisons show that the new approach is more effective than other documented methods and more feasible due to smaller TMD parameters.

1. Introduction

The tuned mass damper (TMD) is a passive control system consisting of mechanical components such as mass, springs and viscous dampers. Tuned mass dampers have been installed in high rise buildings for damping vibrations. Examples include: Citigroup Center in New York City, Yokohama Landmark Tower in Yokohama, Burj Al Arab in Dubai, Trump World Tower in New York City, Taipei 101 in Taipei. A pendulum type TMD was implemented to Taipei 101 building in Taipei, Taiwan in order to reduce vibrations (Fig. 1).

Although active vibration control is more effective for control of structures, passive control techniques are still important for practical use because of high costs and unreliability of active systems. Also, passive systems especially tuned mass dampers are very practical for retrofit of structures. Tuned mass dampers can be easily attached to a floor or especially to the top of a main structure without any renovation.

In 1909, Frahm invented a device for damping resonance vibrations and this device is the basic form of tuned mass dampers [3]. This device was effective only when the absorbers' natural frequency was very close to the excitation frequency because it did not have any inherent damping. Ormondroyd and Den Hartog attached viscous dampers with a certain amount of damping in order to obtain beneficial results under changing excitation frequency [4]. Den Hartog developed closed form expressions of optimum damper parameters which are frequency ratio and damping ratio of the TMD [5]. These expressions are for only undamped main systems with a single degree of freedom (SDOF). Later, damping in the main system was included by several researches [6–9]. Warburton and Ayorinde showed that when obtaining optimum TMD parameters for complex systems, the problem may be thought as an equivalent SDOF system if its natural frequencies are well separated [10]. Thompson obtained optimum damper parameters with a frequency locus method [11]. Warburton derived simple expressions for optimum TMD parameters for undamped SDOF main systems under harmonic and white noise random excitations [12]. Villaverde et al. suggested that TMDs performed successfully when the first two modes of the modal damping ratio were equal [13–15]. Sadek et al. extended the study of Villaverde [13] because Villaverde's formulation does not result in equal damping in the first two modes of vibration, especially for big mass ratios [16]. Kareem considered the dynamics of base isolated buildings with passive mass dampers and compared different layouts of dampers [17]. Rana and Soong designed a TMD with numerical optimization in order to control a single structural mode only. Also they investigate the possibility of controlling multiple structural modes using multi-tuned mass dampers (MTMD) [18]. Also, optimum parameters of MTMDs were investigated in several studies [19–21]. Carotti and Turci designed an inertial tuned damper using phasers in the Argand–Gauss plane [22]. Chang derived optimum TMD design formulas in closed forms for both wind and earthquake types of loading [23]. Lin et al. used an extended random decrement method to reduce dynamic responses of buildings with TMD. Unlike previous studies they investigated displacement and acceleration response spectra for structures with and without TMD [24]. Aldemir designed an optimum semi-active tuned mass damper

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