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Optimal Design of a Nonlinear Eddy Current Tuned Mass Damper for Single Story Structures Subject to Base Excitation

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Abstract

In this work, a nonlinear tuned mass damper (TMD) is developed using cost effective eddy current damping element for single story structures subject to harmonic base excitation. After developing the design, the governing differential equations are solved using Runge-Kutta method and acceleration of the structure is minimized through simplex optimization algorithm. After finding the optimal function for damping coefficient with more than 15% increase in efficiency comparing the optimal linear case, the required damping element is designed base on aluminum and copper belts. The mechanical design and the results are compared with other references to prove what is claimed.

Keywords: Eddy current TMD, Nonlinear damping, Single story structures, Optimal design.

1. INTRODUCTION

Mitigation of undesirable vibrations in different structures created by different sources including earthquake, wind, motors and even by acoustic waves is a basic matter for which lots of attempt has been made to develop suitable devices and strategies. Tuned mass dampers (TMD) as a well-known method for vibration attenuation of the structures do not necessitate making essential changes in the main structure and accordingly can be used efficiently in appropriate cases. Different types of these kinds of vibration absorbers have been developed for different kinds of external actuations including harmonic and random ones [1-4]. The designs include using multiple tuned mass dampers [1], nonlinear viscous dampers [2], controllable viscosity [3] and nonlinear spring with nonlinear dry friction [4] in order to get better optimal responses from the design. It must be noted that, mechanical design, fabrication and testing of nonlinear elements require lots of attempts to be properly established. However, all the works confirm that it is required to use a tuned mass with a mass ratio of at least 0.1 (mass ratio = mass of TMD / mass of main structure) to be able to damp the undesirable vibrations in a specified actuation frequency ranges.

As another important concept, when a permanent magnet moves along a diamagnetic non-ferrous metal, a damping force proportional to the relative velocity will be created due to the eddy currents induced in the metal. The first step in calculation and modeling of such damping force is to have the magnetic field components of the permanent magnet which is extremely dependent on its geometry, size and remanence magnetic field [6]. Valuable experimental works together with modeling and simulations have been done to evaluate the eddy current damping forces and even use them to actuate and make a structure to vibrate [7, 8]. The results demonstrate that it is possible to create the damping coefficients ratio up to 0.5 by choosing proper magnets and conducting elements [7]. In addition, comparing eddy current dampers with viscous ones [5], it is concluded that, these are much simpler in design and fabrication and changing the damping coefficient to another desired value for other similar problems simply by adding the number or changing the size of magnets. Besides, some researches are focused in preparing a novel design for magnet and conductor elements to catch a desired damping coefficient for some especial cases [9]. In continue, it has been tried to use eddy current dampers in TMDs for light and heavy duty structure developing new mechanical mechanisms to produce the damping and stiffness elements [10-14]. It is theoretically and experimentally proved that such dampers can be developed for heavy weight structures such as wind turbines, sky scrapers