7th National Congress on Civil Engineering, 7-8 May 2013
University of Sistan and Baluchestan, Zahedan, Iran

Semi-active control of vertical vibration of suspension bridges subjected to earthquake, using MR dampers and fuzzy logic

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Abstract

In this paper, fuzzy control strategy is presented to enhance the seismic performance of suspension bridges using MR dampers. MR dampers are semi-active control devices that MR fluid used in their structure. They have received significant attention in recent years because of their adaptability of working as active control devices without requiring large power source and also because they can be viewed as fail-safe in that they become passive dampers in lack of the power source. Semi-active control devices require a controller to determine the desired control force. The fuzzy logic is a kind of controller that can directly determine the input voltage of an MR damper from the responses of the structure.

In the present paper, Thomas Suspension bridge located in los Angeles, U.S.A. is chosen as a case study. The responses of the bridge have been studied under application of 15 major worldwide earthquake accelerations. The comparison between the uncontrolled responses and semi-active fuzzy controlled responses indicates that the proposed semi-active control technique can effectively suppress the vertical responses of the suspension bridges.

Keywords: Semi-active control; suspension bridges; MR damper; vertical vibration; fuzzy logic.

1. INTRODUCTION

Cable supported bridges have received great attention in recent years because of their advantageous such as elegant appearance as well as convenience in choosing the bridge site. These structures are highly vulnerable to dynamic loads such as earthquakes and strong winds due to their high flexibility and low structural damping. Therefore, the vibration control of these bridges is an important issue to keep them safe and serviceable.

There are generally two main strategies to mitigate seismic responses of suspension bridges; strengthening, to increase the capacity to resist the seismic demand, or using energy dissipation to minimize the damage caused by the ground motion of strong earthquakes. Both approaches can also be used to aim an optimal solution [1].

Some measures such as passive viscous dampers, tuned mass dampers, tuned liquid column dampers, active mass damper have been studied for seismic retrofit of long span bridges. More recently magneto-rheological (MR) dampers have got a significant attention as a seismic retrofit due to their great advantageous such as: low power consumption, force controllability, large force capacity, rapid response and safe manner operation in case of fail. MR dampers have been mainly applied in vibration control of high way bridges, cable supported bridge and tall buildings [2].

A lot of mathematical models have been proposed to model the intrinsic non-linear behavior of MR dampers, such as Bingham model, the viscoelastic-plastic model, the Bouc-Wen model, the phenomenological model, the improved Bouc-Wen model, the modified Dahl, model and many others. Some of the models cannot capture the force-velocity non-linear behavior of the damper well such as the Bingham model. It's very important for a model that can portray the non-linear behavior of the damper and also ease in model parameter identification [3].

The damping force exerted by an MR damper is mainly dependent on the input voltage to the damper However estimation of the appropriate input voltage to a damper is not so easy due to the highly nonlinear behavior of the damper to the input voltage. Therefore, it's important to choose a suitable control algorithm to estimate the appropriate voltage. Dyke et al. proposed a clipped optimal control strategy based on acceleration feedback for controlling a single MR damper, Dyke and spencer extended the control algorithm to the control