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Semi-active control of wind excited building structures using MR/ER dampers

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Abstract

A semi-active control strategy for building structures subject to wind loading and controlled by MR/ER dampers is proposed. The power spectral density (PSD) matrix of the fluctuating part of wind velocity vector is diagonalized in the eigenvector space. Each element of the diagonalized PSD matrix is modeled as a set of second-order linear filter driven by white noise. A Bingham model for MR/ER dampers is used. The forces produced by MR/ER dampers are split into passive and active parts and the passive part is combined with structural damping forces. A set of partially averaged Itô equations for controlled modal energies are derived by applying the stochastic averaging method for quasi-integrable-Hamiltonian systems. The optimal control law is then determined by using the stochastic dynamical programming principle and the cost function is so selected that the optimal control law can be implemented by the MR/ER dampers. The response of semi-active controlled structures is predicted by using the reduced Fokker–Planck–Kolmogorov equation associated with fully averaged Itô equations of the controlled structures. A comparison with clipped linear quadratic Gaussian (LQG) control strategy, for an example, shows that the proposed semi-active control strategy for MR/ER dampers is superior to clipped LQG control strategy.

Keywords: Tall building; Wind excitation; MR/ER damper; Bingham model; Stochastic optimal control; Stochastic averaging; Stochastic dynamical programming

1. Introduction

Structural control of large civil engineering structures has been studied for more than two decades. It evolves from passive control, active control to semi-active control. Recently, semi-active control systems attract much attention for their low-energy requirement and cost, and having best features of both passive and active controls, offering the reliability of passive devices yet maintaining the versatility and adaptability of active systems. A number of semi-active control devices have been developed, such as variable-orifice dampers, variable-friction dampers, controllable tuned liquid dampers, semi-active impact dampers and controllable-fluid dampers, etc. [1]. Because of the intrinsically nonlinear nature of semi-active control devices, the feedback control law must be nonlinear. The development of such control strategy that is practically implementable and can fully utilize the capabilities of these unique devices is an important and challenging task. Some semi-active control strategies have been developed. Leitmann applied Lyapunov's direct approach for the design of a semi-active controller [2]; McClamroch and Gavin used a similar approach to develop the decentralized bang-bang control law for using an ER damper [3]; Inaudi developed the modulated homogeneous friction controller for a variable-friction damper [4]; Sun and Goto used the fuzzy control method [5] and Dyke et al. presented the clipped linear optimal control law that has been shown effective for MR damper [6]. Recently, a stochastic optimal semi-active control strategy for MR/ER damper was proposed [7]. It has been shown that if parameters were properly selected, then the MR/ER damper can fully generate the optimal control force and the control effectiveness and efficiency are better than those of clipped linear quadratic Gaussian (LQG). In this paper, this stochastic optimal semi-active control strategy is extended to wind excited tall building structures.

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