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Suppressing vibration using sliding mode control

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Abstract

In the present paper, Sliding mode controller (SMC) is proposed to alleviate dynamic response of structure subjected to seismic excitation. Stability of this method against uncertainties of system parameters and uncertain dynamic loadings has made it a proper algorithm to reduce the building vibrations. The main drawback of SMC is the so-called chattering phenomena which is highly undesirable. Therefore, chattering is eliminated by smoothing the control force in a thin boundary layer with a specified thickness and introducing saturation function. Designing an optimal sliding surface coefficient matrix makes the response trajectories to move toward the sliding surface and stay on it, so the system remains stable. The robustness of control method and the control effectiveness are all demonstrated by numerical simulation results. Simulation results indicate that the performance of the sliding mode control methods is remarkable.

Keywords: Sliding mode control, Structural control, Uncertainty, Chattering, Boundary layer

1. Introduction

The control of the response of buildings subjected to uncertain dynamic loadings, such as wind load and earthquake load, has drawn the interest of many practical civil engineers. As a result, various control schemes such as passive and active methods have been developed to reduce the building vibrations. Among these two control schemes, active control has recently emerged as a new structural control strategy.

In contrast with linear feedback control theories, non-linear control theories possess various merits which can make them a suitable choice for the control of vibration problems in the civil engineering field. The property of adaptiveness and robustness to the changes in the responses, imparted to the non-linear control actions, makes them a superior choice over the linear feedback control schemes [1, 2, 3]. Several other arguments about suitability of the non-linear control over linear control scheme for the civil engineering problems can be found in Bhartia et al [4].

In this paper, we choose a non-linear control scheme known as the Sliding Mode Control (SMC) which is known to be robust against variations in certain system parameters or external excitations [1, 2, 5-9]. Sliding mode control was first proposed in the Soviet Union by Emelyanov[10] and Utkin's paper pioneered many studies about sliding mode[11]. Recently, with reference to the control of the civil structures, SMC has been studied by Yang et al [12]. Sabanovic proposed an effective method to eliminate vibration of control force [13]. First implementation of sliding mode control in civil structures suggested by Yang et al [14, 15].

The purpose of the paper is to apply Sliding mode control method on a structural system by designing an optimal sliding surface, eliminate the chattering phenomenon and compare the controlled responses with the uncontrolled ones. The ground acceleration of El Centro occurred in May 18, 1940 in Imperial Valley has been used to as a dynamic excitation to evaluate the effectiveness of the proposed method.

2. Equation of motion for the structural system

The equation of motion for a system modeled by n-degrees-of-freedom system subjected to ground excitation $\ddot{x}_g$ can be expressed as follows:

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