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Fuzzy sliding mode control of structures

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Abstract
This paper examines the feasibility of applying fuzzy sliding mode control (FSMC) strategies to reduce the dynamic responses of a seismically excited structure. FSMC is a combination of sliding mode control (SMC) and fuzzy control which gather advantages of sliding mode, fuzzy inference mechanism to enhance robustness and sliding performance of the system. First, the control rules are constructed according to the concept of SMC, and then fuzzy sets, whose membership functions are symmetrically covered in the state space, are defined. Switching-type control law of the conventional SMC and uncertainty part of the equivalent control is approximated by fuzzy controller to attenuate the chattering phenomenon and harmful effects caused by uncertainties. Numerical results indicate that applying this FSMC to control a seismically excited structure can reduce the response quantities to a satisfactory level.
Keywords: chattering, fuzzy control, sliding mode control

1. Introduction

Over the past three decades, various control devices and algorithms have been developed and investigated to reduce responses of structures subjected to earthquake, wind, and other dynamic loads [1-9]. Fuzzy logic control as an alternate algorithm to linear control algorithms has found extensive applications for plants that are complex and ill-defined. In most of these applications, the rule base of the fuzzy controller is constructed from expert knowledge. Fuzzy logic control (FLC) was introduced by Zadeh [10] as a means pf processing imprecise and vague linguistic information to reason and derive control actions [11], which has received some attention in the field of structural vibration control [12-16]. However, conventional FLC has some difficulties to face: parameters such as membership functions, control rules are difficult to be determined, and its inadequate stability analysis. To improve the performance of the conventional FLC, Zhou [17] and LI et al [18] employed adaptive technique to FLC to adjust the fuzzy controller parameters on line.

Sliding mode control (SMC), which aims to provide as popular robust strategy to treat system parameter uncertainty and external disturbance, is widely accepted as a powerful control method to solve the tracking control uncertain systems. Previous studies in structural vibration control show the advantages of sliding mode control (SMC), which have been done by Yang and his co-authors [19, 20, 21].However it inherits a discontinuous control action and hence chattering phenomena will take place when the system operates near the sliding surface. Sometimes this discontinuous control action can even cause the system performance to be unstable. The discontinuous switching function and uncertainty terms of the equivalent control are replaced by fuzzy system to attenuate the chattering phenomenon and harmful effects caused by uncertainties.

The purpose of this paper is to apply fuzzy sliding mode control (FSMC) to a seismically excited structure and attenuate responses of the structure to a reasonable level.

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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