SLIDING MODE CONTROL OF STRUCTURES WITH UNCERTAIN COUPLED SUBSYSTEMS AND ACTUATOR DYNAMICS

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Keywords: Sliding Mode Control, uncertain couplings, flexible structure, actuator dynamics

Abstract

This paper deals with the problem of stabilizing a class of structures subject to an uncertain excitation due to the temporary coupling of the main system with another uncertain dynamical subsystem. A sliding mode control scheme is proposed to attenuate the structural vibration. In the control design, the actuator dynamics is taken into account. The control scheme is implemented by using only feedback information of the main system. The effectiveness of the control scheme is shown for a bridge platform with crossing vehicle.

1 Introduction

Vibrations in dynamical flexible structures, as those encountered in civil engineering, are often caused by environmental (seismic or wind) excitations and human made (traffic or heavy machinery) excitations. One way for attenuating the structural vibrations is to use the active control systems so that the safety of the structure and comfortability of the human beings are improved [1]. Different active control methods have been used to account for uncertainties in the structural models and the lack of knowledge of the excitations [2]−[6]. This paper considers a class of structures whose excitation comes through the uncertain coupling with another dynamical system during a certain time. One prototype of this class of systems is illustrated by considering a bridge platform with an unknown moving vehicle as a coupled exciting subsystem. A sliding mode control scheme is proposed to reduce the vibration of bridge induced by the crossing vehicle. In the control design, only the feedback information from the controlled structure (bridge) is used. Numerical simulation is done to show the effectiveness of the proposed active control scheme for an elastically suspended bridge when a truck crosses it.

2 Problem formulation

Consider the problem of active control of an elastically suspended bridge with crossing vehicles as shown in Figure 1. The bridge section consists of a rigid platform with elastic mounts on the left-hand and right-hand sides [7]. The main variables to be measured are the vertical deviation z of the center of mass of the bridge and the inclination Θ with respect to the horizon of the bridge platform. Vibration of the bridge is produced when a truck crosses the bridge with velocity $v(t)$ within a time interval $[t_0, t_f]$. Without the loss of generality, t_0 is set to zero and t_f denotes the final time of interaction between the structure and the truck. The truck is modelled by a mass m with an elastic suspension of damping c and stiffness k. Additional variables ξ, η and ζ are chosen according to Figure 1. The mass of the platform is given by M, and the moment of inertia with respect to C by the parameter J.

The active control is implemented by two actuators located between the ground and the bridge at the left and the right ends respectively. The actuators A_1 and A_2 supply vertical control forces Mu_1 and Mu_2 which complement the resistant passive forces F_1 and F_2 given by the elastic supports. u_1 and u_2 are the control variables. The objective is to attenuate the vibration of the bridge induced by the crossing vehicle by using active forces Mu_1 and Mu_2.

Equations of motion of the truck:

When the truck is not in the bridge (for $t < 0$ and $t > t_f$), the equation of motion of the truck is $m\,\ddot{\eta} = k\,\eta_0 - m\,g$, where η_0 is the position of relaxed suspension. When $t \in [0, t_f]$, the truck is crossing the bridge. Assume that the declination angle Θ is small, then the dynamic motion of the truck is described ny the following equation

$$\left\{ \begin{array}{lcl} m\ddot{\eta} & = & F - mg \\ F: & = & k[\eta_0 - (\eta + \zeta)] - c(\dot{\eta} + \dot{\zeta}) \\ \zeta: & = & z + (\xi - a)\Theta \end{array} \right. \tag{1}$$

Equations of motion of the bridge:

For $t < 0$ the bridge is in a steady state. For $t \in [0, t_f]$, the dynamic behavior of the bridge is described by the following equations of motion:

$$\left\{ \begin{array}{lcl} M\,\ddot{z} & = & M\,g + F - F_1 - F_2 - Mu_1 - Mu_2 \\ J\,\ddot{\Theta} & = & (\xi - a)F + aF_1 - bF_2 + aMu_1 - bMu_2 \\ F: & = & k[\eta_0 - (\eta + \zeta)] - c(\dot{\eta} + \dot{\zeta}) \\ F_1 & = & k_1(-z_{1,0} + z - a\Theta) + c_1(\dot{z} - a\dot{\Theta}) \\ F_2 & = & k_2(-z_{2,0} + z + b\Theta) + c_2(\dot{z} + b\dot{\Theta}) \end{array} \right. \tag{2}$$