ROBUST VIBRATION CONTROL FOR FLEXIBLE ARMS USING THE SLIDING MODE METHOD

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ABSTRACT

The vibration control of flexible arms is accomplished here using the sliding mode method, where the traditional discontinuous approach is modified by a differentiable one. The higher order modes of the flexible arm are treated as disturbances and are compensated by introducing a disturbance observer. Simplified expressions of the motor angular and the strain moment for the flexible arm with a disturbance observer are obtained, where the remaining disturbance and the model uncertainties are considered as system uncertainties. The robustness of the sliding mode control is effectively employed to cope with the system uncertainties, where the bounds of the uncertainties are adaptively updated. The proposed control law simultaneously causes the motor angular to track a desired signal and the strain moment to approach zero. The stability of the controlled flexible arm is analyzed based on the obtained important fact that a part of the control input is the approximate estimate of a special signal generated by the uncertainty. The motor angular tracking error and the converging speed of the controlled signals are determined by means of design parameters. Experimental results demonstrate the robustness of the proposed method.

KeyWords: Flexible arm, vibration control, sliding mode method, higher order vibration modes, bounds of the uncertainty.

I. INTRODUCTION

In recent decades, there has been growing interest in the study of flexible systems due to the need for fast, precise manipulators in various industrial and space applications. In future space applications, manipulators will need to be lighter and be able to move faster with higher accuracy. The reduced inertias of these lighter and faster manipulators unavoidably result in vibration. Thus, it is important to investigate the dynamics and control problems of manipulators with structural flexibility.

The motion of a flexible system is usually described by a set of partial differential equations with appropriate boundary conditions [9,14]. The commonly used approach is to express the solutions as an infinite sum in terms of the eigenfunctions corresponding to the relevant (linear) partial differential equation [19]. Thus, a flexible arm can be modeled as an infinitely dimensional system (with an infinite number of modes). The standard method in the past is to consider only a finite number of terms [14]. Because the control law for reduced order systems does not always work well for the original set of equations (e.g., one might encounter so-called “spill-over” problems [1]), many excellent works have focused recently on the infinitely dimensional model. Typical studies may be found in [8,12,13,16].

The desired control strategy for flexible arms should not only control the motion of the rigid mode with reasonable accuracy, but also control the vibration model of the arm to achieve high speed and precise tip position. The most commonly used methods described in the literature on this subject can be summarized as follows: frequency domain techniques [2]; linear control [3]; time delay methods [10]; input shaping techniques [11];