Second-order sliding mode control for a magnetic levitation system

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Abstract

This paper presents a second-order sliding mode position control design for robust stabilization and disturbance rejection of the magnetic ball suspension system. With respect to conventional sliding mode control, the second-order sliding mode technique shows the same properties of robustness to uncertainties of model and external disturbances. The proposed second-order sliding mode control has the continuous control signal that improves the chattering phenomenon. Finally, we employ the experiments to validate the proposed method.

keyword : second-order sliding mode control, magnetic levitation system, Lyapunov function.

1. Introduction

The magnetic suspension systems use the magnetic force to make the translation and rotation systems in frictionless, oscillation and noise reducing. In recent years, magnetic levitation systems [1-8] have been successfully implemented in many applications, such as magnetic frictionless bearings, vibration isolation tables, high-speed maglev passenger trains and fast-tool servo systems. The magnetic levitation system is an open-loop unstable and nonlinear in electromechanical dynamics. Therefore, it is an interesting and impressive system for engineers and researchers.

The PID controller is a simple method for the operation point linearization in nonlinear system. It is suitable in the small region of operating point and sensitive to the parameter variations and external disturbances. In [1-3], a feedback linearization controller was discussed. The feedback linearization method utilizes a complete nonlinear description and yields consistent performance largely independent of the operation point. The feedback linearization control does not guarantee robustness in the presence of modeling errors.

There are several methods for nonlinear system control, for example H∞ control, H₂ control, Fuzzy control and sliding mode control [4-6,9,10]. Sliding mode control (SMC) [4-6] is one of those methods in robust control for nonlinear systems. However, SMC makes a discontinuous dynamic system which has serious chattering phenomenon. Therefore, reducing the magnitude and frequency of chattering is very important for SMC. Using Second-order SMC (SOSMC) [11, 12] is a straight way to improve the chattering phenomenon. Ervin et al. [13] proposed an SOSMC repulsive maglev system which the simulation results were shown. The second-order sliding mode technique has the property of robustness to resist uncertainties and external disturbances.

In this paper, a Lyapunov-based SOSMC [12] design is proposed for robust stabilization and disturbance rejection of the magnetic ball suspension system (MBSS) position control.

2. Structure of Magnetic Ball Suspension System

The single-axis MBSS diagram is shown in Fig. 1, which consists of a levitation object, an electromagnetic coil, a sensor system, a current diver and a controller. The levitation object is a ping-pong ball which a permanent attached inside it to provide an attractive force. The sensor system of a light source and a light receiver is used to determine the height of the magnetic ball. The attraction force of the magnetic ball is controlled by the electromagnet currents of the current driver which is computed by the controller.

![Fig. 1. Schematic diagram of MBSS](image)

According to Newton motion law, we have:

\[
m\ddot{x} = mg - F - F_d
\]

where \( x \) is the distance from upper edge the ball to the electromagnetic in milli-metres, \( m \) is the mass of levitation ball in grams, \( g \) is the gravity of 9.8 m/sec², \( F \) is the magnetic control force in milli-newton and \( F_d \) is the external load disturbance.

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