DESIGN AND IMPLEMENTATION OF 2 TERM AND 3 TERM CONTROLLERS FOR MAGNETIC LEVITATION SYSTEM

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ABSTRACT
Objective of the work is to control a magnetic levitation system with control techniques to levitate and stabilize a spherical steel ball at a desired vertical position using various controllers. This paper tells about PD and PID controller for compensating a physical magnetic levitation system. Due to the implementation of controllers, the result shows that increasing transient response of the magnetic levitation system can be changed into a desired manner. The results are verified using simulation and experimental results. Both the simulation and experimental analysis has been made to stabilize the ball position in the desired position. Controllers like Proportional Derivative (PD) and Proportional Integral Derivative (PID) are designed to get fix the ball position in the desired level. Finally PID controller is given the best result.

Keywords: Magnetic Levitation, Proportional Derivative controller, Proportional Integral Derivative controller.

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1. INTRODUCTION
The magnetic levitation system (MLS) is an electromechanical devices used for control laboratory. It is mainly used in magnetic levitated trains, in order to maintain a metallic ball in an electromagnetic field. This system is based on electromagnetism, which was characterized by open loop instability and nonlinear dynamics that suggest the need of stability controllers. This system consists of a controller that is used for levitation and stabilization of a steel ball in an operating region. The basic principle of MLS operation is to apply the voltage to an electromagnet to keep a ferromagnetic object levitated. The object position is determined
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through a sensor. Some of the engineering applications are high speed trains, magnetic bearing and high precision platforms. Corresponding Control input of the ball and beam system with various controllers are also noted.

The error wind phenomena during actuator is failure is found using PID controller [1]. Arun Ghosha et al [2] was compared both 1 DOF and 2 DOF controllers. 2 DOF controller has feed forward parameter so that the instead the performance of the magnetic levitation system was improved than 1 DOF controller.

Dhannraj Suman and Rajech Bhatt [3] implemented Fuzzy logic controller for the magnetic levitation system. Authors claimed that the FLC can stabilize the system accurately and efficiency than other controllers. YANJUN et al [4] has implemented Neural Network Generalized Inverse (NNGI) control and Model Reference Adaptive (MRA) controllers for the magnetic levitation wind turbine.

Adrian et al [5] has taken Internal Model Control (IMC) for the nonlinear unstable magnetic levitation device. In this paper a linear model that represents the nonlinear dynamics of the magnetic levitation system is first derived. he also presented various applications like active magnetic bearings, vibration damping, suspension of wind tunnel models, transportation systems. Shekhar et al [6], insisted that the system performance is improved in terms of time and frequency domain by optimizing the parameters of the PID controller using grey wolf optimizer (GWO).

Qiang Chen et al [7], has introduced Decentralized Proportiona l integral Derivative (PID) control structure to the magnetic levitation systems due to its model-free nature as well as the simplicity. It was very exciting to tune PID parameters for each suspension point to ensure that the closed-loop system is less sensitive to uncertainties/disturbances.

Jing Liu et al [8], has considred AC superconducting windings are implemented to increase the levitation force. Authors also said that, the inductive eddy magnetic field acts back on the primary field, and the levitation force and rotation torque will be produced between the primary and the secondary. A multistage primary is implemented to eliminate the rotation torque and enhance the levitation force.

Highly efficient liquid hydrogen storage system is studied by Toshiyuki Mito et al [9], with magnetic levitation using high-temperature superconducting (HTS) coils.

Venghi et al [10], was developed a control system for the magnetic levitation system. He has linearized the non-linear system model in an around the operating point. Two control loops, an inner current loop and an outer position loop are designed using the linear system obtained. The hardware implementation is described. The work was done in both the Simulation and experimental mode. Peter Balko and Danica Rosinova [11] find the modelled and indentified the parameters of MLS.

Wolfgang Amrhein et al [12], said that the field of small electric drives and their applications, it is becoming increasingly difficult to meet the rapidly growing technical and economic demands of the market.

Anh Tuan et al [13], validated the control performance of the MLS using linear and nonlinear controllers. It was confirmed that, based on the comparison table optimal nonlinear controller was able to stabilize the ball and satisfies the constraints in the experiments. Due to various uncertainties, such as the modeling errors, disturbance and measurement noises, etc., when implementing the input modification algorithm to the linear controller to make it satisfy the constraints, it is not possible to stabilize the ball. This phenomenon confirms the robustness of the lookup table based nonlinear controller in the experiments against uncertainties. Also the controller design method was verified in the experiments on a
magnetic levitation system. The comparison with an linear optimal controller with a control input modification algorithm confirms the effectiveness of the nonlinear one.

Chang-Hyun Kim [14], is proposed robust control method for air-gap positioning of magnetic levitation systems considering levitation disturbance forces caused by propulsion systems. Even though the disturbance effect occurs inevitably by propulsion systems, it is very difficult or impossible to be measured by sensors in real time. In order to maintain the constant air-gap position according to the reference command in the propulsion state of the vehicle, robust control for electromagnetic suspension against levitation disturbance force is highly required.

Huy Nguyen [15], formed a new framework for linear permanent-magnet (PM) machines with applications in precision motion control is proposed and validated. A

Assis and Galvao [16], concerned with the application of sliding mode predictive control (SMPC) on a magnetic levitation system. Multi-parametric programming technique was considered to reduce the computational workload required for real-time implementation.

Tilo Espenhahn [17] considered the Superconducting levitation systems mainly use permanent magnetic tracks to generate the magnetic field required for levitation. However, switchable tracks are necessary for crossings or turnouts.

Jae-Hoon Jeong et al [18] describes the levitation and guidance characteristics of a semi-high-speed magnetic levitation (MAGLEV) vehicle.

Mojtaba Naseh and Hossein Heydari [19] explain High-speed rotatory electromechanical devices can be practically implemented using magnetic bearings that provide a contactless operation. Besides the contactless operation, high temperature superconducting (HTS) bearings possess an exclusive feature.

2. MAGNETIC LEVITATION SYSTEM MODEL

The magnetic levitation systems are appealing in vibration damping. This can be done by various control algorithms implementations without any modifications to the mechanical parts of the whole system. Sandeep et al referred some papers and insisted that Magnetic Levitation system was successfully implemented in high speed train. For accurate tracking of the desired setpoint Proportional and Integral controller was designed. Also minimized the integral windup problem so that anti reset wind up was also suggested.

Highly efficient liquid hydrogen storage system is studied by Toshiyuki Mito et al, with magnetic levitation using high-temperature superconducting (HTS) coils. Every control project starts with plant modeling, so as much information as possible is given about the process itself. The maglev mechanical unit is presented in Fig.1.
2.1. Development of Magnetic Levitation Model

The simplest nonlinear model of the magnetic levitation system relating to the ball position and the coil current \( I \) is the following

\[
m \ddot{x} = m \cdot g - k \frac{i^2}{x^2}
\]

Where \( k \) is the constant depending on the coil parameters. To present the full Phenomenological model a relation between the control voltage \( u \) and the coil current would have to be introduced analyzing the whole maglev circuitry. However maglev is equipped with an inner control loop providing a current proportional to the control voltage that is generated for control purpose:

\[
i = k_1 \cdot u
\]

Equations (1) and (2) constitute a nonlinear model. The bound for the control signal is set to \([-5V \text{ to } +5V]\).

To carry out analysis of the model dynamics for open loop systems using techniques such as bode plots, poles and zeros maps, Nyquist plots, root locus the model has to be linearized. Such a linearization is done in the equilibrium point of \( x_0, i_0 \)

\[
\ddot{x} = g - f(x, i), f(x, i) = k \frac{i^2}{m \cdot x^2}
\]

After linearization

\[
\frac{\Delta x}{\Delta t} = \frac{-K_i}{s^2 + K_x}
\]

Where

\[
K_i = \frac{2mg}{i_0} \text{ and } K_x = \frac{-2mg}{x_0}
\]

2.2. Development of Magnetic Levitation Model

A PID controller consists of 3 blocks. They are proportional, Integral and Derivative. The equations governing PID controller is as follows.

\[
u(t) = P \cdot e(t) + I \int e(t) \, dt + D \frac{de(t)}{dt}
\]

e(t)= Setpoint – Process variable.

Laplace transform of an equation is represented by

\[
U(s) = (P + \frac{1}{s} + D \cdot s)E(s)
\]

\[
C(s) = \frac{U(s)}{E(s)} = (P + \frac{1}{s} + D \cdot s)
\]
Here Ziegler – Nichols method is used to tune controllers. Mat lab delivers a root locus tool, which helps in such analysis. to gain an understanding of root locus controllers design and its effects on the system, a motor velocity control exercise in proposal.

To design PD controller is also needed to control the magnetic levitation system. So the design of PID controller is essential. Root locus of the identified model with controller is presented in Figure.

Venghi et al, was developed a control system for the magnetic levitation system. He has linearized the non-linear system model in an around the operating point. Two control loops, an inner current loop and an outer position loop are designed using the linear system obtained. The hardware implementation is described. the work was done in both the Simulation and experimental mode.

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3. RESULTS AND ANALYSIS
Anh Tuan et al, validated the control performance of the MLS using linear and nonlinear controllers. It was confirmed that, based on the comparison table optimal nonlinear controller was able to stabilize the ball and satisfies the constraints in the experiments. Due to various uncertainties, such as the modeling errors, disturbance and measurement noises, etc., when implementing the input modification algorithm to the linear controller to make it satisfy the constraints, it is not possible to stabilize the ball. This phenomenon confirms the robustness of the lookup table based nonlinear controller in the experiments against uncertainties. Also the controller design method was verified in the experiments on a magnetic levitation system. The comparison with an linear optimal controller with a control input modification algorithm confirms the effectiveness of the nonlinear one.

The zeros, poles and gain to get faster step response of the closed loop system. The values of the proportional, integral and derivative gains in the controllers are changed.

Control input response of ball and beam system using PD controller is shown in Fig 2. Experimental output response of ball position using PD controller is shown in Fig 6. The parameters of the PD controller are obtained using the PD tool of MATLAB and tuned by Z-N tuning rule. The PD controller improves the settling time of the system but unable to obtain the desired overshoot as shown Fig 3.

![Figure 2 Control input response of ball and beam system using PD controller](image-url)
Simulation response of the ball position using PD controller is shown in Fig 4. Experimental output response of ball position using PD controller is shown in Fig 7. The PID controller improves the settling time of the system but unable to obtain the desired overshoot as shown Fig 4. Control input response of ball and beam system using PID controller is shown in Fig 5.
4. CONCLUSION

An optimized PD and PID controllers are designed to levitate the metal ball of the Magnetic Levitation System. Because of the mechanic couplings among suspension points, tuning of PID controller parameters are very challenging. Based on the simulation and experimental results, it is recorded that PID controller can stabilize the system efficiently and accurately. The mathematical model has been developed and the transfer function of the MLS has been established. The performance indices chosen in this paper are Peak Overshoot, Peak Time and Settling Time. For future scope Fractional Order Controller can be applied to Magnetic Levitation System for improving the performance indices.

REFERENCES


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