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Review Article

Maglev Feedback Control: A State-Of-The-Art

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Abstract
Magnetic levitation is an area of interest in research whose application is of paramount impact in various area specially in electric train where frictionless bearing is required. In this state of the art report, a review of literature is performed and suggestions where proposed to improve the control performance of the system.

Keywords: Magnetic levitation, model, control, controller.

INTRODUCTION

A magnetic levitation (abbreviated as MAGLEV) is a highly advanced technological innovation that captured the interest of engineers due to its vast area of application especially in industries, mechatronics, electrical and electronics, automobiles, electric train, frictionless bearing, vibration isolation of sensitive machinery, artificial heart, etc. [1]. A common point of its application is the lack of contact (of the moving ball levitated) with any other part, thereby eliminating wearing and tearing away of parts due to friction, these consequently increases the efficiency of the system.

Magnetic Levitation can be defined as a system in which an object is levitated without any support with the help of magnetic field. It is overcoming the gravitational force on an object by applying counteracting magnetic field.

Figure 1: SCHEMATIC DIAGRAM OF MAGLEV

A schematic diagrammatical representation of a maglev is as shown in figure 1. The system is characterized by a nonlinear behavior and also unstable as such possess a great challenge on its control model. Only the position of the ball is controlled (labeledx_b) which is downward reference to the positive x-axis, but not the velocity of the moving ball [1],[2].

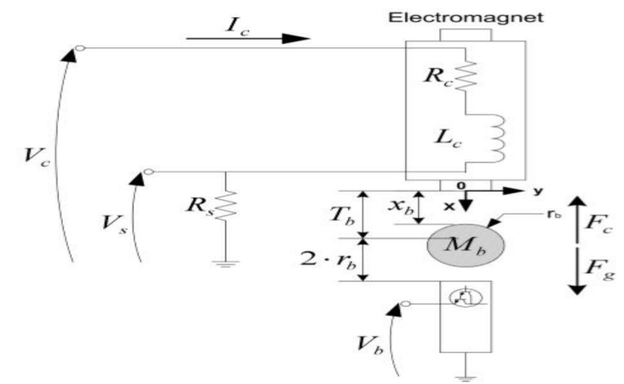

Figure 2: Maglev system parameters

The system, as seen in figure 2 consists of a position sensor that measures the position of the ball (the parameter to be controlled), but no any available sensor to measure the velocity of the ball [3].

The two main ideas involved in magnetic levitation are the lifting force providing an upward force sufficient to counteract gravity, and secondly, ensuring the stability of the system, such that it does not spontaneously slide or flip into a configuration where the lift is neutralized [3].

MAGLEV LEVITATION SYSTEM

The maglev system consists of an electromagnet, a steel ball, a ball post, and a ball position sensor. The schematic diagram of the magnetic levitation system shown in figure 3 display the sections cascaded. The entire system is encased in a rectangular enclosure which contains three distinct sections. The upper section contains an electromagnet, made of a solenoid coil with a steel core. The middle section consists of a chamber where the ball suspension takes place. One of the electro magnet poles faces the top of a black post upon which a one-inch steel ball rests. A photo sensitive sensor embedded in the post measures the ball elevation from the post. The last section of maglev system houses the signal conditioning circuitry needed for light intensity position sensor.

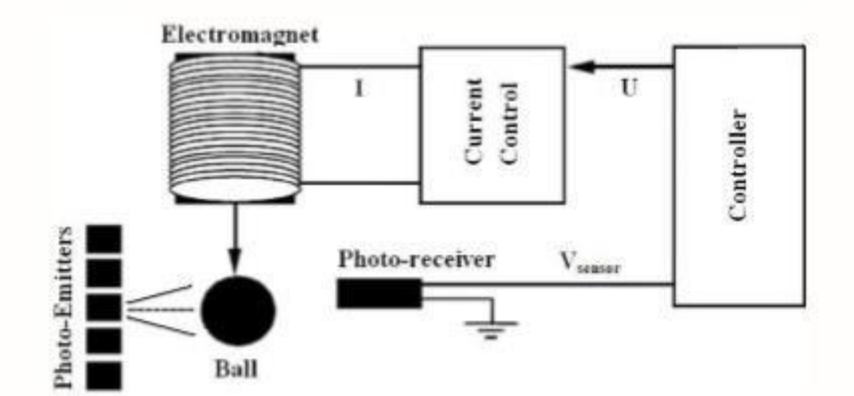

Figure 3: Maglev system cascaded sections

LITERATURE REVIEW:

They are many research in academia about the control of a ball's position in MAGLEV QUANSER system, mainly because of the challenging nature of the problem, considering that the system dynamics are highly nonlinear. In addition, the robustness issue is also complicated to achieve because of heating in the electromagnets which leads to some variances in the resistance and inductance of the current coil [1].

Many attempts had been made in the literature about MAGLEV, there are mainly three control techniques which are implemented to gain a good tracking of the ball's position and establish stability against various types of uncertainties and disturbances. The first technique deals with a linearized model acquired using Taylor's series, the second depends on nonlinear techniques and the third uses a gain scheduling technique with approximate linearization.

In [1] a cascaded sliding mode control (SMC) is applied, so for the electrical subsystem of MAGLEV a disturbance observer based (DO) SMC is designed, whereas for the electromechanical subsystem a state and disturbance observer based (SDO) based SMC is designed. The principal limitations of SMC are stated, as well as the different ways to overcome these limitations, one of them is the using of sliding mode observers. A sliding surface is selected to enable the design of control law, then the stability of the system is proved by choosing an appropriate Lypanove function based on the sense of ultimate boundedness, which had been cited in the article. An experimental validation as well as simulation are made in different cases and by comparing the SMC results with the results of a linear quadratic regulator (LQR) companied PI controller. In conclusion, the effectiveness of the method is proved compared with LQR method, also the robustness of SMC is showed and one can notice that there are almost no changes with or without the existence of uncertainties and with different inputs.

In [2] the effectiveness of LQR method is checked, by using LQR for the tuning of a PID plus feed forward controller to track the ball's position. The equation of motion is obtained, the linearized model is obtained using Taylor's series. Dynamic disturbance around the linear operating point will be atoned by PID controller, while the feed forward gain will compensate the gravitational bias. The cost function is determined in order to be minimized, and the continuous form of algebraic Riccati equation is used, then elements of the symmetric positive definite matrix "P" are determined, hence the remaining weighting factor R and matrix Q are specified. An experimental validation is done and the results proved both the stability of the ball and the capability to track reference trajectory with different inputs (square, ramp and sinusoidal). It is important to mention that a low pass filter is used to reduce the high frequency noise current.

In [3] the disturbance and the velocity of the ball in MAGLEV are estimated, besides the tracking of the ball’s position. Inertial delay observer (IDO) with state feedback control (SFC) is suggested. The mathematical model of the system is obtained. Inertial delay controller (IDC) is designed, considering that the current and voltage are measurable amounts, then by selecting the control input and optimizing it, and because (IDC) is used to estimate the lumped uncertainty, so a low pass filter is used. State feedback control is used to get the poles of the dynamical system at aimed position. The inertial delay observer is obtained to estimate the states; hence from the matrix form of the dynamics the stability and observability of the system are proved. Simulation "without experimental validation" is done and the results confirmed the ability of estimating disturbance as well as tracking the reference.

In [4] a self- sensing Maglev system is designed by replacing the position sensor with theoretical estimation technique which estimates the states of the system depending on the mathematical model. The estimation is done by using dynamic regressor extension and mixing (DREM) along with parameter estimation-based observers (PEBO), the nonlinear observers for both vertical velocity and position are derived. The full state feedback IDA-PBC is used as a sensorless controller and the literature of the controller is cited in the article. Simulation is done by comparing two cases scenarios “with and without disturbance" and by considering the system is in a closed loop with the controller, and the controller showed the ability of reference tracking but after excitation.

In [5] A Gain Scheduling (GS) controller is designed for magnetic levitation device using the redundant descriptor representation. The main work of this is to stably float a steel ball and make the distance between a coil and a steel ball follow the reference without any error. Gain scheduling control has ability not only to deal with large variation range but it can be also use to improve the control performance. GS controllers are able to make a steel ball float stably in not a one equilibrium point, it can also float on variation ranges by scheduling an equilibrium point. The usefulness of the GS controller is verified after comparing the simulations and experiments by robust LQ controller. The GS controller improves the control performance in a specific situation. In addition, the GS controller is more robust than the robust LQ controller for the time-varying parameter. This research proposed Gain scheduling controller is effective for larger parameter variations of a magnetic levitation device.

In [6] a fault tolerant control strategy combining a fault detection and identification method based on an invariant-set approach with controller reconfiguration based on the use of a virtual sensor, is implemented on a MAGLEV system. The MAGLEV system includes two sensors which, together with a nominal observer-based feedback controller with integral action, are used to stabilize a steel ball at a desired position in the air. The second fault detection and identification unit use two observers that can detect the faulty and healthy situations based on a “set-separation” approach. The closed-loop system is reconfigured by a virtual sensor which is adapted to the fault situation detected by the fault detection and identification. All the experimental results show the effectiveness of the Virtual-Sensor-Based Reconfiguration.

CONCLUSION

A wide range of possibilities in control theory dealing with MAGLEV is considered, reference to different research papers. It is proposed that the control problem can be tackled using Model Predictive Control, a better result is expected. Also, a comparison of H-infinity control with typical PID with feed forward controller, should technical problem be faced through experimental validation is recommended. Fault detecting systems based on supervision is recommended and try to add low pass filter to improve the result. A multiplicative uncertainty can be included to check robustness behavior.

REFERENCES

1. Raheleh Nazari†, Alain Yetendje, Maria M. Seron ©2010 IEEE: Fault-tolerant Control Levitation system using Virtual-Sensor-Based Reconfiguration.
2. Tatsuro KUMADA, Gan CHEN and Isao TAKAMI: Gain scheduling control for magnetic levitation device using redundant descriptor representation.
3. Neha Singru1, Divyesh Ginoya2, P. D. Shendge3, S.B. P hadke4 College of Engineering Pune, India: A state feedback control approach via inertial delay observer for magnetic levitation system.
4. Divyesh Ginoya, Chandrashekhar M Gutte, PD Shendge and SB Phadke Transactions of the Institute of Measurement and Control1–13 The Author(s) 2016: State and disturbance observer based sliding mode control of magnetic levitation system.
5. Vinodh Kumar Ea, Jovitha Jeromeb: LQR based optimal tuning of PID controller for trajectory tracking of magnetic levitation system.
6. A.A. Bobtsov et al. Automatica 97 (2018) 263–270: A state observer for sensorless control of magnetic levitation system.

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