

**MODELING AND CONTROL OF MAGNETIC LEVITATION
SYSTEM**

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To my mother, father and family for their encouragement and blessing,

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ABSTRACT

Magnetic levitation technology had received more attention since it helps minimize friction due to physical contact. Example of engineering applications includes magnetic levitated vehicle, high speed bearings, and precision platform. Magnetic levitation system consists of electro-magnetic actuator where its supply current needs to be controlled in achieving equilibrium force in vertical position with a permanent magnet. Too much force inserted will pull the object towards the actuator. Its instability and non-linearity characteristics pose challenges in modeling and control of the system accurately. The objective of this study was to obtain mathematical model of a small scale magnetic levitation system using MATLAB. The system was excited with three MLS of PRBS signal. Parametric approach using ARX structure was used to approximate the model. The best model was accepted based on the best fit criterion and pole-zero analysis through SI toolbox. The result showed that lower order model the best; meanwhile higher order model exhibits noise characteristics. PID and LQR controller was designed for the model through the simulation. The result showed that PID controller provides better output than open-loop control. LQR controller exhibits faster response to the system with undesired transient error. The designed PID and LQR controller can be applied to the magnetic levitation system with further optimization. An implementation to real-time system would validate the result in simulation. Self-tuning or robust controller could be developed in future to increase the reliability of the controller.

ABSTRAK

Teknologi apungan magnetik semakin mendapat perhatian kerana ia dapat mengurangkan geseran disebabkan sentuhan fizikal. Antara contoh aplikasi kejuruteraan termasuklah kenderaan terapung, gelas kelajuan tinggi, dan pelantar kepersisan tinggi. Sistem apungan magnetik terdiri daripada penggerak elektromagnet dimana bekalan arus yang dibekalkan hendaklah dikawal bagi mendapatkan kesamaan daya pada posisi menegak dengan objek bermagnet. Sifat tidak stabil dan tidak linear merupakan cabaran utama dalam mendapatkan model dan kawalan sistem yang tepat. Objektif kajian ini adalah untuk mendapatkan model matematik bagi sebuah sistem apungan magnetik berskala kecil, dengan menggunakan MATLAB. Sistem tersebut telah diuja dengan tiga MLS dari isyarat PRBS. Kaedah parametrik dengan struktur ARX telah digunakan bagi menganggar model matematik. Model yang terbaik telah diterima berdasarkan kriteria penyuaian terbaik dan analisa kutub dengan menggunakan alatan SI. Keputusan mendapati model berdarjah rendah dapat disuaikan dengan baik, manakala model berdarjah tinggi menunjukkan kriteria hingar. Pengawal PID dan LQR direka dengan menggunakan kaedah simulasi. Keputusan mendapati pengawal PID menghasilkan keluaran yang lebih baik berbanding kawalan gelung terbuka. Pengawal LQR menunjukkan reaksi yang lebih pantas, tetapi dengan sambutan fana yang tidak tepat. Pengawal PID dan LQR boleh diaplikasikan kepada sistem apungan magnetik dengan sedikit penambahbaikan. Perlaksanaan pengawal kepada sistem sebenar akan mengesahkan keputusan dalam simulasi. Pengawal talaan sendiri atau pengawal lasak boleh dibangunkan pada masa hadapan dalam meningkatkan kebolehpayaan pengawal sistem tersebut.

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LIST OF ABBREVIATIONS

AR	- Auto-Regressive
ARX	- Auto-Regressive with Exogenous
ARMAX	- Auto-Regressive Moving Average with Exogenous
BJ	- Box-Jenkins
FPE	- Final Prediction Error
GUI	- Graphical User Interface
LQR	- Linear Quadratic Regulator
NARX	- Non-linear Auto-Regressive with Exogenous
NARMAX	- Non-linear Auto-Regressive Moving Average with Exogenous
OE	- Output Error
P	- Proportional
PI	- Proportional – Integral
PD	- Proportional - Derivative
PID	- Proportional Integral Derivative
PRBS	- Pseudorandom Binary Sequences
SI	- System Identification
SISO	- Single Input Single Output

CHAPTER 1

INTRODUCTION

1.1. Project background

Magnetic levitation system has practical importance in many engineering applications such as in high-speed Maglev passenger trains, frictionless bearings, vibration isolation of sensitive machinery, and more. However, magnetic levitation system is considered as a non-linear, open-loop unstable system and therefore it is extremely challenging to control robustly. Therefore the ability to control supply voltage is crucial in achieving stable levitation. In this project, Zeltom Maglev laboratory scale magnetic levitation system is selected as a model system which needs to be maintained at a certain level of levitation.

A system could be controlled accurately if the physical characteristics can be represented in a mathematical model. The process of obtaining the model can be realized either by using analytical analysis or using experimental procedures. The process of constructing models from experimental data is called system identification. System identification is a process where the data collected in an experiment is used to obtain a mathematical model of a particular system. This technique is gaining its popularity since it solves the problem of modeling the complex industrial system. Popular identification techniques commonly used, are theoretical and empirical modeling.

In this project, empirical model will be applied to the system with very minimal or none of the characteristics is known. This technique requires least effort in gaining insight into a system, thus save much time in identifying the system. A mathematical model will be developed through an experimental process by

determining the input and output relationship. In this approach, a constant excitation of input signal is crucial, since it influences the data reliability. There are several types of input signal that may serve the purpose such as multi-sine, random signal, pseudo-random binary sequence (PRBS), and more. However, PRBS signal will be chosen because of its large energy content in a large frequency range. The results from the experimental data will be fed into the System Identification Toolbox in Matlab. From the experimental data, parametric approach using Autoregressive with Exogenous input (ARX) structure approximates the Maglev plant, among ARMAX, OE, and BJ.

Controller designs are also included in this project through closed-loop Matlab simulation using approximated model of the plant. Discrete PID and LQR controller will be considered due to its simplicity and the most suitable way to determine controllability of a system. Finally, discussion, conclusion and further work are drawn based on the findings.

1.2. Project Objectives

The project objectives are;

- i. To construct a test bed of magnetic levitation system.
- ii. To develop a mathematical model that describes the dynamics of magnetic levitation system using system identification approach.
- iii. To design a suitable controller for the estimated model via software in order to stabilize the system and levitate spherical magnet at desired vertical position.

1.3. Project scope

The scope of work in fulfilling the project objectives are;

- i. To study the concept of magnetic levitation system by referring to previous papers or available information regarding the system, possibly from early stage of development to date.

- ii. To construct or acquire a laboratory scale magnetic levitation system that can be excited with an external signal.
- iii. To perform experimental set-up and data collection using data interface card which suits with data processing software such as Matlab. To study the procedure of system identification using Matlab System Identification Toolbox for processing batch input output data.
- iv. To design and simulate discrete Proportional-Integral-Derivative (PID) controller and a Linear Quadratic Regulator (LQR) for the identified model.

1.4. Project Report Outline

This project report is organized in five chapters. The first chapter gives an overview of the project and some possible application. Chapter 2 covers literature review on the chronological advancement of the project area, system, parameter identification as well as controller design issues. Chapter 3 covers the flow of the methodology and description of each procedure. Chapter 4 focuses on the result obtained from the experiment and discussion on the findings. Chapter 5 summarizes the conclusion and recommendations on the future works of the project.

1.5. Summary

A laboratory scale magnetic levitation system, Maglev will be used in approximating the mathematical model of the system. A digital control will be realized using HILINK interface board. Experimental data collection will be performed to obtain the input and output data. System Identification Toolbox in Matlab will be used to process the data and finally approximating the model parameter. ARX model will be used due to its simplicity and capability in producing good results. PRBS with three length of signal will be used as excitation signal in the experiment in concluding which length is most convenience to apply in estimating a Maglev model. Finally a digital PID and LQR controller will be developed in establishing control of the model.

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