"I hereby declare that I have read through this report entitle "Robust Positioning Control of Magnetic Levitation System" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation & Automation)"

Signature : ………………………………..

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Date : ....

ROBUST POSITIONING CONTROL OF MAGNETIC LEVITATION SYSTEM

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A report is submitted in partial fulfilment of requirement for the Degree of Bachelor of Electrical Engineering (Control, Instrumentation & Automation)

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I declare that this report entitle "Robust Positioning Control of Magnetic Levitation System" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date	:	....

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ABSTRACT

Magnetic levitation system is a non-contact system that uses the electromagnetic force to levitate object such as bearing, ball, train and others on air. With this basic working principle, magnetic levitation system can be used in lots of application like maglev train with the advantages of frictionless, high speed, required little maintenance, low noise and so on. However, due to its nonlinear characteristic and open-loop unstable system, it is very hard to realize the system in practical and achieve a high performance control system. This is because it is very difficult to construct a high performance controller to control the position of the levitated object. Moreover, the magnetic levitated system is always facing the poor transient performance and the problem of stability especially in the presence of parametric uncertainties. In order to solve this problem, a robust controller is necessary needed to give a high positioning performance and robust system. Therefore, a fuzzy logic controller is proposed for the positioning control of magnetic levitation system. Both Mamdani's approach and Sugeno's approach are used to design fuzzy logic control system and examine and evaluate in simulation and experiment. In order to examine the robustness of the proposed controller, different mass of ball is levitated. Then, the results of conventional controller will compare with the results from proposed controller, fuzzy logic controller. The positioning results of fuzzy logic controller are validated experimentally and in simulation in comparison with PID controller too. As a results, fuzzy logic controller that designed with Sugeno's approach is able to control and improve the positioning performance of the mechanism and also more robust to the uncertainty different mass of ball.

ABSTRAK

Sistem pengapungan magnet merupakan satu sistem yang menggunakan daya elektromagnet untuk mengapungkan objek-objek seperti bearing, bola dan lain-lain lagi di udara. Dengan meggunakan prinsip asas ini, sistem pengapungan magnet dapat digunakan dalam pelbagai aplikasi. Sebagai contoh, kereta api yang menggunakan sistem ini dapat mengurangkan geseran, mempunyai kelajuan yang tinggi dan penyelenggaraan yang sedikit dan sebagainya. Akan tetapi, sistem pengapugan magnet merupakan sistem yang bukan linear, tidak stabil dan bergelung buka. Dengan ini, sistem ini adalah amat sukar untuk dikawal dan sukar untuk merealisasikan sistem ini dalam praktikal dan mencapai prestasi yang baik. Hal ini adalah disebabkan satu pengawal yang berprestasi tinggi adalah sangat sukar direka untuk mengawal kedudukan objek yang diapungkan. Selain itu, sistem pengapungan magnet juga mempunyai sambutan fana yang tidak baik dan sukar untuk mencapai kestabilan. Oleh itu, pengawal logik kabur akan dicadang dan direka untuk sistem ini. Untuk pengawal logic kabur, terdapat dua cara untuk mereka iaitu pendekatan Mamdani dan pendekatan Sugeno dan kedua-dua pendekatan ini akan digunakan dalam projek ini juga. Keputusan kedudukan objek akan dinilai melalui simulasi dan eksperimen dan kemudian dibincangkan. Bola yang berlainan berat akan digunakan untuk sistem yang sama dan sambutan fana akan dinilai dengan menggunakan kedua-kedua pengawal yang direka untuk keteguhan. Selepas itu, keputusan yang dapat daripada pengawal PID dan pengawal logik kabur akan dibandingkan dan dibincangkan. Kedudukan bola yang diapungkan juga akan dinilai melalui simulasi dan eksperimen. Sebagai kesimpulan, pangawal logik kabur yang direka dengan menggunakan pendekatan Sugeno dapat memberi sambutan fana yang baik dan teguh kepada perubahan parameters seperti jisim bola.

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MLS	-	Magnetic levitation system
LCR	-	Inductor, capacitor and resistor
DC	-	Direct current
RC	-	Resistor and capacitor
PID	-	Proportional, integral and derivative
PD	-	Proportional and derivative
PC	-	Personal computer
PI	-	Proportional and integral
FLC	-	Fuzzy logic controller

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Magnetic levitation system (MLS) is a nonlinear and open-loop unstable electromechanical system that uses electromagnetic force to levitate an object in the air. Because of these characteristics of magnetic levitation system, the control of the system will be much difficult. Yet, it is still receives lots of attention and widely used in engineering applications especially due to its advantages. The applications of magnetic levitation are magnetic actuator, high speed maglev train, frictionless bearing and others. Since it is a system without any mechanical contact, there are a lot of advantages can be clearly seen. The most important advantage of magnetic levitation system is frictionless. For example, the high speed maglev train can travel from one place to another in faster speed if compare with the conventional train due to it is frictionless. Therefore, time consume for travelling is also reduced at the same time. Besides that, it is also required little maintenance, more safe and long-life.

The magnetism used is actually same as the magnetism on earth as there is North and South pole which rotating the earth and create magnetic forces that required. Magnetic levitation uses the same concept which uses repulsion force to levitate or suspend object on the air. In between year 1960 and 1970, technology of Maglev using superconducting magnet is developed and carried out by Brookhaven National Laboratory and others. Because of the problem of funding, United State has to stop the research work in year 1975 and the research work is continued by other countries such as Japan and Germany. Those countries work hard on the research and proposed a track for testing first. In order make sure the issue of engineering, environmental, economical and safety of Maglev, the Department of Transportation, NASA, Department of Energy and Department of Army Corp. are work together on the development of Maglev. Since there is a lot of advantages of magnetic levitation system and receive a lot of attention, so it still has a lot of research work can be carried out in order to fully used the advantages of magnetic levitation system and bring benefits to peoples.

Figure 1.1: Maglev train in Yamanashi, Japan.

Figure 1.2: Transrapid in Germany.

Figure 1.3: Conical magnetic bearing stator.

1.2 Problem Statement

Since the magnetic levitation system is in nonlinear and open-loop unstable condition, the control of the system will be much difficult. Therefore, it is always a challenge to construct a high performance controller to maintain the levitated object at its desired position. Consequently, magnetic levitation system always faces poor transient performance especially in the presence of parameter uncertainties.

1.3 Objectives

The objectives of this project are:

- To design a robust controller for positioning control of a magnetic levitation system.
- To validate and compare the positioning results experimentally and in simulation.
- To examine the robustness of the control system in the presence of parameter uncertainties.

1.4 Scopes

The scopes of this project are:

- To study and understand the background of the project.
- To implement the system with MicroBox 2000/2000C.
- To determine the working range and the maximum input voltage of the system.
- To design a fuzzy logic controller.
- To implement the proposed approach experimentally and in simulation.
- To evaluate the positioning results.
- To compare the performance of the proposed controller with the existing PD controller.

CHAPTER 2

LEVITATION SYSTEM AND CONTROLLER

Since the most attractive advantages of magnetic levitation system are frictionless, therefore the application of frictionless using magnetic levitation system has receives a lot of attention. There is nine ways to levitate or suspend object on air [1]. The ways are as follow:

i. Levitation using forces of repulsion between permanent magnets.
ii. Levitation using forces of repulsion between diamagnetic materials.
iii. Levitation using superconducting magnets.
iv. Levitation by forces of repulsion due to eddy current induced in a conducting surface or body.
v. Levitation using the force which acts on a current-carrying linear conductor in a magnetic field.
vi. Suspension using a tuned LCR circuit and the electrostatic force of attraction between two plates.
vii. Suspension using a tuned LCR circuit and the magnetic force of attraction between electromagnet and a ferromagnetic body.
viii. Suspension using controlled DC electromagnets and the force of attraction between magnetised bodies.
ix. Mixed μ system of levitation, where μ is permeability of the material.

However, the most useful ways to implement in magnetic levitation system are use permanent magnet, superconducting magnet and electromagnetic magnet [1,2]. For permanent magnet, it basically uses the concept of North pole and South pole since it is a material that can create both poles initially. It can create magnetism by repels at North pole and attracts at South pole. However, it is not suitable to use in large applications as it will need high cost to develop. It is only suitable for small applications such as clocks, compasses and so on [2]. Figure 2.1 shows the permanent magnet with repels at North pole and attracts at South pole.

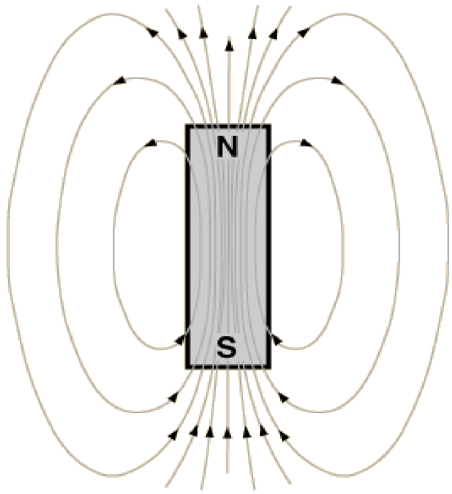

Figure 2.1: Permanent magnet that repels at North pole and attracts at South pole.

For superconducting magnets, it is made from coil of superconducting materials such as niobium-tin powder and is able to uphold high current density in desired magnetic field [1, 2]. Most of the superconducting magnets operate at temperature -258°C. Since the current can flow through the superconductors once there is current flow into the coil, so it can operate independently without using any external sources to support it. There are two principles of levitation using superconducting materials [1], namely:

i. Levitation using Meissner effect
ii. Levitation using eddy current induced by motion of superconducting magnets.

Electromagnetic magnet is the magnet that can produces the magnetic field by simply cover the magnet with wire as coil and supply electric current into it. The working principle of electromagnetic magnet is same with permanent magnet. Yet, the different between permanent magnet and electromagnetic magnet is the magnetic field that produced by electromagnetic magnet is depends on how long is the current flow into the coil and induces the magnet to produce electromagnetic field. Because of this advantage, it allows peoples to control how strong the magnet by supply the needed current into the coil.

For magnetic levitation system, there are two way can be implemented to control the system. The ways are analogue mode control and digital mode control [3]. For analogue mode control, the magnetic levitation system can operate itself by using RC circuit. Therefore, it can work independently without using any computer software. On the other hand, digital mode control is based on computer software. For example, the magnetic levitation system can operate with Matlab and simulink software. The advantage of using digital mode control if compare with analogue mode control is digital mode control will be more users friendly and easier to analyze the performance of the system. Apart from that, digital mode control also can use to determine the parameters of the system and use it to model the system. Basically, Matlab and simulink are used for simulation and develop control algorithm based on the design requirement. Therefore, it will be easier to implement different control algorithm into the system and analyze the transient performance of the system with Matlab and simulink. Therefore, digital mode control will be implemented in this project rather than using the analogue mode to analyze the performance of the magnetic levitation system.

Frictionless bearings [4], maglev train [5, 6, 7], educational kit [8, 9, 10] and high-resolution positioning system are some of the examples of magnetic levitation technology. Since magnetic levitation technology is able to give a stable condition while there is no mechanical contact with others, therefore, it can bring lots of benefits to peoples nowadays. For example, the system is frictionless, high speed, ease of maintenance, low noise and so on. Yet, it is difficult to control magnetic levitation system and give a good performance which is high precision and high robustness system. In initial condition, magnetic levitation system is in open-loop conditions and will lead to the system become unstable. Therefore, it is important to focus on controlling this system and realize it for practical usage. From the educational kit [8], it is an one-degree-of-freedom magnetic levitation system which used to levitate a ball in air. This educational kit is needed to be improved due to it is a nonlinear system and needed to improve its precision and robustness problems.

Recently, there is lots of study on control of magnetic levitation system like classical control, adaptive control [11], switching mode control [12], feedback linearization method [10, 13] and H_∞control [14] are published and all is mainly focus on nonlinear control. For classical control, PID controller is widely used in a lot of engineering application to give a better performance by improve the transient performance with PD controller then integrate with PI controller for reduce steady-state error. However, PID controller is not suitable for magnetic levitation system due to the system required a better controller to give high and robust performance.

Since magnetic levitation system is a voltage-controlled third-order nonlinear system, it is wise that design a nonlinear controller to transform it into a linear model. Thus, a feedback linearization technique [10, 13] is used to transform the nonlinear model into a linear model. However, the robustness of the system is not guaranteed due to there are some uncertainties or disturbances occur in the system and these uncertainties is needed to develop a linear model. In spite of that, this technique also required perfect model to cancel the exact nonlinear terms. Therefore, it needs a lot of work to study and design. Then, a sliding-mode control [12, 15] is proposed to make sure the robustness of the system in this project instead of using adaptive controller [11]. This is because the adaptive controller does not give a good transient response although sliding-mode control needs a lot of control effort. Apart from that, H_∞ method [12] is used with sliding mode control to solve the problem of robustness of the system. Nevertheless, the sliding-mode control only can use for reject the matched uncertainties and cannot deal with the unmatched uncertainties. So, an integral sliding-mode control need to be developed to overcome this problem.

Dynamic surface control technique [12], modified switching algorithm [16] and robustness control [17, 18] is developed to overcome and deal with the unmatched uncertainties. However, three of the methods mention above has their own disadvantages. For example, a complex set of theory needed to proof the stability of the system if dynamic surface control technique is used. Then, for modified switching algorithm, it required a nonlinear switching algorithm in order to meet sliding behaviour while linear matrix