INTELLIGENT CONTROL OF MAGNETIC BEARING SYSTEM

MOHD SAHRIL BIN AMAT ARIPI

This report is submitted in partial fulfillment of the requirements for the award of Bachelor of Electronic Engineering (Computer Engineering) With Honours

Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka

May 2008

UNIVERSTI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : Intelligent control of magnetic bearing system

Sesi Pengajian : 2007/2008

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SHARATUL IZAH BT SAMSUDIN
Pensyarah
Fakulti Kej Elektronik dan Kej Komputer (FKEKK),
Universiti Teknikal Malaysia Melaka (UTeM),
Karung Berkunci 1200,
Ayer Keroh, 75450 Melaka

Alamat Tetap: NO. 229, JALAN NANGKA,
FELDA LINGGIU,
81900 KOTA TINGGI,
JOHOR.

Tarikh: 12 MAY 2008

Tarikh: 12 MAY 2008

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Author : MOHD SAHRIL BIN AMAT ARIPI

Date : 12 MAY 2008

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Signature : ....
Supervisor's name : PN. SHARATUL IZAH BINTI SAMSUDIN
Date : 12/5/08

Dedicated to my beloved family especially my parents

ACKNOWLEDGEMENT

I would like to take this opportunities to express my profoundest gratitude and deepest regards to all those who gave me support to complete this PSM. I am deeply indebted to my Project Supervisor Pn. Sharatul Izah Binti Samsudin and wishes to express a million thanks for her exemplary guidance, monitoring and constant encouragement through out the development project. The blessing, help and guidance given from time to time shall indeed carry me a long way in the journey of life on which I am embark in near future. Last but not least, to all whom had helped me both directly and indirectly, I virtually fall to short words to express my gratitude.

ABSTRACT

A magnetic bearing is a bearing which supports a load using magnetic levitation. Magnetic bearings support moving machinery without physical contact. It can be divided into two categories which are passive and active magnetic bearing. For active magnetic bearing, the force on the rotor can be controlled by changing the current flow through the magnet coils. The problem exist is that it can only exert an attractive force that cause the system inherently unstable and requiring the use of controller. The objectives of the project are to design fuzzy logic controller which is able to stabilize the position of the rotor of magnetic bearing system and to analyze the performance of the controlled system using Matlab/Simulink. Here, fuzzy logic controller using Mamdani approach is applied to control the MBC 500 magnetic bearing system and the performance of the controlled system will be analyzes using Matlab/Simulink. At the end of the project, a fuzzy logic controller system using Mamdani approach which is able in stabilizing the position of the rotor for magnetic bearing system will be design.

ABSTRAK

Bebola magnetik adalah bebola yang menyokong beban menggunakan apungan magnet. Bebola magnetic boleh menyokong pergerakan mesin tanpa sentuhan secara fizikal. Ia boleh dibahagikan kepada dua iaitu bebola magnetik pasif dan aktif. Untuk bebola magnetic aktif, daya terhadap pemutar boleh dikawal dengan mengubah pergerakan arus yang melalui gegelung magnet. Masalah yang timbul adalah ia hanya boleh menyerap daya tarikan yang mana menyebabkan system menjadi tidak stabil dan memerlukan pengawal untuk mengawalnya.Tujuan projek ini adalah untuk merekabentuk pengawal fuzzy logic yang boleh menjadikan posisi pemutar sistem bebola magnetik menjadi stabil dan menganalisis prestasi sistem pengawal tersebut menggunakan perisian Matlab/Simulink. Disini, pengawal fuzzy logic menggunakan kaedah Mamdani akan digunakan untuk mengawal system bebola magnetik MBC 500 dan prestasi pengawal akan dianalisis menggunakan perisian Matlab/Simulink. Di akhir projek ini nanti , Sistem pengawal fuzzy logik dengan menggunakan kaedah Mamdani yang mana dapat menstabilkan posisi pemutar sistem bebola magnetik akan direkabentuk..

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LIST OF ABBREVIATION

AMB	-	Active Magnetic Bearing
DSP	-	Digital Signal Processig
FIS	-	Fuzzy Inference System
GUI	-	Graphical User Interface
PLC	-	Programmable Logic Controller
PWM	-	Pulse Width Modulation

CHAPTER I

INTRODUCTION

Many applications of active magnetic bearings are widely used so the importance for designing the appropriate and efficient controller to monitor the magnetic bearings becomes vital. For this intelligent control of magnetic bearing system project, a fuzzy logic controller using Mamdani approach is design to control the rotor of MBC 500 magnetic bearing system.

1.1 Project introduction

Magnetic bearing system can be described as a device that uses electromagnetic forces to support a rotor without mechanical contact. It can be divided into two categories which are passive and active magnetic bearing. For active magnetic bearing, the force on the rotor can be controlled by changing the current flow through the magnet coils. The problem exist is that it can only exert an attractive force that cause the system inherently unstable and requiring the use of controller. An intelligent controller as an alternative control strategy is proposed. Here, fuzzy logic controls using Mamdani approach will be identified and designed in controlling and stabilizing the position of the rotor of the magnetic bearing system. This project will be implemented using Matlab/Simulink.

1.2 Objectives

Objectives of this project are to design a fuzzy logic controller which is able to stabilize the position of the rotor of magnetic bearing system and to analyze the performance of the controlled system using Matlab/Simulink.

1.3 Problem statement

Nowadays, many applications based on magnetic bearing system have been developed but it rarely to find the controller that used fuzzy logic controller to monitor the magnetic bearing system. The problem for active magnetic bearing system is it can only exert an attractive force that causes the system inherently unstable.

1.4 Scope of project

While doing this project, the scope of the project is very important because it is use as the guideline to fulfill the requirement of the project.

In this project, a controller will be designed in stabilizing the position of the rotor of magnetic bearing system. Here, fuzzy logic approach is applied using Mamdani approach. Mamdani method is chosen because it is intuitive, widespread acceptance and also it well suit to human input. The design of the controller and the performance of the controlled system will be implementing and analyzed using Matlab/Simulink. This project will be focused on MBC500 magnetic bearing system

1.5 Report structure

This thesis contains four chapters that will explain the detail about this project. The first chapter is about the introduction of the project. This chapter contains about the project introduction, project objective, project problem statement and project scope.

The second chapter is about the literature review of the project. The literature reviews includes the study of the component in the project such as active magnetic bearing system, MBC 500, fuzzy logic and Mamdani approach. This chapter will explain the theory of each aspect of the project.

The third chapter is about the project methodology. Here the step of the project will be show. The process of the project is shown in the flowchart of the project. All the process is elaborate in this chapter.

The fourth chapter contains the final result of the project. The system stability, controllability and performance are being analyzed in this chapter.

The fifth chapter contains conclusion of the overall achievement of the project and the suggestion to improve the project.

CHAPTER II

LITERATURE REVIEW

2.1 Active magnetic bearing

Active magnetic bearing system have been increasingly used for industrial applications because of the advantages of noncontact, elimination of lubrication, low power loss and controllability of the bearing system characteristics. Some typical industrial application fields include turbo machinery, space and vacuum technology, bearings in machine tools, etc. Several active magnetic bearing have been developed in the laboratory since 1988, with the progressive performance improvement: typically precision of less than 2 recently developed active magnetic bearing is equipped with two sets of built-in piezoelectric-type force transducers so that in-plane forces generated by a pair of magnetic bearings can be measured. The measured force signals can be used as useful and essential information for accurate system parameter identification, self-monitoring and self-diagnosis. Further improvements are in progress for the more reliable and intelligent active magnetic bearing system.

An active magnetic bearing (AMB) consists of an electromagnet assembly, a set of power amplifiers which supply current to the electromagnets, a controller, and gap sensors with associated electronics to provide the feedback required to control the position of the rotor within the gap. These elements are shown in the diagram. The power amplifiers supply equal bias current to two pairs of electromagnets on opposite sides of a rotor. This constant tug-of-war is mediated by the controller which offsets the bias current by equal but opposite perturbations of current as the rotor deviates by a small amount from its center position.

The gap sensors are usually inductive in nature and sense in a differential mode. The power amplifiers in a modern commercial application are solid state devices which operate in a pulse width modulation (PWM) configuration. The controller is usually a microprocessor or DSP.

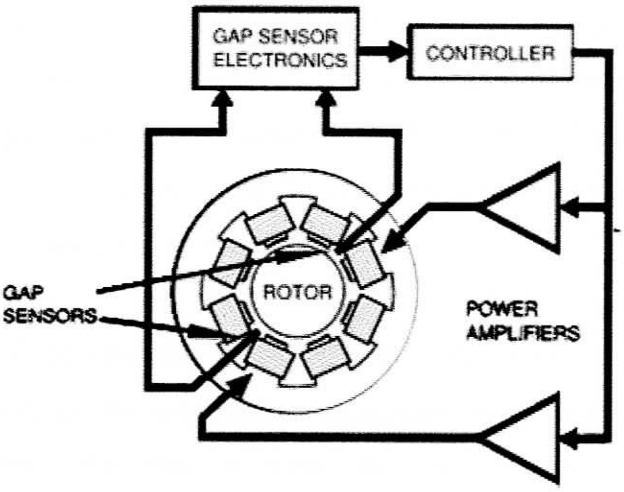

Figure 2.1: Active magnetic bearing system

2.1.1 Application of magnetic bearing system.

Magnetic bearings are increasingly used in industrial machines such as compressors, turbines, pumps, motors and generators. Magnetic bearings are commonly used in watt-hour meters by electric utilities to measure home power consumption. Magnetic bearings are also used in high-precision instruments and to support equipment in a vacuum, for example in flywheel energy storage systems.

A flywheel in a vacuum has very low windage losses, but conventional bearings usually fail quickly in a vacuum due to poor lubrication. Magnetic bearings are also used to support maglev trains in order to get low noise and smooth ride by eliminating physical contact surfaces. Disadvantages include high cost, and relatively large size. A new application of magnetic bearings is their use in artificial hearts.

2.2 MBC 500 magnetic bearing system

The magnetic bearing system that will use in this project is MBC 500 magnetic bearing system. This MBC 500 contains a stainless steel shaft or rotor which can be levitated using eight horseshoe electromagnets, four at each end of the rotor. Hall Effect sensors placed just outside of the electromagnets at each end of the rotor, measure the rotor end displacement. This system is a four degree of freedom system with two degrees of freedom at each end of the rotor. These two degrees of freedom are translation in the horizontal direction perpendicular to the z axis and translation in the vertical direction y axis.

The front panel is a graphical representation of the system dynamics with 12 BNC connections for easy access to system inputs and outputs. Four front panel switches allow the user to open the loop for the internal axis controllers independently. By switching off only a single loop the user can perform simple single-input single-output control design experiments. With all internal loops open a sophisticated 4 by 4 external controller can be implemented. The control bandwidth is roughly 1 kHz so external controllers are typically DSP-based or analog.

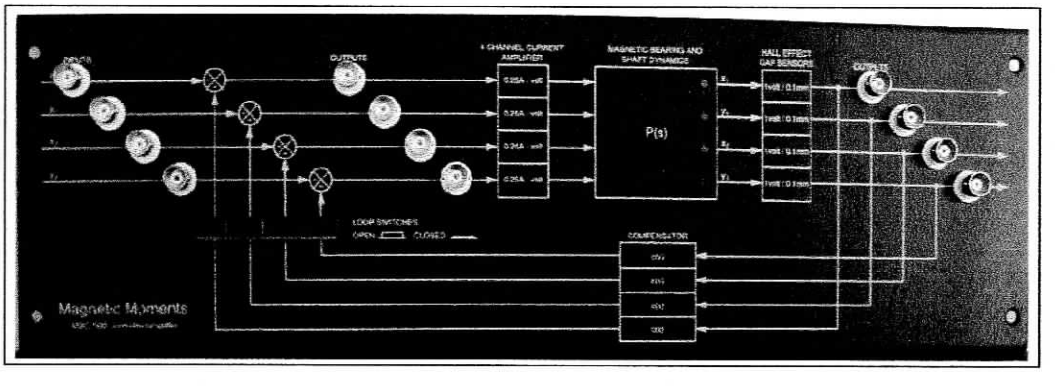

Figure 2.2: Front panel block diagram

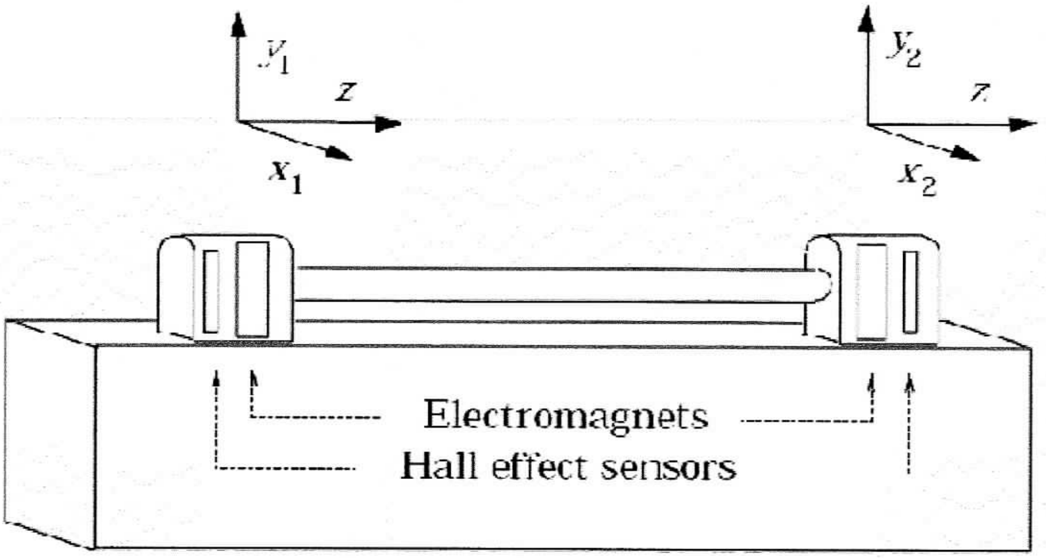

Figure 2.3: MBC 500 block diagram

The MBC 500 rotor operates identically in the x and y directions except for the additional constant force due to gravity acting in the y direction. This constant force is not linear and cannot be modeled by a linear system model so the analysis will focus on the horizontal or x direction motion. From Figure 2.4 below, the nominal rotor position is corresponding to the $x_1=0$ and $x_2=0$ or equivalently $X_1=0$ and $X_2=0$. With this, the position of the rotor is centered horizontally with respect to the front and back electromagnets on each end, and its long axis is parallel to the z axis.

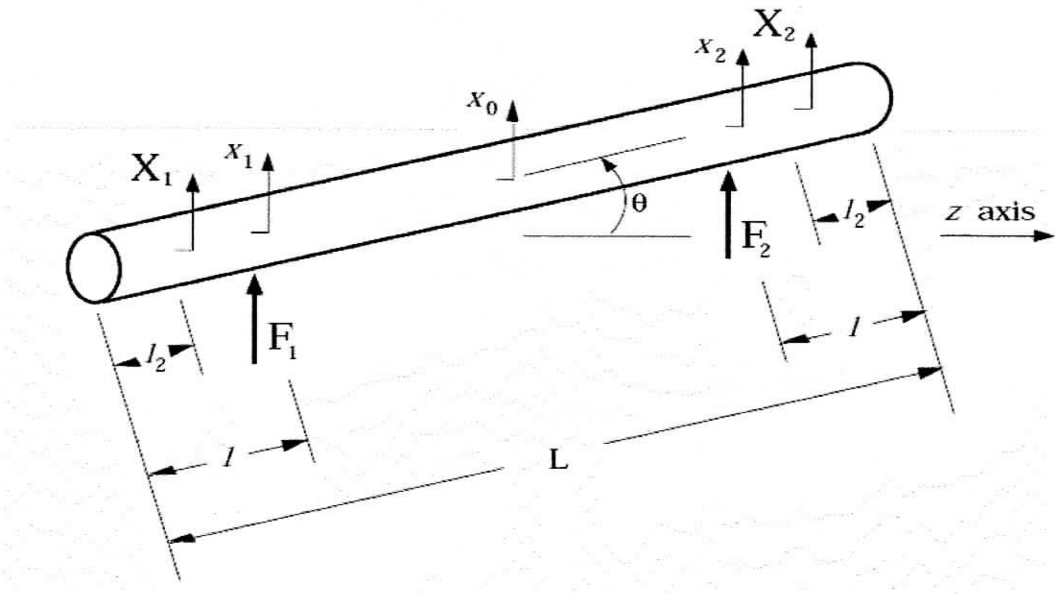

Figure 2.4: Rotor configuration

An analysis of the geometry of the rotor will yield the following relationships.

$$x_1 = x_0 - \left(\frac{L}{2} - l\right) \sin\theta \qquad (2.1)$$

$$x_2 = x_0 + \left(\frac{L}{2} - l_2\right) \sin\theta \qquad (2.2)$$

$$X_1 = x_0 - \left(\frac{L}{2} - l_2\right) \sin\theta \qquad (2.3)$$

$$X_2 = x_0 + \left(\frac{L}{2} - l_2\right) \sin\theta \qquad (2.4)$$

$$\Sigma F = m\ddot{x}_0 = F_1 + F_2 \qquad (2.5)$$

$$\Sigma F = I_0\ddot{\theta} = F_2\left(\frac{L}{2} - l\right)\cos\theta - F_1\left(\frac{L}{2} - l\right)\cos\theta \qquad (2.6)$$

Table 2.1: System parameter

Symbol	Description	Value
L	Total length of the rotor	0.269m
L	Distance from each bearing to the end of the rotor	0.021m
l_2	Distance from each Hall-effect sensor to the end of the rotor	0.0028m
l_0	Moment of inertia of the rotor with respect to the rotation about an axis in the y direction	1.5881×10^{-3} kgm^2
M	Mass of the rotor	0.2629kg

Table 2.2: System variable

Symbol	Description
x_0	The horizontal displacement of the center of mass of the rotor.
x_1 and x_2	The horizontal displacements of the rotor at left and right bearing positions, respectively
X1 and *X2*	The horizontal displacements of the rotor at left and right Hall-effect sensor positions, respectively
Θ	The angle that the long axis of the rotor makes with the *z* axis
F1 and *F2*	The forces exerted on the rotor by left and right bearings, respectively