OPTIMAL TUNING OF CONTROLLER PARAMETERS FOR A MAGNETIC LEVITATION SYSTEM USING RADIAL BASIS BASED NEURAL NETWORK METAMODELING APPROACH

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DEDICATION

This thesis is dedicated to my father and mother who have been very supportive in ensuring that I come this far and continually encouraging me to aspire for more. It is also dedicated to all my siblings who were always there to encourage me when the going got tough and supported me through-out.

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ABSTRACT

The Magnetic Levitation System (MLS) is a challenging nonlinear mechatronic system in which an electromagnetic force required to suspend an object (metal sphere) in the air. The electromagnetic force is very sensitive to the noise, which can create acceleration forces on the metal sphere, causing the sphere to move into the unbalanced region. Maglev's benefits the industry, and the system has reduced power consumption, has increased power efficiency, and reduced maintenance cost. The typical applications for Maglev's Power Generation, for example, wind turbine, Maglev's trains, and Medical Device (magnetically suspended Artificial Heart Pump). This project presents a comparative assessment of controllers for the magnetic levitation system and the way of optimally tune of the PID parameter. The magnetic levitation system divided into two types, attractive and repulsive, in this project attractive type has been chosen. The analysis will be performed after finding the state space model of magnetic levitation system, and simulation will be performed using MATLAB Simulink. The optimal tuning based PID controller will offer a transient response with better overshoot and rise time than the standard optimization methods. For the trained networks, metamodel radial basis function networks perform more robustly and tolerantly than the gradient descent method even when dealing with noised input data set. The simulation output using the radial basis based metamodel approach showed an overshoot of 9.34% and rise time 9.84ms, which is better than the gradient descent and conventional PID methods.

ABSTRAK

Magnetic Levitation System (MLS) adalah sistem mekatronik nonlinier yang mencabar di mana daya elektromagnetik yang diperlukan untuk menggantung objek (sfera logam) di udara. Daya elektromagnetik sangat sensitif terhadap kebisingan, yang dapat membuat daya pecutan pada sfera logam, menyebabkan sfera bergerak ke wilayah yang tidak seimbang. Maglev memberi keuntungan kepada industri, dan sistemnya telah mengurangkan penggunaan kuasa, meningkatkan kecekapan kuasa, dan mengurangkan kos penyelenggaraan. Aplikasi khas untuk Penjanaan Kuasa Maglev, misalnya, turbin angin, kereta api Maglev, dan Peranti Perubatan (Pam Jantung Buatan yang digantung secara magnetis). Projek ini menyajikan penilaian perbandingan pengawal untuk sistem levitasi magnetik dan cara penyesuaian parameter PID secara optimum. Sistem levitasi magnetik terbahagi kepada dua jenis, menarik dan menjijikkan, dalam projek ini jenis menarik telah dipilih. Analisis akan dilakukan setelah mencari model ruang sistem sistem levitasi magnetik, dan simulasi akan dilakukan menggunakan MATLAB Simulink. Pengawal PID berasaskan penalaan yang optimum akan menawarkan tindak balas sementara dengan lebihan masa dan masa kenaikan yang lebih baik daripada kaedah pengoptimuman standard. Untuk rangkaian terlatih, rangkaian fungsi asas radial metamodel berkinerja lebih mantap dan bertoleransi daripada kaedah penurunan gradien walaupun berhadapan dengan set data input berisik. Output simulasi menggunakan pendekatan metamodel berasaskan radial menunjukkan kelebihan 9.34% dan masa kenaikan 9.84ms, yang lebih baik daripada kaedah kecerunan dan kaedah PID konvensional.

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LIST OF ABBREVIATIONS

ANN	-	Artificial Neural Network
RBF		Radial basis Function
GA	-	Genetic Algorithm
PSO	-	Particle Swarm Optimization
PID	-	Proportional Integral Derivative
UTM	-	Universiti Teknologi Malaysia
MLS	-	Magnetic Levitation System
FLC	-	Fuzzy Logic Controller
CDM	-	Coefficient Diagram Method
LQR		Linear Quadratic Regulator

LIST OF SYMBOLS

η	-	Learning rate
α	-	Momentum factor
F	-	Force
v	-	Velocity
p	-	Power
U	-	Stored Energy

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Magnetic levitation systems have described for a decade as a revolutionary means of travel in science fiction. In (1726), Jonathan Swift has described the magnetic levitation system for the first time. Also, in (1842) an English clergyman called Samuel Earnshaw described the importance of Maglev and its limitation, he shows that the system of Maglev has instability issues where the force between the static magnets and the contactless levitated part was impossible to be stable. The free levitated part has unstable displacement in at least one direction. [1]

Not just engineering and industry fields are concerned with the magnetic levitation system., but also the medical and natural fields have used Maglev in many applications. In 2010 a group of researchers from the university of and Rice University had developed a three-dimensional tumour model related to magnetic levitation. They have had injected the cancer cells with magnetic iron oxide and gold nanoparticles. Moreover, by installing a coin size magnet near the infected area, they have successfully lifted the cells.[2]

Recently, magnetic levitation systems have been appreciated for removing mechanical contact friction, reduce maintenance costs and achieve high-precision positioning. MLS system is also commonly used in various applications, such as high-speed trains, magnetic bearing systems, vibration insulation systems, wind tunnel lifting and photolithographic measures. Reduce operating costs and achieve high precision performance. They are therefore widely used in a variety of fields, such as high-speed trains, vibration insulation systems, magnetic bearings, stepper photolithography, and wind turbine.[3]

Magnet levitation techniques can be classified into two types: Electro Dynamic Suspension (EDS) and Electro Magnetic Suspension (EMS). EDS systems are often known as "repulsive levitation." Superconductivity magnets [4] or permanent magnets [5] provide corresponding levitation sources. Nevertheless, it is difficult to activate the repulsive magnet poles at the law speed of superconductivity magnets, so they are usually used in a high-speed passenger train. The EDS magnetic levitation force is partly stable and allows a high clearance. Nevertheless, the magnetic materials manufacturing process is more complicated and expensive compared to the EMS system. Attractive levitation refers to the EMS system; inherently, the magnetic levitation force is unstable, thus controlling the system is much harder than the EDS system. The process and cost of manufacturing of EMS are lower than EDS, but additional electricity is required to maintain levitation height.

1.2 Problem Statement

Maglev system (MLS) referred to electromechanical systems and used electromagnetic field to levitate an object in a space with no human assistance. Over the years, engineers and researchers have been paying great attention to stabilize the magnetic levitation system. The characteristics maglev system is extremely nonlinear. It is unstable and considerable uncertainty. For the magnetic levitation system has a high nonlinear open-loop instability, due to the relationship between the magnetic force and ferromagnetic material.

“Proportional Integral and Derivative” (PID). for so many years it has been used in industry field. PID controllers has been utilized since 1890s for controller design.[6] until today the industrial field still uses PID controllers with other different optimization techniques. The PID controller will stabilize the system, although the control performance of the system is limited due to the fixed controller parameters.

1.3 Project Objectives

The project aims to achieve the best results and overcome the limitation of the review papers, the specific objectives are as follows:

- To obtain a mathematical model of a maglev system in state space and transfer function form.
- To design a PID controller and stabilize the system performance.
- To develop a PID optimal tuning approach using metamodel based radial basis function neural network.
- To verify the effectiveness of the tuning approach for maglev system with SIMSCAPE multibody.

1.4 Scope of the Project

The following describe the scope of the project:

1. The mathematical model respect to Transfer function and state-space forms are used to describe the system model.
2. The controllers are to be designed based on PID and optimal tuning using neural network (metamodel radial base function).
3. MATLAB software will be used to implement the controllers to test their performance.
4. Solid works will be used to design the 3D diagram of magnetic levitation system and simulated using MATLAB and **SIMSCAPE Multibody** plugin.
5. The Metamodeling approach will be used to optimize the system parameters.

1.5 Organization of The Report

The project report prearranged as follows. Chapter two discusses and assesses the efficiency of the previous design controllers used for the maglev system and describes the basis of the study. Chapter three discuss the modeling of the magnetic levitation system and methodology used to design the Radial Basis Function based PID with metamodel approach. While chapter four and five presents the project results and conclusion.

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