

**AUTOMATED MEASUREMENT OF LEVITATION FORCE USING
LABVIEW PROGRAMMING LANGUAGE**

By

ABDUL MAJEED BIN MOHAMED SHARIFF

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirement for the Degree of Master of Science**

November 2006

DEDICATION

In memory of my parents,
Abbah and Bibi,

Special thanks to
My parents-in-law
Gulam Nabi and Mariam

Wife
Khursaid Bebe

Children
Hazim and Nuur Aqilah

fellow course mates and friends.
Who had been a source of flames of inspiration and perspiration.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

**AUTOMATED MEASUREMENT OF LEVITATION FORCE USING
LABVIEW PROGRAMMING LANGUAGE**

By

ABDUL MAJEED BIN MOHAMED SHARIFF

November 2006

Chairman: Professor Abdul Halim Shaari, PhD

Faculty: Science

This study deals with the development of an automated system for the investigation of levitation forces through three sets of experiments. The first set is a study of levitation forces between moving superconductors or conductors with a permanent magnet. The superconductors were used in field cooled and zero field cooled states. The second set deals with the study of levitation forces between a moving small discs shaped magnet with a much larger square magnet. The third set deals with the study of levitation forces between two identical magnets with a superconductor placed between them. An automated experimental setup was successfully setup that uses a computer, together with the LabVIEW software, an electronic balance, a DC motor controlled by a PWM circuit, a rpm sensor circuit and an actuator to achieve the stated objectives. The superconductors used were $\text{Bi}_{1.6}\text{Pb}_{0.4}\text{Sr}_2\text{Ca}_{2-x}\text{Cd}_x\text{Cu}_3\text{O}_{10}$ (where $x=0.00$ (pure), $x=0.02$, $x=0.05$, $x=0.07$ and $x=0.1$).. The conductors used were copper and aluminium of various thicknesses. The levitation force between a moving conductor and a permanent magnet can be measured and compared to its calculated values. It was shown that the levitation forces can be used to find the lift off speed of aluminium of thickness 4.75 mm to be 14.88 m/s. The first set of

experiments revealed that levitation forces are depended upon the speed of the moving conductors but not on moving superconductors. It was also found that the levitation forces for superconductors are stronger in the zero field cooled states then the field cooled state. The second set of experiments showed that the levitation force between two magnets varies in a rotating field. The third set of experiments showed that the levitation forces between two identical magnets are not affected by the presence of a disc shaped superconductor. The system that has been developed can be used as an effective teaching aid for the teaching of magnetic levitation principles.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

**PENGUKURAN DAYA APUNGAN SECARA AUTOMATIK DENGAN
MENGUNAKAN LABVIEW**

Oleh

ABDUL MAJEED BIN MOHAMED SHARIFF

November 2006

Pengerusi: Professor Abdul Halim Shaari, PhD

Fakulti: Sains

Penyelidikan ini bertujuan membangunkan suatu sistem automatik untuk mengkaji daya apungan melalui tiga siri eksperimen. Siri yang pertama ialah mengkaji daya apungan diantara konduktor atau superconductor yang sedang bergerak dan magnet kekal. Superkonduktor telah digunakan dalam keadaan medan magnet beku dan tidak beku. Siri kedua ialah berkenaan daya apungan diantara sebuah magnet berbentuk cakera yang bergerak dan sebuah magnet besar. Siri ketiga ialah mengkaji daya apungan diantara dua magnet yang serupa dengan meletakkan suatu superkonduktor berbentuk cakera diantara mereka. Penyusunan eksperimen secara automatik bersama penggunaan komputer digabungkan dengan software LabVIEW, alat penimbang elektronik, aktuator, pengesan kelajuan serta sistem pengawalan kelajuan motor DC dengan menggunakan litar PWM telah berjaya melakukan semua siri eksperimen tersebut. Superkonduktor $\text{Bi}_{1.6}\text{Pb}_{0.4}\text{Sr}_2\text{Ca}_{2-x}\text{Cd}_x\text{Cu}_3\text{O}_{10}$ (dimana $x=0.00$ (tulen), $x=0.02$, $x=0.05$, $x=0.07$ dan $x=0.1$) telah digunakan. Konduktor yang digunakan merupakan kepingan kuprum dan aluminium yang berlainan tebal. Daya apungan diantara konduktor yang bergerak dengan magnet boleh diukur dan dibandingkan dengan nilai yang dikirakan. Ia dapat ditunjukkan bahawa nilai daya-

daya apungan boleh digunakan untuk mencari halaju apungan bagi aluminium ketebalan 4.75 mm ialah 14.88 m/s. Siri eksperimen yang pertama menunjukkan daya apungan bergantung kepada halaju konduktor tetapi tidak kepada halaju superkonduktor. Ia juga telah didapati bahawa daya apungan lebih kuat didalam medan magnet tidak beku berbanding dengan medan magnet yang beku. Siri eksperimen kedua telah menunjukkan daya apungan diantara dua magnet berubah dengan putaran magnet. Siri eksperimen ketiga telah menunjukkan daya apungan diantara dua magnet yang serupa tidak berubah dengan kehadiran superkonduktor yang berbentuk cakera. Sistem yang dibangunkan boleh digunakan sebagai alat bantu mengajar yang berkesan untuk mengajar prinsip-prinsip keapungan magnet.

ACKNOWLEDGEMENTS

Faithful thanks and appreciation are extended first to my supervisor, Professor Dr. Abdul Halim bin Shaari, co supervisor Associate Professor Dr. Ionel Valeriu Grozescu and Professor Dr. Elias Saion; for their charismatic guidance, prevailing assistance in all aspects, priceless suggestions, comments and advice; from the beginning of this project till the curtains are drawn.

Financial support from the Ministry of Education, Malaysia is gratefully acknowledged. I would also like to thank laboratory assistants Mr. Razak Harun and Mr Roslim bin Mohamed for their invaluable assistance. Thanks and appreciations are also extended to my fellow course mates in the Superconductor and Thin Films Laboratory, Physics Department, UPM for their invaluable and generous assistance. They are Walter and Faisal.

I also would like to specifically thank Mr. Arrifin bin Abas for supplying the superconductor samples for magnetic levitation studies. Credit is also given to anyone who had either directly or indirectly contributed to the completion of this thesis and also this research project.

I certify that an Examination Committee met on to conduct the final examination of **Abdul Majeed Bin Mohamed Shariff** on his **Master of Science** thesis entitled “AUTOMATED MEASUREMENT OF LEVITATION FORCE USING LABVIEW PROGRAMMING LANGUAGE ” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Jumiah Hassan PhD

Faculty of Science
Universiti Putra Malaysia
(Chairman)

Zaidan Abdul Wahab PhD

Associate Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

Zulkifly Abbas PhD

Faculty of Science
Universiti Putra Malaysia
(Member)

Mohamed Deraman PhD

Professor
Faculty of Science and Technology
Universiti Kebangsaan Malaysia
(Independent Examiner)

HASANAH MOHD. GHAZALI PhD.

Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 8 FEBRUARY 2007

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Master of Science. The members of the Supervisory Committee are as follows:

Abdul Halim bin Shaari, PhD

Professor
Faculty of Science.
Universiti Putra Malaysia
(Chairman)

Ionel Valeriu Grozescu, PhD

Associate Professor
Faculty of Science.
Universiti Putra Malaysia
(Member)

Elias Saion PhD

Professor
Faculty of Science.
Universiti Putra Malaysia
(Member)

AINI IDERIS PhD

Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date : 8 FEBRUARY 2007

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

ABDUL MAJEED BIN MOHAMED SHARIFF

Date: 27 DECEMBER 2006

TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	vii
APPROVAL	viii
DECLARATION	x
LIST OF TABLES	xv
LIST OF FIGURES	xvii
LIST OF SIMBOLS/ABBREVIATIONS	xxv

CHAPTER

1 INTRODUCTION

1.1	Background of the study	1
1.2	Scope of the present study	1
1.3	Problem statement	2
1.4	Research objectives	2
1.5	Significance of the study	3
1.6	Outline of the thesis	3

2 LITERATURE REVIEW

2.1	The discovery of eddy current levitation	4
2.2	Discovery of superconductor levitation	5
2.3	Methods for measuring eddy current magnetic levitation	7
2.3.1	A simpler method.	7
2.3.2	A more accurate system for measuring electromagnetic lift and drag forces	7
2.3.3	A method for measuring lift and drag forces for an attractive electromagnetic suspension system	11
2.3.4	A method for measuring lift and drag forces for an electromagnetic suspension system	11
2.3.5	Experimental data obtained from other methods regarding eddy current levitation	14
2.4	Research and Methods for measuring superconductor levitation phenomena	17
2.4.1	Method for measuring levitation force between a magnet and a rotating superconductor	17
2.4.2	Method for measuring lateral force with flux frozen into a superconductor	19
2.4.3	Method for measuring lateral force without flux being	22

	frozen into a superconductor	
2.4.4	Another method to measure lateral force between a superconductor and a magnet with minimal frozen-in flux	22
2.5	A method for measuring the shielding properties of superconductors	23
3	THEORY AND OPERATING PRINCIPLES OF MEASUREMENT SYSTEMS	
3.1	Introduction	27
3.2	Eddy current levitation	27
3.3	Forces between a permanent magnet and moving conductors	28
3.3.1	Lift force	28
3.3.2	Drag force	29
3.3.3	Current heating and the warming rate	30
3.3.4	Skin depth	32
3.3.5	Forces between two magnets	32
3.4	Types of permanent magnets	32
3.5	The structure of metals	34
3.6	The structure of superconducting Bismuth Strontium Copper Oxides	37
3.7	Superconductor	37
3.7.1	Type I superconductor	38
3.7.2	Type II superconductor	39
3.7.3	Properties	39
3.7.4	Zero resistance	40
3.7.5	The Meissner Effect	41
3.7.6	Flux Pinning and the vortex state	41
3.7.7	The Suspension Effect	42
3.8	The rotating superconductor and magnetic force	45
3.9	Conductors and superconductors with magnetic shielding	46
3.10	Theory hardware and software for experiment setup	47
3.10.1	Electronic Balance Scientech SA 120	47
3.10.2	Interfacing electronic balance with PC	52
3.10.3	Handshaking between computer and electronic balance	52
3.11	DC motors	55
3.11.1	Driver circuits for DC motor	56
3.11.2	Using a transistor as a switch	58
3.11.3	Protection diode	58
3.11.4	Connecting a transistor to the output of the DAQ	59
3.12	Stepper motors	61
3.12.1	Operation of a stepper motor	61
3.12.2	The full and half step modes of operation	62
3.12.3	Angular Resolution	66
3.12.4	Drive Board for stepper motors	67
3.13	Safety Opto-Isolator and output signal amplification circuits	67
3.14	Opto switches or rpm sensors	71
3.14.1	Opto switches	71
3.14.2	Driver circuit for opto switches	72
3.15	Data acquisition board	75

3.16	The software: Introduction to LABVIEW programming	75
3.16.1	Front panel	76
3.16.2	Block diagram	76
4	METHODOLOGY	
4.1	Introduction	78
4.2	Hardware of System	78
4.2.1	Stepper Motor Configuration	78
4.2.2	Complete wiring diagram	79
4.2.3	Electronic Balance Interfacing	87
4.3	The Software of System: LabVIEW Programming	87
4.3.1	Experiment Information	88
4.3.2	Device Driver for Electronic Balance	88
4.3.3	Stepper Motor Control Function	89
4.3.4	Measuring rpm	96
4.3.5	Measuring rpm via frequency to voltage converter	96
4.3.6	Pulse Width Modulation Circuit	97
4.4	Experimental Set-Up	102
4.4.1	Setup for measuring levitation force versus speed of conductor	102
4.4.2	Setup for measuring electromagnetic drag force versus speed of conductor	105
4.4.3	Setup for measuring repulsive force between two identical magnets	107
4.4.4	Setup for measuring magnetic shielding between two identical magnets with similar or opposite poles facing each other	107
4.4.5	Setup for measuring levitation force versus speed of the rotating superconductor in zero field cooled and field cooled state	110
4.4.6	Setup for measuring the drag force between a fast rotating superconductor and a magnet in the zero field cooled and field cooled states	111
4.4.7	Setup for the superconductor rotating slowly while in a zero field cooled or field cooled state	111
4.5	LabVIEW Programs and Flowcharts	115
4.5.1	Positioning PCB drill vertically by forward motion	115
4.5.2	Positioning PCB drill vertically by reverse motion	116
4.5.3	Program for rotating superconductor or conductor while taking measurements	121
4.5.4	Program for rotating superconductor using actuator for step movement while taking measurements	121
4.5.5	Program for measuring force between two magnets with distance while taking measurements for reverse movement	129
4.5.6	Program for measuring force between two magnets with distance while taking measurements for forward movement	129

5 RESULT AND DISCUSSION	
5.1	Introduction 134
5.2	The Feature of the Automation System's User Interface 134
5.3	The results of measurement and calculation of the repulsive force between two identical magnets 137
5.4	The results of moving conductor and stationary magnet 137
5.4.1	Lift force, drag force and lift/drag force ratio for copper thickness 3 mm with a gap of 14 mm at room temperature 138
5.4.2	Lift force, drag forces and lift/drag force ratio for aluminium thickness 0.5mm, 1 mm and 4.75 mm with a gap of 14 mm at room temperature 142
5.4.3	Lift force, drag forces and lift/drag force ratio for aluminium thickness 4.75 mm with a gap of 14 mm, 18 mm and 22 mm at room temperature 143
5.4.4	Lift force, drag forces and lift/drag force ratio for copper thickness 1 mm and aluminium thickness 4.75 mm with a gap of 14 mm for room temperature 143
5.5	Levitation or lift force of type II superconductors for various speeds 148
5.6	Drag force of type II superconductors for various speeds 148
5.7	The force between a rotating magnet and a fixed magnet at constant gap 152
5.8	The rotational repulsive force of a type II superconductor 152
5.9	Force between two magnets with and without a superconductor placed in between 159
5.10	Comparison between lift off speed for aluminium with results obtained by other experimenters 161
5.11	Error analysis 161
6 CONCLUSION	
6.1	Automation Design 163
6.2	The Variation of magnetic force between a permanent magnet and moving conductors of various types and thickness 163
6.3	The measured lift/drag force ratio and the relationship with the calculated lift/drag ratio 164
6.4	The behaviour of the levitational forces of superconductors 164
6.5	Shielding force of a superconductor 165
6.6	The rotational repulsive force between identical permanent magnets 165
6.7	Suggestions 165
BIBLIOGRAPHY	167
APPENDICES	171
BIODATA OF THE AUTHOR	202