SENSOR MATERIAL CHARACTERISATION FOR MAGNETOMETER APPLICATION

NABIAH BTE ZINAL

KOLEJ UNIVERSITI TEKNOLOGI TUN HUSSEIN ONN

KOLEJ UNIVERSITI TEKNOLOGI TUN HUSSEIN ONN

BORANG PENGESAHAN STATUS TESIS◆

JUDUL : SENSOR MATERIAL CHARACTERISATION FOR MAGNETOMETER APPLICATION

SESI PENGAJIAN: 2003/2004

Saya **NABIAH BTE ZINAL**
(HURUF BESAR)

mengaku membenarkan tesis (~~PSM~~/Sarjana/ ~~Doktor Falsafah~~)* ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Tesis ini adalah hakmilik Kolej Universiti Teknologi Tun Hussein Onn
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☑ TIDAK TERHAD

Disahkan oleh:

(TANDATANGAN PENULIS)	(TANDATANGAN PENYELIA)
Alamat Tetap:	Nama Penyelia:
NO. 4, JALAN DUKU, TAMAN MAJU, PARIT RAJA 86400 BATU PAHAT, JOHOR	PROF. MADYA DR. ZAINAL ALAM BIN HARON
Tarikh: 4 JUN 2004	Tarikh: 2 JUN 2004

CATATAN:
* Potong yang tidak berkenaan.
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT atau TERHAD.
◆ Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah dan Sarjana sec penyelidikan, atau disertasi bagi pengajian secara kerja kursus dan penyelidikan, at Laporan Projek Sarjana Muda (PSM).

I have read this thesis and in my opinion
it is suitable in terms of scope and quality for the purpose of
awarding a Master Degree of Electrical Engineering.

Signature : --
Supervisor I : Assoc. Prof. Dr. Zainal Alam Bin Haron
Date : 2nd JUNE 2004

SENSOR MATERIAL CHARACTERISATION FOR MAGNETOMETER APPLICATION

NABIAH BTE ZINAL

A project report is submitted as partial fulfillment
of the requirements for the award of the
Master Degree of Engineering (Electrical)

Department of Electrical Engineering
Faculty of Engineering
Kolej Universiti Teknologi Tun Hussein Onn

APRIL 2004

"I declare that this project is the result of my own work except for the ideas and summaries of which I have clarified their sources."

Signature : ....

Author : NABIAH BTE ZINAL

Date : ....4 JUN 2004....

DEDICATION

Special dedication to my beloved husband Khairul Anuar and daughter Nurin Najihah , my parents, my parent-in-laws and my families for all your love, support and care.

ACKNOWLEDGEMENT

I would like to express my greatest appreciation to my project supervisor, Assoc. Prof. Dr. Zainal Alam Bin Haron for his excellent guidance, suggestions and contributions throughout this study. Also, I would like to convey my gratitude to all my friends who have been very supportive and cooperative in helping me out to complete this project successfully.

ABSTRACT

AC and DC magnetic field measurements require a highly sensitive and stable magnetic sensor. In order to achieve these requirements, good properties and criteria of magnetic materials are identified. A few types of different magnetic materials have been used to study their characteristics and effect towards magnetic fields. The ring cores made from several different types of magnetic materials are designed having the same dimension so that they can be compared among each magnetic material easily. For this project, single and dual rod cores have been used as a fluxgate sensor core to observe the resulting sensor performance. Both sensors are tested with two magnetic sources; permanent magnet bar and solenoids with different diameters of wires. The output of each fluxgate sensor was processed to identify their relation with the test magnetic field density.

ABSTRAK

Pengukuran dan gangguan medan magnet arus terus dan arus ulang-alik memerlukan penderia medan magnet yang mempunyai kepekaan yang tinggi dan stabil. Untuk menghasilkan penderia tersebut, ciri-ciri bahan magnet yang baik telah dikenalpasti. Beberapa jenis bahan magnet yang berbeza telah digunakan untuk mengkaji ciri-ciri dan kesannya terhadap medan magnet. Teras gelang yang diperbuat daripada bahan-bahan magnet tersebut direkabentuk dengan dimensi yang sama bagi membolehkan perbandingan dibuat dengan mudah. Selain itu, rod tunggal dan berkembar juga telah digunakan sebagai teras penderia fluxgate, untuk melihat prestasi setiap jenis penderia tersebut. Kedua-dua penderia tersebut telah diuji dengan menggunakan dua sumber bahan magnet iaitu bar magnet tetap dan solenoid dengan diameter dawai yang berbeza. Isyarat keluaran bagi setiap penderia fluxgate seterusnya diproses bagi mengenalpasti hubungannya dengan ketumpatan medan magnet.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATION

H	-	magnetic field intensity
B	-	magnetic flux density
G	-	Gauss
T	-	Tesla
Hz	-	Hertz
DC	-	Direct current
AC	-	Alternating current
μ	-	permeability
μ_r	-	relative permeability
χ	-	susceptibility
μ_o	-	permeability in vacuum
μi	-	initial permeability
M	-	magnetization
H_c	-	coercive force
H_{ci}	-	intrinsic coercivity
M_R	-	remanent magnetization
B_R	-	remanent or residual flux density
B_s	-	saturation flux density
μ_d	-	differential permeability
E_p	-	primary voltage
E_o	-	secondary/output voltage
N	-	number of turns
N_p	-	number of primary winding
V_{sec}	-	Induced voltage

A	-	Cross section area
D'	-	Demagnetization factor
f_r	-	resonance frequency
L	-	inductance
C	-	capacitor
l	-	length of coil
D_i	-	inner diameter
D_o	-	outer diameter
R_2	-	outer radius
R_1	-	inner radius
h	-	height of ring core
w	-	width of ring core
r	-	mean radius
I_{max}	-	maximum current

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

1.1 Foreword

In this chapter, the background, purpose, objectives, and the scope of the project are discussed.

1.2 Problem Statement

Magnetic field sensing technology has been driven by the need for improved sensitivity, smaller size, and compatibility with electronic systems. Nowadays, various types and applications of magnetic sensors are produced. The techniques used to produce magnetic sensors encompass many aspects of physics and electronics.

Magnetic properties of the core such as differential permeability, coercive force, and demagnetizing factor were contributed to the sensitivity of the sensor and in producing magnetometer with better performance. This project approached various types of materials with same geometry to compare which is most suitable to be used as the core sensor, in order to produce high sensitivity magnetic field sensor and to compete with existing sensor in the marketplace.

1.3 Objectives of The Project:

This project is motivated by the following objectives:

i. To be familiar with the state of the art in magnetometer design.
ii. To identify suitable magnetic field sensor configuration for DC magnetic measurements.

1.4 Scope of Project:

The scopes of the project are as followed:

i. To implement experimental works that related to magnetic measurements.
ii. To identify the core materials properties that is most suitable for producing high sensitivity magnetic field sensors.

CHAPTER II

LITERATURE REVIEW

Magnetic field sensors play an important and continuously increasing role in many fields of science and of modern technique. Early applications of magnetic sensors were for directions finding or navigation. But today, many more uses have evolved and the technology for sensing magnetic fields has also evolved driven by the need for sensitivity improvement, smaller size, and compatibility with electronic systems.

A number of papers have been published on fluxgate magnetometer, showing different types of configurations and explaining the mechanism, importance and use of each one. The first patent on the fluxgate sensor (in 1931) was credited to H.P. Thomas. Aschenbrenner and Goubau worked on fluxgate sensors from the late 1920s; by 1936 they reported 0.3nT resolution on a ring core sensor. Since the 1980s, magnetic variation stations with fluxgates supported by a proton magnetometer have been used for observing changes in the Earth's magnetic field. Fluxgate compasses are extensively used for aircraft and vehicle navigation. Forster [1] started to use the fluxgate principle for the nondestructive testing of ferromagnetic materials. The fluxgate principle is also used in current sensors and current comparators. Compact fluxgate magnetometers are used for navigation, detection and search operations, remote measurement of dc currents and reading magnetic labels and marks.

W. Hernandez [2] has been presented a fluxgate magnetometer for high magnetic fields (<100μT). He used ferrite as the material of the core and relatively high sensitivity and linearity characteristics have been achieved, which simplified the signal processing circuit. The fluxgate magnetometer used the ring core sensor geometry, which was found to be the best for low noise sensors [3]. This is well suited for elimination of offset and instabilities of the sensor with time and temperature variations.

Fluxgate sensors serve for the measurement of DC and low frequency AC magnetic field in the range of approximately 1nT to 1mT with possible resolution of 50pT. Their principle is based on modulation of the flux in the pick-up coil by changing the permeability of the ferromagnetic core by means of the AC excitation field [4]. According to [4], most of the fluxgate magnetometers work in the feedback mode to improve the sensor linearity and increase the measurement range.

Kurt Weyand and Volker Bosse [5] have developed a new fluxgate magnetometer for measuring both magnetic dc and ac fields, with frequencies up to 2 kHz. The magnetometer has been designed using a pulse-width modulator and has a resolution of 10nT. It is possible to link up ac field quantities with dc field standards in a simple way.

Fluxset sensor is a new type of magnetometer sensor, which belongs to the family of fluxgate sensors. It has been developed and capable of measuring DC and AC (up to 200 kHz frequency) low-level magnetic fields with high accuracy. This device has sensitivity better than 100pT, operates in a wide temperature range, simple and