UNIVERSITI PUTRA MALAYSIA

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DEVELOPMENT OF MOBILE MAGNETIC IMAGING SYSTEM BASED ON 1-D HALL SENSOR ARRAY

By

NG WEI SHIN

**Thesis Submitted to the School of Graduate Studies,
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Abstract of thesis presented to the Senate of University Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

DEVELOPMENT OF MOBILE MAGNETIC IMAGING SYSTEM BASED ON 1-D HALL SENSOR ARRAY

By

NG WEI SHIN

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Chairman: Associate Professor Norhisam Misron, PhD

Faculty: Engineering

Non-destructive evaluation (NDE) is one of the most common methodologies in the industries proposed to examine the properties of ferromagnetic materials. The NDE technique includes some kind of microscopy to examine the external surfaces of specimens in detail which rely upon magnetic, ultrasonic and radiographic methods. Therefore, NDE technique can be used to perform shapes evaluation of ferrous objects without permanently altering its characteristic. The NDE technique used in this thesis for shapes evaluation is based on the magnetization characteristic of ferrous objects.

This thesis describes the development of prototype Mobile Magnetic Imaging System applying the NDE technique for the shapes evaluation of ferrous objects. The Mobile Magnetic Imaging System is able to evaluate the shapes of ferrous objects underneath a non-ferromagnetic surface with the application of magnetic imaging technique proposed in this research. The magnetic imagings for the shapes of ferrous objects are

accomplished by performing the 2-D contour plot with 2-D array matrix of induced voltage signal, V_H and magnetic field, B.

The operation of Mobile Magnetic Imaging System is based on the magnetic flux leakage testing (MFLT) principle performed on the surface of ferrous objects. As the system navigates across a ferrous object, the permanent magnets on the system magnetize the ferrous object. The magnetized ferrous object forms the magnetic circuit with permanent magnets, thus, develops the closed loop flow of magnetic flux, Φ_m. The 1-D Hall sensor array on the system is exposed to the magnetic field, B caused by the flow of magnetic flux, Φ_m from permanent magnets to the ferrous object. The 1-D Hall sensor array consists of linearly integrated solid state Hall effects sensors to detect the magnetic field, B and translate to Hall induced voltage signals, V_H. The Hall induced voltage signals, V_H from 1-D Hall sensor array are constructed into a 2-D array matrix which is employed for magnetic imaging.

Lastly, the prototype of the Mobile Magnetic Imaging System is presented. In addition, the performance parameters of Mobile Magnetic Imaging System are identified which include the size of the specimen under evaluation, moving speed of system and thickness of non-ferromagnetic surface above ferrous objects. Therefore, experimental results to study the performance of Mobile Magnetic Imaging System are presented in this thesis. Firstly, it presents the ability of the system in visualizing the shapes of ferrous object specimens with magnetic images. In addition, the improvements towards magnetic imaging technique of ferrous objects are proposed by considering the absolute value of

induced voltage signals, $|V_H|$ and magnetic field, |B|. Secondly, the result presents the ability of the system to visualize the shapes of actual ferrous objects employing improved magnetic imaging technique. Lastly, the effect of perpendicular gap towards accuracy of Mobile Magnetic Imaging System in shapes evaluation is studied. Based on the experimental results, the optimized perpendicular gap for shapes evaluation is at 10mm.

In summary, the Mobile Magnetic Imaging System is proven to be able to visualize the shapes of ferrous objects embedded underneath a non-ferromagnetic surface.

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

PEMBANGUNAN SISTEM PENGIMEJAN MAGNETIK MUDAH ALIH BERDASARKAN SUSUNAN PENGESAN HALL 1-D

Oleh

NG WEI SHIN

Februari 2012

Pengerusi: Profesor Madya Norhisam Misron, PhD

Fakulti: Kejuruteraan

Kajian Tanpa Kemusnahan (NDE) merupakan salah satu cara yang paling dikenali umum dalam industri untuk mengkaji sifat-sifat bahan ferromagnetik. Teknik NDE termasuk beberapa jenis mikroskopi untuk memeriksa permukaan luar spesimen secara terperinci yang bergantung kepada magnetik, ultrasonik dan radiografi. Maka, teknik NDE boleh digunakan untuk melaksanakan penilaian keatas bentuk-bentuk objek ferus tanpa mengubah ciri-cirinya secara kekal. Teknik NDE yang digunakan dalam tesis ini untuk penilaian bentuk-bentuk adalah berdasarkan ciri magnetik objek-objek ferus.

Tesis ini menghuraikan pembangunan prototaip Sistem Pengimejan Magnetik Mudah Alih dengan teknik NDE untuk mengkaji bentuk objek ferus. Sistem Pengimejan Magnetik Mudah Alih ini mampu untuk mengesan bentuk objek ferus di bawah permukaan melalui teknik pengimejan magnetik yang dicadangkan dalam penyelidikan.

Pengimejan magnetik untuk bentuk objek ferus dicapai melalui perlaksanaan plot kontur 2-D dengan susunan matrik 2-D isyarat voltan dorongan, V_H dan medan magnetik, B. Operasi Sistem Pengimejan Magnetik Mudah Alih adalah berdasarkan prinsip Ujian Kebocoran Fluk Magnetik (MLFT) yang dilaksanakan pada permukaan bentuk objek ferus. Apabila sistem melalui objek ferus, magnet kekal pada sistem akan memagnetkan objek ferus. Objek ferus yang dimagnetkan akan membentuk litar magnetik dengan magnet kekal, maka, gelung tertutup dibentuk untuk pengaliran fluk magnet, Φ_m. Susunan pengesan Hall 1-D pada sistem didedahkan kepada medan magnet, B yang dihasilkan daripada pengaliran fluk magnet, Φ_m dari magnet kekal ke bahan ferromagnetik. Susunan pengesan Hall 1-D yang terdiri daripada pengesan Hall keadaan pepejal linear digunakan untuk mengesan medan magnet, B dan menterjemahkannya kepada isyarat voltan dorongan Hall, V_H. Isyarat voltan dorongan Hall, V_H dari susunan pengesan Hall 1-D membina susunan matrik 2-D yang digunakan untuk pengimejan magnetik.

Akhirnya, prototaip Sistem Pengimejan Magnetik Mudah Alih telah ditunjukkan. Di samping itu, parameter-parameter untuk mengkaji prestasi Sistem Pengimejan Magnetik Mudah Alih yang telah dikenal pasti termasuk saiz spesimen untuk penilaian, kelajuan sistem dan ketebalan permukaan bukan ferromagnetik di atas objek-objek ferus. Maka, hasil-hasil eksperimen untuk mengkaji pretasi Sistem Pengimejan Magnetik Mudah Alih telah dibentangkan dalam tesis ini. Dalam bahagian pertama, ia membentangkan keupayaan sistem dalam memaparkan bentuk-bentuk objek ferus dengan imej magnetik. Tambahan pula, peningkatan keatas pengimejan magnetik untuk bentuk-bentuk objek

ferus telah dicadangkan dengan mengambil nilai mutlak isyarat voltan dorongan, $|V_H|$ dan medan magnetik, |B|. Dalam bahagin kedua, hasil eksperimen membentangkan keupayaan sistem untuk memaparkan bentuk-bentuk objek ferus melalui peningkatan keatas teknik pengimejan magnetik. Dalam bahagian ketiga, kesan jurang serenjang ke atas ketepatan Sistem Pengimejan Magnetik Mudah Alih dalam penilaian bentuk telah dikaji. Berdasarkan keputusan eksperimen, jurang serenjang yang dioptimumkan untuk penilaian bentuk adalah pada 10mm.

Dalam ringkasan, Sistem Pengimejan Magnetik Mudah Alih ini terbukti mampu untuk memaparkan bentuk-bentuk objek ferus terbenam di bawah permukaan bukan ferromagnetik.

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I certified that a Thesis Examination Committee has met on 27 February 2012 to conduct the final examination of Ng Wei Shin on his thesis entitled "Development of Mobile Magnetic Imaging System Based on 1-D Hall Sensor Array" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follow:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follow:

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DECLARATION

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

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NG WEI SHIN
Date: 27 February 2012

TABLE OF CONTENTS