# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## DEVELOPMENT OF CRACK ON COMPOSITE DETECTION SENSOR USING MAGNETIC INDUCTION CONCEPT

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electronics Engineering Technology (Telecommunications) with Honours.

by

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# DECLARATION

I hereby, declared this report entitled "PSM Title" is the results of my own research except as cited in references.

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| Date | : | 20 DECEMBER 2017 |

# ABSTRAK

Laporan ini membentangkan sensor pengesanan komposit untuk mengesan retak menggunakan konsep induksi magnetik. Pengesanan retak sangat penting untuk mengawal kualiti komposit itu sendiri yang digunakan secara meluas dalam industri. Objektif kajian semasa adalah untuk membangunkan sensor yang dapat mengesan retak pada komposit, membuat kualiti pemeriksaan komposit dan membezakan antara retak dan tidak retak bahan komposit. Projek ini memberi tumpuan kepada mereka bentuk dan melaksanakan sistem untuk mengesan retak pada bahan komposit menggunakan konsep induksi magnetik. Miniatur sensor pengesanan komposit menggunakan konsep induksi magnet direka menggunakan perisian Comsol Multiphysics untuk melihat arus yang diinduksi dari sistem. Nilai semasa dari sensor diukur berdasarkan konsep induksi magnetik. Arus induksi yang dihasilkan dari sensor menunjukkan keadaan komposit. Isyarat yang dihasilkan akan dikuatkan atau dilemahkan oleh litar penyaman isyarat sebelum dihantar ke penapis pas rendah atau tinggi untuk menolak isyarat yang tidak diingini bagi kesan sampingan dan untuk mendapatkan output DC bersih daripada isyarat input AC. Output dari isyarat akan ditukar dari analog ke isyarat digital menggunakan penukar digital analog kemudian menggunakan Bluetooth sebagai perisian antaramuka melalui litar modul Arduino Uno. Aplikasi Bluetooth Elektronik digunakan sebagai antara muka untuk memaparkan keadaan bahan

# ABSTRACT

This report presents a composite detection sensor to detect crack using magnetic induction concept. A crack detection is very important to control the quality of the composite itself that been widely used in industry. The objectives of the current study are to develop a sensor that able to detect crack on composite, make an inspection quality of the composite and distinguish between crack and not crack on composite material. This project focuses on designing and implementing the system to detect crack on composite material using magnetic induction concept. The miniature of composite detection sensor using magnetic induction concept is designed using Comsol Multiphysics Software to see the current induced from the system. The current value from the sensor is measured based on magnetic induction concept. The induced current produced from the sensor shows the condition of the composite. The signal produced will be amplified by amplifier before sending to RC filter for rejecting the unwanted signal of the fringe effect and to get the clean DC output from AC input signal. The output from the signal will be converted from the analog to digital signal using analog digital converter then using Bluetooth Electronic as interface application via the Arduino module circuit. The Bluetooth Electronic software is used as interface to display the condition of composite materials

# DEDICATION

Special dedicated to
my beloved parents and siblings, my friends and y supervisor who have encourage, guided and supported me throughout my study.

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# LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

| | | |
|---|---|---|
| AC | - | Alternating Current |
| ADC | - | Analog to digital converter |
| mm | - | millimeters |
| MIS | - | Magnetic induction sensor |
| MIT | - | Magnetic Induction Tomography |
| MT | - | Magnetic particle Testing |
| NDE | - | Non-destructive evaluation |
| NDT | - | Non-destructive technique |
| RC | - | Resistor-capacitor |
| Vp-p | - | Voltage peak-to-peak |

# CHAPTER 1
# INTRODUCTION

## 1.0 Introduction

This chapter presents the overview for overall description for this project. It's including the background of project, problem statement, objective and scope of study. The thesis structure of the report also state in this chapter for the preview of the report ahead. This will further explain in subtopic below.

## 1.1 Background of Project

Composites are widely used in high performance products, such as aerospace components or storage tanks. It often exposed to harsh loading conditions. This may lead to crack formation and propagation. However, visible cracking is one aspect that occasionally causes problems and dangers to community. Thus, a numerous crack detection have been develops in the past decades. In previous study, there was an implementation of crack by using various method of non-destructive technique (NDT). NDT have been widely used for evaluating the condition of composite. Visual inspection, radiography, ultrasonic, eddy current, magnetic particle and penetrant testing are the most widely applied NDT techniques.

However, from all this method, this paper aims to detect cracks on composite via magnetic induction concept. This concept was related to electromagnetic induction and eddy current concept and was similar to eddy current testing technique of NDT. This project is carried out to show evidence that it is possible to detect crack in composite using magnetic induction concept. The basic principle is that magnetic induction is the process by which a substance, such as iron or steel, becomes magnetized by a magnetic field. According to Bird (2001), electromagnetic induction is when a conductor is moved across a magnetic field so as to cut through the lines of force (or flux), an electromotive force (e.m.f.) is produced in the conductor and causes an electric current to flow round the circuit. Hence an e.m.f (and thus current) is 'induced' in the conductor as a result of its movement across the magnetic field. This effect is known as 'electromagnetic induction'. Eddy currents are loops of electrical current induced within conductors by a changing magnetic field in the conductor, due to Faraday's law of induction.

Magnetic induction sensor (MIS) can be classified as one of the type of non-destructive testing technique. This system is adopted from the Magnetic Induction Tomography (MIT) concept which a new imaging modality that being developed for the process industry and for medical imaging. Magnetic Induction method will be used for fatigue crack detection based on the alternating magnetic field produces around it. The focus of the test is to determine the changing of the current based on different types of composite material. Experimental using magnetic induction concept will be carried out on the not cracked and cracked composite materials to validate the simulation results.

## 1.2 Problem Statement

Non-destructive detection of cracks in composite material is an important practical issue in several critical environments including surface transportation, aerospace transportation and power plants. Cracks in composite present a great threat to any civil structures; they are very dangerous and have caused a lot of destruction and damage. Some of the composite are poorly in condition without inspection.

Sometimes it is difficult to distinguish between crack and not crack in composite material.

## 1.3 Objective

The goal of this project is to detect crack on composite. The specific objectives that need to be achieved are:

a) To develop a sensor that able to detect crack on composite.
b) To make an inspection quality of the composite.
c) To distinguish between crack and not crack on composite material.

## 1.4 Scope of Project

This project will focus on development of crack on composite detection sensor using magnetic induction concept. The scope of the project have been defined as follows:

a) Develop a sensor to detect any crack in composite.
b) Using Bluetooth Electronic application for inspection whether there are any crack or not in the composite.
c) Construct a signal conditioning circuit to distinguish between cracks and not crack in the composite.

## 1.5 Thesis Structure

This report consists of five chapters. The first chapter is an introduction chapter that covers about introduction including background of the project, problem statement, and objective, scope of project and thesis structure of report.

The second chapter provides literature reviews which emphasize on theory magnetic induction, non-destructive testing method that available used in industry to detect crack on composite and some previous research paper related to the project.

The following chapter describes the detailed methodology used in this project. This chapter explains in detail the procedures and steps that have been done to complete this project.

In chapter four, the result and discussion involve are analyzed. This chapter describes the analysis, explanation and discussion of this project.

Lastly, chapter five concludes the outcome of this project and provides some recommendations to improve this project.

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# CHAPTER 2

## LITERATURE REVIEW

### 2.0 Introduction

In this chapter will discuss the literature review of this project. A literature review will provide the review from previous research that is related to this final year project and will discuss a background study related to the project, which includes a fundamental and the history of the creation of the device in order to enhance the understanding of the concept that will be used throughout this research. This project is the new improving technology that is applied to the composite.

### 2.1 Non-destructive Testing (NDT)

Non-destructive testing (NDT) is the inspection of the structure using a technique that does not risk inducing damage in the construction. Non-destructive testing is sometimes distinguished from non-destructive evaluation (NDE) which is the stipulation of the fitness for purpose of a structure by methods that do not endanger its fitness. Non-destructive evaluation therefore combines NDT with a valuation of the significance of any damage found (Cawley, 2001). Non-destructive testing is commonly used for the detection of composite defects. Visual inspection, radiography, ultrasonic, eddy current, magnetic particle and penetrant testing are the most widely applied NDT techniques. Each of these methods complements the others in various applications, while in many cases they overlap in function.

### 2.1.1 Visual inspection

The basic procedure used in visual NDT involves illumination of the test specimen with light, usually in the visible region. The specimen is then examined with eye or by light sensitive devices such as photocells. The equipment required for visual inspection is extremely simple, but adequate illumination is absolutely essential. The surface of the specimen should be adequately cleaned before being inspected (Baldev Raj, 2002, p4). However, Allgaier et al (1993) said that the general advantages of visual inspection techniques of being straight forward and inexpensive may no longer hold. Careful surface cleaning and preparation is required with visual inspection.

#### 2.1.1.1 Types of Discontinuities

a) Surface deposits
b) Scaling
c) Erosion
d) Discoloration
e) Missing parts

### 2.1.2 Radiography

The historic discovery of X-rays by W.C.Roentgen in 1895 and radioactivity by Becquerel in 1896 and their subsequent and logical application to he examination of material objects provided the starting point for the development and advancement of industrial radiography. The purpose of radiography is to show the presence and nature of defects or other structural discontinuities in the interior of the materials under examination. The principle of radiographic examination is shown in Figure 2.1. This technique makes use of the ability of short wavelength electromagnetic radiations, such as X-rays or gamma rays, to penetrate objects. In general, the shorter the wavelength, the greater is the penetrating power (Baldev Raj et al, 2002, p55). MR Jolly et al (2015) claimed that radiography involves penetrating the object with short wavelength electromagnetic radiation. The amount of radiation that passes through the object is captured by a detector. The absorption is a function of density and thickness of the material. Cavities and discontinuities lead to a detectable variation in absorption. This statement is parallel with Baldev Raj et al (2008) and Prakash (1980). The advantages of this method are data is presented pictorially and permanent record is created which may be seen at a time and place distant from the test, suitable for thin sections, very sensitivity declared on each film and useful for any material. Radiography is an expensive NDT technique. Thick sections consume a substantial amount of time and energy cost associated is also high (Harara, 2008).

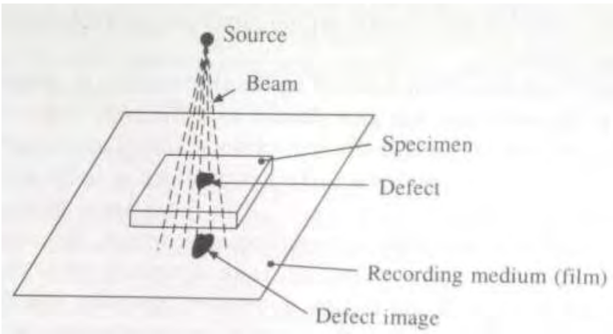


Figure 2.1: Principle of radiographic examination (Baldev Raj *et al*, 2002)

#### 2.1.2.1 Types of Discontinuities

a) Cracks (parallel to the radiation beam)
b) Porosity
c) Material thickness
d) Blockage inside the pipe lines

### 2.1.3 Ultrasonic

Ultrasonic waves are sound waves with frequencies ranges from 500 kHz to 10 MHz. These are more directional than audible sound waves and travel freely in liquid & solid, depending on density and elastic properties of the medium. Ultrasonic waves are widely used for NDT applications that was stated by MR Jolly et al (2015) and supported by Adamowski (2008) which is applicable to most materials, metallic or non-metallic. By this method, surface and internal discontinuities such as laps, seams, voids, cracks, blow holes, inclusions, and lack of bond can be accurately evaluated from one side. The basic technique of ultrasonic inspection is simple: a transducer transforms a voltage pulse into an ultrasonic pulse (wave). One places the transducer onto a specimen and transmits the pulse into the test object. The pulse travels through the object, responding to its geometry and mechanical properties. The signal is then either transmitted to another transducer (pitch-catch method) or reflected back to the original transducer (pulse-echo method). Either way, the signal is transformed back into an electrical pulse, which is observed on a oscilloscope (Peter J. Shull, 2016).

An open crack filled with air has very low acoustic impedance so it reflects virtually all the acoustic energy incident on it. It can be detected either by the increase in the reflected signal or by the reduction in the transmitted signal. Since the speed of sound in the parent material is known, the arrival time of the reflected signal provides information on the crack location. Figures 2.2 show the reflected signals obtained from good and delaminated areas of a carbon fibre composite laminate. The back surface echo is lost in the delaminated region and there are earlier reverberations of the ultrasound between the delamination and the front surface. Measurement of reflection arrival time is the basis of ultrasonic thickness gauges which measure the separation between the signals from the front and back surfaces of a structure. This is a very common method for assessing the extent of corrosion in, for example, pipes and storage tanks (Zahran et al, 2002). The advantages of this technique is ultrasonic NDT is a very flexible and robust technique, with applications in a wide range of industries. But ultrasonic techniques do have some disadvantages. First, they require a highly experienced technician. In addition, although noncontacting methods exists, in the majority of cases the transducer must be in contact with the object, though a water or gel coupling layer. Also, ultrasonic waves typically cannot reveal planar flaws (cracks) whose length lies parallel to the direction of wave travel.

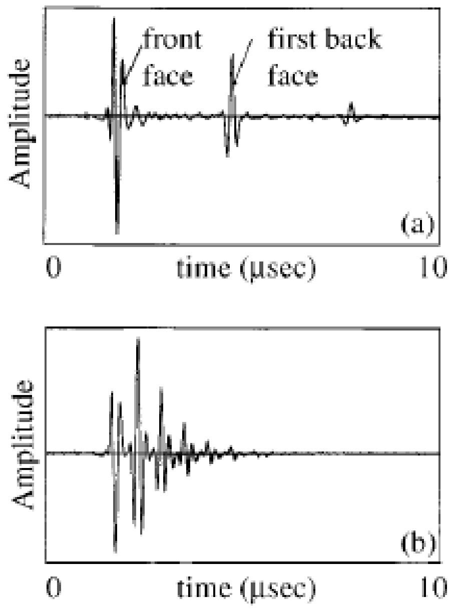


Figure 2.2: Ultrasonic 'A-scan' of composite material using a normal incidence compression probe: (a) good area; (b) delaminated area (Zahran *et al,* 2002)

**2.1.3.1 Types of Discontinuities**

a) Laps
b) Laminations
c) Porosity
d) Creep
e) Surface breaking and hidden cracks in any orientation

f) Intergranular cracks

### 2.1.4 Eddy current

Karbhari (2013) mention that Eddy current technology is a well-established non-destructive method for the characterization of surfaces or material incontinuities by analyzing conductivity and permeability variations. A primary magnetic field is generated when alternating current is applied to an induction coil. Eddy currents are generated in a conductive specimen when the coil is placed near that specimen as in Figure 2.3. Eddy current testing is another important nondestructive evaluation technique used to quickly characterize materials, because eddy currents are influenced by microstructural alterations due to precipitates, cold work, deformation, etc. and the coil impedance or induced voltage in pick-up coil changes accordingly. The magnitude and phase of induced voltage or impedance change are used to correlate with the microstructures and mechanical properties (Tariq, 2012). Like other NDT technique, this method has certain limitations. The major limitations of this method is that only electrically conductive materials can be inspected. Since too many parameters affect the eddy current probe impedance, eddy current testing is not effective when more than one variable is present.

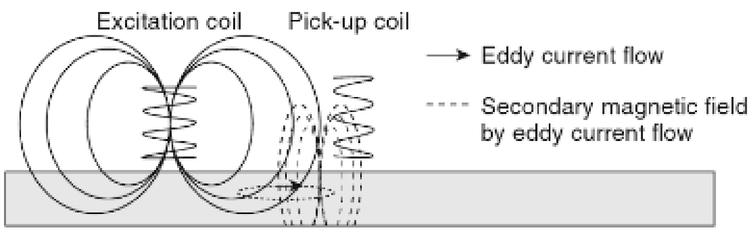


Figure 2.3: Schematic diagram of probe and specimen configuration for eddy current testing (Karbhari, 2013).

#### 2.1.4.1 Types of Discontinuities

a) Electrical conductivity
b) Heat treatment condition
c) Hardness
d) Cracks
e) Voids
f) Porosity
g) Corrosion
h) Fatigue cracks

### 2.1.5 Magnetic particle

Magnetic particle Testing (MT) uses ferromagnetic material after being magnetized, since the existence of discontinuity, making workpiece surface and near-surface magnetic-curve generate a leakage magnetic field (namely the magnetic field formed when line of magnetic induction leaving and entering the surface), which can absorb magnetic particle on workpiece surface and form visible indications in the right light, thereby revealing the location, shape, size and severity of the discontinuity. Therefore, the magnetic particle indications can be used to reveal the defects of ferromagnetic material and its products. Magnetic particle Testing can detect the exposed small defects which cannot be directly observed by naked eye or magnifying glass, and also can detect near-surface defects which are not exposed but a few millimeters below the surface. Lu Zhiyong (2013) mention that although this method can also be used to detect volume type defects such as gas pole, slag and incomplete fusion, it is more sensitive to area type defects and more suitable for testing cracks caused by quenching, rolling, forging, casting, welding, plating, grinding and fatigue.