Faculty of Electrical and Electronic Engineering Technology

DEVELOPMENT OF ELECTRICAL CAPACITANCE SENSOR FOR NON-DESTRUCTIVE TEST ON COMPOSITE

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Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours

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DEVELOPMENT OF ELECTRICAL CAPACITANCE SENSOR FOR NON-DESTRUCTIVE TEST ON COMPOSITE

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A project report submitted
in partial fulfillment of the requirements for the degree of
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DECLARATION

I declare that this project report entitled "**DEVELOPMENT OF ELECTRICAL CAPACITANCE SENSOR FOR NON-DESTRUCTIVE TEST ON COMPOSITE**" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date : 9/1/2022

APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours

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DEDICATION

This project is especially dedicated to the Lecterur, who assisted and directed us in completing it successfully. I also want to thank our parents for never failing to provide us with financial and spiritual support, for providing us with all of our requirements throughout the time we were developing our system, and for showing us that even the most difficult endeavour can be completed if done one step at a time.

ABSTRACT

Today, new powerful appliances and instruments, and simple techniques for the application of NDT methods in the qualitative control of materials and manufacturing, are being developed. Nondestructive Testing (NDT) consists of a variety of non-invasive inspection techniques used to evaluate material properties, components, or entire process units. The techniques can also be utilized to detect, characterize, or measure the presence of damage mechanisms. Many NDT techniques are capable of locating defects and determining the features of the defects, such as their size, shape, and orientation. We applied Non-contact capacitive sensors work by measuring changes in an electrical property called capacitance. Capacitance describes how two conductive objects with a space between them respond to a voltage difference applied to them. If the polarity of the voltage is reversed, the charges will also reverse.Capacitive sensors use an alternating voltage which causes the charges to continually reverse their positions. The moving of the charges creates an alternating electric current which is detected by the sensor. current flow is determined by the capacitance, and the capacitance is determined by the area and proximity of the conductive objects. The capacitance is also affected by the type of nonconductive material in the gap between the objects. For the implementation of this project, the use of COMSOL Multiphysics computer software can build the design of the capacitive parallel plate as the main design needed to detect and release different readings on composite items that will serve as a testament to being placed in the middle of the parallel plate. Thus, the production of data released with different capacitance readings on each item can classify the types of composites that are included in detecting damage or cracks in the composite material as the main objective of this project.

ABSTRAK

Hari ini, peralatan dan instrumen baru yang kuat, dan teknik mudah untuk penerapan kaedah NDT dalam kawalan kualitatif bahan dan pembuatan, sedang dikembangkan. Nondestructive Testing (NDT) terdiri daripada pelbagai teknik pemeriksaan bukan invasif yang digunakan untuk menilai sifat bahan, komponen, atau keseluruhan unit proses. Teknik ini juga dapat digunakan untuk mengesan, mencirikan, atau mengukur adanya mekanisme kerosakan. Banyak teknik NDT mampu mengesan kecacatan dan menentukan ciri-ciri kecacatan, seperti ukuran, bentuk, dan orientasi mereka. kami menggunakan kerja sensor kapasitif Noncontact dengan mengukur perubahan dalam sifat elektrik yang disebut kapasitansi. Kapasiti menerangkan bagaimana dua objek konduktif dengan ruang di antara mereka bertindak balas terhadap perbezaan voltan yang dikenakan padanya. Sekiranya kekutuban voltan dibalikkan, cas juga akan terbalik. Sensor kapasitif menggunakan voltan bergantian yang menyebabkan cas terus membalikkan kedudukannya. Pergerakan cas menghasilkan arus elektrik bergantian yang dikesan oleh sensor. aliran arus ditentukan oleh kapasitansi, dan kapasitansi ditentukan oleh kawasan dan jarak objek konduktif. Kapasiti juga dipengaruhi oleh jenis bahan bukan konduktif dalam jurang antara objek. Untuk pelaksanaan projek ini, penggunaan perisian komputer Multifizik COMSOL dapat membina reka bentuk plat selari kapasitif sebagai reka bentuk utama yang diperlukan untuk mengesan dan melepaskan bacaan yang berbeza pada item komposit yang akan berfungsi sebagai bukti untuk diletakkan di tengah-tengah plat selari. Oleh itu, pengeluaran data yang dikeluarkan dengan bacaan kapasitansi yang berbeza pada setiap item dapat mengklasifikasikan jenis komposit yang termasuk dalam mengesan kerosakan atau retakan pada bahan komposit sebagai objektif utama projek ini.

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C	-	capacitance
Q	-	magnitude of charges
V	-	voltage
$\varepsilon 0$	-	dielectric constant of free space
εr	-	the permittivity of the material
m	-	meter
d	-	distance
A plate	-	area of the capacitive plate
+	-	positive electrical charge
-	-	negative electrical charge
F	-	Farad

CHAPTER 1

INTRODUCTION

1.1 Project Background

The rapid development of technology, with intense competition between countries, is an aim in this era of globalisation. It is to develop the country's economy and at the same time to demonstrate the skills and knowledge that this small country can compete with large countries. Composite materials are currently used in many applications where light weight and highly specific module and strength are critical. Composites also contribute decisively to our society's sustainable development. Furthermore, NDT (non-destructive techniques) are popular in the industry and are used by ECT (Electrical Capacitance Tomography). This project proposes a conceptual framework for non-destructive testing to identify the material defects by using parallel plates and electrical capacitance tomography, which is particularly useful for construction or related projects. The likelihood of employing this method is simulated in the first stage using Comsol Multiphysical software.

1.2 Problem Statement

Surprisingly, although it has been around for decades, the application of electrical capacitance tomography (ECT) in composites has not yet been studied thoroughly. In only a few published studies, the effectiveness of ECT on dielectric materials has been thoroughly tested. NDT has been used in a few investigations to examine problems with composite materials using ECT. This means that numerous opportunities and studies in the use of ECT on composite materials can be conducted. The aim of this research is to assess how effective electric capacitance tomography on parallel plates is in detecting defects in composites. This study contributes significantly because the findings can be used as a springboard to investigate further the possible use of ECT as one of the composite NDT techniques.

1.3 Research Objective

The main aim of this project:

- To classify type of composite
- To stimulate the behavior of capacitance sensor
- To create capacity of differentiate type of cracks.

1.4 Scope of Research

The scope of this research are as follows:

- Copper, concrete, PVC, uluminium and brick are uses as a testing material to detect element in composite.
- Comsol Multiphysics and solidworks software
- Four type of crack such as circle, straight line, parallel line and zigzag line.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The analysis in different zones a recently constructed design will be reviewed in this chapter. Literature reviews were compiled from a variety of publications, including informative articles, papers, study reports, trustworthy websites, and other sources. The following keywords have been used to categorise the scriptures for this task: simulation of parallel plates, Dielectric, non-destructive testing technique and electrical capacitance tomography.

2.2 Non-destructive testing (NDT) technique

Non-Destructive testing is form of testing, examination, or assessment on an object in order to study the absence or presence of conditions or imperfections which may have an impact on the functions of the objects as they do not cause any change or alteration to the object's performance. Also, The non-destructive test includes all of the technology to detect and measure significant properties and imperfections, from research specimens to finished hardware and products[1]. In general, the goal of NDT is to figure out what properties a material has. It can also be used to identify, characterise, locate, and size product discontinuities and defects[2].

2.3 Electrical Capacitance Tomography

The multiple measurements at the periphery of a process vessel or pipeline are used and combined to inform the process volume about electrical properties in accordance with the basic principles of Electrical Capacitance Tomography.[3]Also stated that, Electrical capacitance tomography (ECT) is a technique for determining capacitance variations between electrode pairs and generating a cross-sectional image that depicts permittivity and material distribution[4]. The sensors for tomographic imaging must allow for multiple, localised measurements throughout the investigation area, according to the requirements. For example, resistance tomography is used to determine conductivity distributions, capability tomography detects different permittivities, and inductance tomography detects the distribution of permeability. Impedance tomography is useful for determining both the resistive and reactive components of a system[5].

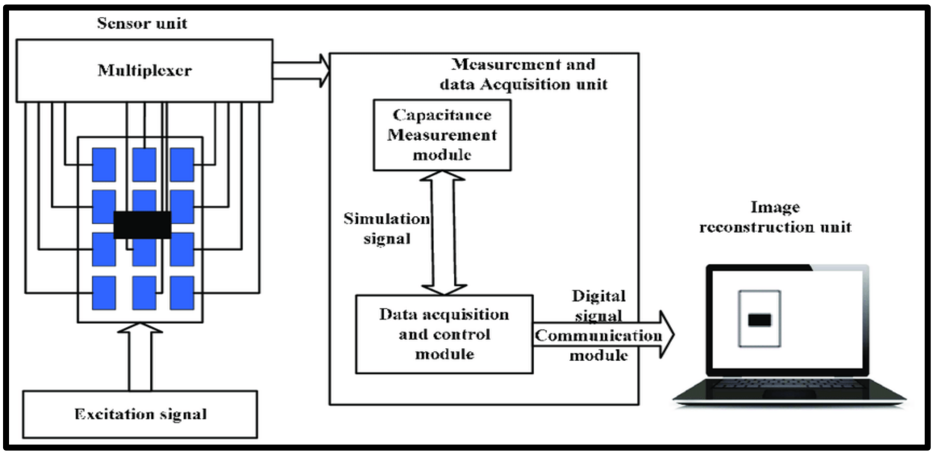


Figure 2.1: Block Diagram of the Electrical Capacitance Tomography (ECT)

An ECT system consists of three modules as shown in Figure 2.1 such as module for capacitance sensing, a module for measurement and data collecting, and a module for picture reconstruction. The ECT system operates in the following manner. The capacitance data are recorded using capacitance sensors, then communicated to the computer, where the field distribution image is rebuilt.

2.3.1 Concept of Capacitance Sensor

The capacitance is calculated by multiplying the magnitude of charges (Q) on both electrodes by the potential difference (V) between them.

$$C = \frac{Q}{V}$$

Capacitance can also be calculated as a function of the distance between two electrodes Where, ε0 is the dielectric constant of free space (εr) is the permittivity of the material, A plate is the area of the capacitive plate (m2) and distance (d) is the spacing between the two plates (m).

$$C = \frac{\varepsilon_0 \varepsilon_r A_{plate}}{d}$$

The capacity of the insulator between the plates increased it because, the capacity factor is raised since the material between plates is relatively permitted. Permittivity is defined as electrical field potential of the substance. This equation suggests that the ability is proportional to permittivity. Furthermore, an ECT sensor must be constructed to satisfy specific requirements to obtain high performance. The distribution of capacity and ability of the medium in the vessel or pipe is also crucial in the ECT idea. The measured element is identifiable by knowing the capacitance and voltage between the electrodes since each measured element's permittivity is constant[6].

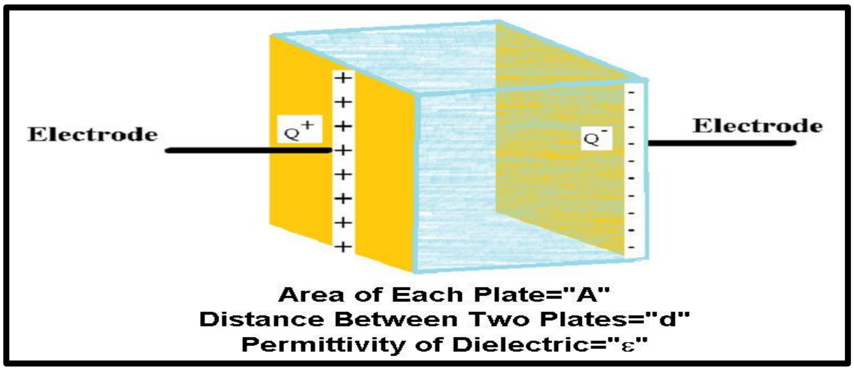


Figure 2.2: Parallel plate of Capacitor

2.4 Liquid Penetrant Testing

Cracks or other faults in materials related to their surface may be detected through fluid penetrating tests. Due to the ambiguous proof of faults in porous materials, liquid penetration is the most useful for non-porous materials. As part of this test process, materials are coated or soaked in an indication fluid. This fluid flows through the surface of the material and into the openings. When the liquid is removed from the surface, the liquid returns from the fissures. A flaw emerges whenever a liquid resurfaces; the greater the flaw, the more liquid resurfaces. The fluid cannot penetrate a defect without a pathway linking it to the surface. As a result, other methods for detecting enclosed voids or honeycombing must be used. Oils and other residues must not obstruct the liquid's ability to penetrate cracks, so the material's surface must be clean as well. In addition, handling liquid penetrant necessitates a significant amount of equipment, setup, and clean up. While this technique is effective, it is often slower and more difficult to use than other NDT techniques[7].

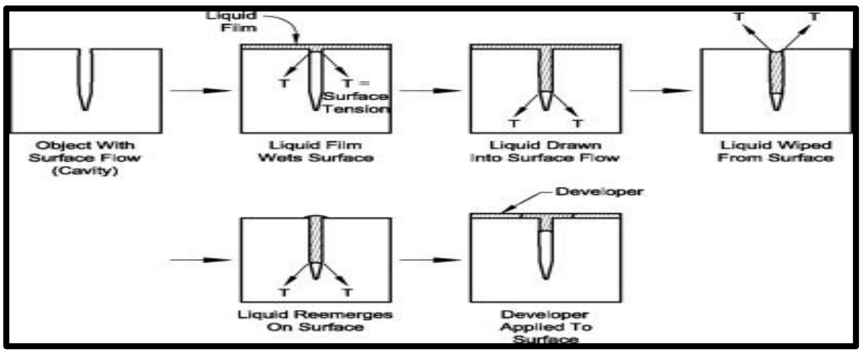


Figure 2.3: Physical principles of dye-penetrant examination

2.4.1 Magnetic Particle Testing

The movement of the indicator particles used by the magnet particle test shows internal discontinuities in ferromagnetic materials. The test part must be covered with teared magnetic particles, either in dry powder form or in liquid suspension. A magnet induces the test material with an electromagnetic field. This field causes magnetic particles to move in the direction of the magnetic field towards any discontinuity's transverse, which provides visual indications of defects. Magnetic particulate testing is a wide range of methods and can be used to induced magnetic fields. Magnetic particles testing requires considerable set-up, cleanup and cannot be done easily on the ground [8].

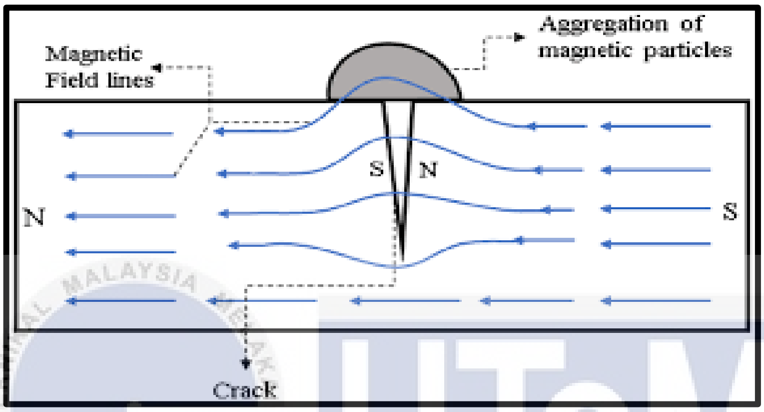


Figure 2.4: Principle of magnetic particles non-destructive testing.

2.4.2 Radiographic Testing

Radiographic testing through x-ray machines has entered the public imagination. The method penetrates an object and a radiation medium. Darker zones on the recording medium indicate more radiation that crosses the object area, indicating cracks, voids or variation in density. X-rays are usually used in the case of thinner materials, thicker gamma rays. As recording media, film or computerised sensors can be used. Extensive equipment and expertise as well as safety precautions are required to prevent over-exposure to radiation in radiographic testing. Neutron radiographic testing uses a concentrated ray of neutrons instead of X- or gamma rays to penetrate objects. To generate these neutron beams, a linear or particles accelerator must be used. Neutrons, but not most organic materials pass through metals. This provides a more detailed picture of the interiors of objects when combined with standard with radiography. This technology is used only in laboratory environments[9].

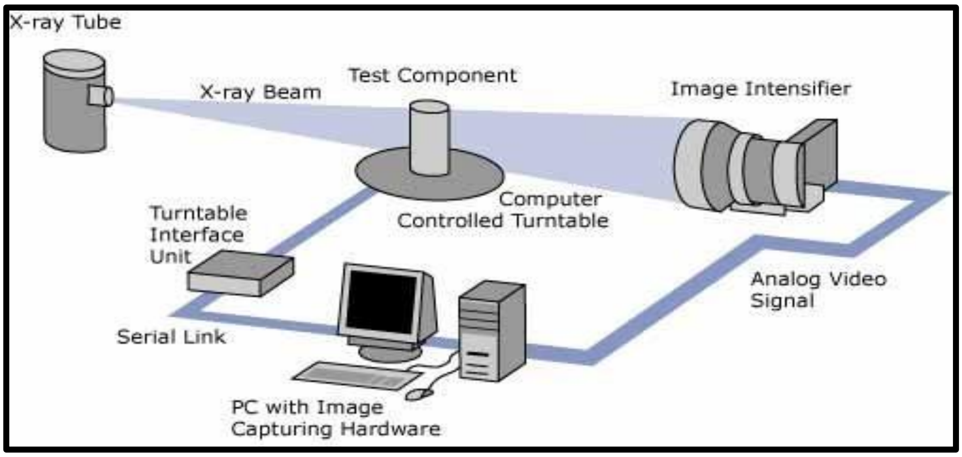


Figure 2.5: Process of Radiographic Non-Dectructive Testing

2.4.3 Ultrasonic Testing

Ultrasonic tests have shown to be one of the most efficient methods of current NDT. This process is used to transform high-frequency soundwaves, generally metals or composites, into solid things. Irregularities like density variations, fissures, vacancies, honeycombs, or foreign objects influence the travel of sound waves. Ultrasound test equipment can map many solid things through the collection and interpretation of returning sound waves. Waves can be caught as they are reflective or pass through the scanned substance, depending on the technology employed and the application requirements. Ultrasound tests are conducted using electrical energy transducer to convert ultrasound waves. While previous systems are using one transducer simultaneously, new PAUT (Phased Array Ultrasonic Testing) technology employs a number of transducers operating in combination. Modern PAUT equipment approach enhances examination speed, coverage and specificity greatly[10].

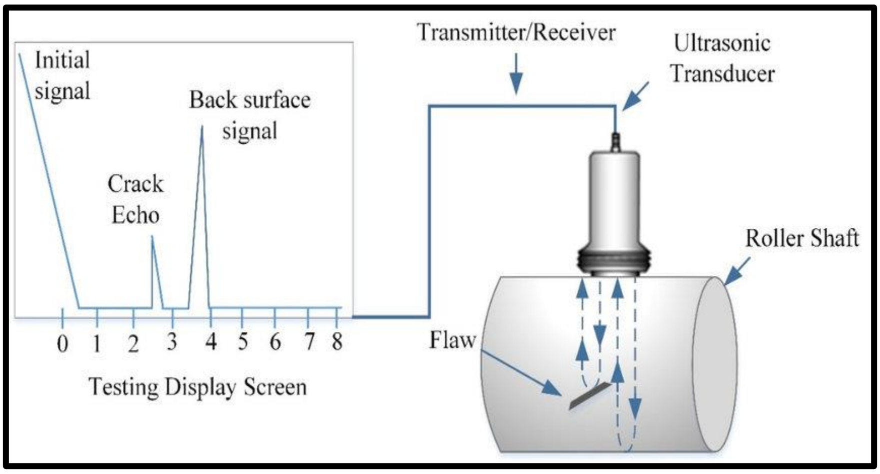


Figure 2.6: Schematic Diagram of Ultrasonic Inspection

2.4.4 Eddy Current Testing

Eddy current is non-destructive tests may be utilised to swiftly evaluate wide regions, and coupling liquids are not required. Eddy current is also utilised for finding and cracking metal stress breaks and other cracks, as well as for checking metal hardness and conductivity when such features are of importance. It is also often used to inspect thin layers of non-conductive coatings like as paint on metal components. Because of these constraints, eddy current testing only works on materials that carry electrical energy, such as metals, and can therefore not be used for plastics. In some instances, eddy current and ultrasonic tests are utilised as additional approaches, eddy current is helpful for fast measurement of surface characteristics, and ultrasonic tests provide superior penetration of depth.

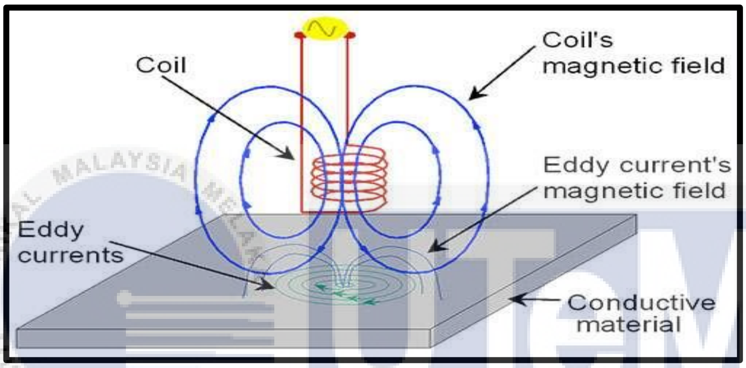


Figure 2.7: Diagram of Operation of Eddy Current Testing

Eddy's current testing figures out the physical phenomena of electromagnetic induction. An alternative current passes by across the wire belt and forms a magnetic field termed in an eddy current samples. A whirling electron stream is sometimes referred to as an eddy current when a conducting object like a metal probe is placed near a magnetic probe. The magnetic flux in turn interacts through mutual inductance with the coil and its field because of the eddy stream that passes through the metal. Any variations in metal thickness and flaws such as near- surface cracking disrupt or affect the magnitude and pattern of the eddy current. When the electrical impedance of the spindle is different, this is turn changes the electrons moving in the spindle. A skilled operator can utilise the Eddy Current to determine changes to the amplitude and phase angle of the test piece[11].

2.4.5 Acoustic Emission Testing

In acoustic emission testing, sensors are attached to the component being tested. When a stressed person goes about their day, stress sensors on their body convert the stress waves into electrical signals, which are then transmitted to an acquisition PC for processing. When an external stimulus, such as high pressures, loads, or temperatures, is applied to the component, the waves are caught. The energy released is proportional to the damage that occurs in the component. To help assess structural integrity and overall health, the rate at which the acoustic emission is detected the activity and the intensity of the acoustic emission, the loudness, are monitored and used. Acoustic emission is a type of seismic activity which occurs in materials, and that is exactly what it is: small quakes. The method of global monitoring provides for the accurate detection of defects in large-scale structures and machines while they are operating, in contrast to destructive testing. Acoustic emission sources and hence the damage can be located using multiple sensors. The distinct origin of each source mechanism can be deduced through signal analysis [12].

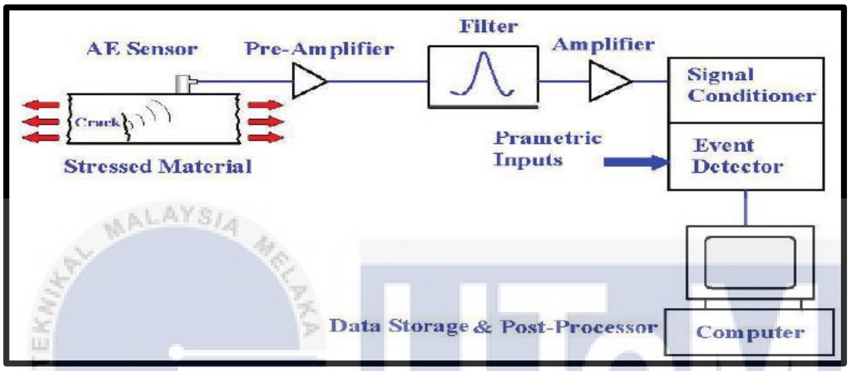


Figure 2.8: Schematic of Acoustic Emission Testing

2.4.6 Leaking Testing

Leak detection's basic functions include locating and measuring the leak's size in products and systems that are closed. To ensure device integrity, a leak test procedure is a one-time non-destructive test. “Leak” and “leakage” refer to the physical hole and the flow of a fluid through a leak in non-destructive testing. therefore, Vessel or system leaks such as holding or process tanks, radiators, empty vessels, tanks, liquid containment systems, pipe system, pipe system, or hydraulic systems must be detectable and repairable in order to maintain vessel or system safety[13].

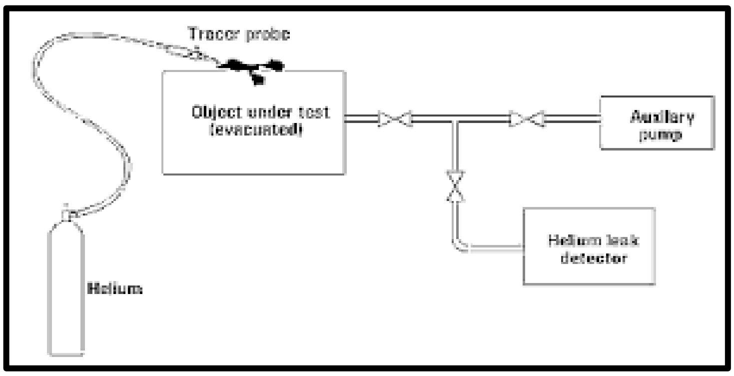


Figure 2.9: Application of Leaking Testing

2.4.7 Thermal Infrared Testing

Therma Infrared or IR thermography is a non-destructive test that measures component temperature variances as the heat flows through, from or to that component. Informal names for IR thermography include IR testing, thermal testing, thermal imaging, and IR thermometry. Changes in temperature cause thermal radiation. As a component warms, the amount of radiation it emits changes. Electromagnetic waves, invisible to the human eye, are utilised in this form of radiation analysis. Thus, components must be examined using infrared cameras. The infrared cameras can detect and display infrared energy that is emitted, reflected, or transmitted. After taking the thermal image, the temperature can be read on the component. Furthermore, it is able to detect corrosion damage, delaminations, voids, inclusions, and other flaws that affect heat transfer[14].

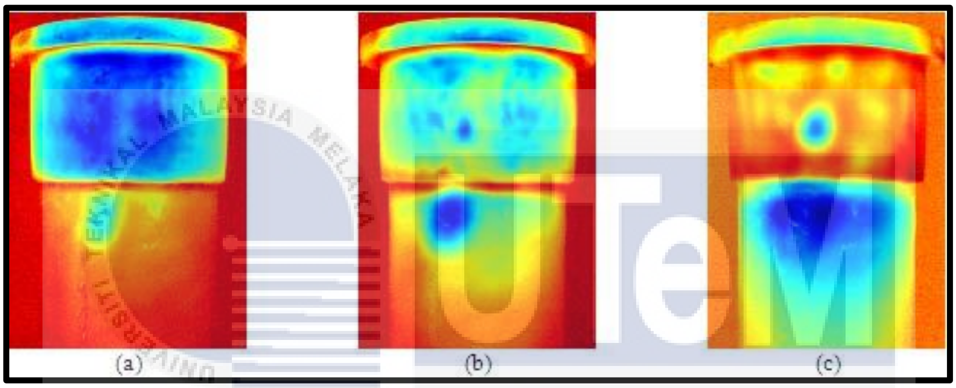


Figure 2.10: Characteristic of Infrared Thermography

2.4.8 Visual Testing

Also known as visual testing examination, non-destructive inspection, or non-destructive evaluation or examination, VT is an example of visual testing. The most common non-destructive testing method is visual testing. Because it is easy to do, inexpensive, and requires minimal equipment, visual testing is frequently used for NDT. In VT, you examine a component to see if there are surface discontinuities using your naked eye. In addition to using visual magnifying glasses, boroscopes, mirrors, and other computer equipment, VT can also benefit from optical equipment such as microscopes, teleziers, and magnifying glasses. Non-destructive testing is used to detect if components can be viewed, so visual testing is used as the first step in the NDT process. Welds, storage tanks, piping, boilers, and pressure vessels are some of the components that can be examined for visible corrosion or degradation to evaluate the integrity of their components[15].

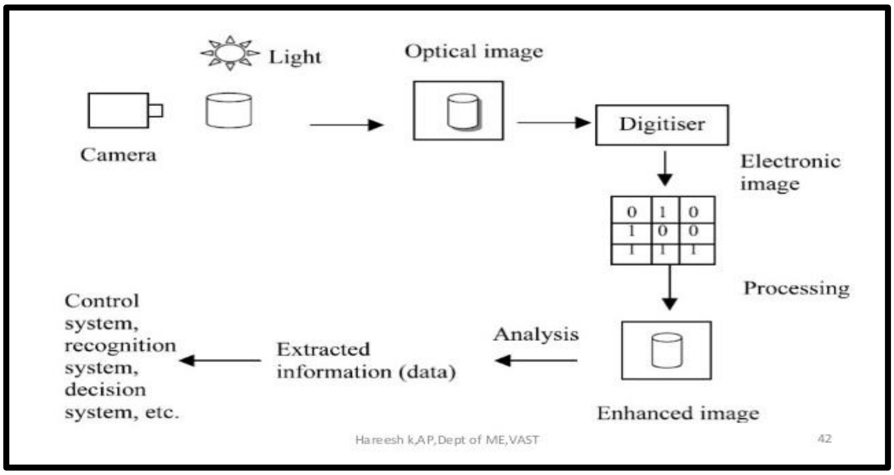


Figure 2.11: Inspection of Visual Testing

2.5 Comparison of major NDT methods

NDT method	Applications	Advantages	Limitations
Penetrant Testing	Materials with uncoated surfaces that are not contaminated and are solid nonabsorbent materials.	-Easy and inexpensive. -Very sensitive versatile. - Minimal training required.	The discontinuities must be open to the surface in order to be visible. The surface must be generally smooth and free of impurities in order for this to be successful.
Magnetic Particle Testing	For surface and slightly subsurface discontinuities, use ferromagnetic materials.	-Easy to operate -the equipment is inexpensive. - Highly sensitive and very fast.	surface are limited to the inspection area. Only ferromagnetic substances.
Radiography Testing	Be used for almost any manufactured or in-service materials, forms and structures.	- Provide a permanent record. - heightened sensitivity. - Used and accepted widely.	The thickness of the inspection is based on the material density. It is important to orient discontinuities and radiation is sometimes harmful.
Ultrasonic Testing	In most cases, if the conditions for the transmission and finishing of the sound are satisfactory and the shape of the object is not complex,	-The precise and sensitive results can be achieved very quickly. -Material information such as thickness, depth	In many circumstances, there is no lasting record of what happened. Couplant is required for testing.

	virtually any material can be used.	and flaw can be got only from one side of the object.	
Eddy Current Testing	All leading materials can be inspected.	-Absolutely Non-contacting -easy to operate. -The testing is fast and versatile.	It is difficult to interpret the measured signal. It is necessary to the penetration depth, lift-off effect, and surface condition.
Acoustic Emission Testing	Include detection of abnormalities in fluidized beds and batch granulation end points	-Large areas can be tested	Sensors must make physical contact with the test surface.
Leaking Testing	that makes use of either a pressurised or an evacuated system to detect the location of a leak and, if possible, measure the amount of leakage that is passing through the leak	Can detect many types of defects such as surface defects, cavities, corrosion, pitting.	When there is a significant leak and the water is pumped out during the pump down phase of the leak testing procedure. Helium is removed from the atmosphere before the LD can detect it.
Thermal Infrared Testing	Condition monitoring and predictive maintenance are widely used in the oil and gas industry as inspection tools for condition monitoring and predictive maintenance.	Sensitive to slight temperature change	Discontinuities in surface and near surface can be found
Visual Testing	Surface condition of a component and the alignment of mating surfaces are being investigated. In addition to that Identifying the presence of leaks	-Inexpensive -minimal training required.	It is necessary to have good vision or to have your vision corrected to 20/40. Internal defects may go unnoticed.

Table 2.1: Comparison of major NDT methods

2.6 Past Project

Title	Objective	Description	Author	Year
An Electrical Capacitance array for Imaging of water leakage inside insulating slabs with pronous cells.	in order to detect water leakage within insulating slabs that contain porous cells	Using the suggested capacitance sensor array, the map of electrical distribution and sensitivity was calculated using the methodology of the finite element. It comprises of a sensor range of eight electrodes and a commercially accessible capacitance bridge tool for capacity measurements.	Rui Li, Yi Li and Lihui Peng	2019
Curing and subsurface damage monitoring of epoxy-based on composite.	to use electrical capacitation tomography for the monitoring of nanocomposite epoxy and quantification of subsurface damage.	The circle-shaped arrangement of noncontact electrodes to interrogate a sensing area by applying different patterns of electric field excitations. In order to address the reverse electric capacitance tomography problem, the concurrently measured border capacitance is employed to rebuild the electric permittivity distribution in the sensor region.	Kenneth J Loh	2018
Capacitive measuring of crude palm oil-water mixture.	To determine whether the electrical capacitance measuring technique can be used as a low–cost, non–destructive alternative to traditional methods.	All ultrasonic shakes are concerned with the immiscible fluid and another. The mass concentration (x) of CPO was varied from 0 g/cm3 to 0.9 g/cm3, and then all experiments were carried out at room temperature to verify their results (25o C). A parallel guard structure with AD7747 capacitive to digital converter was used to obtain capacitance value.	Pongsakun Sriphant	2017

Noise diagnostics of composite materials by using spectral characteristics of electromagnetic emission.	Use of electromagnetic emission signals and spectrum signals for mechanical composite load evaluation damages..	The measured voltage at the output of the sensor system is used to measure the power spectrum density of the crack dipole electric moment waveform.	Pavel Koktavy	2013
Electronic design for portable electrical capacitance sensor: a multiphase flow measurement.	By monitoring fluctuations in the dielectric permittivity of the material, this non-intrusive technique may be used to determine the concentration of flow inside a closed pipe.	The development consists of a signal processing circuit and a sensing electrode built into a single module. The manufacturing of the sensor electrodes, including information on the signal conditioning circuit/electronic measuring portion, such as the stray immune capacitance measurement circuit, amplifier circuit, an AC to DC circuit, and a filter circuit, were described in depth.	E.Johana Mohamad, O.M. Faizan Marwah	2011
Distributed sensing in capacitive conductive composites.	The concept is demonstrated in a one-dimensional scenario using finite element simulation.	the spatial distribution of strain is resolved by employing several stimulation frequencies at different frequencies. Specifically, the system we describe is an illustration of a condenser built from an acrylic binder with a silicone dielectrical layer on the top, a graphite-based conductor elastomer composite. Based on the magnitude of the measured impedance, the strain was rebuilt using an artificial neural network.	Edward L. White, Michelle C. Yuen, and Rebecca K. Kramer	2017

ECT sensor simulation and fuzzy optimization design base on multi-index orthogonal experiment.	Two-phase flow and multiphase flow are both detected using this technique.	Demonstrate that the fuzzy optimization design based on the experiments of multi-index orthogonal sensors allows the sensor to achieve simultaneous uniform sensitivity of field distribution and high image quality reconstruction while retaining a uniform sensitive field distribution.	Haijun Tian	2020
Analysis study on surface and sub-surface imperfections through magnetic particle crack detection for nonlinear dynamic model of some mining components.	Surface and sub-surface defects are detected using a Magnetic Crack Detection test without impairing the integrity of material.	MPCD is currently a globally acceptable technology, simplifying inspection procedures that result in considerable cost reductions and strengthening of quality control and trust. It is important to detect surface defects in magnetic materials such as mild and alloy steels, cast iron. The methodology not only reveals non-visible surface faults in the naked eye but also aids the detection of fissures only identified in closer and painstaking surveys of the surface under normal circumstances.	Umesh Singh1*, Mohan Singh2 and M. K. Singh	2012
Leak detection with linear soil gas sensors under field conditions.	Validation of linear sensors and presentation of results from repeated carbon dioxide injection and watering operations on a newly constructed field.	Soil test field has been established with a gas injection system that allows the experimental validation of linear gas sensors in an application on a scale relevant for specific applications and gases. Several injection and soil watering tests with carbon dioxide (CO2) were carried out on different days and	Patrick P. Neumann	2016

		with variable boundary conditions, demonstrating the method's potential.		
Infrared thermography for temperature measurement and non-destructive testing.	temperature measurement and non-destructive testing are two of the most common applications for infrared thermography-based sensors, and they are the topic of this paper.	When it comes to non-destructive testing, infrared thermography is an established approach. Recent advancements in this sector have made it possible for this technology to detect a wide range of problems. Although a flaw can be discovered using infrared thermography, it can only be noticed if it opposes enough thermal resistance to provide visible thermal contrast.	Rub´en Usamentiaga	2014
Electromagnetic stimulation of the acoustic emission for fatigue crack detection of the sheet metal.	Small fractures in thin-walled metallic constructions are more easily detected using this technique.	The use of transient electromagnetic fields induced by a coil to produce localised dynamic stresses is described in detail here. This may be used to discover faults in a component after it has been assembled. The deformation of the sample generated by local dynamic stress may result in the generation of an auditory emission signal. Acoustic emission may be produced by electromagnetic stimulation, and this emission may be utilised to detect and find flaws in the system.	Liang Jin, Qingxin Yang, Suzhen Liu, Chuang Zhang, and Peng Li	2010

Investigation on velocity effect in pulsed eddy currect technique for detection cracks in ferromagnetic material.	to demonstrate the efficiency of an innovative high inspection methodology for crack characterisation in ferromagnetic material components.	thorough research of the velocity effect for the PEC technique is carried out, and the correlations between the speed and the PEC signal are discovered. The velocity impact can cause the baseline value of the detection signal in a PEC detecting system to fluctuate significantly. Furthermore, when the crack occurs in the high-level stage of the excitation signal, PEC with high-speed may be used to characterise the position, width, and depth of the crack. In comparison to static PEC testing, motion detection has a greater ability to characterise the fracture depths.	Fei Yuan, Yating Yu	2015
Ultrasonic sensing of temperature of liqueids using inexpensice narrowband piezoelectric transducers.	The possibility of significantly reducing the costs of the minimum intrusive NDE (NES) of liquids, in particular temperature sensing, with the use of low-cost narrowband transducers was examined.	the ultrasonic transducers utilised in this investigation were designed for air operation, they were able to function properly while submerged in liquid for extended periods of time. They have number of frequency resonances that make them suited for functioning in a liquid environment. The centre frequencies of most resonances are several times greater than their centre frequencies in air, indicating that they are more powerful.	Said Alzebda and Alexander N. Kalashnikov	2010

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter purpose to discuss the various stages of developing the methodology in details such as overview of the project, block diagram, flowchart, hardware and software development and lastly the gantt chart of the project report progress. Process of developing the research methods needed to complete the experimentation portion of the capacitor sensor.

3.2 Project Flow

This section will summarise the project's process flow. All data are gathered from the start, and a composition analysis is conducted based on the problem's articulations. The analysis assists in clearly explaining the concept, methodology, and some of the terminology used throughout the project. Following the completion of the written audit, the entire project's enhancement is only one section, the software, as previously referenced. The flowchart for this project is shown in Figure 3.0 below, along with a description of how the project was carried out from start to finish.

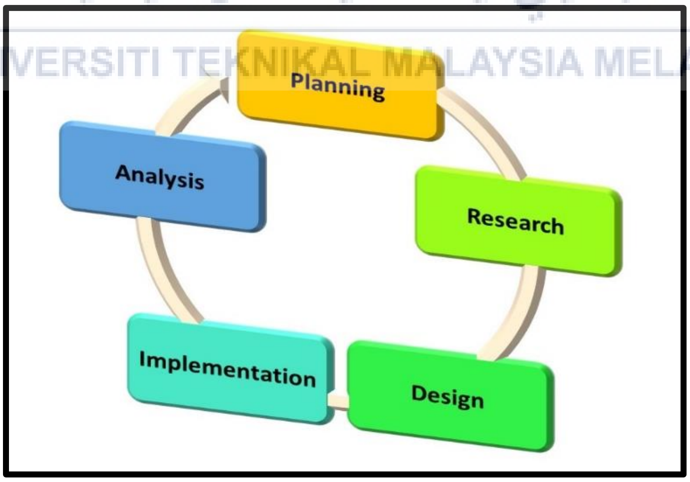
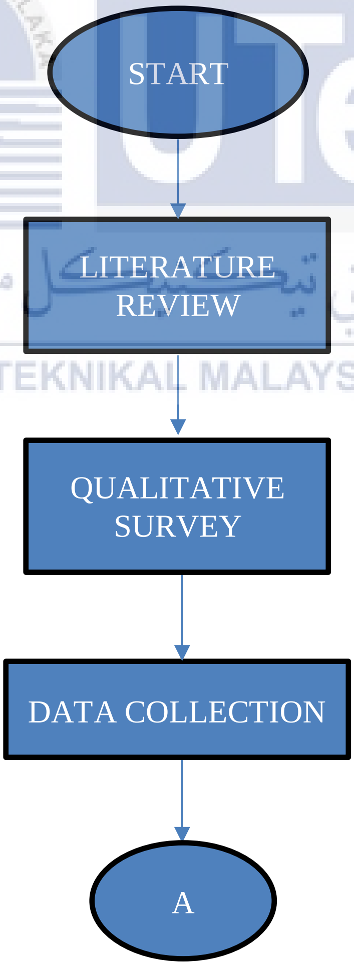


Figure 3.1: Project flow

3.2.1 Planning

The motive was conceived during the planning stage, when a capacity sensor was designed to detect cracking and elements withi te using non-destructive testing (NDT). To create a schedule, a Gantt chart wa finance the task on a scheduled basis. The details of this project are shown in Figure 3.3. With the variable detail, this flowchart starts at the beginning and ends with the system flow. Because non-destructive testing (NDT) plays a key role in the safety of numerous products, transportation systems, and infrastructure used around the world, the goal of the project was to test a new and more detailed system that can be used without damaging the material in current industrial technology. To solve this problem, all of the information gathered during the research was used to provide a simple and basic solution. In addition, all research-related information will be gathered and continued through the creation of a literature review. The capacitance sensor detector technique is examined in this review of the literature. The following step is to plan the software design.



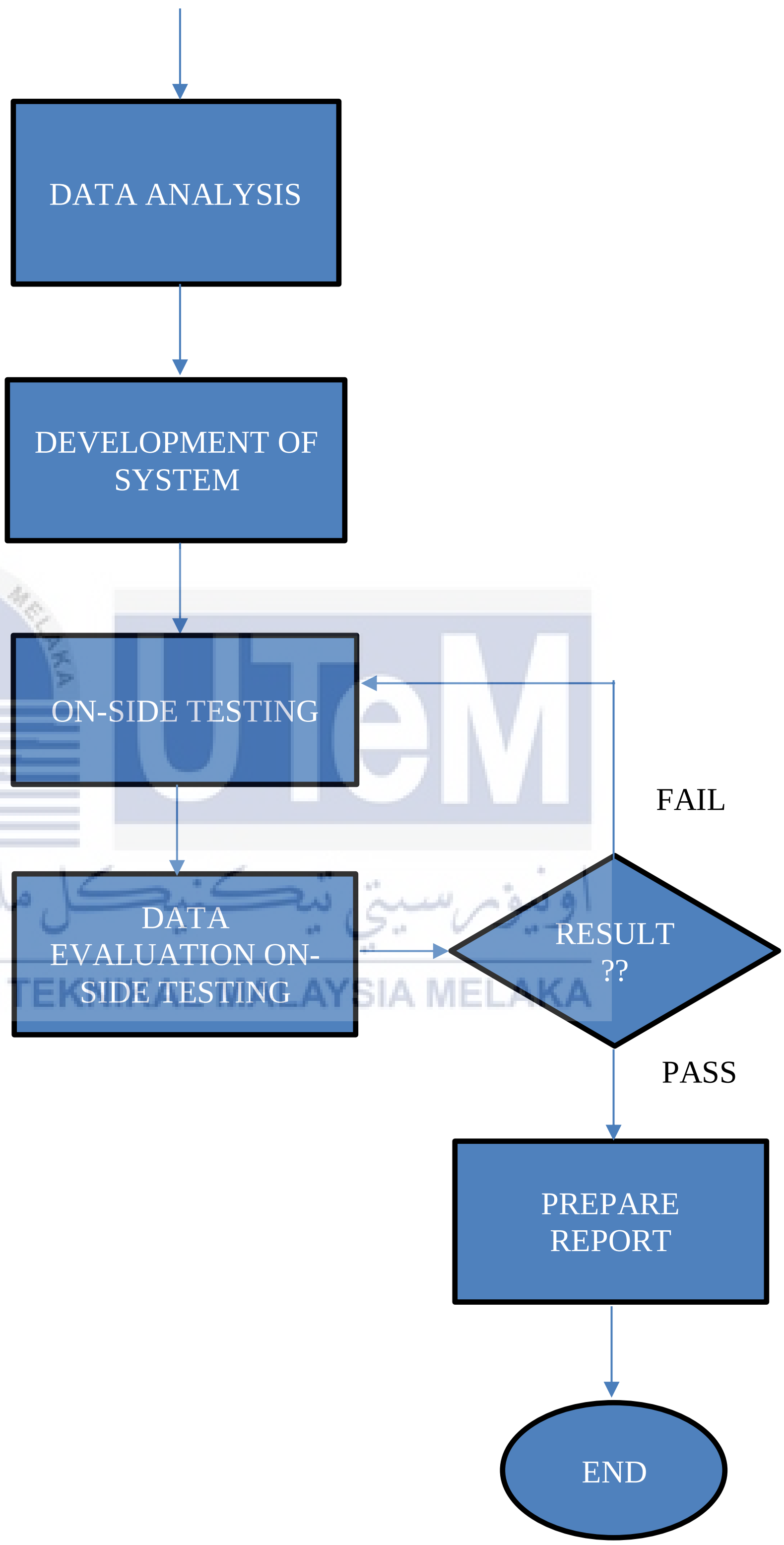


Figure 3.2: Flowchart of Research Progress

No	Task Name	ACHIEVEMENT	WEEK										
			1	2	3	4	5	6	7	8	9	10	11
1	*Title Selection And Briefing*	TARGET											
		ACTUAL											
2	*Introduction, Problem Statement, Objective and Scope*	TARGET											
		ACTUAL											
3	*Literature Review*	TARGET											
		ACTUAL											
4	*Project Flow, Planning, Research*	TARGET											
		ACTUAL											
5	*Design, Implementation*	TARGET											
		ACTUAL											
6	*Software Configuration*	TARGET											
		ACTUAL											
7	*Preliminary Result*	TARGET											
		ACTUAL											

Table 2.3: Gant Chart of progress

3.2.2 Information of Past Study

In a project's progress or development process, it is important to mention current and previous innovation and information that is available. To move any project forward, creativity and analysis of the main project are absolute necessary. The method for organising that information and providing it as a reference will be composing evaluation. The review provides users with a practical perspective on the appropriate data working standard as well as recommendations for the most effective way to improve it.

3.3 COMSOL Multipyhsics Simulation

Through software analysis, a process of simulating reality is carried out in an environment that is appropriate. Calculations at a high rate are actually one of the boundary conditions to see what results will be obtained from costly experiments and can also comprehend something outside of the confines of a laboratory experiment. Also, to evaluate a system's performance and generate new ideas quickly. Other than that, the use of Comsol multiphysics is essentially environmental, it is scientifically reliable. Experts in engineering and physics have also recommended it with accuracy in the relatively fast calculation. In addition, features that enable easy access in the calculation, the Finite Element Method (FEM) is used. It also showcases new areas of research such as photonic, plasmonic, electronic, and material engineering. So, I decided to use this software as a simulation for NDT on capacitance sensor for testing on composite.

3.4 Solidworks Software

The concepts of this software are the SOLIDWORKS software's basic building blocks. Assemblies are made up of parts or other assemblies known as subassemblies.
A SOLIDWORKS model is made up of three-dimensional geometry that defines its edges, faces, and surfaces.SOLIDWORKS software allows you to create models quickly and precisely. Models in SOLIDWORKS are defined by 3D design and also by components. SOLIDWORKS employs a three-dimensional design approach. It is possible to create a 3D model when designing a part, from the initial sketch to the final result. This software can generate 2D drawings from this model or mate components made up of parts or subassemblies to generate 3D assemblies. It is also possible to create 2D drawings of 3D assemblies. When using SOLIDWORKS to design a model, it can visualise it in three dimensions, allowing you to see how the model will look once it is manufactured.

3.5 Design

3.5.1 Development of Parallel plate capacitive sensor

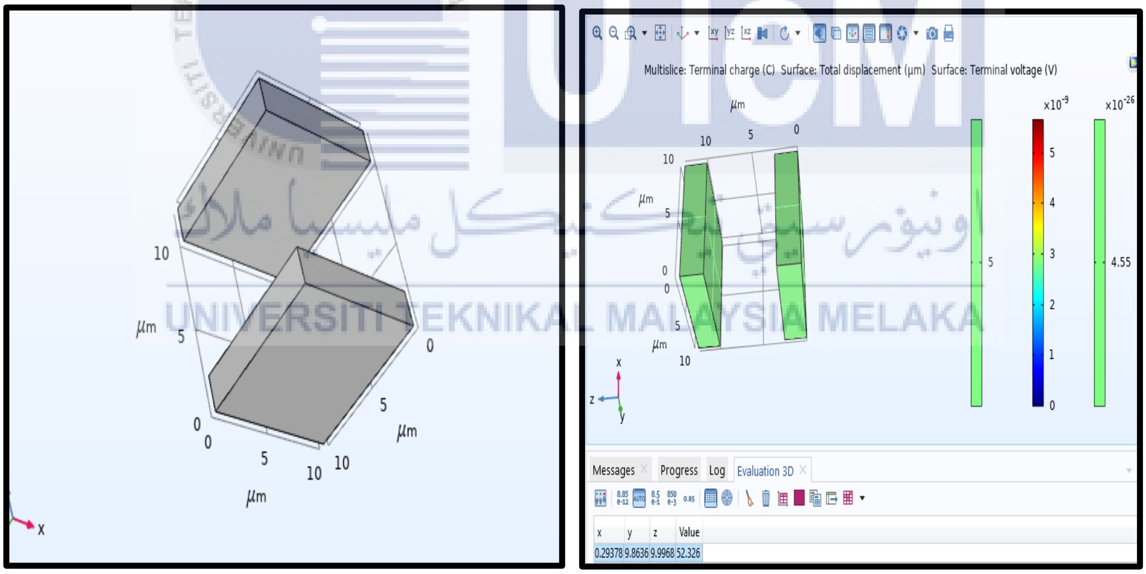


Figure 3.3: Parallel plate capacitive sensor

The main process of this project is to find a more reliable solution for applications measuring material composition. The basic capacitive sensor is any metal or conductor and can detect anything like cracks in conductive materials or has different dielectric constants from the air. For this project, a composite material will be placed in the middle of a parallel plate in the simulation, and the capacitance reading is taken.

3.5.2 Capacitor sensor and material plate

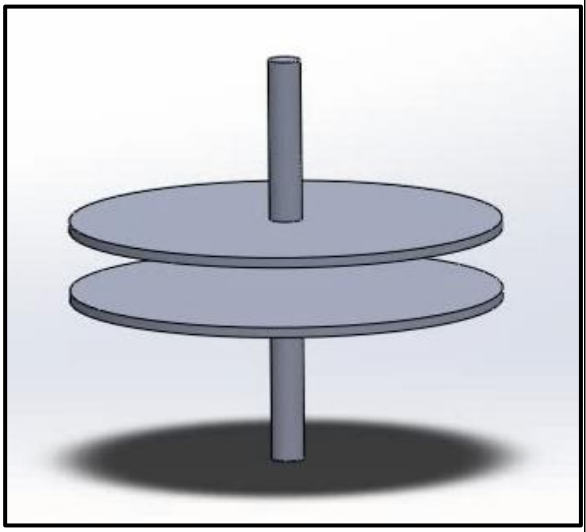
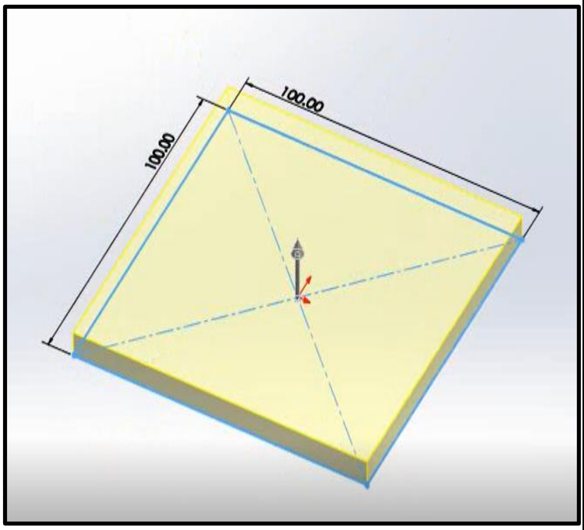
	
Capacitor sensor plate	**Material plate**

Figure 3.4 : Capacitor sensor and material plate

The beginning of prosess with a sketch and then transformed into a 3D design by using Solidworks Software, as shown in figure 4.1, where the diameter of the design sensor capacitor plate is 200mm with distance between capacitor plate is 30mm and the measurements on the plate are 100mm X 100mm X 5mm.

CHAPTER 4

DISCUSSION AND RESULTS

4.1 Introduction

The process flow will be clarified and analysed in this chapter, as well as the challenges encountered during the development phase, the performance evaluation of the data obtained from the experiment, and the study for the proposed capacitance sensor that has been developed. This chapter dealt with the gathering of data.

4.2 COMSOL Multiphysics Simulation

4.2.1 SOLIDWORKS Livelink with COMSOL

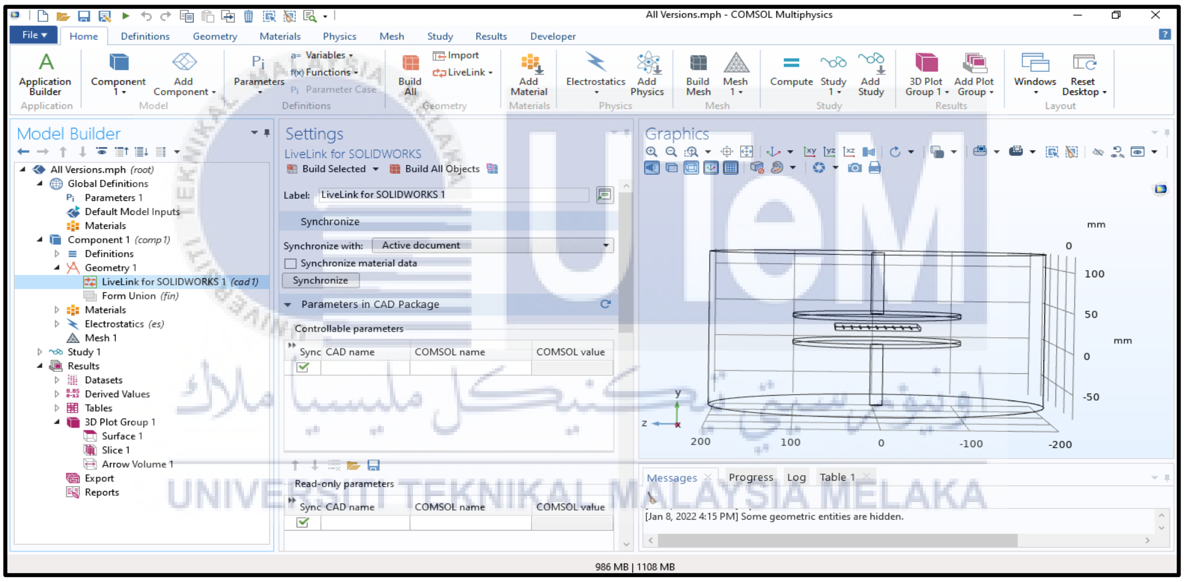


Figure 4.1 : Livelink with COMSOL

LiveLink for SOLIDWORKS also simplifies and expedites simulation setup on the synchronised CAD design. In SOLIDWORKS software, I can create selections such as bodies, faces, edges, or points that are synchronised with the COMSOL model and may be used to assign materials, physics settings, or any other model specifications. Make selections from the SOLIDWORKS software's Feature Manager Design Tree as well as the CAD assembly's components. Additionally, LiveLink for SOLIDWORKS may generate and synchronise selections based on material allocations in the SOLIDWORKS software CAD design. The simulation can also control the SOLIDWORKS software file's CAD design parameters.

4.2.2 Electrostatic(es) selection design

4.2.2.1 Charges conservation

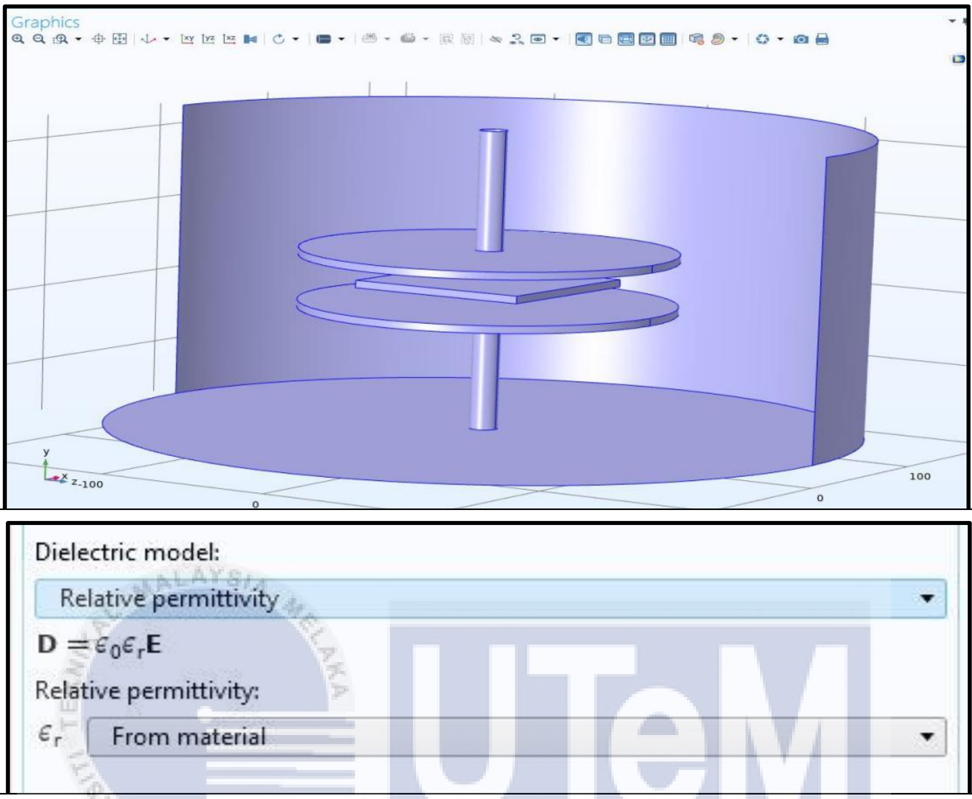


Figure 4.2 : Charges conservation selection

A closed system's total electric charge does not change, as shown in figure 4.2. The total amount positive and negative charge in the universe is always conserved. In an isolated system, the net charge is always constant because of the law of charge conservation. System net charges are then evenly distributed among each object. When electrons are transferred from higher to lower polarity rather than concentrated in few objects, the charge on the object is evenly distributed. Electrons, not protons, are capable of participating in the transfer of charge.

As shown in figure 4.2, the formula chosen to charge for the Electric Flux Density is referred to as Electric Displacement, denoted by D. This is a type of vector field found in Maxwell's equations. It is equal to the electric field strength multiplied by the permittivity of the material (ϵ_r) through which the electric field extends. The Electric Flux Density (**D**) is proportional to the Electric Field (E).

4.2.2.2 Zero Charges

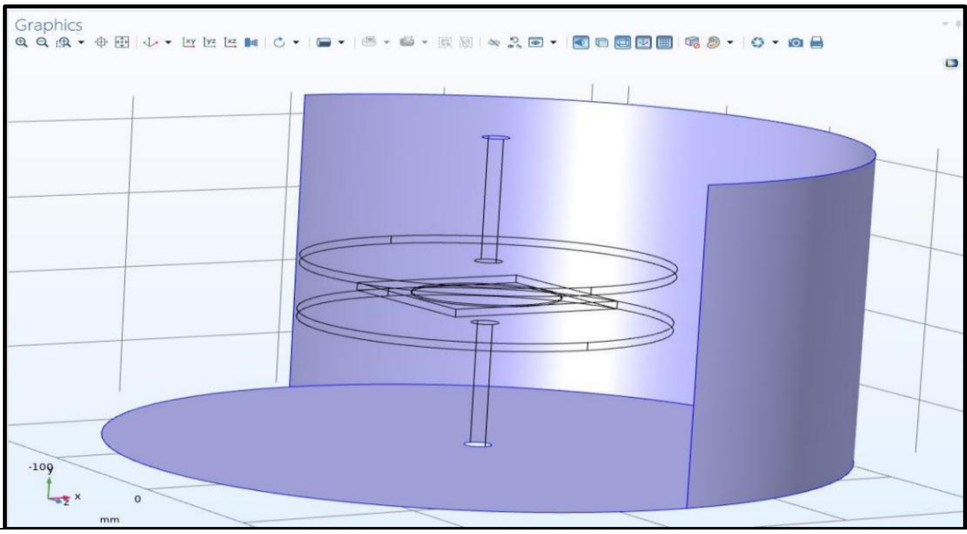
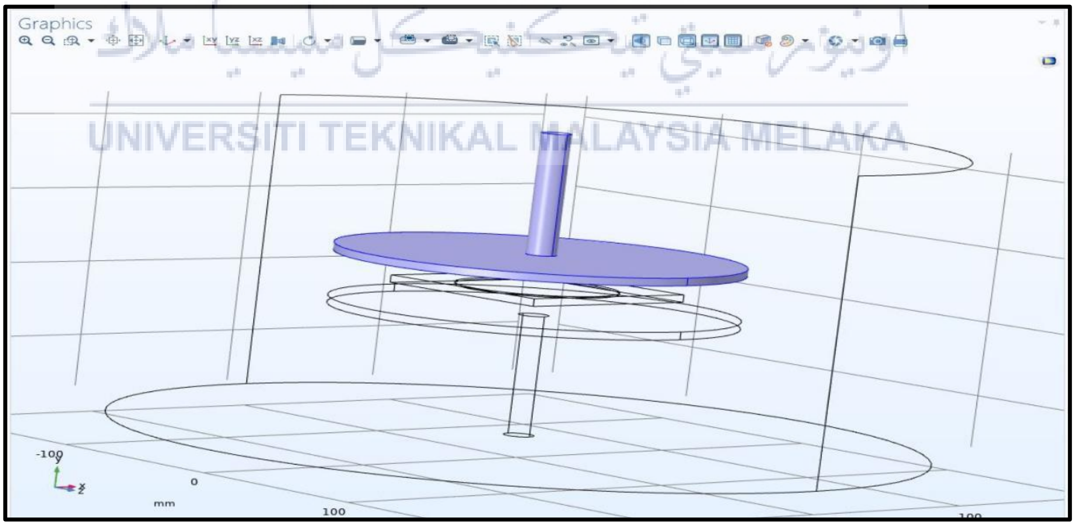


Figure 4.3 : Zero Charges selection

The energy stored in the capacitor changes as it charges or discharges. Additionally, the total amout of energy supplied by the voltage remains constant. As can be seen, the loop rule expresses this fact of energy conservation. The sum of all possible variations around the design is zero.

4.2.2.3 Terminal



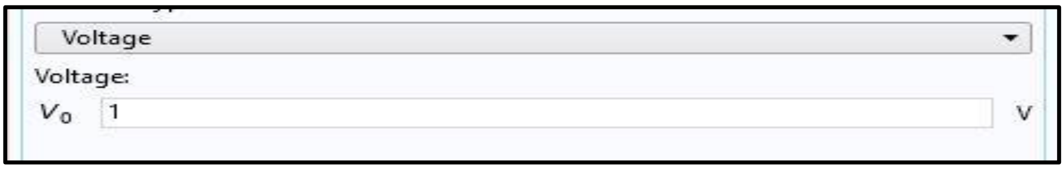


Figure 4.4 : Terminal selection

4.2.2.4 Ground

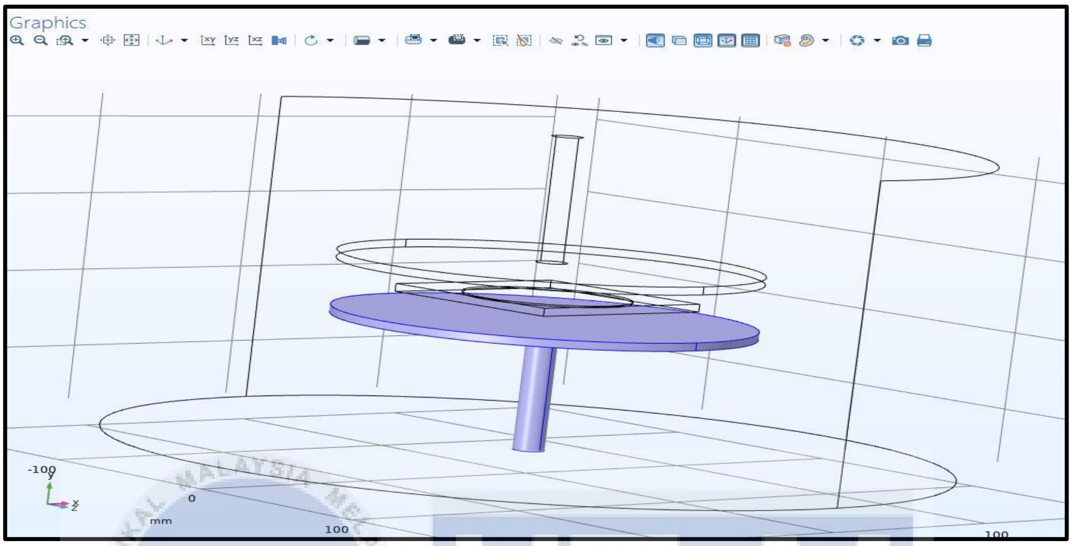


Figure 4.5 : Ground selection

As we have seen, two conducting plates, one for the positive terminal on the upper plate and one for the negative terminal on the lower plate, or we can call ground as shown in figure 4.5, then the charges will move through, since they continuously repel one another, these conducting paths, and the furthest distance that they can travel away from one another is the boundary of this surface, which is the lower surface of the upper plate.

As illustrated in Figure 4.4, the voltage in the terminal is V=1, because if the voltage becomes too high, the dielectric will breakdown, allowing a discharge. If someone overcharge a capacitor, for example by applying a high voltage for an extended period of time, the gap voltage may become excessively large. Thus, the more appropriate value to enter at the terminal is one that is closer to zero, which is 1.

4.2.3 Plate

The Solidworks software assisted me in creating four designs in which the plate had a sketch of 100mm X 100mm X 5mm on each plate of the material, as well as a different crack on each plate of the material.

Types of crack	Height(mm)	Length(mm)	Width(mm)
Circle	5	100	100
Straight line	5	100	100
Parallel line	5	100	100
Zig-Zag line	5	100	100

Table 4.1 : Size of plate of material

4.2.4 Difference value of relative permittivity of Material

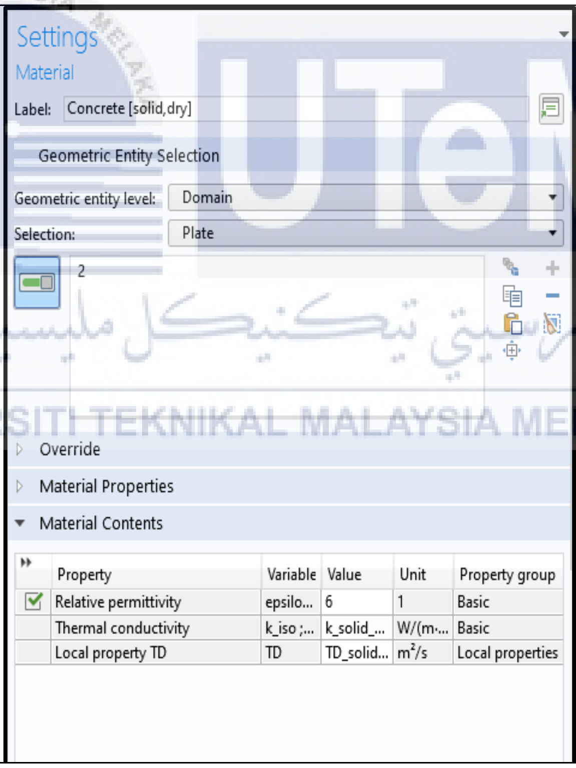


Figure 4.6 : Label of material

MATERIAL	RELATIVE PERMITTIVITY
COPPER	10
CONCRETE	6
PVC	3
ALUMINIUM	1
BRICK	4

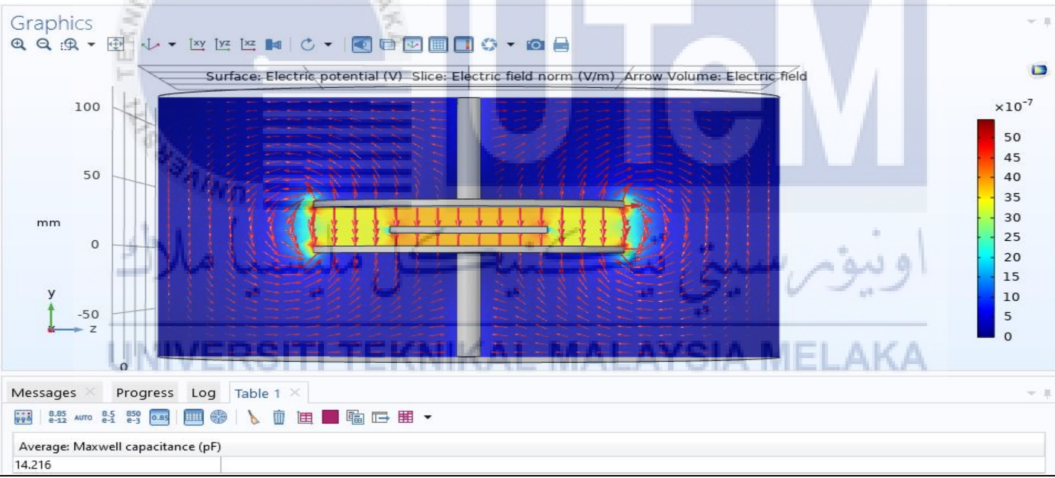
Table 4.2 : Value of relative permittivity

As shown in figure 4.6, a selected material is a concrete with a relative permittivity of 6 and has been chosen as a study material for the purpose of this experiment. In addition, as shown in table 4.2, I have placed 5 difference values of relative permittivity of the material to be studied in the appropriate locations.

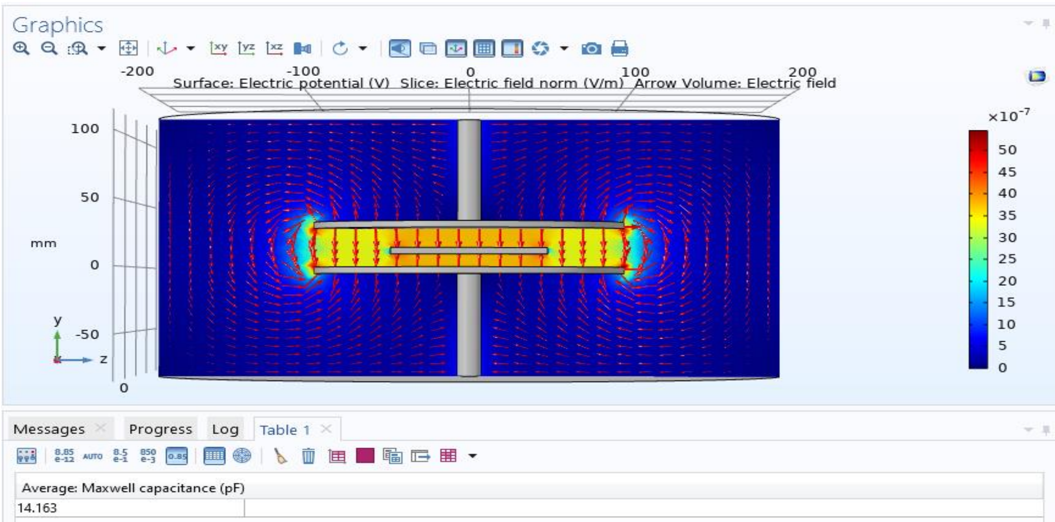
4.4 Result

4.4.1 Simulation of circle crack

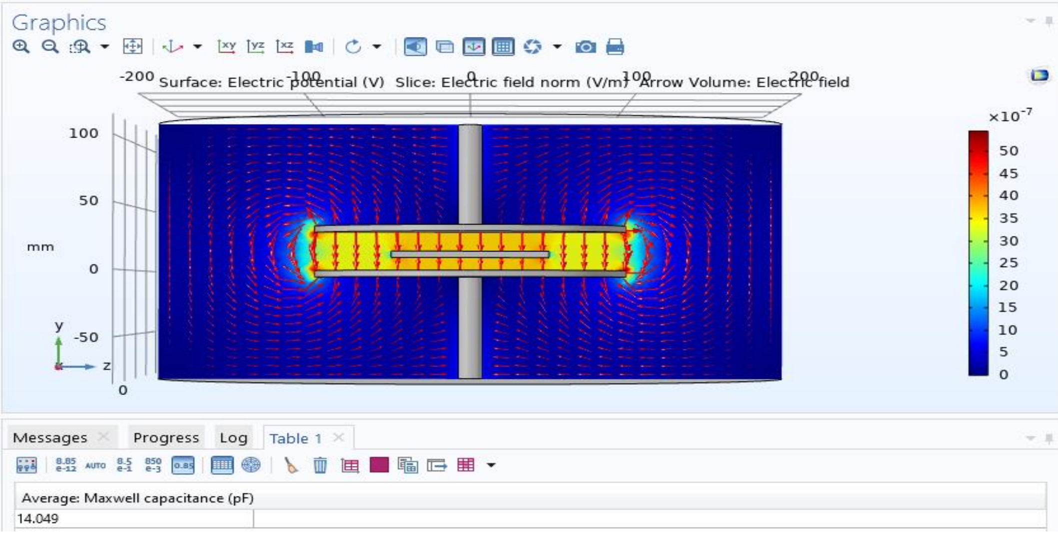
COPPER



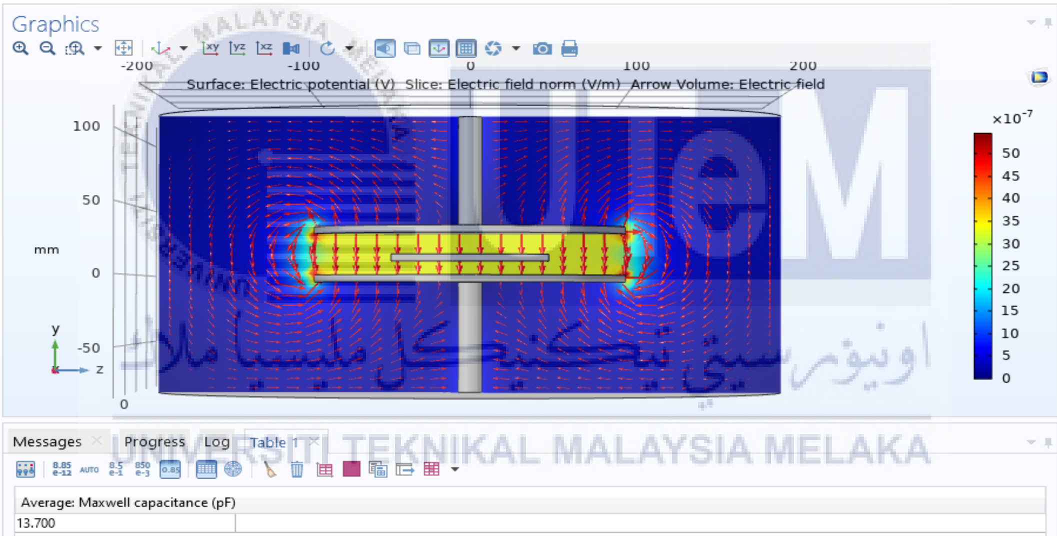
CONCRETE



PVC



ALUMINIUM



BRICK

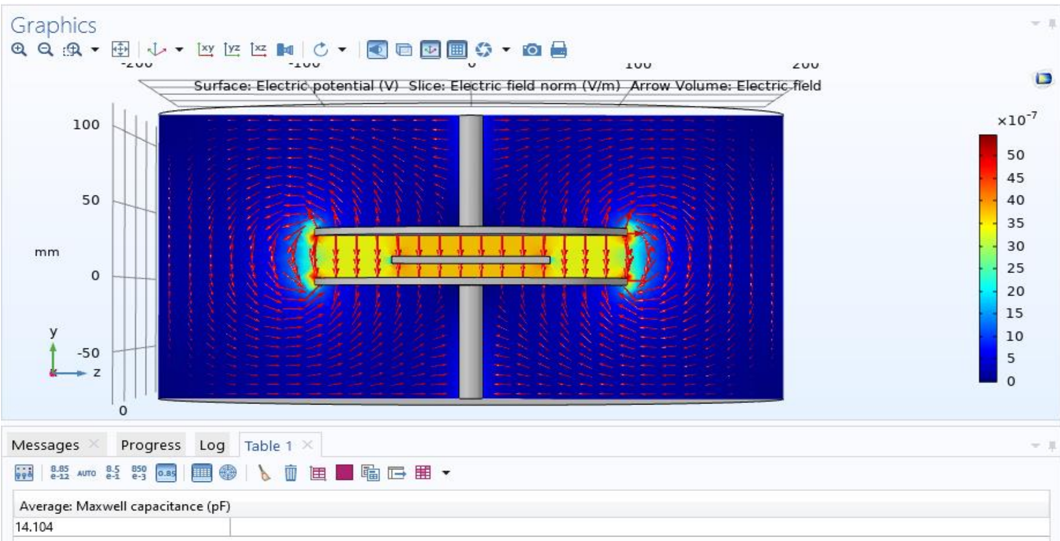
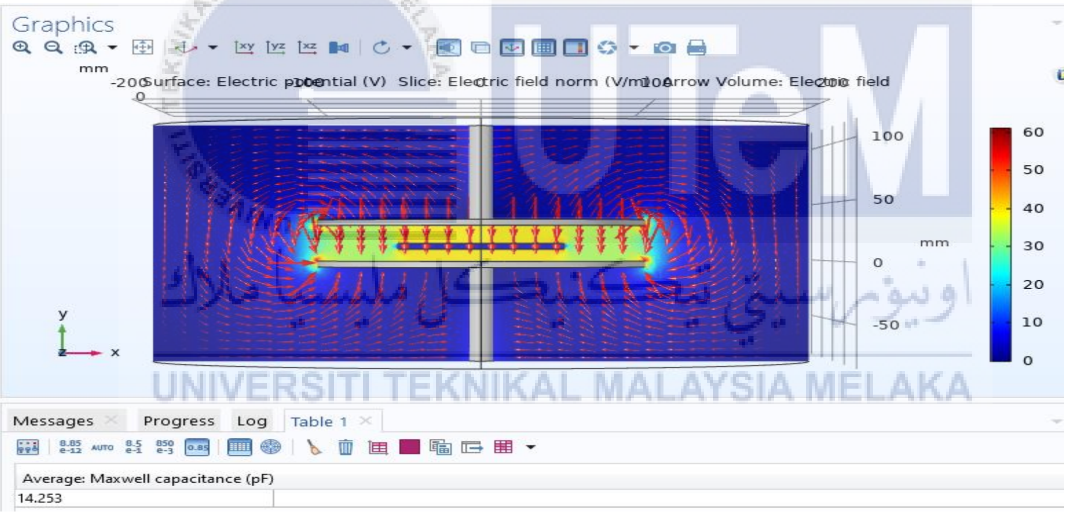


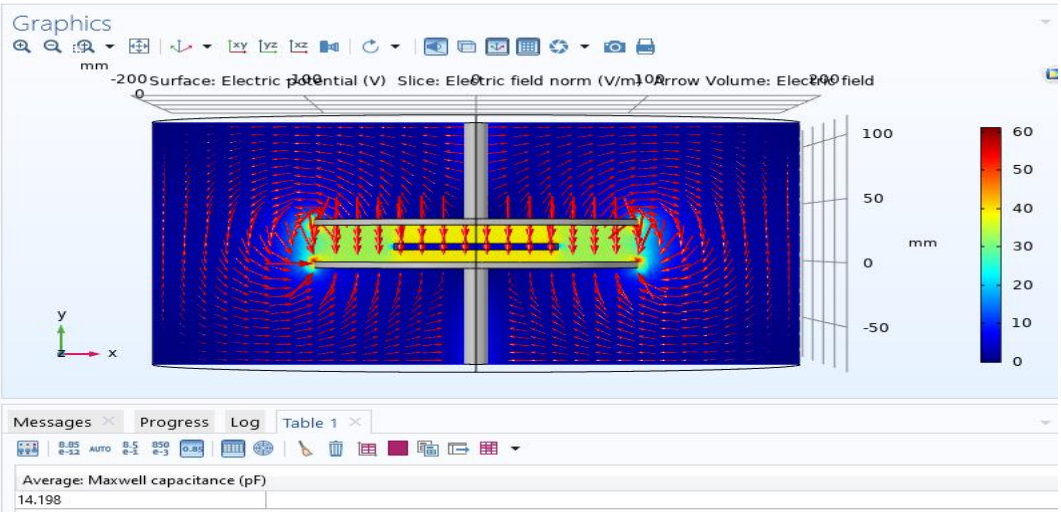
Figure 4.7 : Strength of Electric Field of circle crack plate

4.4.2 Simulation of straight line crack

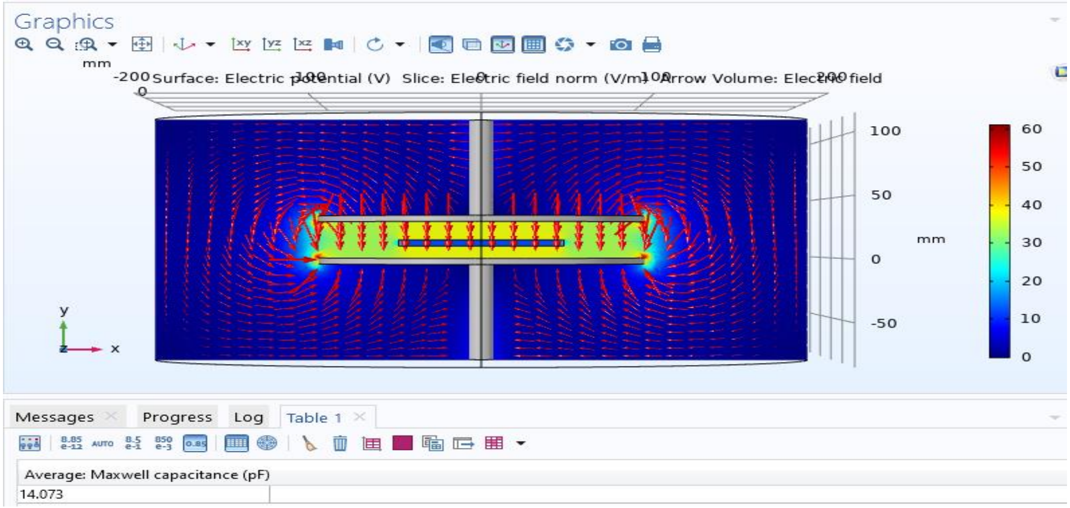
COPPER



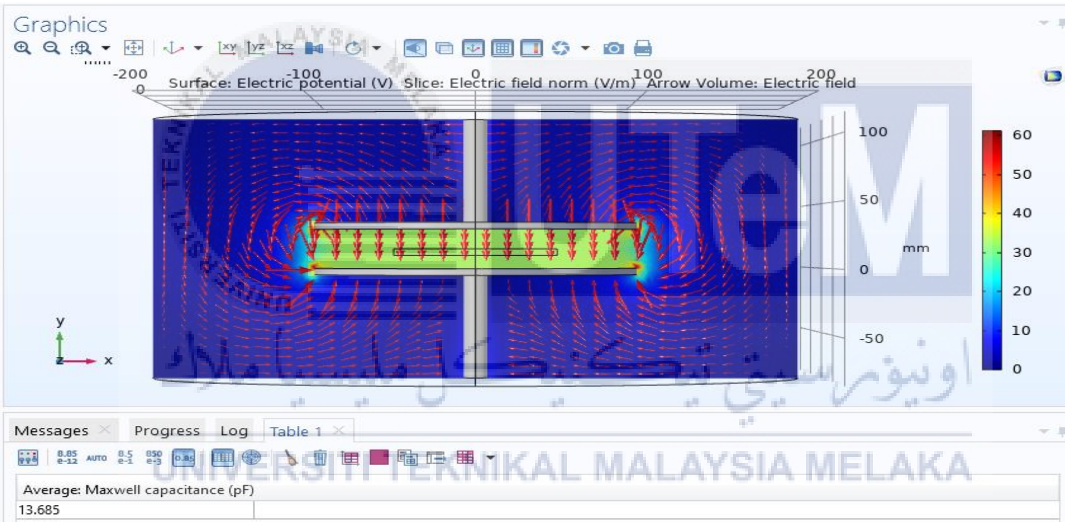
CONCRETE



PVC



ALUMINIUM



BRICK

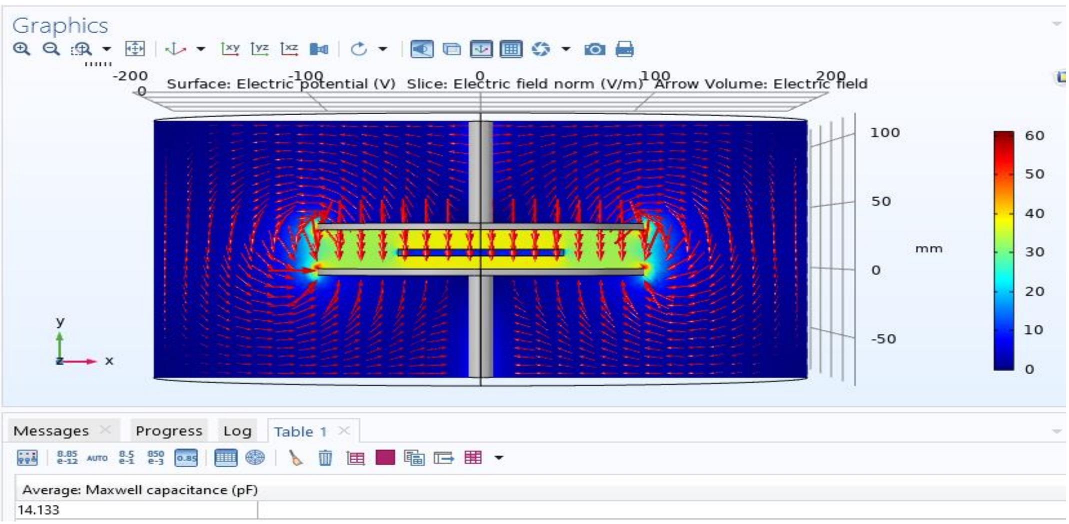
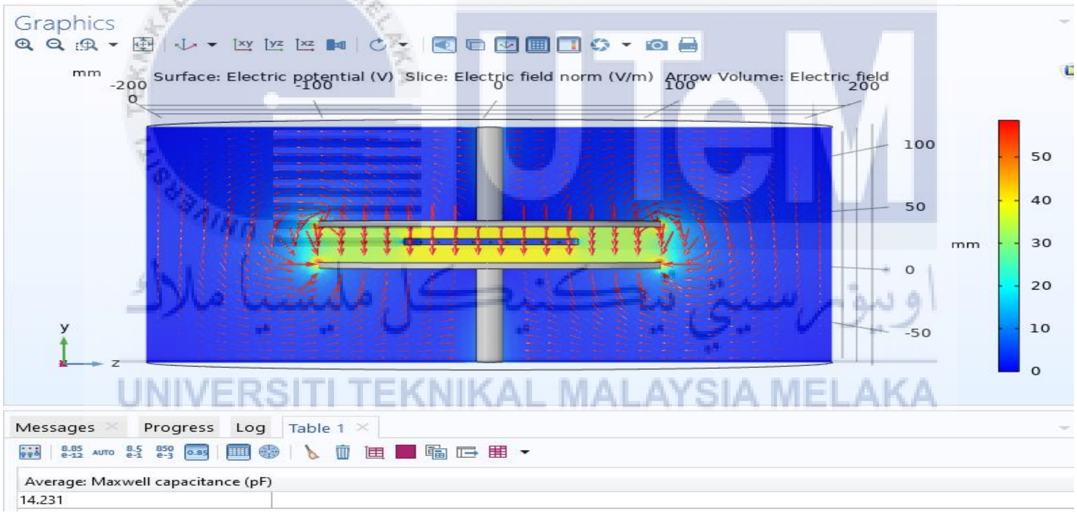


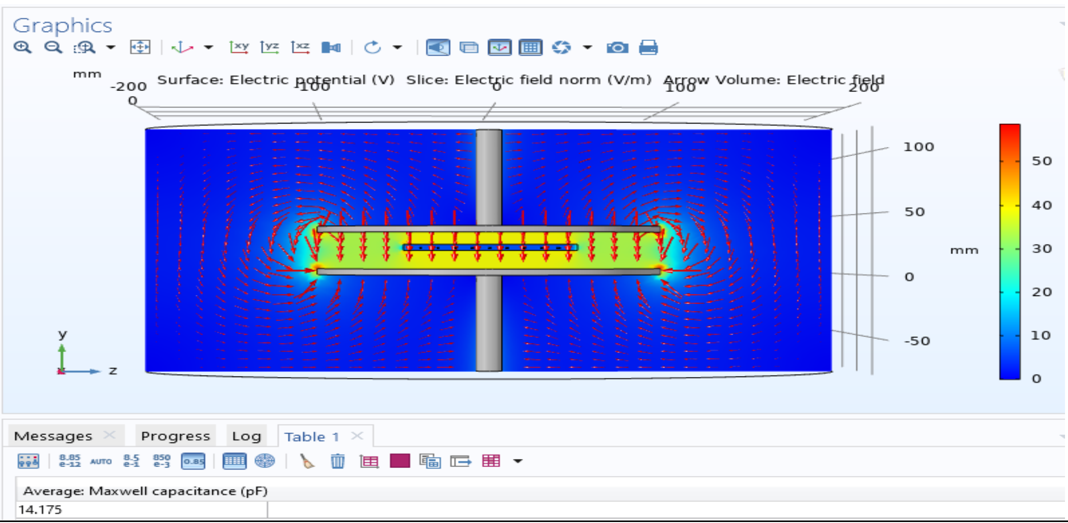
Figure 4.8 : Strength of Electric Field of straight line crack

4.4.3 Simulation of parallel line crack

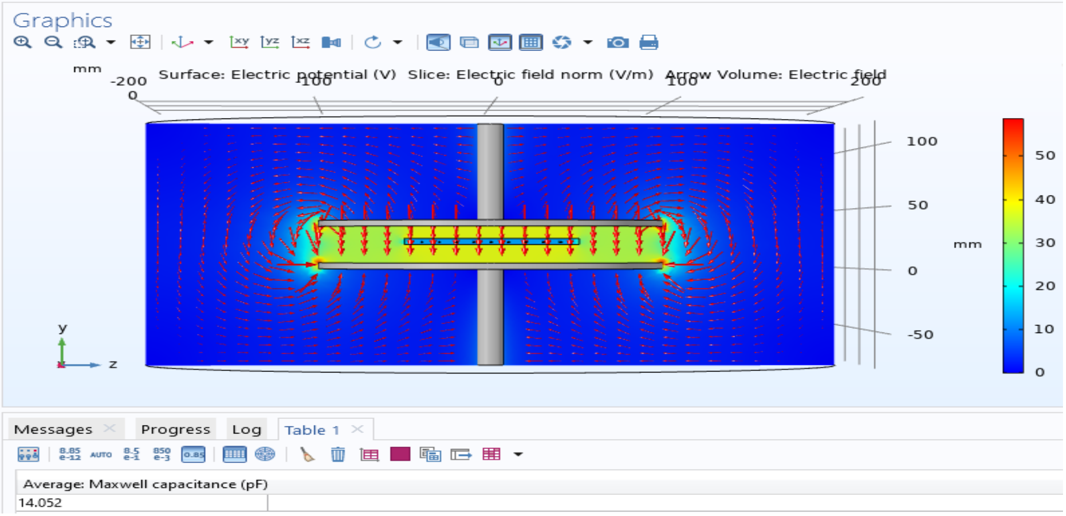
COPPER



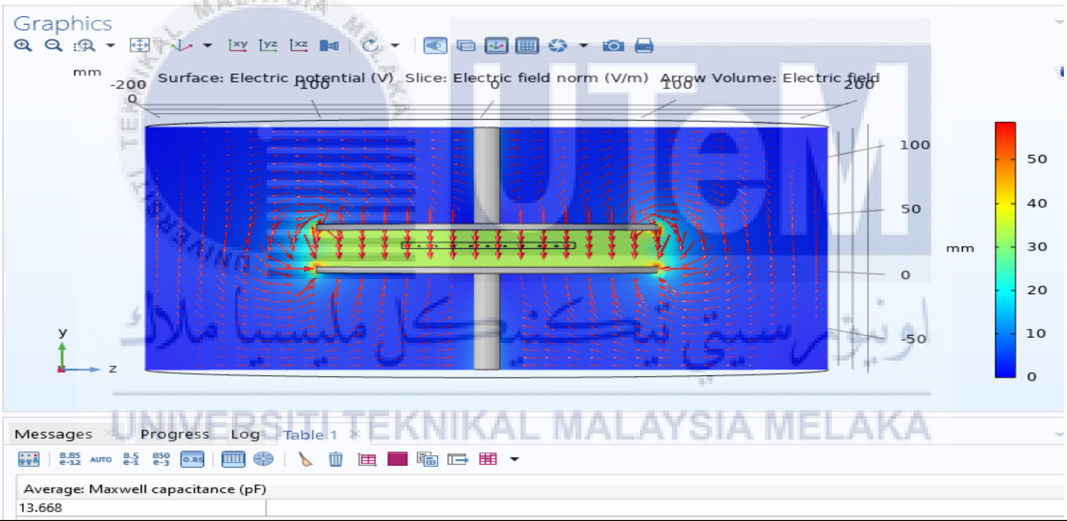
CONCRETE



PVC



ALUMINIUM



BRICK

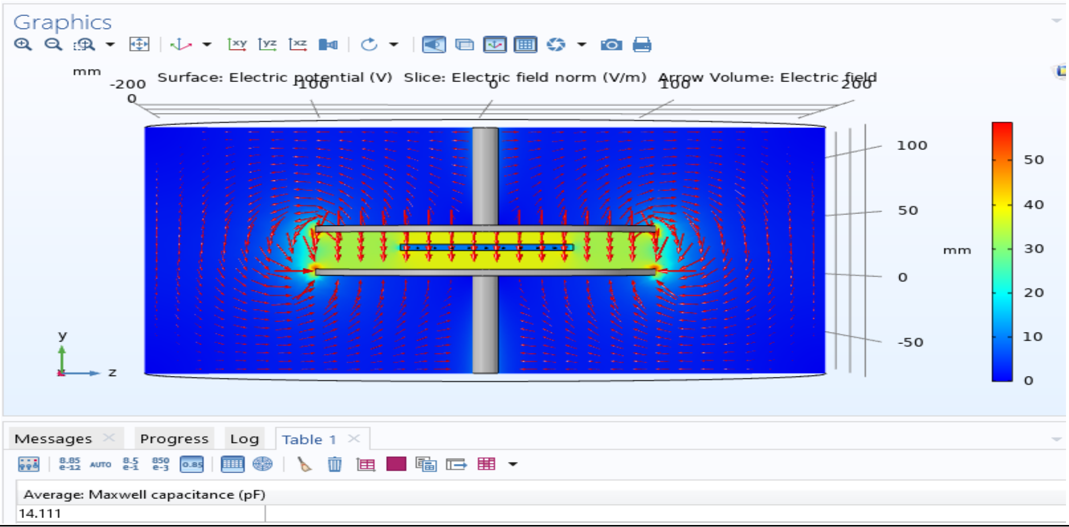
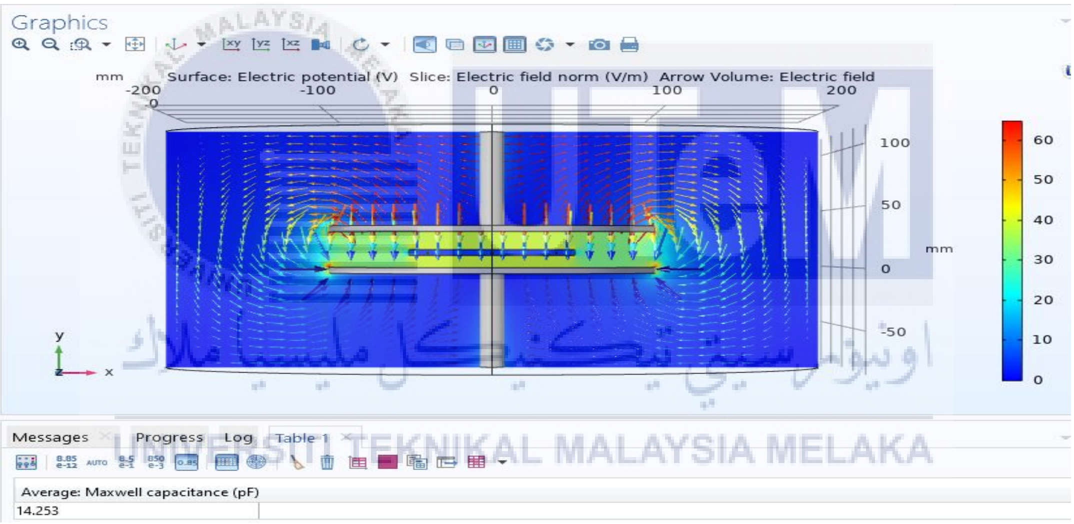


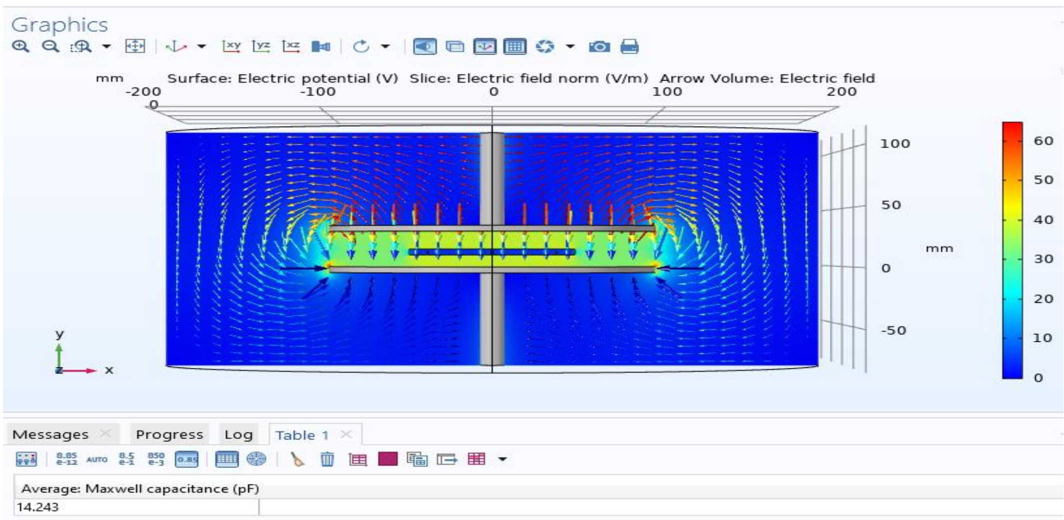
Figure 4.9 : Strength of Electric Field of parallel line crack

4.4.4 Simulation of Zig-Zag line crack

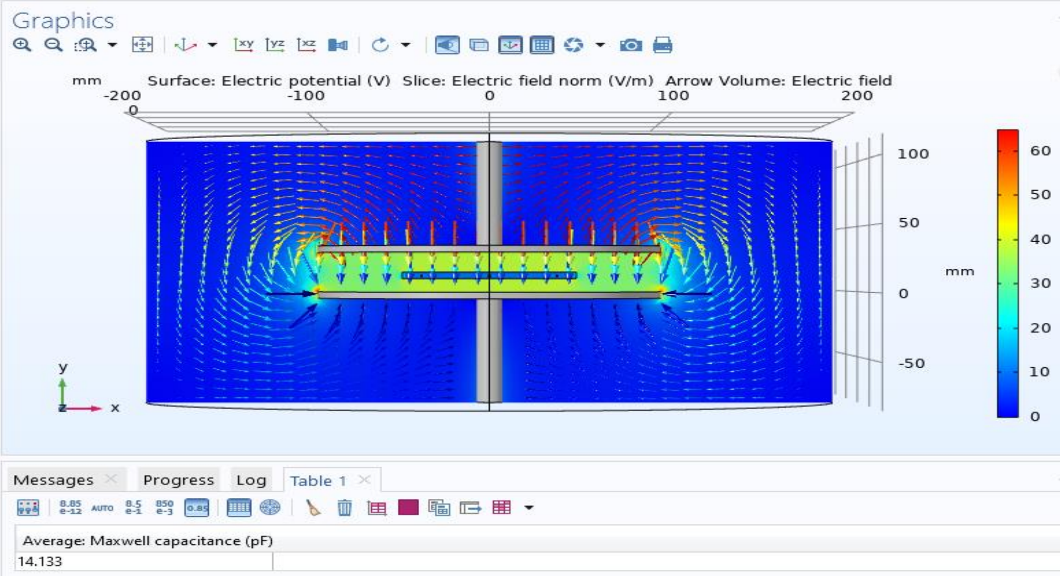
COPPER



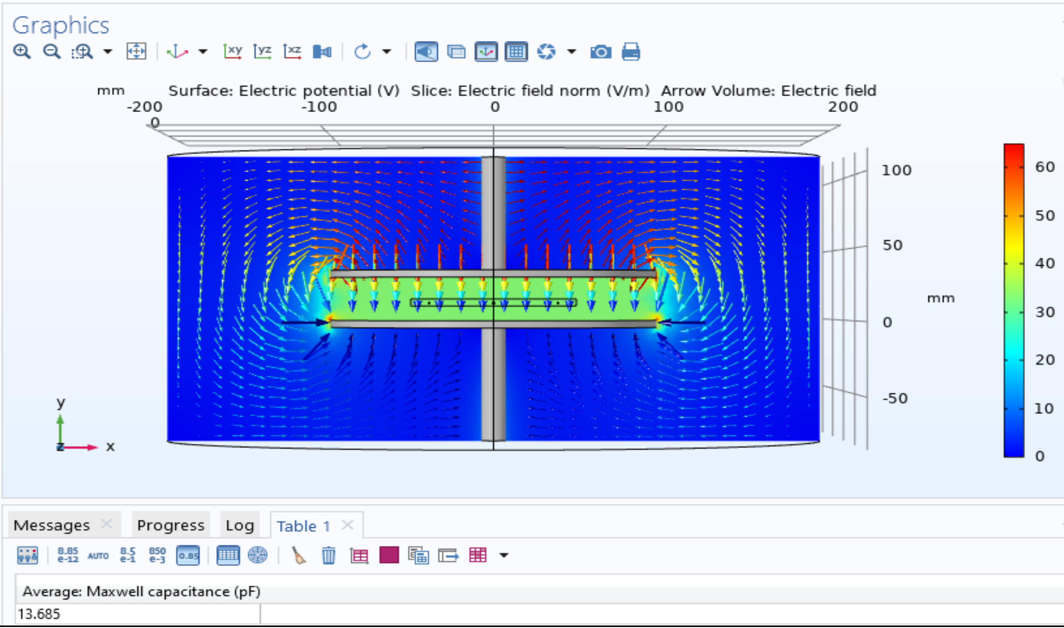
CONCRETE



PVC



ALUMINIUM



BRICK

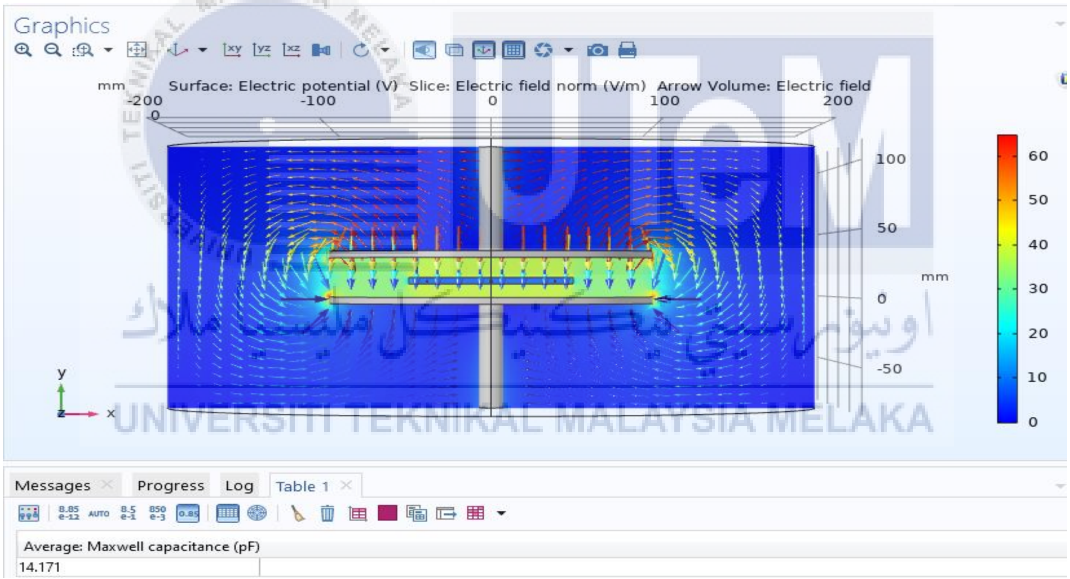


Figure 4.10 : Strength of Electric Field of zig-zag line crack

The electric field at a parallel plate, as simulated by the COMSOL Multiphysics simulation software. The figure above shows two identical conducting plates, each with a surface area (A), that are separated by a distance (d), indicating that they are separated by a different material from one another. In this case, the bottom plate is negatively charged, while one of the top plates is positively charged. An electric field is created between the plates of the capacitor sensor's plates and a central plate of the capacitor sensor's plates, as indicated by an arrow surrounding the capacitor sensor.

Near the edges of the plates, however, there are some noticeable variations in colour. It has been observed that the fringing fields extend only a short distance away from the capacitor when the capacitor is turned off. It is necessary to determine the capacitance of the device. In accordance with the different materials with different relative permittivity used, the average capacitance value varies accordingly.

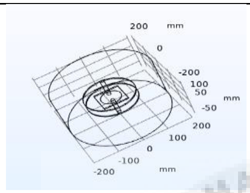
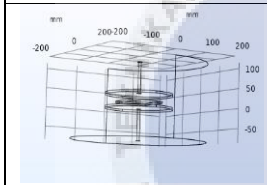
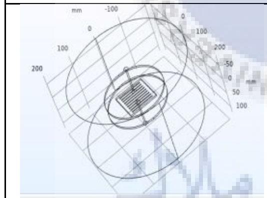
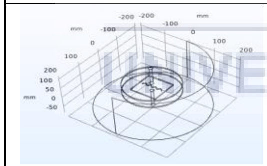
4.3 DATA SIMULATION		Average value of capacitance (pF)				
Type of material		Copper	Concrete	PVC	Aluminium	Brick
Type Of Crack	 Circle	14.216	14.163	14.049	13.700	14.104
	 Straight	14.253	14.198	14.073	13.685	14.133
	 Parallel	14.231	14.175	14.052	13.668	14.111
	 Zigzag	14.243	14.197	14.133	13.685	14.173

Table 4.3 : Data comparison with different crack and material

4.3.1 Line Graph

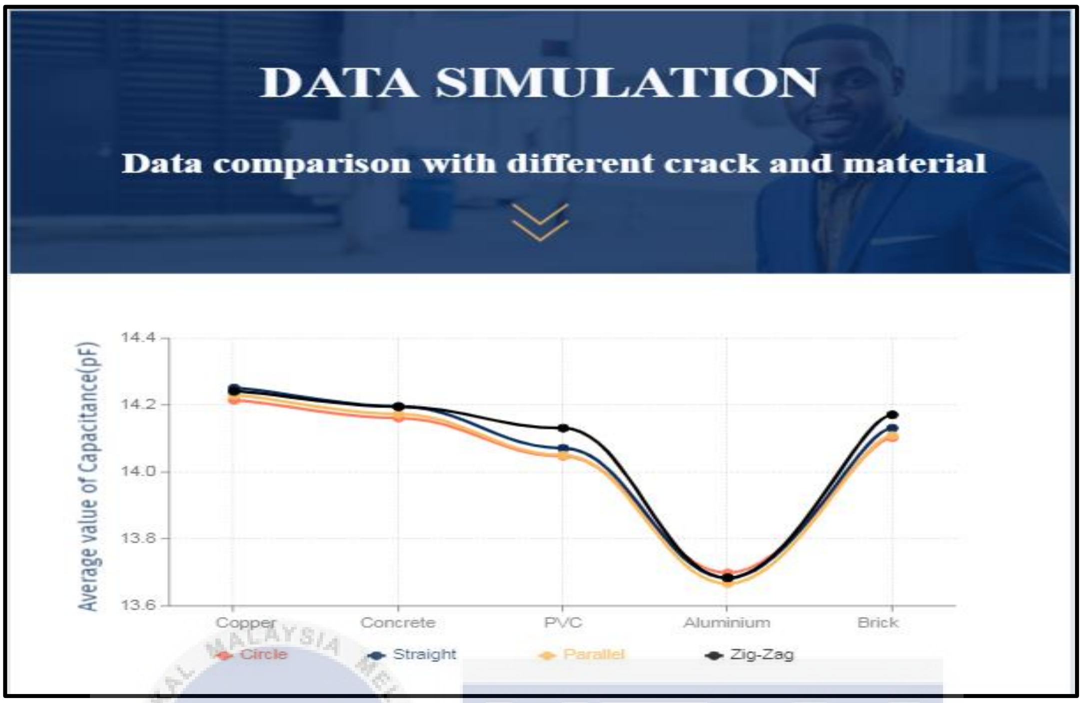


Figure 4.11 : Average value of Capacitance vs crack of material

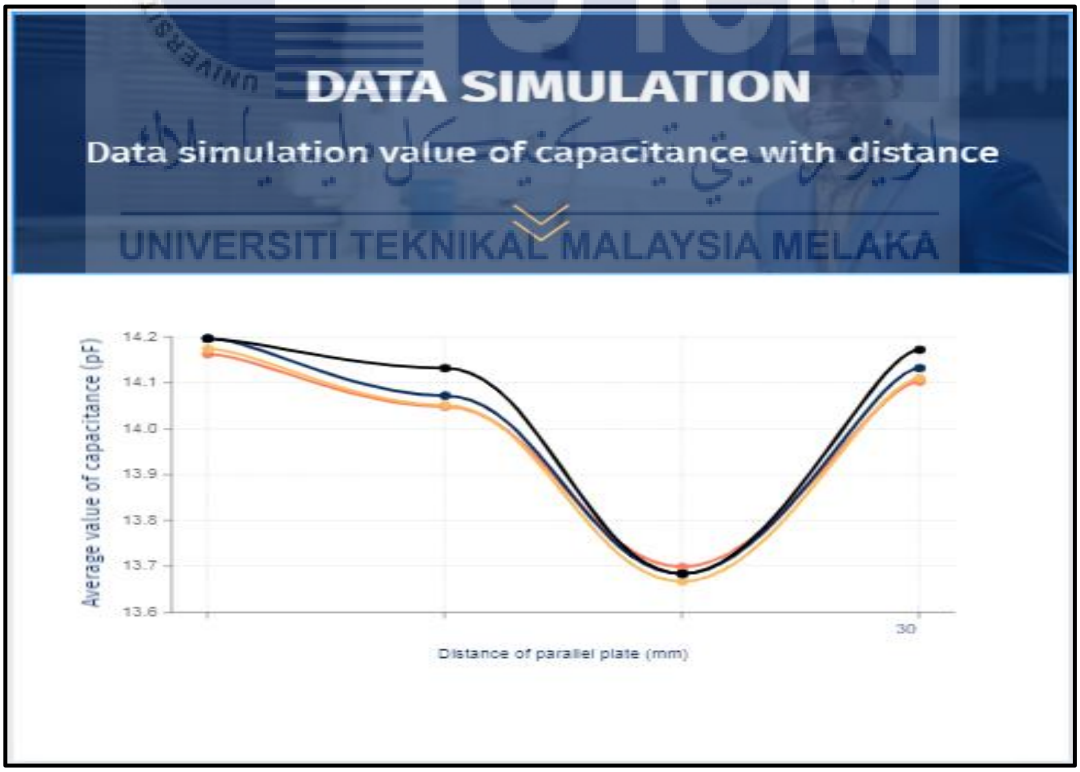


Figure 4.12 : Average value of capacitance vs Distance

As demonstrated in figures 4.11 and 4.12, the data simulation graphs have factors affecting capacitance. Three fundamental factors in capacitor construction affect the amount of capacitance generated. These factors all contribute to capacitance by determining the amount of electric field flux, or the relative difference of electrons with both plates, that will develop for a given amount of electric field force.

The average value of capacitance versus crack for each material is shown in Figure 4.11, indicating that each material has a different amount of relative permittivity and thats already mention at table 4.2. Greater permittivity of the dielectric results in greater capacitance; conversely, if less permittivity of the dielectric results in less capacitance, it demonstrates that copper has greater capacitance in the graph line because its relative permittivity is 10. Otherwise, aluminium has a lower relative permittivity, one, and thus a lower capacitance. Certain materials exhibit less resistance to flux when subjected to a given amount of field force. Additionally, materials with a higher permittivity permit more field flux, which results in less opposition.

Capacitance is affected by a number of factors, one of which is plate spacing. Why? As demonstrated in figure 4.12, increasing the plate spacing, or the distance between parallel plates, results in decreased capacitance, while decreasing the plate spacing results in increased capacitance. When closer spacing results in a greater field force, defined as the voltage across the capacitor divided by the distance between the plates, it also results in a greater field flux, defined as the charge collected on the plates for a given applied voltage. Unfortunately, I was unable to alter the distance between the parallel plates due to technical issue with the SolidWorks software used to create the design, but in theory, the formula demonstrated that such an alteration would occur when altering the distance between the parallel plates.

The capacitor plate area is the final factor that affects the amount of capacitance. I even mentioned the diameter in figure 3.4, where I specified 200 mm for the capacitor plate's diameter. As a result, the larger plate also provides more capacitance, while the smaller plate provides less. For a given field force, which is voltage across the plates, a larger plate area results in more field flux, which is charged collected on the plates.

CHAPTER 5

CONCLUSION

5.1 Introduction

About this chapter, it is explained the conclusions reached for this FYP 2 (Final Year Project) in terms of achieving the research goal. This chapter emphasises the importance of the research.

5.2 Conclusion

COMSOL Multiphysics and Solidworks software were used to successfully simulate the image reconstructed from the parallel plate and various types of material cracks. The electrical parameters of two electrodes can be determined using simulation results, and capacitor sensors with 2D and 3D geometries have been successfully implemented. When I conducted this experiment, I discovered that the capacitor sensor I designed was capable of detecting changes in capacitance or anything else associated with capacitor effects, such as the electrical field between the capacitive sensor and the intended material plate. Additionally, I discovered that it can sense both metallic and non-metallic objects and can thus vary in response to changes in the plate distance, the effective plate surface, or the dielectric. For non-conducting materials, the sensor concept is based on changes in dielectric constant, while for conducting materials, the sensor concept is based on changes in plate distance.

5.3 Recommendation

Numerous recommendations for future work on the development of a non-destructive electrical capacity sensor for composites are included. As previously stated, a few points need to be improved and upgraded to ensure that the simulation runs flawlessly.

Additional research should be conducted to determine the effect of varying the parallel plate's distance from the material plate on the simulation and the size of the material plate. Due to flaws in my project, one of which is that I am unable to adjust the distances between parallel plates due to technical difficulties with SolidWorks Software, we can proceed to the hardware implementation stage once the simulation is complete. To comply with industry specifications, it is necessary to implement hardware that generates accurate data results during testing in order to inspect for metal flaws or cracks, as well as material differences that occur in the majority of industrial sectors.

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APPENDIX

Appendix 1: Gantt Chart for Project

A. PROJECT PLANNING

PROJECT NAME: Development of Eddy Current as Sensor to Detect Crack on Metal.

	PSM 1																		PSM 2																			
Project Activity	FEB		MAC					APR				MAY					JUN		J	A	OCT				NOV				DEC				JAN					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	X	X	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Project Planning	PSM 1 Briefing							Mid Term Break								Study Week	Final Semester Examination		Semester Break									Mid Term Break								Study Week	Final Semester Examination	
Literature Review																																						
Study on Relay																																						
Research About Software and Hardware																																						
Prepare Chapter 1 (Introduction)																																						
Prepare Chapter 2 (Literature Review)																																						
Prepare Chapter 3 (Methodology)																																						
Design transformer in simulation																																						
Analyzing data from simulation																																						
Construct a modelling for eddy current sensor																																						
Design geometry of substance																																						
Compute the simulation																																						
Troubleshoot simulation																																						
Analysis Result and Data																																						
Preparing Chapter 4 & Chapter 5																																						
Editing Project Report																																						
Presentation PSM 2																																						
Submission of Project Report																																						