# Faculty of Electrical and Electronic Engineering Technology

**DEVELOPMENT OF FIBER OPTIC SENSOR USING DIFFERENT TYPE OF PALM OIL**

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**Bachelor of Electronics Engineering Technology with Honours**

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# DEVELOPMENT OF FIBER OPTIC SENSOR USING DIFFERENT TYPE OF PALM OIL

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**A project report submitted**
**in partial fulfillment of the requirements for the degree of**
**Bachelor of Electronics Engineering Technology with Honours**

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**2021**

**DECLARATION**

I declare that this project report entitled “Development Of Fiber Optic Sensor Using Different Type Of Palm Oil” 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.

| | | |
|---|---|---|
| Signature | : | |
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| Date | : | 11 JANUARY 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 with Honours.

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Co-Supervisor Name (if any) : MD ASHADI BIN MD JOHARI

Date : 11 JANUARY 2022

## DEDICATION

*My special dedication is directed to my parents, siblings and friends who have always supported me and who have always encouraged me to help me complete my final year project successfully. Meanwhile, I am dedicating this thesis to my beloved supervisor, DR. AMINAH BINTI AHMAD and co. supervisor, Sir MD ASHADI BIN MD JOHARI who has given me a lot of guidance and guidance on how to achieve success for my final year project. Thank you very much. I appreciate it. I am grateful for their inevitable sacrifice, tolerance, and consideration in making this effort feasible. I cannot provide the appropriate words that can accurately describe my appreciation for their loyalty, support, and belief in my ability to achieve my dreams.*

# ABSTRACT

Sensors for fiber optics have become one of the most prosperous and powerful people in the world applications of sensor and optical fiber technologies. In recent years, with the rapid development of microns or nanotechnology, the need for fiber optic sensors has become increasingly high. Having higher performance and flexibility, and occupying a small space is also one of the current fiber optic sensor trends. Fiber optic sensors have recently attracted a lot of attention due to its high sensitivity, fast detection speed, and ability to work in difficult conditions. This research is on the Optimisation Performance of Fiber Optic Sensors at different palm concentrations. Fiber optic sensors were developed to detect the concentrations of various types of oil palm. The objective of this project is to use optical fiber as a liquid sensor to detect various types of palm oil. This project requires an understanding, development and analysis of oil concentration sensors from optical loop fibers and needs to know how to perform fiber splicing, cutting and stripping for this purpose. There will be three samples of palm oil to be tested. Before each test, the fibers will be dipped into palm oil and then measured. In the line graph, each measurement will have a different result. The experimental findings will be explained in terms of sensitivity, correlation, and graphical determination coefficients, all of which depend entirely on the concentration of palm oil and the light source. At the end of the project, an optical liquid concentration sensor with high sensitivity readings was formed. Next, the results were analysed using the factorial design method. This will determine the type of palm oil concentration that has the optimum performance in terms of concentration.

# *ABSTRAK*

Sensor untuk gentian optik telah menjadi salah satu yang paling makmur dan berkuasa di dunia aplikasi teknologi sensor dan serat optik. Dalam tahun-tahun kebelakangan ini, dengan perkembangan mikron atau nanoteknologi yang pesat, keperluan untuk sensor gentian optik menjadi semakin tinggi. Mempunyai prestasi dan kelenturan yang lebih tinggi, dan menempati ruang kecil juga merupakan salah satu trend sensor gentian optik semasa. Sensor gentian optik baru-baru ini menarik banyak perhatian kerana kepekaannya yang tinggi, kelajuan pengesanan yang cepat, dan kemampuan untuk bekerja dalam keadaan sukar. Penyelidikan ini adalah mengenai Prestasi Pengoptimuman Fiber Optic Sensor pada kepekatan sawit yang berbeza. Sensor gentian optik dikembangkan untuk mengesan kepekatan pelbagai jenis kelapa sawit. Objektif projek ini adalah menggunakan gentian optik sebagai sensor cecair untuk mengesan pelbagai jenis minyak sawit. Projek ini memerlukan pemahaman, pengembangan dan analisis sensor kepekatan minyak dari gentian gelung optik dan perlu mengetahui bagaimana melakukan penyambungan, pemotongan dan pelucutan serat untuk tujuan ini. Akan ada tiga sampel minyak sawit yang akan diuji. Sebelum setiap ujian, serat akan dicelupkan ke dalam minyak sawit dan kemudian diukur. Dalam grafik garis, setiap pengukuran akan mempunyai hasil yang berbeza. Penemuan eksperimen akan dijelaskan dari segi kepekaan, korelasi, dan pekali penentuan grafik, yang semuanya bergantung sepenuhnya pada kepekatan minyak sawit dan sumber cahaya. Pada akhir projek, dibentuk sensor kepekatan cecair optik dengan bacaan kepekaan tinggi. Seterusnya, hasilnya dianalisis menggunakan kaedah reka bentuk faktorial. Ini akan menentukan jenis kepekatan minyak sawit yang mempunyai prestasi optimum dari segi kepekatan.

## ACKNOWLEDGEMENTS

First and foremost, all praise be to Allah the Almighty God for giving me the strength, health, and patience to complete this project entitled “Development of Fiber Optic Sensor Using Different Types of Palm Oil”. With the strength given, I was able to complete my project on time and overcome the difficulties that occurred during the research period.

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Finally, I would like to thank all the staffs at the Faculty of Electronic Engineering and Computer Engineering, fellow colleagues and classmates, the faculty members and classmates, as well as other individuals who are not listed here for being co-operative and helpful.

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## LIST OF SYMBOLS

| | | |
|---|---|---|
| $\mu m$ | - | Micrometer |
| $\theta_1$ | - | The incident angle between the light beam and the normal |
| $\theta_2$ | - | The refractive angle between the light ray and the normal |
| $n_1$ | - | The refractive index of the medium the light is leaving |
| $n_2$ | - | Refractive index of the material the light is entering |
| $F$ | - | Fahrenheit |
| $mm$ | - | Millimeter |
| $nm$ | - | Nanometer |
| $dbm$ | - | Decibels per miliwatt |

# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| $EMI$ | - | Electromagnetic interference |
| $RFI$ | - | Radio frequency interference |
| $PMMA$ | - | Polymethyl methacrylate |
| $SiO2$ | - | Silicon dioxide |
| $UV$ | - | Ultraviolet |
| $IR$ | - | Infrared |
| $GB$ | - | Gigabyte |
| $MMF$ | - | Multimode fiber |
| $SMF$ | - | Single mode fiber |
| $LED$ | - | Light-emitting diode |
| $ISI$ | - | Intersymbol interference |
| $PKO$ | - | Palm kernel oil |
| $FFB$ | - | Fresh fruit bunch |

**LIST OF APPENDICES**

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Fiber optics, often known as optical fiber, is a medium and system for sending data as light pulses through a glass or plastic strand or fiber. In data networking, fiber optics is utilised for long-distance and high-performance communication. Fiber optics use light particles, or photons, to transmit data across a fiber optic connection. The refractive index of each glass fiber core and cladding is different, bending the incoming light at a different angle. When light signals are sent through fiber optic cable, they bounce in a zig-zag pattern off the core and cladding, a phenomenon known as total internal reflection.



Since the last decade, electronic communications continued to evolve and increase the development demand to transmit and process large data signals in a short period. Therefore, optical fiber is increasingly accepted because it can achieve the desired electronic communication and function as a sensor. The properties of fiber optic sensing set it apart from other sensing systems. These optical fiber sensors are capable of measuring a wide range of chemical and physical factors with excellent sensitivity and speed. One of the primary factors that describes light emission is that a fiber optic detector can test or monitor many physical and chemical properties. Light intensity, phase, polarisation, and wavelength are all important elements to consider. Fiber optic sensors are appealing due to their unique features and prospective potential, which place them at the forefront of Photonics technology. The perceived signal in fiber optic sensing devices is immune to electromagnetic interference (EMI) and radio frequency interference (RFI). We can employ fiber optics for remote sensing applications since the signal they transport has low losses.

The purpose of this study is to develop a fiber optic sensor using several types of palm oil. An SMF28 optical cable or fiber optic pigtail under test, a laser source with a wavelength of 1550nm, an Optical Power Level and Optical Power Meter, and three different palm oils are required for this project. And each oil is tested three times, with the results being the loss (dBm) at the peak of the spectrum obtained with the Optical Power Level and Optical Power Meter equipment. A single optical concentration with high sensitivity was created towards the end of the research.

## 1.2 Problem Statement

The purpose of this study is to analyse the palm oil in three different scenarios using fiber optics as a tool for the industry. Because palm oil is one of the most important elements in the production of foods, its condition is one of the most important aspects of health. Normally, some in the industry are worried with the status of the palm oil, which has the potential to harm human health. Each type of palm oil utilised today has its own results of concentration, thus we want to know which palm oil has the highest sensitivity.

Next, there are numerous sensors available for measuring liquid concentration, particularly when employing electronic devices. Despite the fact that electronic sensors perform well in practise, they are not user-friendly due to their flammability due to EMI. This difficulty can be remedied by utilising a fiber optic sensor composed of silica glass, which is EMI resistant. During the monitoring procedure, it solely employs light pulses to send the signal. As a result, no EMI from the environment will impair its performance.

Besides, to monitor the liquid concentration, the electronic sensor requires a large amount of power. As a result, the electronic sensor's power consumption will rise, increasing the industry's expense. The cost of employing a fiber optic sensor, on the other hand, can be decreased because it only requires a tiny amount of electricity to provide the optical power source for detection.

Futhermore, some palm oil has a less or high sensitivity and its performance. Therefore, the idea development of fiber optic sensor is to determine which measurements require a low or high sensitivity. As a result, a fiber optic sensor will be used in this investigation to analyse and check the performance of each palm oil.

## 1.3 Project Objective

The main objectives of this project:

a) To design fiber optic sensors with different type of palm oil.

b) To analyse the performance of fiber optic sensors with different type of palm oil.

## 1.4 Scope of Project

The purpose of the project is to research fiber optic sensors and create a fiber optic sensor for detecting palm oil concentrations. The performance of the developed sensors will also be evaluated. Single mode fibers are spilced and the fiber optic sensor is spliced using a commercial splicer Fujikura FSM-18R. The fibers are cleaned with alcohol to remove dust and cleaved with a Fujikura CT-30 Fiber Cleaver to obtain a smooth cleavage surface and clean end-uncoated fiber before the sensors are spliced. The 1550nm input wavelength was collected from an optical power source during the testing process, and the output signal was measured in (dBm) units using an optical power meter.

Next, the splicer connects the two fiber optics by splicing the sensors together. Then, for each fiber optic sensor, an optical power supply and an optical power meter are connected to detect and analyse palm oil content.

Furthermore, the three types of palm oil are ready to be placed into the plastic container. As a result, there are three processes in this project for testing palm oil content. The palm oil concentration is tested using the sensors created as part of this project. By utilising an optical power meter, the findings are converted to watts (dBm).This project guarantees that the project is moving in the right path to achieve its objectives.

**Table 1.1: Equipment used during this project**

| **Equipment** | **Experiment Details** |
|---|---|
| Round basin | To concentration the sensors with liquid material |
| Fiber optic | Single mode (fiber optic pigtail) |
| Size | 125 nm |
| Liquid material | Brand A(Buruh Oil), Brand B(Alif Oil), and Brand C(Saji Oil) |
| Hardware | Optical Power Meter |
| | Optical Power Level/Source (1550nm) |
| | Commercial splicer Fujikura FSM-18R |
| | Fujikura CT-30 Fiber Cleaver |

## 1.5 Thesis Organisation

The thesis consists of five chapters, namely Introduction, Literature Review, Methodology, Results and Conclusions. Chapter 1 introduces the project idea briefly. It covers the project background, problem statement, project objectives and project scope. Next, Chapter 2 discusses a review of the literature and theory that has been done from the previous article. Chapter 3 provides an overview of the project methodology. It consists of all the methods used in the previous article, including algorithm design, research and laboratory practice. The initial results described in Chapter 4 and the final chapter are Chapter 5, which is the conclusion of the entire project.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

Optical sensing technology has taken on new dimensions as a result of recent breakthroughs in the science of optics. They set the norm for a robust optical fiber class sensor when combined with unique but effective transducing technology [1]. The first fiber optic sensors were patented in the 1960s and relied on free-space optics. About ten years later, researchers developed the first intrinsic fiber optic sensor. This improvement provides significant engineering benefits over independent space sensors to obtain reliable mechanical measurements. The use of fiber allows signals to be transmitted in usable media, whereas free space optics depend on viewing distance and cannot be used in operating structures or vehicles. Commercialised in the 1980s, fiber optic gyroscopes were one of the earliest applications of fiber optic sensors and have become important components in stabilisation and navigation systems. In the early 1990s, the civilian industry began applying various fiber-optic sensors in several applications to measure temperature, pressure, pressure, and more. In the early 2000s, another optical fiber sensing technology, distributed sensing, emerged and showed its greatest potential in the oil and gas industry. This technology is mainly used for temperature measurement along the length of the fiber to help improve various drilling processes, including leak detection, injection process monitoring and flow analysis. Although they provide distributed measurements, these technologies have slower refresh rates (a few seconds between optimal acquisitions) and spatial resolution according to the meter sequence [2].

## 2.2 Fiber Optic

Fiber optics transformed the telecommunications sector when it was introduced in the early 1980s, giving an ideal transmission medium with unparalleled ultra-wide bandwidth and extremely low spread loss. Fiber optic cable is made up of three major components. The core, the coating, and the coating are the three components [3]. The core is a cylindrical rod of dielectric material composed of glass, as depicted in Figure 2.1. Meanwhile, the coating is comprised of a dielectric substance with a lower refractive index than the core, allowing light scattering to occur solely in the core. In addition, the coating protects the fibers from absorbing surface impurities and adds mechanical strength by reducing light loss from the core to the surrounding air, reducing scattering loss on the core surface, and adding mechanical strength. On the other hand, a layer is a material layer that protects the optical fiber from physical damage. Usually, the lining is made of plastic because it must be elastic in nature and prevent abrasion [4].



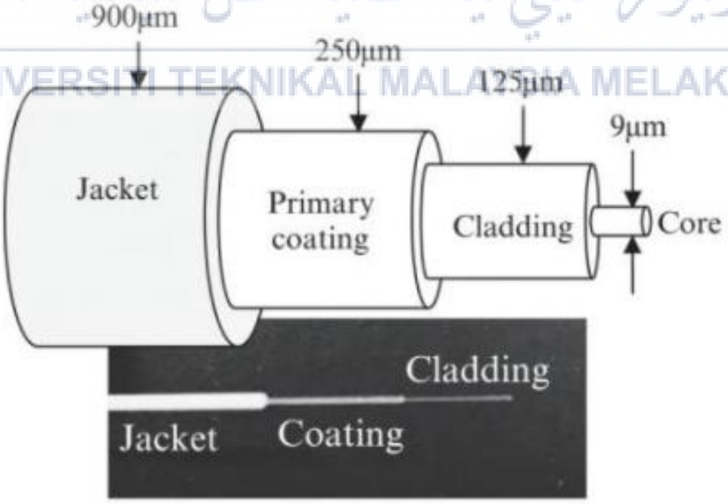



**Figure 2.1: The basic structure of Optical Fiber**

### 2.2.1 Total Internal Reflection

The guidance of light through fibers is based on the principle of total internal reflection. The angle at which the amount of internal reflection occurs is called the critical angle of occurrence [5]. Referring to Figure 2.2, light reflects inside the core continuously and cannot escape outwards when the incident angle exceeds the critical angle. Usually, light propagates in a straight line, but light reflections are present when light changes phase due to changes in the degree of freedom. Light reflection and refraction occur when an unexpected phase shift or phase breaks at the interface between two mediums [6].

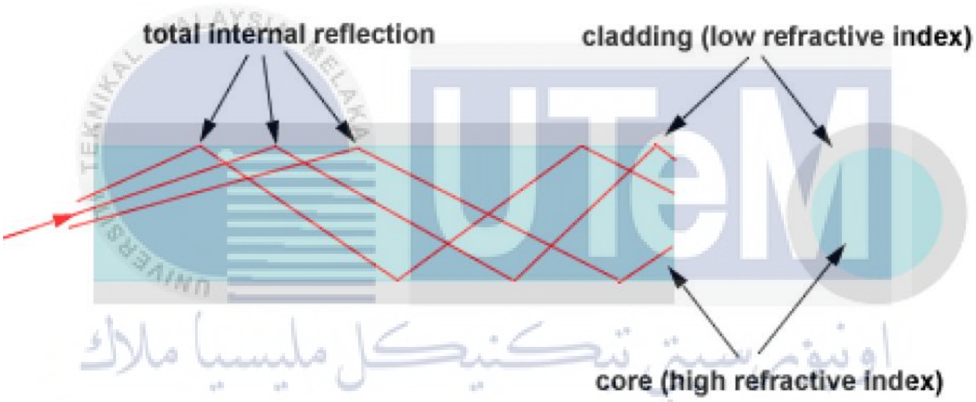





**Figure 2.2: Total internal reflection inside the core**

### 2.2.2 Snell's Law

Snell's law describes the relationship between the angle of incidence and the angle of refracted light at the interface of two different mediums. Based on Figure 2.3 and Snell's law equations, the incident sine ratio and refractive angle are equivalent to the phase velocity ratios in the two mediums. Therefore, it is also equivalent to the reciprocity of the refractive index ratio.

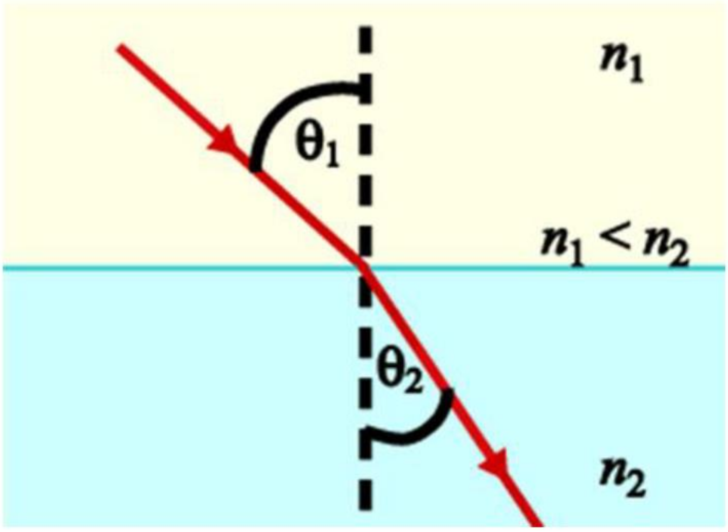



**Figure 2.3: Snell’s law concept**

Based on the figure above, Snell’s law can be stated:

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}\ or\ \frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} \qquad (2.1)$$

Where: $\theta_1$ is the angle of incidence

$\theta_2$ is the angle of refraction

$n_1$ is an index of the first medium



$n_2$ is an index of the second medium

$v_1$ is the speed of light at first medium

$v_2$ is the speed of light a second medium

The angle of refraction can be calculated using Equation 2.1 and the refractive indices of the two media. The angle of refraction will be smaller if the second medium's refractive index is greater than the first medium's, and vice versa.

## 2.3 Types of Optical Fiber

Fiber optic cables transmit information using an optical power source to an output such as an optical power meter or an optical spectrum analyser. Fiber optic cables are very well used for environmental monitoring as they have many advantages over conventional electronic sensors. First, it is easily assembled into various structures such as composite materials with little interference due to its small size and cylindrical geometry. Second, the optical fiber is immune to EMI, which is flammable and harmful to its surroundings. In addition to its light and high sensitivity, it is also more resistant to harsh environments such as very high and low temperatures, vibration, radiation, pressure, and corrosive conditions [7].

There are two types of optical fibers, which is plastic optical fibers and glass optical fibers. The use of the type of optical fiber is based on the desired application.

### 2.3.1 Plastic Optical Fiber



**Figure 2.4: Plastic Optical Fiber**

Plastic optical fibers are usually made from polymethyl methacrylate (PMMA) as the core material and silicone resin as the coating material. It uses red and green light that is harmless to the eyes and is suitable to be installed at home without harming people. There are several pros and cons to using plastic fibers. One of the advantages of plastic optical fiber is that it has a range of diameters from 0.15mm to 20mm. In addition, it is more flexible and can bend further without cracking or breaking. It can also withstand vibrations and unstable environments [8][9]. These features make it suitable for use for automotive and industrial lighting purposes. Furthermore, it uses lower material costs, and its manufacture is more complicated.

Some drawbacks make it less preferred compared to glass optical fibers. First, it is a narrower numerical opening that ranges from 0.48 to 0.63. Therefore, it has low light accumulation capability, which makes it capture less light. Next, it cannot withstand harsh environments, and the fibers will easily deteriorate over time.

### 2.3.2 Glass Optical Fiber



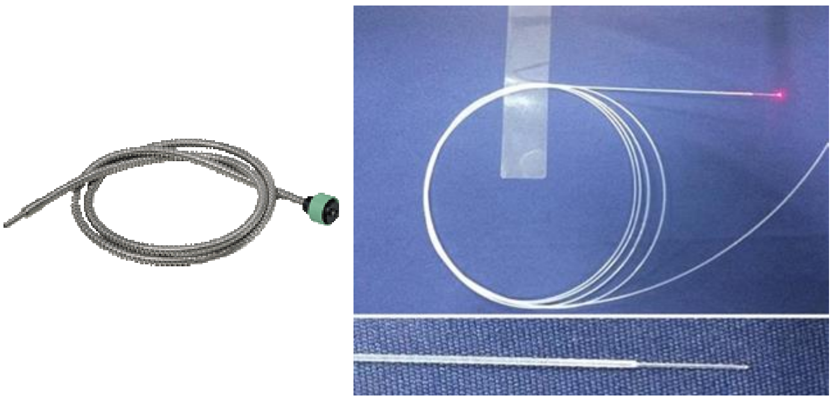


**Figure 2.5: Glass Optical Fiber**

Glass optical fibers usually consist of pure glass or silica, $SiO_2$ as the core material and less pure glass or plastic as the coating material [8][10]. It has several advantages over plastic optical fibers. The first advantage is a larger numerical aperture that allows more light to enter the system from 0.25 to 1. The second advantage, it can withstand extreme temperatures as low as -40F and up to + 900F. Therefore, it is useful and can be used for many applications such as ovens, machines and cold storage. The third advantage can transmit a wider spectrum ranging from ultraviolet (UV), visible light, and infrared (IR) light. The fourth advantage, it is also able to adapt to wet and corrosive environments without damaging its performance.

Unfortunately, it also has some disadvantages that are limited to diameter measurements between 0.05 mm to 0.15 mm and are more brittle and easily broken if not handled carefully. Also, it is harder to handle and finer than plastic optical fibers. Therefore, the implementation cost of glass fiber optics is more expensive.



**Table 2.1: Comparison between plastic and glass optical fibers**

| Consideration | Plastic Optical Fiber | Glass Optical Fiber |
|---|---|---|
| Cost | Cheaper | More expensive |
| Transfer speed | Slower | Faster |
| Loss | Higher Losses | Lower Losses |
| Numerical Aperture | Lower | Higher |
| Temperature | Not suitable for extreme temperature | Able to withstand extreme temperature |
| Flexibility | More flexible | More fragile |
| Distance | Used for shorter distance | Used for longer distance |

## 2.4 Single Mode Fibers

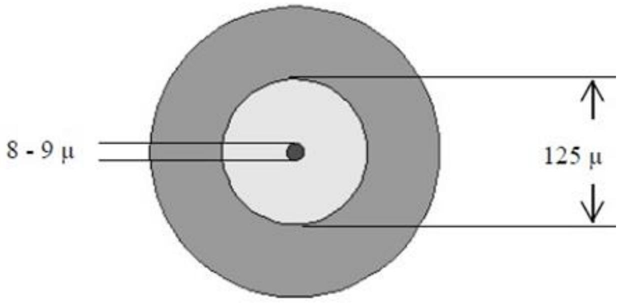



**Figure 2.6: Single mode core and cladding measurement**

SMF has a small core diameter of 8 to 9 μm and a coating diameter of 125 μm, as shown in Figure 2.6. Therefore, the ratio of core to cladding is usually equal to 9:125. Due to the narrow core design, it only allows one light scattering band, as shown in Figure 2.7 [11] below.



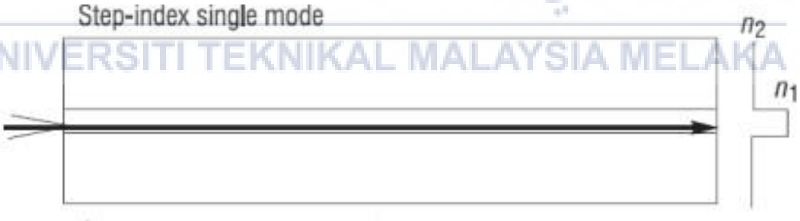



**Figure 2.7: Step-index single mode**

The advantage of having a narrow diameter is that light can move farther with low damping because low light reflection occurs when passing through the core. Therefore, it has lower data loss and better data transmission capabilities, making it suitable for communication. It can transmit up to 40 GB of information within hundreds of kilometers, with a lower data loss rate and faster than MMF.

However, due to the limited mechanical tolerances of the connection with the connector, the narrow SMF core is difficult to insert the light into the core. As a result, it is more difficult to construct. Therefore, its cost is more expensive than MMF.

## 2.5 Fiber Optic’s Application

The main field of application for optical fiber is communication. These have been widely used for public communications and local area networks in factories, laboratories, office buildings and others. However, there is also a wide range of applications available as sensing devices, optical power transmission and image transmission that are growing rapidly.

### 2.5.1 The Fiber Optic as a Communication

A fiber optic communication system delivers data across optical fibers using light waves. Since 1980, such systems have been used globally and have revolutionised the telecommunications sector. Along with microelectronics, lightwave technology eventually contributed to the beginning of the “information era” in the 1990s. Communication with optical fibers can be described as a comprehensive system [12].



Fiber optic technology provides connectivity for data centre operations. Fiber optic technology is used across the board in data centre networks, from short to vast distances. Power, cost, and space profile are critical to the continuous scalability of warehouse computers for close-range intra-centre interconnection. Potential technologies for next-generation intra-centre interconnections include integrated photonic circuits, advanced signal modulation and compensation for electronic propagation [13].

### 2.5.2 The Fiber Optic as a Sensor

There are three types of fiber optic sensors: first, location sensing, operations, and applications. Fiber optic sensors are categorised as extrinsic or intrinsic based on the location of the sensing. These fibers are only utilised to send and receive light from the external optical equipment that performs the sensing. Fiber is merely the component that transports light in this scenario. Figure 2.8 shows a comparison between extrinsic and intrinsic optical sensors [14].

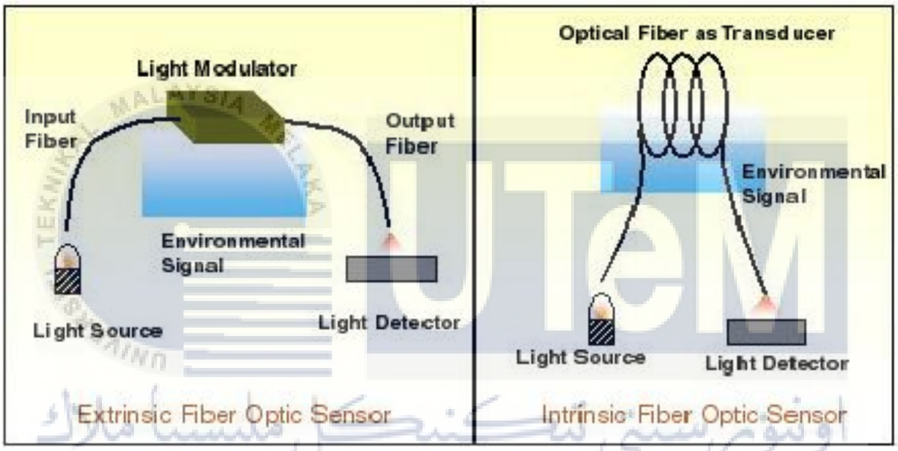



**Figure 2.8: Extrinsic and Intrinsic are Types of Fiber Optic Sensors**



Fiber optics has the fundamental advantage of being able to work in extreme conditions such as high temperature, chemical corrosion, high pressure, and high voltage. The second benefit is its tiny size, passive nature, and low force. The third benefit is superior performance, which includes great sensitivity and a broad bandwidth. Multiple or distributed measurement, the fourth and last long-range operation, is commonly utilised to mitigate its primary disadvantages of high cost and end-user uncertainty [14].

For varied sizes and uses, many ideas have been offered, and numerous methodologies have been created. A fiber optic sensor system's general structure is as follows: (shown in Figure 2.9). Optical sources (lasers, LEDs, laser diodes, and so on), optical fibers, sensors or modulator components (transducers that measure optical signals), and optical and electrical sensors make up the system (oscilloscopes, optical spectrum analysers etc). [14].

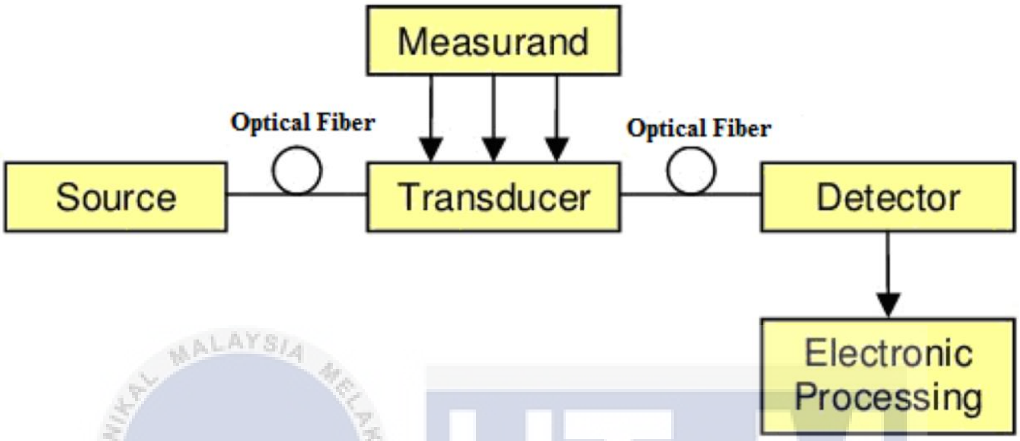



**Figure 2.9: A Fiber Optics sensor system's basic components**

Fiber optic sensors have several advantages, including being lightweight, compact, and tiny. The light is widely used in a range of fields due to its ease of installation, low ISI, electromagnetic interference resistance, high sensitivity, bandwidth, and environmental resistance. According to all criteria, the optimal use of optical fiber as sensors and optical fiber network is extremely beneficial in the industry for long-term investment [15].

## 2.6 Palm Oil

Palm oil is edible oil. FAO/WHO Codex Alimentarius (FAO/WHO, 2001) mentions that it is derived from the fleshy mesocarp of the palm fruit. Palm oil is reddish-brown in its unprocessed form and has a semi-dense consistency at ambient temperatures. Palm oil should not be confused with palm kernel oil (PKO), which is generated from palm fruit seeds, whereas palm oil is generated from the fruit's mesocarp or flesh. Both oils have different chemical compositions and physical properties, and they are used and marketed separately according to their supply and demand conditions.

As the palm oil fresh fruit bunch (FFB) matures, the oil content in the peel and kernel increases. Figure 2.10 shows one ripeness indicator: when easily removed from the bunch. Bunches of 50-200 loose fruits had 1.9 percent more oil per bunch than a bunch of one loose fruit [16].

**Figure 2.10: Ripe palm oil fresh fruit bunches with detached fruit**



The industry purchases palm oil FFB from smallholder farmers based on FFB maturity. The grinder has traditionally determined the maturity of oil palm FFB by counting the number and discolorations of each bunch of separated fruits. Immature and overripe FFBs are returned to smallholder farmers. Since the grader only looks at the external characteristics of FFB, small farmers can separate the fruit from the FFB, so it looks like a mature FFB. This classification method is very subjective. Therefore, the main problem or research question is how to objectively classify the FFB maturity of blackberry varieties.

Makky and Soni recorded diffuse reflectance using fiber optic reflectance probes in 2014. Between 250 and 1000 nm, these probes gave spectral information. They used spectral information from 400, 540, 560, 590, 670, 800, 910, 940, and 1000 nm to successfully classify seven FFB maturities. They also created an oil content prediction model based on spectral data from the 440, 470, 480, 510, 610, 690, 720, 750, 760, 880, 900, 910, 940, 980, 990, and 1000 nm wavelengths. The internal properties of FFB are determined using visible light stoichiometric analysis and NIR spectroscopy. It is critical to introduce the palm oil industry's modern technology. Figure 2.11 shows the suggested system, which consists of a silicon-based photodetector and 16 LEDs arranged in a single plane [16].

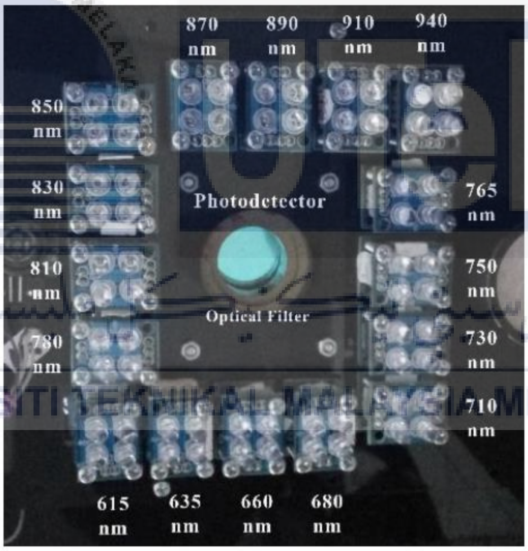





**Figure 2.11: Proposed Methodologies**

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

This chapter introduces the design process of a single-mode fiber sensor which includes detailed information on the tools and components used, the sensor manufacturing process, prototypes and other topics. The goal of the proposed study is to create a sensor that can detect the concentration of various types of palm oil.

## 3.2 Project Flow Chart

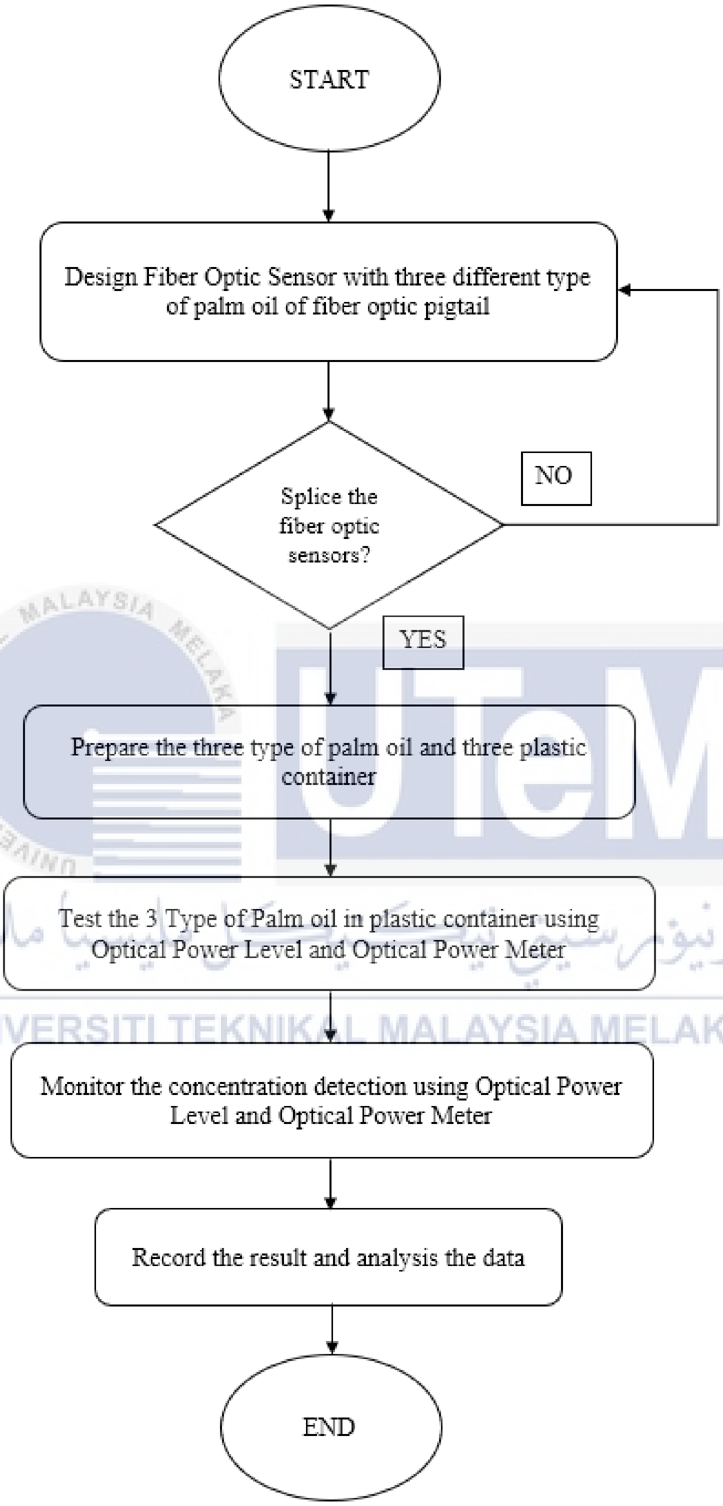



**Figure 3.1: Project Flow Chart**

With reference to Figure 3.1, the project started with the design fiber optic sensor with three different type of palm oil for fiber optic pigtail. There are three preparations as there are three types of palm oil to be used. The fiber selected for use as the sensor is a 125nm single-mode fiber. All fibers were cut to the same length to reduce losses during the experiment. The mounting part to be stripped for use as a sensor also becomes a strip of the same length. If the splice the fiber optic sensors are work can proceed to the next step if not work go to the fiber optic sensor setup.

The next step was to prepare the three type of palm oil and three plastic containers that would be used as experimental sites. The container will be punched to fit the fiber. Then the container will be filled with three types of palm oil brands namely (Brand A (Buruh Oil), Brand B (Alif Oil), and Brand C (Saji Oil)).

Once the setup is complete, the Optical Power Level and Optical Power Meter will emit a ray to the fiber and the result will be shown on the screen. Each fiber will be tested and minotoring at least three times to obtain an average measurement and the results recorded. Also, each part will take 30 minutes for three different type of palm oil. Following the fiber results, the results will be analysed and summarised in tables and graphs. In conclusion, concentrations on various types of palm oils will be identified.



## 3.3 Method of Project

There are several methods to expand the sensor structure. They can be achieved by performing all the procedures below.

### 3.3.1 Splicing Process

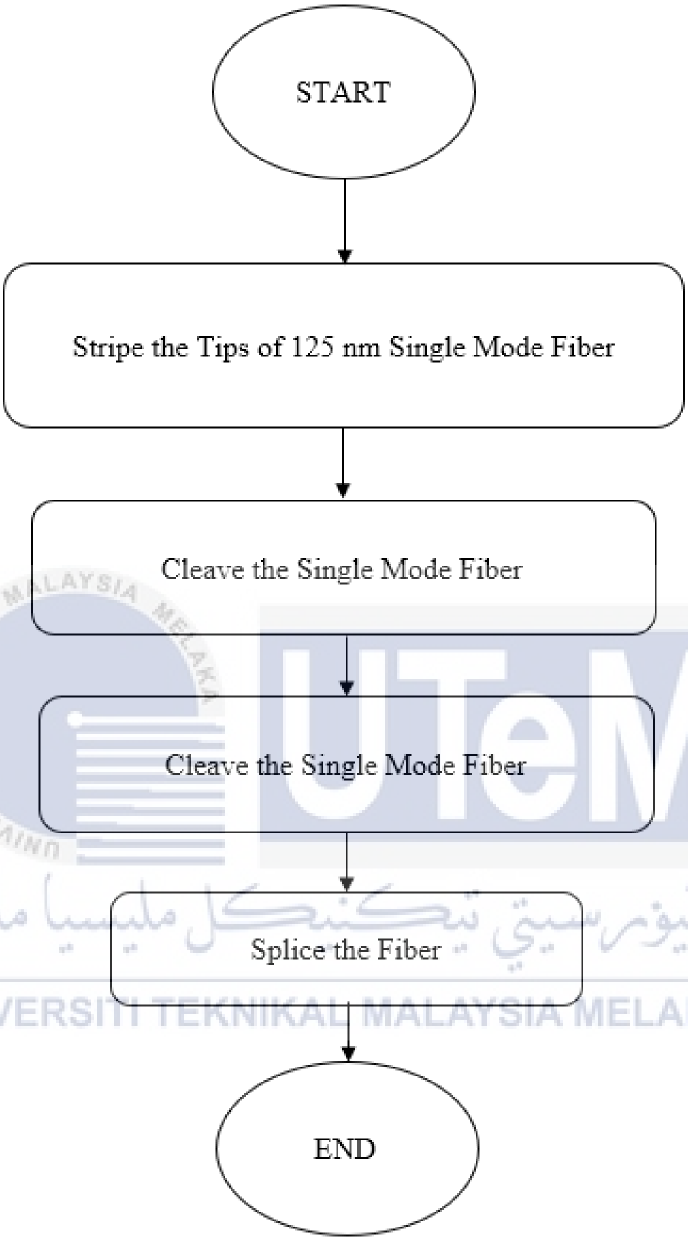


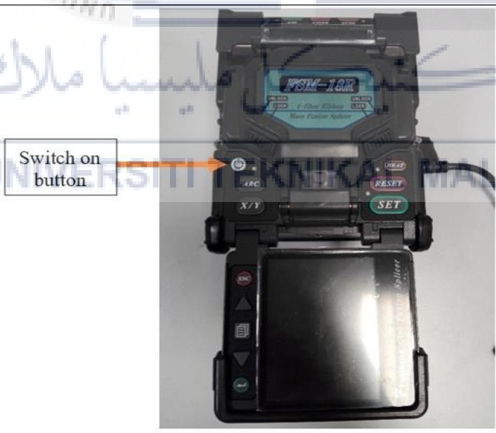


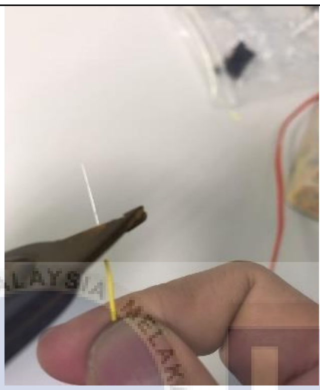
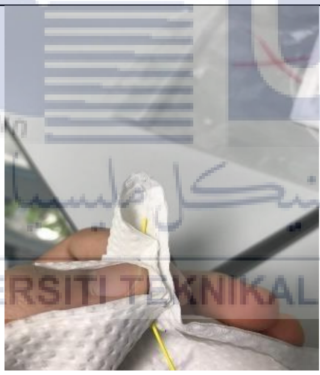

**Figure 3.2: Flowchart of Splicing Process**

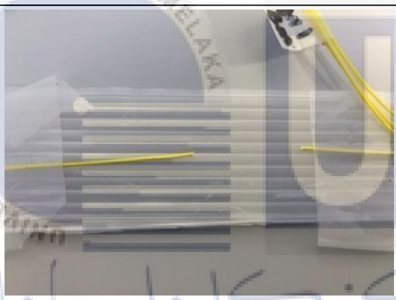
First, a fiber optic cable stripper is used to remove the Single-Mode Fiber layer. Afterwards, the fibers are cleaned with alcohol to remove coating residues or dust. After that, the fibers are cut using a high-quality Fujikura CT-30 cutter to achieve a flat face.

The Fujikura FSM-18R splicing tool is used to join two fibers that have been stripped from their lining and cleaned. The fibers will be placed on top of the separator, with the fibers aligned in the same location. The complete procedure on how to connect is shown in Table 3.1.

**Table 3.1: Complete steps for Splicing using Fujikura FSM-18R**

| No | Procedure | Description |
|---|---|---|
| 1 |  | List of the apparatus that used in splicing. |
| 2 |  | Press the on the button to turn on the Fujikura FSM-18R |

| | | |
|---|---|---|
| 3 |  | Cut the outer layer of the optical cable |
| 4 |  | Remove the second layer (cladding) on the optical cable. |
| 5 |  | Remove dust using alcohol and tissues. |
| 6 |  | Cut the optical cable using a high-precision cutter. |

| | | |
|---|---|---|
| 7 |   | Place the cable on the separator, and make sure the cable is in the same position. |
| 8 |   | Press start, and what until the connection is complete. |
| 9 |  | The connecting cable is ready to be laid on the stage. |



### 3.3.2 Experimental Setup Process

This section will proceed with the process from the beginning until the end of the procedure to achieve the purpose of this project.

#### 3.3.2.1 Preparations of three fiber optic sensors

For the process preparations of fiber optic sensors can see in Table 3.1 and make three fiber optic sensors for different type of palm oil as shown in Figure 3.3.

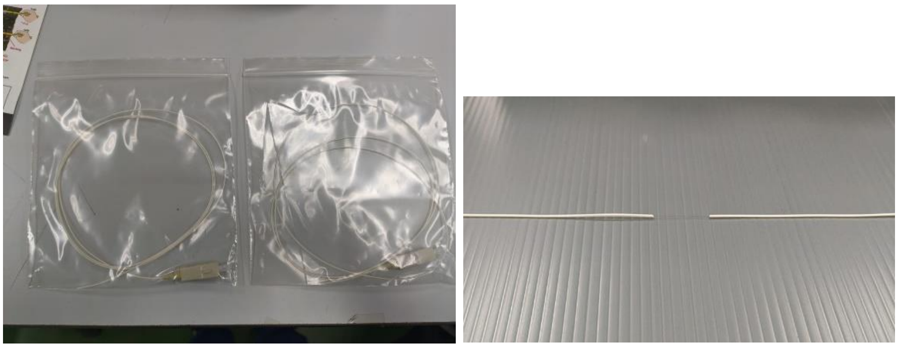


**Figure 3.3: Fiber Optic Pigtail**

#### 3.3.2.2 Make three plastic container for fiber optic sensors

Make three plastic containers and a hole inside each one to place the fiber optic inside the plastic container illustrated in Figure 3.4 after splicing the fiber optic. After placing the fiber optic, glue the hole inside the plastic container to ensure that the oil does not came out.



**Figure 3.4 Three Plastic Container for different type of palm oil**

#### 3.3.2.3 Procedure material and equipment setup

Firstly, prepare the Optical Power Level and Optical Power Meter by setting the wavelength to 1550nm and plugging the fiber optic pigtail illustrated in Figure 3.5. Then, as shown in Figure 3.6, place the palm oil in the plastic container and run the process by taking data with the Optical Power Level and Optical Power Meter for concentration of palm oil. Finally, for each palm oil, monitor the Optical Power Level and Optical Power Meter for 30 minutes, with the output measured in decibels (dBm) as shown in Figure 3.7, and taken every 3 minutes at a wavelength of 1550nm.


**Figure 3.5 Optical Power Level and Optical Power Meter.**


**Figure 3.6 Concentration of palm oil process**

**Figure 3.7 Monitoring for each palm oil process**

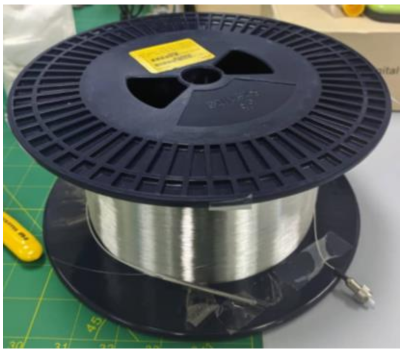
## 3.4 Tools and materials

All materials and equipment used in the project are shown in Table 3.2.

**Table 3.2: Equipment and material used in the project**

| No | Material and Equipment | Description |
|---|---|---|
| 1 | SimpliFiber® Optical Power Level   | - Source of input that is connected to the fiber.<br>- The wavelength is set at 1550nm. |

| | | |
|---|---|---|
| 2 | SimpliFiber® Optical Power Meter<br><br> | - The output is measured and sent to the display.<br>- The device that displays the result is the output device. |
| 3 | Commercial Splicer Fujikura FSM-18R<br><br> | - Splice the fibers together. |
| 4 | Cleaver Fujikura CT-30<br><br> | - Obtain the flat tip of the fiber. |
| 5 | Fiber Optic Stripper<br> | - Remove the cladding on the optical fiber. |

| | | |
|---|---|---|
| 6 | Single mode fiber  | - Used in sensor development.<br>- The size of fiber optic is 125nm. |
| 7 | Single mode connector (pig tail)  | - Use to connect an optical spectrum analyser to a sensor. |
| 8 | Rubbing Alcohol  | - To remove residue/dust after splitting and before connecting. |
| 9 | Tissue  | - Use alcohol to clean the fibers. |

| | | |
|---|---|---|
| 10 | Plastic container  | - Place the sensor to immerse in the oil. |
| 11 | Impra board 27" x 30"  | - To lay the fiber after the fiber becomes a splice.<br>- Used as the main supply point for experiments. |
| 12 | Brand A (Buruh Oil), Brand B (Alif Oil), and Brand C (Saji Oil)   | - Main equipment for experimenting. |

## 3.5 Experimental Setup of Circuit

In this section, the fiber optic sensor setup will show the flow of connection of components and equipment with its function as shown in Figure 3.3 below.

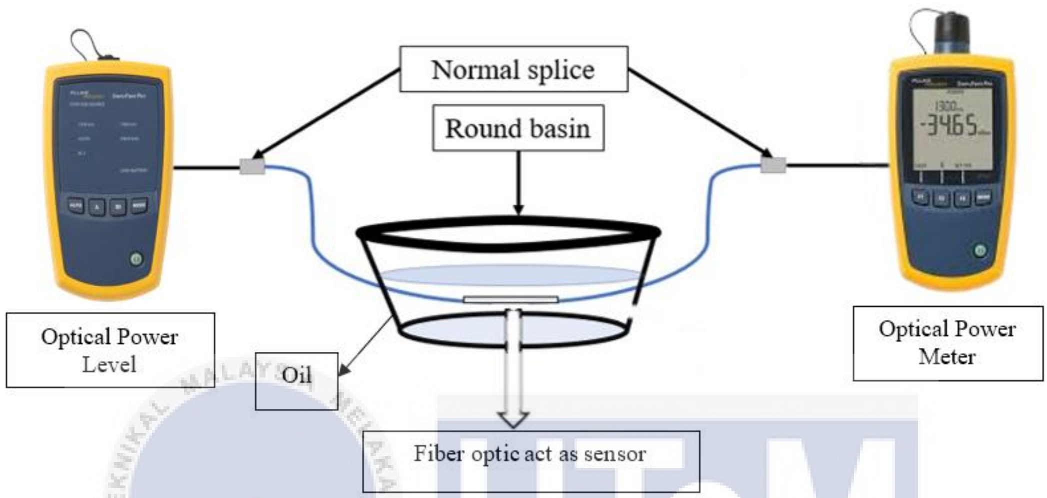



**Figure 3.8 Model of Project**

To evaluate oil concentration, single mode fiber optic sensors are connected to an Optical Power Level at the input. The Optical Power Level emits a wavelength of 1550nm to the fiber. The result is then recorded in dBm by the Optical Power Meter.

Each palm oil will be put into a container that has been prepared before the experimental test. In the container provided, the sensor is tested. The sensor will be tested three times with palm oil of the same type to achieve an average measurement. Each type of palm oil will go through the same process.

The results were analysed based on the type of palm oil and their respective concentrations. Then from the results, it is used to draw a graph to observe the concentration of each palm oil.

### 3.6 Summary

The proposed methodology for developing fiber optic sensors using various types of palm oil is presented in this chapter. The proposed methodology's main goal is to achieve an excellent outcome in order to obtain a superior waveform output value from the optical power level and optical power meter. The less rigorous and practical estimation in such a way that the accuracy of the results is not greatly harmed. The same procedure can be used to make several types of oil. The technique's ultimate purpose is to maximise efficiency, ease of use and manipulation, and practicality of fiber optic sensors, rather than to attain the maximum level of accuracy.

# CHAPTER 4

# RESULTS AND DISCUSSIONS

## 4.1 Introduction

The results and analyses of the development of a fiber optic sensor employing several types of palm oil are presented in this chapter. To demonstrate the sensitivity of fiber optic cable, case studies are conducted. Real palm oil is used in the case study to determine the sensitivity of each palm oil. It's worth noting that the purpose of this case study is to demonstrate the recommended methodology regardless of the type of palm oil used. Each palm oil is subjected to the proposed method, which involves testing each oil three times to determine its average value. Each test took about 30 minutes to complete.

## 4.2 Results and Analysis

The following table shows the analysis of oil test results. These analyses are divided into several pieces of information, namely time, number of tests, average of the time spent each time, linearity percentage and sensitivity.

### 4.2.1 Result for Brand A (Buruh Oil)

**Table 4.1 Data collected for the experiment**

| TIME (MINUTES) | TEST 1 | TEST 2 | TEST 3 | AVERAGE |
|---|---|---|---|---|
| 0 | 7.32 | 7.26 | 7.28 | 7.2867 |
| 3 | 7.32 | 7.26 | 7.27 | 7.2833 |
| 6 | 7.31 | 7.25 | 7.27 | 7.2767 |
| 9 | 7.31 | 7.24 | 7.27 | 7.2733 |
| 12 | 7.29 | 7.23 | 7.26 | 7.2600 |
| 15 | 7.29 | 7.22 | 7.26 | 7.2567 |
| 18 | 7.27 | 7.22 | 7.25 | 7.2467 |
| 21 | 7.26 | 7.23 | 7.24 | 7.2433 |
| 24 | 7.27 | 7.24 | 7.24 | 7.2500 |
| 27 | 7.28 | 7.24 | 7.25 | 7.2567 |
| 30 | 7.28 | 7.25 | 7.25 | 7.2600 |

**Table 4.2 Sensitivity and Linearity for Brand A (Buruh Oil)**

| | CYCLE 1 | CYCLE 2 | CYCLE 3 | TOTAL |
|---|---|---|---|---|
| Sensitivity | -0.0018 | -0.0012 | -0.0006 | -0.0012 |
| Linearity (%) | 85.36 | 88.54 | 40.51 | 80.17 |

The first analysis is based on the test or test cycle that was carried out during the test. The first test has a greater sensitivity value than the second and third tests. Brand A (Buruh Oil) has a reduced sensitivity, as evidenced by this. The linearity of each test cycle is then calculated, with the linearity for Brand A (Buruh Oil) being calculated using the average value of all three cycles. In comparison to the other two cycles, we can clearly see that the second cycle has the highest concentration value. The second cycle exhibits an almost perfect correlation (equal to 1), with 88.54% of the Brand A (Buruh Oil) particles interacting with the light source travelling through it and a higher sensitivity value than the preceding cycles.

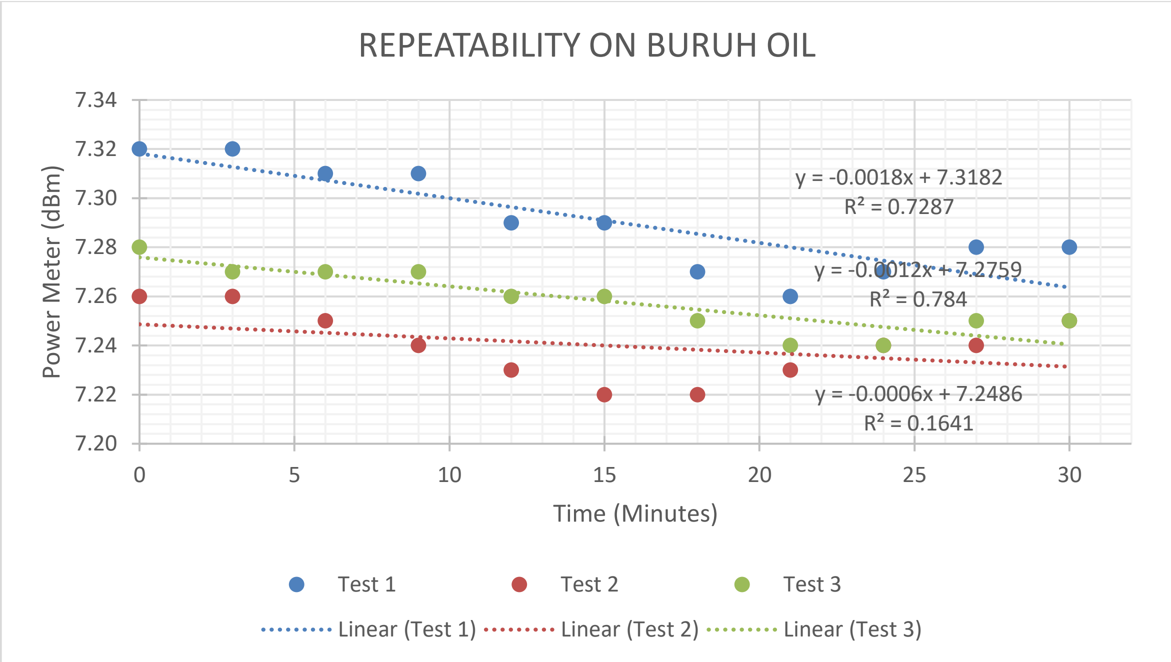



**Figure 4.1 Repeatability on Brand A (Buruh Oil)**

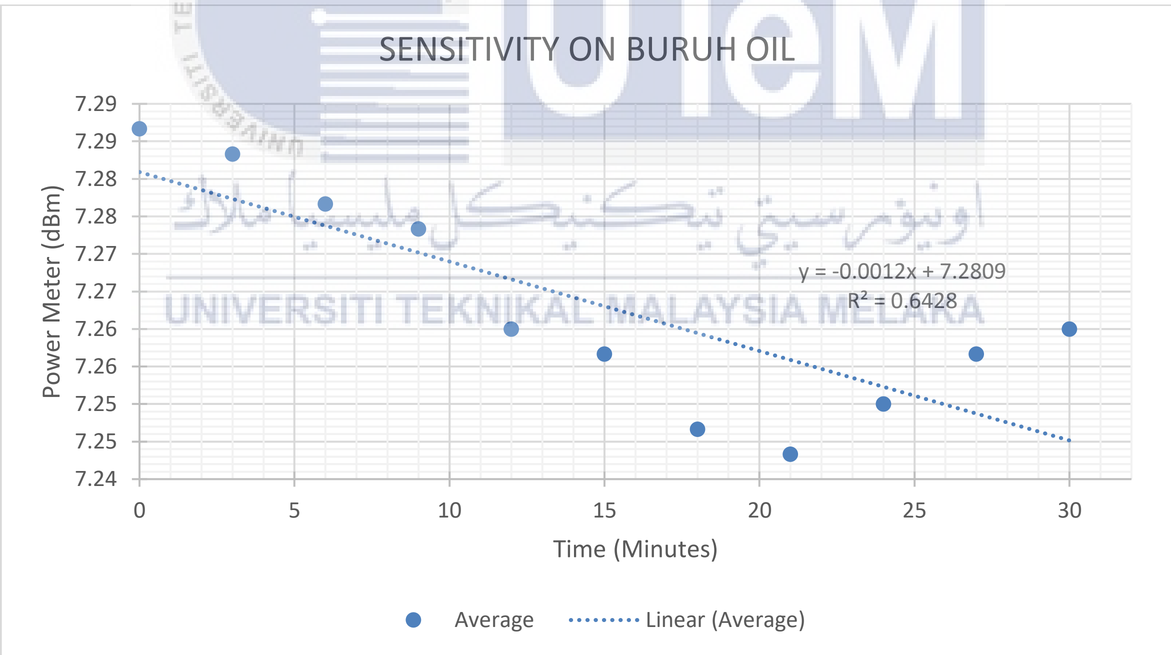





**Figure 4.2 Sensitivity on Brand A (Buruh Oil)**

The graph above depicts the total outcome for Brand A. (Buruh Oil). The graph has three different lines for repeatability (Figure 4.1) and one line for sensitivity (Figure 4.2).

Brand A (Buruh Oil) was sampled in three cycles, each of which was checked continuously for 30 minutes. Each cycle's plotted graph is captured every 3 minutes at a wavelength of 1550nm, with the output measured in decibels (dBm). There is a distinct tendency in which the cycle goes uphill before returning to its initial value. Brand A (Buruh Oil) may detect sensitivity using a fiber optic sensor, according to this investigation.

### 4.2.2 Result for Brand B (Alif Oil)

**Table 4.3 Data collected for the experiment**

| TIME (MINUTES) | TEST 1 | TEST 2 | TEST 3 | AVERAGE |
|---|---|---|---|---|
| 0 | 7.29 | 7.30 | 7.30 | 7.2967 |
| 3 | 7.31 | 7.29 | 7.27 | 7.2900 |
| 6 | 7.33 | 7.28 | 7.27 | 7.2933 |
| 9 | 7.32 | 7.27 | 7.26 | 7.2833 |
| 12 | 7.31 | 7.27 | 7.26 | 7.2800 |
| 15 | 7.31 | 7.27 | 7.26 | 7.2800 |
| 18 | 7.30 | 7.26 | 7.25 | 7.2700 |
| 21 | 7.30 | 7.26 | 7.25 | 7.2700 |
| 24 | 7.29 | 7.27 | 7.24 | 7.2667 |
| 27 | 7.28 | 7.27 | 7.24 | 7.2633 |
| 30 | 7.29 | 7.28 | 7.25 | 7.2733 |



**Table 4.4 Sensitivity and Linearity for Brand B (Alif Oil)**

| | CYCLE 1 | CYCLE 2 | CYCLE 3 | TOTAL |
|---|---|---|---|---|
| Sensitivity | -0.0009 | -0.0007 | -0.0015 | -0.001 |
| Linearity (%) | 58.71 | 59.63 | 86.89 | 91.67 |

The first analysis is based on the test or test cycle that was carried out during the test. The third test has a higher sensitivity value than the first and second tests. Brand B (Alif Oil) has a reduced sensitivity, as evidenced by this. The linearity of each test cycle is then calculated, with the linearity for Brand B (Alif Oil) being calculated using the average value of all three cycles. In comparison to the previous two cycles, we can plainly see that the third cycle has the highest concentration value. The third cycle has an almost perfect correlation (equal to 1), with 86.89% of the Brand B (Alif Oil) particles interacting with the light source passing through it, and the sensitivity value is higher than the others.

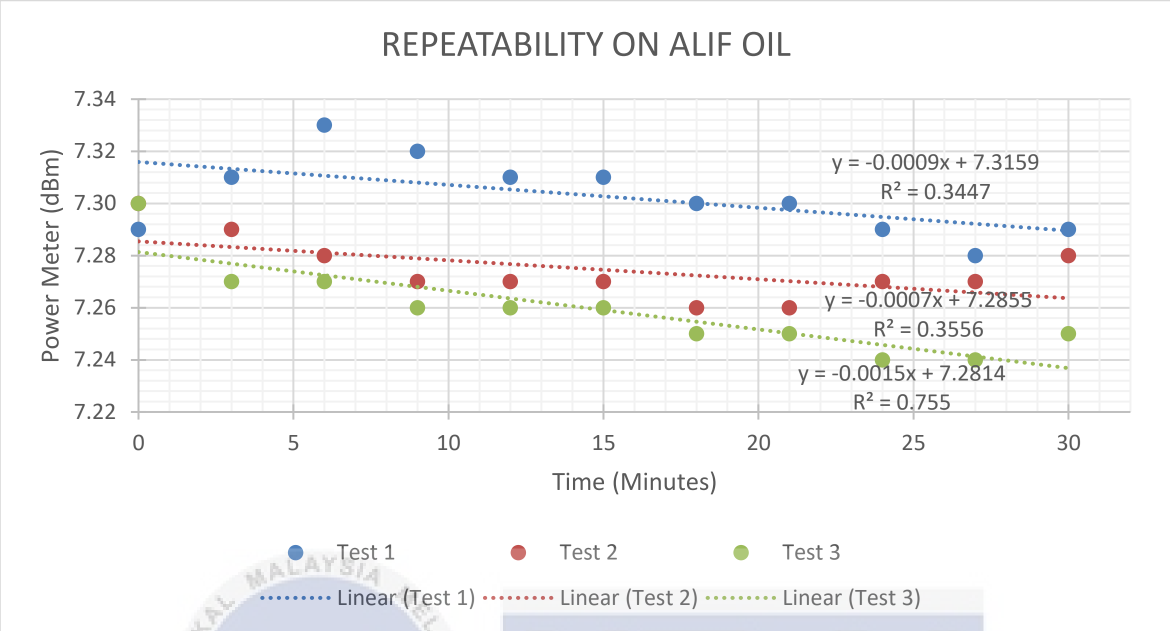



**Figure 4.3 Repeatability on Brand B (Alif Oil)**

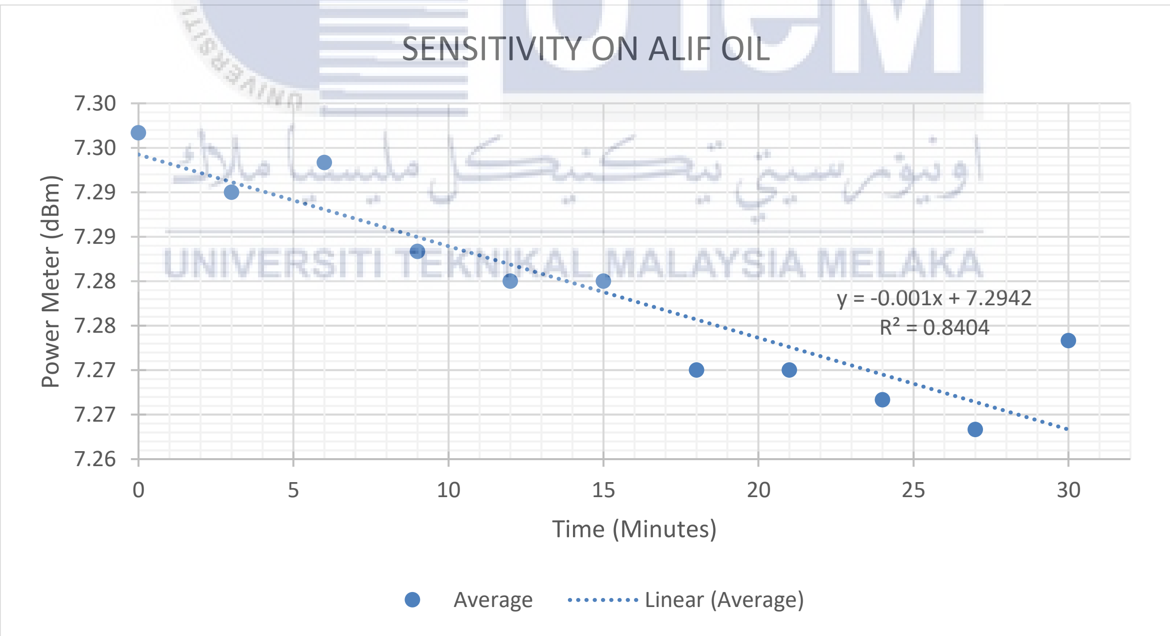



**Figure 4.4 Sensitivity on Brand B (Alif Oil)**

The graph above shows Brand B's overall performance (Alif Oil). Figure 4.3 shows three different lines for repeatability, and Figure 4.4 shows one line for sensitivity. Brand B (Alif Oil) was sampled in three cycles, each of which was checked continuously for 30 minutes. Each cycle's plotted graph is captured every 3 minutes at a wavelength of 1550nm, with the output measured in decibels (dBm). There is different trend where the cycle when uphill and then back up to the original value. This analysis determine that Brand B (Alif Oil) can use fiber optic sensor to sense sensitivity.

### 4.2.3 Result for Brand C (Saji Oil)

**Table 4.5 Data collected for the experiment**

| TIME (MINUTES) | TEST 1 | TEST 2 | TEST 3 | AVERAGE |
|---|---|---|---|---|
| 0 | 7.31 | 7.31 | 7.30 | 7.3067 |
| 3 | 7.31 | 7.30 | 7.29 | 7.3000 |
| 6 | 7.32 | 7.30 | 7.29 | 7.3033 |
| 9 | 7.32 | 7.30 | 7.29 | 7.3033 |
| 12 | 7.32 | 7.29 | 7.28 | 7.2967 |
| 15 | 7.31 | 7.29 | 7.28 | 7.2933 |
| 18 | 7.31 | 7.28 | 7.27 | 7.2867 |
| 21 | 7.29 | 7.28 | 7.28 | 7.2833 |
| 24 | 7.29 | 7.28 | 7.29 | 7.2867 |
| 27 | 7.29 | 7.29 | 7.31 | 7.2967 |
| 30 | 7.30 | 7.29 | 7.31 | 7.3000 |

**Table 4.6 Sensitivity and Linearity For Brand C (Saji Oil)**



| | CYCLE 1 | CYCLE 2 | CYCLE 3 | TOTAL |
|---|---|---|---|---|
| Sensitivity | -0.0009 | -0.0008 | 0.0003 | -0.0004 |
| Linearity (%) | 72.50 | 76.79 | 23.83 | 57.28 |

The first analysis is based on test or cycle of test that being conducted during the test. The sensitivity for the second test is higher that value than the first and third test. This show that Brand C (Saji Oil) has lower sensitivity. Next is the linearity of each cycle of test, the linearity for Brand C (Saji Oil) is obtained using the average value of all the three cycles. From this cycle we can clearly say that all of the cycle does not have good concentration for Brand C (Saji Oil). The second cycle has the highest correlation, which is only 76.79%.

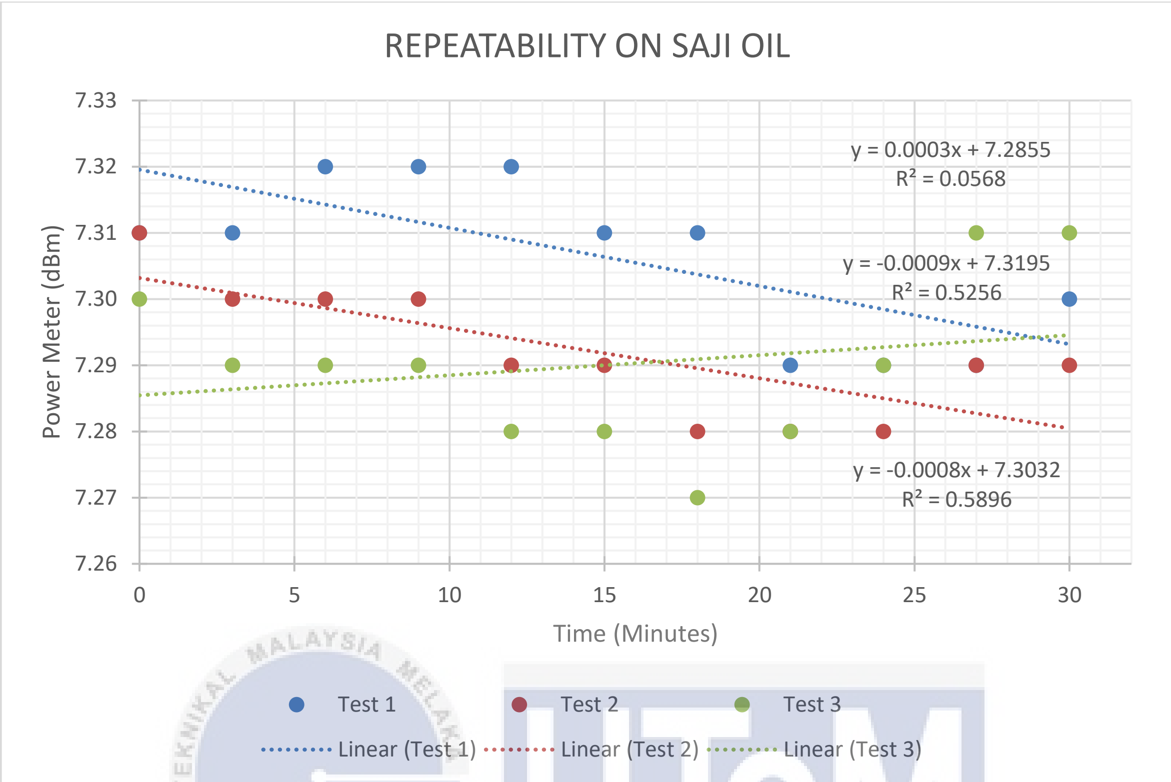



**Figure 4.5 Repeatability on Brand C (Saji Oil)**



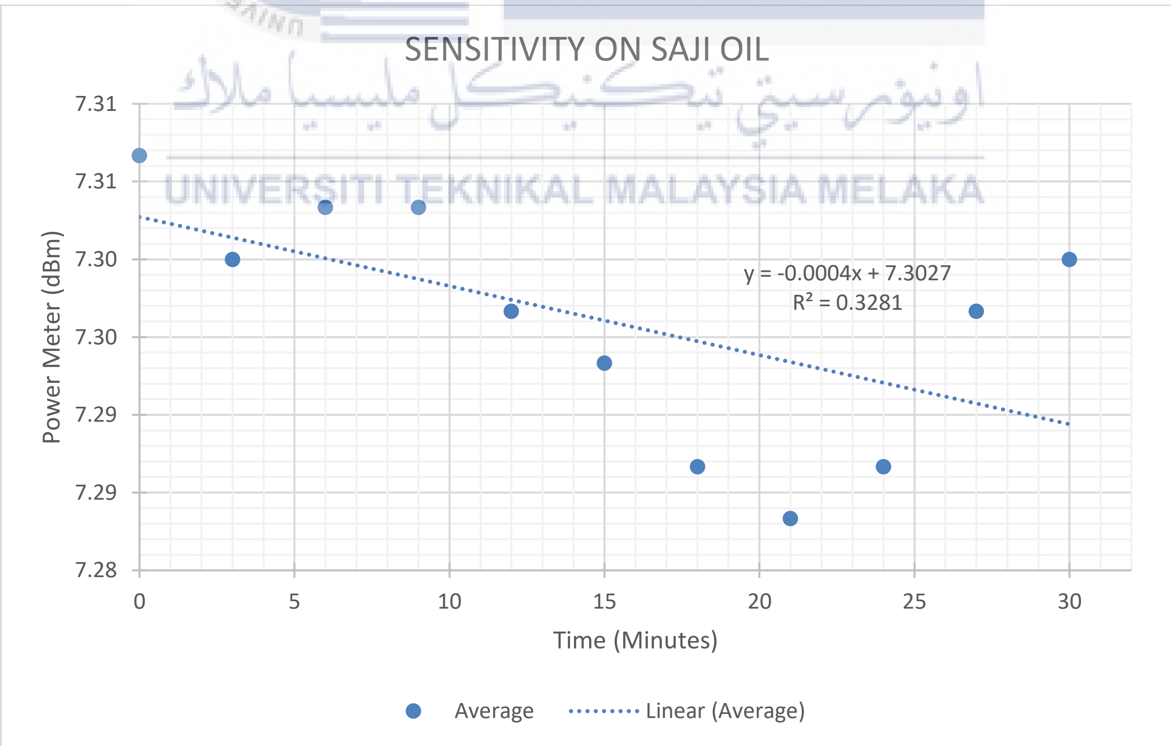



**Figure 4.6 Sensitivity on Brand C (Saji Oil)**

The graph above shows the overall result for palm oil. The three different lines in the graph are for repeatability (Figure 4.5) and one line for sensitivity (Figure 4.6). The Brand C (Saji Oil) has been sampled into three cycles which each cycle is continuously check in time frame of 30 minutes for each cycle. Each of the plotted graph for each cycle are taken every 3 minutes with the wavelength of 1550nm wavelength where the output are in decibel (dBm). The repeatability trend for Brand C (Saji Oil) has inclination for each cycle. This analysis determine that Brand C (Saji Oil) does not have great sensitivity to become a sensor when using fiber optic.

## 4.3 Summary

This chapter provides case studies to demonstrate the applicability of the proposed fiber optic sensor development system employing various types of palm oil. The case study is based on the experimentation of three (3) different varieties of palm oil. The three (3) types of palm oil used in the case study are: (i) Brand A (Buruh Oil), (ii) Brand B (Alif Oil), and (iii) Brand C (Saji Oil). Over the course of a 30-minute period, the proposed method is used throughout the experiment. The experiment uses the experiment setup (described in Chapter 3) to collect data using standard Optical Power Meter and Fiber Test Kits. Only Brand A (Buruh Oil) and Brand B (Alif Oil) are suitable to employ fiber optic as their sensor, according to the results.

# CHAPTER 5

## CONCLUSION AND RECOMMENDATIONS

### 5.1 Conclusion

The method for developing fiber optic sensors using several types of palm oil is presented in this thesis. The proposed methodology is effective and robust for obtaining good results with only somewhat precise data and minimal network measurement information. The proposed analytical method of obtaining the correlation for each palm oil by combining sensitivity and linearity.

Overall, the study provided in this thesis has contributed to a better understanding of sensor relevance in fiber optics. The method given makes fair use of a restricted amount and type of data, uses simple mathematical manipulations, and requires fewer intensive calculations while yet generating quick, compelling, reflective, and somewhat accurate results. In addition, the research focused on developing approaches that would aid in the development of low-cost sensors that are solely dependent on optical fiber sensing. As a result, it paves the way for the recommended extra research.

### 5.2 Future Works

Fiber optic sensors may be employed in a range of industries in the future, including the chemical, biomedical, oil and gas, and food industries, among others. This project demonstrates how sensors may be used as a sensing device for liquid testing. However, it is not restricted to liquid testing; it may also be used to measure other variables such as temperature, pressure, and humidity. Because the main construction of both sensors is glass, they are resistant to harmful interference such as EMI and can tolerate harsh conditions such as high temperatures and pressure.

Fiber optic sensors can be connected to the Internet of Things (IoT) for even greater convenience and ease in monitoring sensor output. The user can monitor from afar using IoT because authorised users have worldwide access to the system. Furthermore, increasing the length of the detecting zone can improve sensor sensitivity. When an optical signal travels through the sensors, this permits them to provide a higher resonant output.

This research will be useful in the future for palm oil suppliers such as Malaysian Palm Oil Board Berhad (MPOB) and Sime Darby Plantation Berhad to determine the quality of palm oil during distillation and cleaning. This project, on the other hand, can be used to monitor the viscosity of palm oil in a tank at a palm oil firm like Felda Global Ventures Holdings Berhad (FGV). Because palm oil is transported through pipelines, the sensors' features and size make them the most appropriate for these businesses.

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# APPENDICES

## Appendix A: Gantt Chart for BDP 1

| NO. | TITLE | WEEK | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1. | Title selection and BDP Registration | | | | | | | | MID-SEMESTER BREAK | | | | | | | |
| 2. | BDP 1 briefing | | | | | | | | | | | | | | | |
| 3. | Module 1 :<br>• How to write the Objectives, Scope, Problem statement.<br>• How to write the Literature Review .<br>• How to write methodology ? | | | | | | | | | | | | | | | |
| 4. | Module 2 :<br>• Tools to improve PSM Report Writing. | | | | | | | | | | | | | | | |
| 5. | BDP implementation and meeting supervisor | | | | | | | | | | | | | | | |
| 6. | Evaluate of Work Progress 1 | | | | | | | | | | | | | | | |
| 7. | Evaluate of Work Progress 2 | | | | | | | | | | | | | | | |
| 8. | Submission and Evaluation of BDP Final Report | | | | | | | | | | | | | | | |
| 9. | Presentation | | | | | | | | | | | | | | | |

**Appendix B: Gantt Chart for BDP 2**

| NO. | TITLE | WEEK | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1. | BDP 2 Briefing | | | | | | | | | MID SEMESTER BREAK | | | | | | |
| 2. | Preparation on fiber optic sensor | | | | | | | | | | | | | | | |
| 3. | Experiment on different type of palm oil | | | | | | | | | | | | | | | |
| 4. | Data Analysis | | | | | | | | | | | | | | | |
| 5. | BDP Final Report | | | | | | | | | | | | | | | |
| 6. | BDP Presentation | | | | | | | | | | | | | | | |

# Appendix C: SimpliFiber® Optical Power Level and Optical Power Mete


| Environmental Specifications | |
|---|---|
| Environmental Specifications | |
| Operating Temperature | -10º C to 50º C |
| Storage Temperature | -20º C to 50º C |
| Operating Humidity | 95% (10º C to 35º C) Non-Condensing 75% (35º C to 40º C) Non-Condensing Uncontrolled <10º C |
| EMI, RFI, EMC | Standards compliant[1] |

[1]Conforms to relevant European Union directives; Conforms to relevant Australian standards; Listed by the Canadian Standards Association; Complies with 21CFR.1040.10,11, and EN60825-1, 2:2007 (Class 1, Hazard Level 1)

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| Optical Power Meter | |
|---|---|
| Optical Power Meter | |
| Detector Type | InGaAs |
| Calibrated Wavelengths | 850 nm, 1300 nm, 1310 nm, 1490 nm, 1550 nm, 1625 nm |
| Measurement Range | +10 to -52 dBm (850 nm)<br>+10 to -60 dBm (1300, 1310, 1490, 1550, 1625 nm) |
| Power Measurement Linearity | ±0.2 dB (850 nm)[1] ±0.1 dB (1300, 1310, 1490, 1550, 1625 nm)[2] |
| Power Measurement Uncertainty[3] | ±0.25 dB |
| Display Resolution, dB or dBm | 0.01 dB |
| Auto Dual-Wavelength Switching | Yes |
| Power Display Units | dBm, mW, µW |
| Auto-Wavelength Detection | Yes |
| Data Storage | 1000 records, multiple wavelengths per record |
| External Interface | USB, 2.0 full speed |
| Optical Connector | Removable adapter, SC adapter as default, optional adapters include LC, ST |
| Display update rate | 1 reading per second |
| Reference | Individually set for each wavelength |
| FindFiber ID detection | Yes |
| Power Requirement | 2 AA Alkaline batteries |
| Battery Life[4] | > 50 Hours (typical) |
| Automatic Power Off | 10, 20, 30 or 60 minutes (can be disabled by user) |
| Low Battery Warning | Yes, low battery icon blinks |
| Size (L x W x H) | 6.4 in x 3.2 in x 1.5 in (16.5 cm x 8.0.cm x 3.9 cm) |
| Weight | 11.5 oz (325 grams) |

[1]For 850nm, ±0.2 dB for power from 0 to -45 dBm, ±0.25 dB for power < -45 dBm
[2]±0.1dB for power from 0 to -55 dBm, ±0.2 dB for power > 0 dBm and < -55 dBm
[3]23°C ±2°C, power level -20dBm, continuous wave, 62.5/125µm at multi mode wavelengths, 9/125 µm at 1310,1490, 1550 and 1625 nm; add 0.1 dB for 1625 nm,
[4]For measured power levels 0 dBm or less, battery life depends on the condition and type of batteries used. Fluke Networks recommends alkaline batteries.

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[2]±0.1dB for power from 0 to -55 dBm, ±0.2 dB for power > 0 dBm and < -55 dBm
[3]23°C ±2°C, power level -20dBm, continuous wave, 62.5/125µm at multi mode wavelengths, 9/125 µm at 1310,1490, 1550 and 1625 nm; add 0.1 dB for 1625 nm,
[4]For measured power levels 0 dBm or less, battery life depends on the condition and type of batteries used. Fluke Networks recommends alkaline batteries.

| Singlemode Optical Source | |
|---|---|
| Singlemode Optical Source | |
| Emitter Type | 1310 nm/1550 nm: dual FP laser<br>1490 nm/1625 nm: dual DFB laser |
| Central wavelength | 1310 nm: ±20 nm<br>1550 nm: ±30 nm<br>1490 nm: ±3 nm<br>1625 nm: ±5 nm |
| Wavelength Accuracy | 1310 nm: +/- 20 nm<br>1550 nm: +/- 30 nm |
| Spectral width (RMS) | 1310 nm: 2 nm (maximum)<br>1550 nm: 3 nm (maximum)<br>1490 nm/1625 nm: 1 nm (maximum) |
| Minimum output power | 1310/1550 nm ≥ -7dBm (typical)<br>1490 nm/1625 nm: ≥ -3 dBm (typical) |
| Power Output Stability[1] | ±0.25 dB over 8 hours |
| Auto Dual-Wavelength Switching | Yes. Can be enabled or disabled by user. |
| Optical Connector | Fixed SC |
| Launch Condition | 9/125 µm fiber |
| FindFiber Code Generation | 1310/1550 source is fixed at ID 2<br>1490 nm/1625 nm is fixed at ID 3. |
| Modes | CW, 2 kHz modulated, Auto-wavelength |
| Power Requirement | 2 AA Alkaline batteries |
| Battery Life[2] | 30 hrs (typical) |
| Automatic Power Off | 30 minutes (can be enabled or disabled by user) |
| Low Battery Warning | LED blinks. |
| Size (L x W x H) | 5.6 in x 3.2 in x 1.6 in (14.2 cm x 8.1 cm x 4.1cm) |
| Weight | 9.8 oz (278 grams) |

[1] 23° C ± 2° C, after 5 minutes warm-up time
[2] In auto-wavelength mode, battery life depends on the condition and type of batteries used. Fluke Networks recommends alkaline batteries.

[1] 23° C ± 2° C, after 5 minutes warm-up time
[2] In auto-wavelength mode, battery life depends on the condition and type of batteries used. Fluke Networks recommends alkaline batteries.

# Appendix D: Commercial Splicer Fujikura FSM-18R

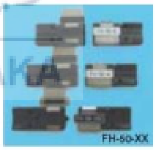
| SPECIFICATIONS | |
|---|---|
| **Applicable fibres** | SM (ITU-T G.652), MM (ITU-T G.651), DS (ITU-T G.653), NZDS (ITU-T G.655) |
| **Fibre Count** | Single, 2 and 4 |
| **Cladding diameter** | 125μm |
| **Coating diameter** | Ribbon fibre thickness 250 and 400μm. Single fibre 250 and 900μm |
| **Fibre cleaved length** | 10mm using FH-50-xx fibre holders, FH-60-250 and FH-60-900 |
| **Actual average splice loss** | 0.05dB with SM, 0.02dB with MM, 0.08dB with DS, 0.08dB with NZDS.<br>Measured by cut-back method relevant to ITU-T standards. |
| **Splice time** | Typical 20sec. with standard SM fibre. |
| **Return loss** | 60dB or greater |
| **Splicing modes** | Total number available equals 100; for pre-set modes and user programmable modes |
| **Splice loss estimate** | Cladding axis offset are taken into account for accurate loss estimate. |
| **Storage of splice result** | The last 2000 results to be stored in the internal memory. |
| **Fibre display** | X/Y, or both X and Y simultaneously |
| **Magnification** | 35x for single X or Y view, or 35x for X and Y view changeable to 90x. |
| **Viewing method** | By two CMOS cameras for fibre viewing and 4.1inches TFT colour LCD monitor |
| **Image change over** | The fibre image is turned upside down automatically according to the monitor position. |
| **Operating condition** | 0-3660m above sea level, 0-95% RH and -10 to 50°C respectively. |
| **Mechanical proof test** | 2N (standard) |
| **Tube heater** | Built-in auto-start tube heater with 10 heating modes and up to 20 for reference |
| **Tube heat time** | Typical 40sec.with FP-03 protection sleeve. |
| **Applicable protection sleeve length** | 60mm, 40mm and a series of micro sleeves. |
| **No. of splice/heating with battery** | 90 cycles with BTR-08. |
| **Power supply** | Auto voltage selection from 100 to 240Va.c. or 10 to 15Vd.c. with ADC-13. 13.2Vd.c. with BTR-08 |
| **Terminals** | USB1.1 (USB-Mini B) for data and video signal transfer to PC. |
| **Wind protection** | Max. wind velocity of 15m/s. |
| **Dimensions** | 136(W) x 161(D) x 143(H) mm |
| **Weight** | 2.1kg, with ADC-13 AC Adaptor, 2.5kg, with BTR-08 Battery |

**STANDARD PACKAGE**

| Description | Model No. | Q'ty | Note |
|---|---|---|---|
| Arc Fusion Splicer | FSM-18R | 1pc. | -- |
| Electrodes | ELCT2-20A | 1 pair | Installed |
| Wind Protector Mirror | WPM-08 | 2pc. | Installed, replaceable by user |
| AC Adaptor/Battery Charger | ADC-13 | 1pc. | -- |
| AC Power Cord | ACC-xx | 1pc. | ACC-16 UK Type |
| Spare Electrodes | ELCT2-20A | 1 pair | -- |
| USB Cable | USB-01 | 1pc. | -- |
| Quick Reference Guide | M-60S/18S-E | 1pc. | English |
| Video Instruction Manual | V-60S-E | 1pc. | CD, English |
| Warning & Cautions | W-60-E | 1pc. | English |
| Splicing Report | - | 1pc. | English |
| J-Plate | JP-05 | 1pc. | -- |
| Carrying Case | CC-24-18R | 1pc. | -- |


**OPTIONAL ITEMS**

| Description | Model No. | Note |
|---|---|---|
| Battery Pack | BTR-08 | -- |
| Battery Charge Cord | DCC-14 | Use for connecting BTR-08 and ADC-13 |
| DC Power Cord | DCC-12 | For ADC-13, cigar lighter socket type |
| | DCC-13 | For ADC-13, alligator clamp type |
| Magnifier | MGS-06 | With bracket |
| Electrodes | ELCT2-20A | -- |
| Wind Protector Mirror | WPM-08 | -- |


Specifications and descriptions are subject to change without prior notice

**OPTIONAL FIBRE HOLDERS**

| Fibre | Single (0.25mm) | Single (0.9mm) | 2-fibre ribbon | 4-fibre ribbon |
|---|---|---|---|---|
| **Model No.** | FH-60-250 | FH-60-900 | FH-50-2 | FH-50-4 |

Fujikura EUROPE LTD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