

Faculty of Electrical and Electronic Engineering Technology



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Bachelor of Electronics Engineering Technology with Honours

2021

Development of Fiber Optic Sensor using Different Type of Cooking Oil.

SHAMSUL BIN MOHAMAD

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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DECLARATION

I declare that this project report entitled "Development of Fiber Optic Sensor using Different Type of Cooking 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.

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APPROVAL

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DEDICATION

My special dedication goes to my beloved parents, siblings and friends who always support me behind and who always encourage me to help me finish final year project successfully. Meanwhile, I dedicate this thesis to my beloved supervisor, DR AMINAH BINTI AHMAD and co. supervisor, DR MD ASHADI BIN MD JOHARI who had taught me a lot and guided me how to achieve success for my final year project. I am humbled and grateful for their sacrifice, patience, and consideration, which were unavoidable in order for this attempt to be considered. I'm at a loss for words to express how grateful I am for their dedication, support, and belief in my abilities to achieve my goals. Thank you very much. I appreciate it.



ABSTRACT

Fiber optics, commonly referred to as optical fiber, is a medium and system for transmitting information as light pulses over a glass or plastic strand. When light signals are transmitted through fiber optic cable, they bounced off the core and cladding in a sequence of zig-zag bounces, a phenomenon known as total internal reflection. Recently, fiber optic sensors receive considerable research efforts due to their high sensitivity, detection speed, and ability to use harsh environments. The bjective of this project was to use fiber optics as a liquid sensor to detect varying types of cooking oil. The end product will provide a better knowledge of fiber optic sensors and might be used other fields such as the food business. There will be three cooking oil samples tested: palm oil, olive oil, and corn oil. Before each test, the fiber would be dipped in the cooking oils and then measured. In a line graph, each measurement would have different results. The experiment's findings will be described in terms of sensitivity, correlation, and coefficient of determination of the graph, all of which are completely dependent on the cooking oil concentration and light source.

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ABSTRAK

Serat optik, biasanya disebut sebagai serat optik, adalah media dan sistem untuk mengirimkan maklumat sebagai denyut cahaya di atas helai kaca atau plastik. Apabila isyarat cahaya dihantar melalui kabel gentian optik, mereka memantul dari teras dan melekap dalam urutan memantul zig-zag, fenomena yang dikenali sebagai pantulan dalaman total. Barubaru ini, sensor gentian optik mendapat banyak usaha penyelidikan kerana kepekaannya yang tinggi, kelajuan pengesanan, dan kemampuan untuk menggunakan persekitaran yang keras. Objektif projek ini adalah menggunakan gentian optik sebagai sensor cecair untuk mengesan pelbagai jenis minyak masak. Produk akhir akan memberikan pengetahuan yang lebih baik mengenai sensor serat optik dan mungkin digunakan dalam bidang lain seperti perniagaan makanan. Terdapat tiga sampel minyak masak yang diuji: minyak sawit, minyak zaitun, dan minyak jagung. . Sebelum setiap ujian, serat akan dicelupkan ke dalam minyak masak dan kemudian diukur. Dalam grafik garis, setiap pengukuran akan mempunyai hasil yang berbeza. Penemuan eksperimen akan dijelaskan dari segi kepekaan, korelasi, dan pekali penentuan graf, yang semuanya bergantung sepenuhnya pada kepekatan minyak masak dan sumber cahaya.

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ACKNOWLEDGEMENTS

First and foremost, I want to thank Allah the Almighty for providing me with the strength, health, and patience to finish this work. I'd like to thank my supervisor, DR AMINAH BINTI AHMAD and co. supervisor, DR MD ASHADI BIN MD JOHARI, for their invaluable advice, wise words, and patience during this research.

I am also indebted to Universiti Teknikal Malaysia Melaka (UTeM) for the financial support through lending me all the equipment that are needed which enables me to accomplish the project. Not forgetting my fellow colleague, Syazwan, Amiruddin, Diana and Daniel for the willingness of sharing his thoughts and ideas regarding the project.

WALAYS/4

My highest appreciation goes to my parents, and family members for their love and prayer during the period of my study. Finally, I would like to thank all the staffs at the Faculty of Electronics and Computer Engineering, fellow colleagues 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

	-	the refractive index of the medium the light is leaving
n 1		
θ_1	-	the incident angle between the light beam and the normal
n 2	-	refractive index of the material the light is entering

 θ_2 - the refractive angle between the light ray and the normal



LIST OF ABBREVIATIONS

OSA - Optical Spectrum Analayzer



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CHAPTER 1

INTRODUCTION

1.1 Background

Fiber optics, commonly referred to as optical fiber, is a medium and system for transmitting information as light pulses over a glass or plastic strand or fiber. Fiber optics is used in data networking for long-distance and high-performance communication. Fiber optics convey data using light particles, or photons, that pulse via a fiber optic connection. Each glass fiber core and cladding has a particular refractive index, which bends the incoming light at a distinct angle. When light signals are transmitted through fiber optic cable, they bounced off the core and cladding in a sequence of zig-zag bounces, a phenomenon known as total internal reflection.

Recently, fiber optic sensors receive considerable research efforts due to their high sensitivity, detection speed, and ability to use harsh environments. A few types of fiber optics but commonly used right now are multimode fiber and single-mode fiber. Because of the smaller diameter of the glass fiber core, which reduces attenuation probability, single-mode fiber is employed over longer distances. In comparison, its broader core diameter allows light signals to bounce and reflect more along the way. On the other hand, multimode fiber is employed for shorter distances. This research is about the Development of Fiber Optic Sensor using Different Type of Cooking Oil. This project requires an SMF28 optical cable under test, a laser source with a wavelength of 1550nm, an Optical Spectrum Analyzer (OSA) and three different cooking oil. And each oil is tested three times, and the results will be the value of loss (dB) at the peak of the spectrum acquired from the OSA instrument. By the end of the project, a single optical concentration with great sensitivity has been established.

1.2 Problem Statement

Currently, health is at the top of humanity's priority list. To be healthy, people must always monitor the amount of fat and cholesterol in their diet. It offers two options: exercise or dietary control. In each of cooking oil used nowadays have their concentration, so we are interested in knowing which oil has better concentration. There are three types of cooking oil under study: palm oil, olive oil, and corn oil. Therefore, fiber optic has been chosen to check each concentration of cooking oil.

1.3 Project Objective

The objectives for this project are as stated below:

- a) To study the fiber optic sensor for varied cooking oils concentration detection.
- b) To develop a Fiber Optic Sensor for varied cooking oils concentration detection.
- c) To optimize the performance of fiber optic sensor for concentration detection activities

1.4 Scope of Project

This project's scope is to study fiber optic sensors and develop the fiber optic sensor for varied cooking oil concentration detection. The developed sensors will also be analyzed for their performance. This project ensures the project is heading in the right direction to achieve its objectives.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, we will go over the literature review. The identical parts have been offered to ensure that all data concerning this project may be classified. Several topics are crucially relevant in this section, such as those listed below, where they can be planned and executed correctly and in a timely and effective manner. This chapter also discussed fiber optic sensing, the application of fiber optic in various fields and some important works related to this project.

2.2 Fiber optic

Originally, fiber optic cable was known as the bundle of glass, transmitting modulated lightwave as massage data. Its capability has been tested over years which are more advantageous than metal cable in data transmissions. The optical fiber consists of the core and the cladding, which have different refractive indexes. The light beam travels through the core by repeatedly bouncing off the wall of the cladding. Fiber optic cable is used to transport data from an optical power source to an output device such as an optical power tester or an optical spectrum analyzer. Depending on the power and transmission distance requirements, the fibers are supposed to help propagate light in conjunction with the optical fiber.

The idea of total internal reflection governs the optical fiber's functioning. Light rays are capable of transmitting vast volumes of data. So, unless we have a long straight wire with no bends, leveraging this benefit will be tough. In contrast, optical devices are designed to bend all light rays inwards (using TIR). As a result, light beams bounce off fiber optic walls forever, transferring data from one end to another. Although light signals degrade with time, mostly on the purity of the material used, the loss is significantly less than when metal wires are used.



Figure 2.1: Total Internal Reaction (TIR) of Fiber Optic

There are few advantages when dealing with fibers. Firstly, its tiny size and cylindrical design integrate well into a wide range of structures, such as composite materials, with minimum interference. Next is Fiber optics are resistant to EMI, although they are combustible and hazardous to the environment. Finally, aside from being lightweight and sensitive, it is also more resistant to hard environmental conditions such as severe high and low temperatures, vibration, radiation, pressure, and corrosive environments.

There are two types of fiber optics which are plastic optical fiber and glass optical fiber. The usage determines the types of fiber optics used.

2.2.1 Plastic types

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Figure 2.2: Plastic Optical fiber

The plastic fiber core is made up of one or more fiberglass fibers 0.25 to 1 mm in diameter that is enclosed in a polyethene sheath. Plastic fibers are the most prevalent form of fiber sensor because they are light, inexpensive, and flexible. It uses red and green light

that is safe for the eyes and maybe put at home without endangering others. There are a few pros and cons when using plastic fibers.

Advantages	Disadvantages		
has a wide range of diameters	narrower numerical aperture,		
which ranging from 0.15mm up to 20mm	which ranges from 0.48 to 0.63		
more flexible and able to bend	has low light gathering capability,		
farther without cracking or breaking	which makes it capture less light		
can withstand vibration and unsteady	not able to withstand harsh		
environments [1]	environments, and the fiber will easily		
	degrade over time		

Table 2.1: Advantages and Disadvantages of Plastic Fiber



Figure 2.3: Glass Optical Fiber

Glass optical fiber normally consists of pure glass or silica, SiO_2 as the core material and less pure glass or plastic as the cladding material [1]. It offers various benefits over plastic optical fiber. First, it has a wider numerical aperture for starters, letting more light into the system and varies from 0.25 to 1. Second, it can endure temperatures as low as -40F and as high as +900F. As a result, it is helpful and may be used in various applications such as ovens, engines, and cold storage. Unfortunately, it also has a few drawbacks, including a limited diameter size range of 0.05mm to 0.15mm and is more delicate and prone to breaking if not managed properly. Furthermore, it is more difficult to manage and fragile than plastic optical fiber. As a result, the cost of implementing glass optical fiber is higher.

Consideration	Glass optical fiber	Plastic optical fiber	
Cost	More expensive	Cheaper	
Transfer speed	Faster	Slower	
Loss	Lower losses	Higher losses	
Numerical Aperture	Higher	Lower	
Temperature	Able to withstand extreme	Not suitable for extreme	
AL MALAY	temperature	temperature	
Flexibility	More fragile	More flexible	
Distance	Can be used for longer	Can be used for shorter	
II.	distance	distance	

Table 2.2: Comparison Between Plastic And Glass Optical Fiber

```
2.3 Single Mode Fiber
```



Figure 2.4: Single mode core and Cladding Measurement

As seen in the figure above, SMF has a modest core diameter of 8 to 9 m and a cladding diameter of 125 m. As a result, the core-to-cladding ratio is typically 9:125. Due to the narrow diameter design of the core only allows one light path of propagation, as displayed in Figure 2.4[2].



Figure 2.5: Step-index Single Mode

The benefit of having a tiny diameter is that light may travel longer with little attenuation due to the extremely low light reflection when it travels through the core. As a result, it has minimal data losses and a higher data transfer capacity, making it suited for communication. It can send data up to 40 GB over hundreds of kilometres with less data loss and quicker than MMF.

2.4 Fiber Optic as A Sensor

Recent advancements in fiber optic technology have substantially altered the telecommunications business. The capacity of optical fibers to transmit gigabits of data at light speed expanded their potential for study. Simultaneous improvements and lower costs in optoelectronic components led to the emergence of analogous new product categories. The previous revolution emerged as engineers combine the product outgrowths of fiber optic telecommunications with optoelectronic devices to create fiber optic sensors. It was soon discovered that material loss almost disappearing and the sensitivity to loss detection increased phase, intensity, and wavelength changes from external disturbances on the fiber itself could be sensed. Hence a sensor by using fiber optic was created [3].

The wavelength modulated fiber optic sensors are next, which detect changes in the wavelength of light. Fluorescence sensors, black body sensors, and the Bragg grating sensor are all examples of wavelength-modulated sensors. Fluorescent-based fiber sensors are widely utilized in medical applications, chemical sensing, and physical parameter measurements such as temperature, viscosity, and pressure. Bragg Grating Sensor is the most widely used wavelength-based sensor. Fiber Bragg gratings (FBGs) are created by periodic changes in the refractive index inside the centre of a single mode optical fiber. This periodic increase in refractive index is usually generated by exposing the fiber core to an extreme

UV-energy interference pattern. The variation in the refractive index thus generated forms a pattern of interference that acts as a grating [3] [4].

Finally, the phase modulated fiber optic sensor detects light in the phase using changes in the phase. The detected field modifies the optical phase of the light travelling through the fiber. The phase modulation is then detected interferometrically by compared the light phase in the signal fiber to the light phase in the reference's fiber.

2.5 Total Internal Reflection

The guiding of light through the fiber is based on the principle of total internal reflection. The angle at which total internal reflection occurs is called the critical angle of incidence [3]. According to the diagram below, light constantly reflects inside the core and cannot escape to the outside when the angle of incidence exceeds a critical angle. Thus, light normally propagates in a straight path; however, when the light changes due to a change in the degree of freedom, light reflection occurs. The reflection and refraction of light occur when there is an unexpected phase shift or phase discontinuity at the interface between two mediums [5].



Figure 2.6: Total Internal Reflection Inside the Core

2.5.1 Refractive and Reflective

Total internal reflection happens when a propagating wave strikes a medium barrier at an angle greater than a specific critical angle with respect to the normal surface. For example, if the refractive index on the other side of the boundary is less than the critical angle and the incidence angle is greater than the critical angle, the wave cannot pass through. The critical angle is defined as the incidence angle above which the entire internal reflectance is visible. Aside from that, light refraction happens when a light beam changes direction as it passes from one transparent substance to another.



Figure 2.7: Total Internal Reflection

Snell's law outlines the connection between incident angle and refracted light angle at two distinct media interfaces. According to Snell's law, the ratio of incidence and refractive angles is identical to the ratio of phase velocities in the two mediums. Therefore, it is also equivalent to the reciprocal of the refractive index ratio.



Figure 2.8: Snell's Law Concept

Based on Figure 2.8, Snell's law can be expressed as:

$$n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$$

Where:

*n*¹ is the refractive index of the medium the light is leaving.

 θ_1 is the incident angle between the light beam and the normal (normal is 90° to the interface between two materials).

 n_2 is the refractive index of the material the light is entering.

 θ_2 is the refractive angle between the light ray and the normal.



CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter covers the design process for Single Mode Fiber optic sensors. It covers details of the tools and components utilized and the sensor-making process, prototype design, and other topics. The proposed research aims to create a sensor that can detect concentration at different types of cooking oils.



3.2 Flowchart

Figure 3.1: Project Flowchart

By referring the Figure 3.1, the project starts with the preparation of a fiber optic sensor. There are three setups as there are three types of cooking that will be used. The fiber that is chosen to be used as the sensor is single fiber mode 125nm. All the fiber are cut using the same length to reduce the loss when the experiment being conducted. The cladding part that will be strip off to use as the sensor also be strip using the same length.

The next step is preparing three plastic containers that will be used as the experiment's testing place. First, the container will be punctured to fit in the fiber. Then the container will be filled with three types of oil (olive oil, corn oil, and palm oil).

After the setup is done, the optical spectrum analyzer will emit a beam to the fiber, and the result will be shown on the screen. Each fiber will be tested at least three times to get an average measurement, and the result was recorded. Following the result of the fibers, the results will be analyzed and summarized in the form of a table and graph. In conclusion, the concentration on various types of oil will be identified.

3.3 Method of project

There are a few methods in order to develop the structure of the sensor. However, they can be achieved by doing all the procedure below.

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3.3.1 Splicing Process



Firstly, a fiber optic cable stripper is used to remove the coating layer of Single Mode Fiber. After that, the fibers are cleaned with alcohol to eliminate any remaining coating or dust. After that, the fiber is cleaved off using a Fujikura CT-30 high-quality cleaver to achieve flat faces.

The Fujikura FSM-18R splicing tool is used to join two fibers that have been stripped of their cladding and cleaned. Then, the fiber will be placed on the splicer, with the fibers aligned in the same location. The completed procedure on how to splice is shown in Table 3.1.



 Table 3.1: Complete procedure on how to splice using Fujikura FSM-18R



3.3.2 Experimental Setup



Single mode fiber optic sensors are linked to an Optical Power Level at the input to test oil concentration. Optical power level emit 1550nm wavelength to the fibre. And from there the optical power meter capture the result in dBm.

Each oil will be placed into the container that has been set up before the trial testing. In the prepared container, the sensor is put to the test. The sensor will be tested three times with the same kind of oils to achieve an average measurement. Each kind of oil will undergo the same process.

The results are analyzed based on the type of oils and their respective concentration. Then, the result was used to tabulate the graph to observe the concentration for each of the oils.

3.4 Tools and materials

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Table 3.2 illustrate all the equipment that used in the project



Table 3.2: Equipment that used in the project





11	Impra board 27" x 30"	-to place the fiber after the	
		fiber been splice	
	AND ADDRESS OF THE OWNER OWNER OF THE OWNER	-used as main setup place	
		for the experiment	
	ATTACA AND A A A A A A A A A A A A A A A A A		
	ARABASASASASASASASASASASASASASASASASASAS		
12	Olive oil, Corn oil, Palm oil	-main equipment to	
		experiment	
	Alun		
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CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results and analysis on the development of fiber optic sensor using different type of cooking oil. Case studies are performed to demonstrate the sensitivity of fibre optic cable. The case study is using real cooking oil as to know the sensitivity of each cooking oil. It is important to note that, these case study aims at illustrating the proposed methodology, regardless of the types of cooking oil use. Each of the cooking oil are using the proposed approach which is to test each cooking oil three time to gain the average value of each oil. Each test were taken around 30 minute each.

4.2 **Results and Analysis**

Table below is the analysis for oil testing result. These analyses are separated into several information which are the time, number of tests, average value for each time taken, the percentage of the linear and sensitivity.

4.2.1 Result for Corn Oil TEKNIKAL MALAYSIA MELAKA

TIME	Test 1	Test 2	Test 3	Average
30	7.9	7.81	7.76	7.823
27	7.86	7.78	7.81	7.817
24	7.88	7.78	7.81	7.823
21	7.86	7.79	7.81	7.820
18	7.75	7.79	7.75	7.763
15	7.7	7.79	7.76	7.750
12	7.69	7.77	7.75	7.737
9	7.65	7.78	7.76	7.730
6	7.64	7.78	7.76	7.727
3	7.64	7.78	7.76	7.727
0	7.65	7.82	7.78	7.750

Table 4.1 data collected for the experiment

	cycle 1	cycle 2	cycle 3	total
sensitivity	0.0101	-0.00003	0.0011	0.0037
linearity	94.11	1.73	42.88	87.73

 Table 4.2 sensitivity and linearity

The first analysis is based on test or cycle of test that being conducted during the test. The sensitivity for the first test is higher that value than the second and third test. This show that corn oil has unstable sensitivity maybe due to the error when the experiment is being conducted. Next is the linearity of each cycle of test, the linearity for corn oil is obtained using the average value of all the three cycles. From this cycle we can clearly say that the first cycle has the highest concentration value compare the other two cycle. The first cycle has the correlation almost perfect (equal to 1), 94.11% of the corn oil particles interacted with light source travelled through it and the sensitivity value is higher than the other cycles.



Figure 4.1 repeatability of corn oil



Figure 4.2 sensitivity Corn Oil

The figure above shows the overall result for corn oil. The three different lines in the graph are for repeatability (fig 4.1) and one line for sensitivity (fig 4.2). The corn 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). There is different trend where the cycle when downhill and then back up to the original value. This analysis determine that corn oil can use fibre optic sensor to sense sensitivity.

4.2.2 Result for Olive Oil

masa	test 1	test 2	test 3	Average
30	30 7.32		7.29	7.313
27	27 7.34		7.3	7.313
24	7.34	7.34	7.3	7.327
21	7.33	7.33	7.33	7.330
18	7.3	7.31	7.32	7.310
15	7.31	7.28	7.33	7.307
12	7.32	7.33	7.32	7.323
9	7.34	7.3	7.3	7.313
6	7.34	7.34	7.28	7.320
3	7.33	7.34	7.31	7.327
0	7.33	7.32	7.31	7.320

1 able 4.5 data collected for the experiment	AK	experiment	or the e	collected	data	4.3	Table	/EF	VIV	J
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	cycle 1	cycle 2	cycle 3	total
sensitivity	-0.0002	-0.0002	-0.00006	-0.0001
linearity	11.18	33.32	3.74	18.30

	Table 4.4	sensitivity	and	linearity	for	Olive	Oil
--	-----------	-------------	-----	-----------	-----	-------	-----

The first analysis is based on test or cycle of test that being conducted during the test. The sensitivity for the first test is higher that value than the second and third test. This show that olive oil has lower sensitivity. Next is the linearity of each cycle of test, the linearity for olive 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 olive oil. The second cycle has the highest correlation, which is only 33.32%.



Figure 4.3 repeatability Olive Oil



Figure 4.4 sensitivity Olive Oil

The figure above shows the overall result for olive oil. The three different lines in the graph are for repeatability (fig 4.3) and one line for sensitivity (fig 4.4). The olive 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 olive oil has inclination for each cycle. This analysis determine that olive oil does not have great sensitivity to become a sensor when using fiber optic.

4.2.3 Result for Palm Oil

masa	test 1	test 2	test 3	average
30	7.32	7.34	7.34	7.333
27	7.31	7.33	7.34	7.327
24	7.32	7.34	7.35	7.337
21	7.31	7.31	7.3	7.307
18	7.31	7.3	7.32	7.310
15	7.3	7.3	7.31	7.303
12	7.29	7.29	7.31	7.297
9	7.29	7.3	7.31	7.300
6	7.3	7.33	7.3	7.310
3	7.29	7.33	7.31	7.310
0	7.28	7.32	7.3	7.300

 Table 4.5 data collected for the experiment

	cycle 1	cycle 2	cycle 3	total
sensitivity	0.0012	0.0005	0.5977	0.001
linearity(%)	90.81	26.89	77.31	74.04

Table 4.6 sensitivity and linearity for Palm Oil

The first analysis is based on test or cycle of test that being conducted during the test. The sensitivity for the first test is higher that value than the second and third test. Next is the linearity of each cycle of test, the linearity for palm oil is obtained using the average value of all the three cycles. From this cycle we can clearly say that the first cycle has the highest concentration value compare the other two cycle. The first cycle has the correlation almost perfect (equal to 1), 90.81% of the corn oil particles interacted with light source travelled through it and the sensitivity value is higher than the other cycles.



Figure 4.5 repeatability Palm Oil



Figure 4.6 sensitivity Palm Oil

The graph above shows the overall result for palm oil. The three different lines in the graph are for repeatability (fig 4.5) and one line for sensitivity (fig 4.6). The corn 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 trend for palm oil are showing that the value going uphill than the original value. This analysis determine that palm oil can use fibre as sensor to check their sensitivity.

4.3 Summary ERSITI TEKNIKAL MALAYSIA MELAKA

This chapter presented case studies to demonstrate applicability of the proposed system of development of fiber optic sensor using different type of cooking oil. The case study is based on three (3) different types of cooking oil that has been use to be experimented on. The three (3) cooking oil selected for the case study are made by three different ingredient, which are: (i) corn oil, (ii) olive oil, (iii) palm oil. All of the experiment is using the proposed approach over a 30-minute period. Using standard Optical Power Meter and Fiber Test Kits , the experiment use the experiment setup (presented in Chapter 3) the data being collected. The result for each cooking oil shows that only corn oil and palm oil is suitable to use fibre optic as their sensor.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This thesis presents a method for Development Of Fiber Optic Sensor Using Different Type Of Cooking Oil. The proposed methodology is effective and robust in order to obtain good results utilizing only fairly accurate information and with a minimum network measurement information. The proposed analytical approach of using sensitivity and linearity to obtained the correlation for each cooking oil.

Overall, the research presented in this thesis has succeeded in making a contribution to understanding the importance of sensor in fibre optic . The presented method makes reasonable use of a limited amount and type of data, employs straightforward mathematical manipulations, and requires fewer intensive calculations whereas still producing quick, convincing, reflective, and relatively accurate results. Additionally, the work focused on the creation of methodologies that facilitate the growth of low-cost sensors that are entirely based on optical fiber sensing. As such, it lays the groundwork for the proposed additional research.

5.2 **UNIVERSITI TEKNIKAL MALAYSIA MELAKA** Future Works

For future improvements, accuracy of the sensor in sensing results could be enhanced as follows:

 Using high technology machine such as optical spectrum analyzer to perfome the the experiment as when using the optical fiber test kit, there might be some error as the data was taken manually

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APPENDICES

Appendix A Example of Appendix

No.	Parameters	No.	Parameters
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Appendix B Example of Appendix B