CHARACTERIZATION OF FUEL DELIVERY SYSTEM COMPONENTS IMMERSED IN DIFFERENT RATIO OF PALM OIL BLENDED WITH DIESEL

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Progress Report II

Projek Sarjana Muda

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SUPERVISOR'S DECLARATION

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ABSTRACT

Due to high demands of diesel todays either for transportation or industry, a lot of study conducted as the pure diesel that extract from the fossil fuel is very harmful to environment and to us living things. Besides, the source of fossil nowadays is limited and one day the fossil fuel will not be found in the earth. Therefore, the alternative fuel is study and investigated to replace the pure diesel such biodiesel that extract from plant. One of the possible biodiesels and Malaysia have many sources of it is Palm Biodiesel. Compare to pure diesel, the exhaust gasses produce from combustion of biodiesel is low in harmful gases such Sulphur dioxide.

Malaysia Palm Oil Berhad (MPOB) give a grant to Universiti Teknikal Malaysia Melaka (UTeM) to perform a study of biodiesel effect on the existing car. One of the proposed study is the degradation of elastomer towards exposure to current implemented biodiesel (B10) and the new blend biodiesel (B30). Therefore, the degradation of elastomer in terms of mass change and mechanical properties such tensile test is perform. The testing is following ASTM D471 for soaking test and mass test. As for tensile test is following ASTM D412.

ABSTRAK

Oleh kerana permintaan diesel yang tinggi hari ini baik untuk pengangkutan atau industri, banyak kajian dilakukan kerana diesel tulen yang mengeluarkan dari bahan bakar fosil sangat berbahaya bagi alam sekitar dan bagi kita makhluk hidup. Selain itu, sumber fosil pada masa kini adalah terhad dan suatu hari bahan bakar fosil tidak akan dijumpai di bumi. Oleh itu, bahan bakar alternatif dikaji dan dikaji untuk menggantikan diesel tulen seperti biodiesel yang dihasilkan daripada tumbuhan. Salah satu kemungkinan biodiesel dan Malaysia mempunyai banyak sumbernya adalah Minyak Sawit. Jika dibandingkan dengan diesel tulen, gas ekzos yang dihasilkan dari pembakaran biodiesel rendah gas berbahaya seperti Sulfur dioksida.

Malaysia Palm Oil Berhad (MPOB) memberikan geran kepada Universiti Teknikal Malaysia Melaka (UTeM) untuk melakukan kajian mengenai kesan biodiesel pada kereta yang ada pada hari ini. Salah satu kajian yang dicadangkan adalah penurunan gred elastomer terhadap pendedahan kepada biodiesel yang dilaksanakan sekarang (B10) dan biodiesel campuran baru (B30). Oleh itu, penurunan elastomer dari segi perubahan jisim dan sifat mekanik seperti ujian tegangan dilakukan. Ujian ini mengikuti ASTM D471 untuk ujian rendaman dan ujian jisim. Adapun ujian tegangan mengikuti ASTM D412.

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LIST OF ABBREVIATIONS

MPOB	Malaysia Palm Oil Board
EPA	Environmental Protection Agency
ULSD	Ultra Low Sulphur Diesel
ASTM	American Society for Testing and Materials
EN	European Standards
ISO	The International Organization for Standardization
NBR	acrylonitrile butadiene rubber
FKM	fluoroelastomer
CR	polychloroprene rubber
SR	Silicone Rubber
HNBR	Hydrogenated acrylonitrile butadiene rubber
EPDM	Ethylene-Propylene-Diene rubber
ACM	Acrylic rubber
ECO	Epichlorohydrin
SBR	Styrene Butadiene Rubber
FDM	Fuel Delivery System
GHG	Greenhouse Gas

EMA	Exponential Moving Average
FAME	Fatty Acid Methyl Esters
NaOH	Sodium hydroxide
KOH	Potassium hydroxide
CN	Cetane Number
CI	Compression Ignition
CO_2	Carbon Dioxide
TPE	Thermoplastics
RTC	Real Time Clock
AMCHAL	Advanced Materials Characterization Laboratory

LIST OF SYMBOLS

ºC Degree Celsius

ºF Degree Fahrenheit

vol% Volume percentage

CHAPTER 1

INTRODUCTION

1.1 Background

Diesel fuel commonly used for transportation such as trucks, buses, and trains. Besides, it is also used to move a diesel engine to produce electricity especially for their emergency power supply. Petroleum diesel which is also known as petro diesel or fossil diesel is a common type of diesel used. Crude oil is refined by undergoes fractional distillation between 200^{o}C (392^{o}F) and 350^{o}C (662^{o}F) at atmospheric pressure which will produce a mixture of carbon chains (Trakarnpruk and Porntangjitlikit, 2008) But there are some disadvantages from using diesel fuel and some of it is harmful to human health as the combustion of diesel contained high quantities of Sulphur (Singh *et al.*, 2019). In 2006, U.S. Environmental Protection Agency (EPA) issued requirement to reduce the Sulphur content and create a standard to be follow by the petroleum industry to produce Ultra Low Sulphur Diesel (ULSD) fuel.

Besides emitting harmful gas, fossil fuel is an unsustainable source of energy which means the source will be getting lesser every day and someday it will finish. This is due to continuous depletion and contamination of environment and to produce back the fossil fuel taking such a long time(Singh *et al.*, 2019). This will cause energy crisis for the next generation. Many studies were conducted to find a solution for this problem and one of it is by using biodiesel instead of using pure fossil diesel. According to American Society for Testing and Materials (ASTM), biodiesel is monoalkyl esters of long-chain fatty acids which is extract from edible oils, non-edible oils, waste oils and assigned as B100, which produced through transesterification process of triglycerides using methanol and catalyst (Hoekman *et al.*, 2012). Triglycerides is produced from animal and vegetables. Whereas for the catalyst that commonly used to produce biodiesel are strong alkaline catalyst, strong acid and enzyme.(Singh *et al.*, 2019)

There are many components in the fuel delivery system that are directly contact with fuel such as the fuel pump, the fuel injector, the engine, and the exhaust system. **Figure 1** shows the position of some of the rubber and metal sections in the traditional automotive fuel system. Among the types of elastomers used in the automotive fuel system are acrylonitrile butadiene rubber (NBR), fluoroelastomer (FKM), poly chloroprene rubber (CR), silicone rubber (SR), hydrogenated NBR (HNBR), ethylene-propylene-diene rubber (EPDM), acrylic rubber (ACM), epichlorohydrin (ECO), styrene butadiene rubber (SBR) and polyurethane (Trakarnpruk and Porntangjitlikit, 2008b; Haseeb *et al.*, 2010; Chandran *et al.*, 2016)

Switching to biodiesel may lead to swelling and degradation of rubber (Chandran, 2019). In fact, the presence of various contaminants, unreacted materials and degradation by-products in biodiesels, when associated with high service temperature and mechanical processing, increases the corrosion of fuel delivery system components in the vehicle. As a result, in addition to the swelling and degradation of the elastomer structure, after exposure to biodiesel, elastomer additives incorporated (such as curing agents, processing aids, expansion oils, stabilizers and fillers) may migrate to the fuel and chemical reactions involving additives and the fuel itself may occur. For fact, this can also happen in the case of metallic parts, when the biodiesel itself can weaken the metal parts, and eventually the oxidation process can occur.

Furthermore, in order to operate in conventional engines, biodiesel blends usually require several additives to improve their lubricity, thermal stability, cold flow and combustion efficiency. Such additives also contain metal-organic or oxygenated compounds, which can also cause degradation of the rubber parts. Biodiesel blend composition and the bio-based element source (palm oil, soybean, etc.) have developed varying effects on the degradation quality of the elastomers (Alves, Mello, & Dutra-Pereira, 2017).

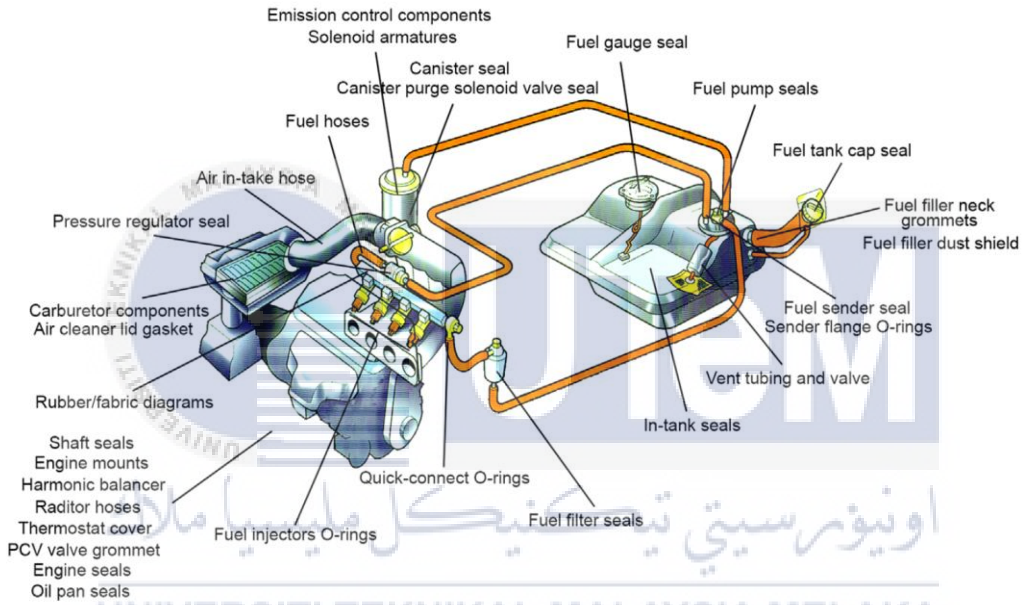


Figure 1.1 The location of some of the rubber parts in a conventional fuel system

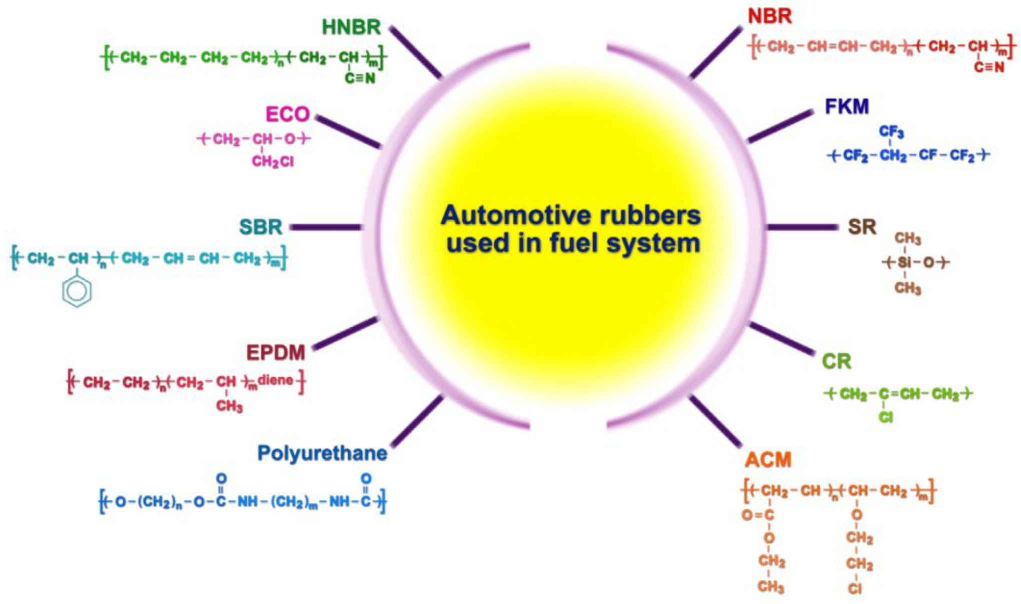


Figure 1.2 Chemical structures of the rubbers most frequently used in automobile fuel systems

In addition to combustion and emission performance, the effect of the biodiesel blend on the elastomer and metallic-based components is also a crucial factor in the performance of the biodiesel blend. It is concluded that there are many factors involved which relate to fuel and elastomeric as well as metal components within the fuel system and need to be fully understood and carefully investigated in order to introduce a successful blend of biodiesel as a substitute for pure diesel for automotive applications. This research is therefore proposed to examine the effect of the B30 palm biodiesel blend on the physical and mechanical properties of the automotive elastomer using mass test and tensile test. The objective is to characterize the effect of the properties of elastomer subjected to a blend of B10 and B30 palm biodiesel and to identify the mechanism of failure associated with it. By acquiring valuable information, any limitation of the performance of the product relating to the blending of biodiesel with elastomer components can be identified and improved in order to achieve the successful B30 blending of biodiesel as a renewable and more sustainable alternative vehicle fuel in the future.

1.2 Problem Statement

Research for an alternative fuel are conducted due to the depletion and environmental degradation. Previous research finds out that a biodiesel could replace the pure diesel that we use today that were produced from fossil fuel. Biodiesel is a product of transesterification process of either vegetable oils or animal fats. But for this project, we are focusing on palm-based biodiesel which are B10 and B30.

The compatibility of biodiesel against petro diesel is different according to the mixture in the fuels where petro diesel contain hydrocarbons whereas for biodiesel is a mixture of fatty acid esters. In diesel engine, fuels in contact with a wide variety of materials especially for the fuel delivery system (FDM). Research for compatibility of hose materials that commonly used for FDM has been established long ago but not yet tested for the new blended palm-based biodiesel B30. Regarding from the research that have been reported using B7, B10 and B20 biodiesel, degradation of certain elastomers is one of the main issues regarding material incompatibility with biodiesel. According to (Haseeb *et al.*, 2011) increased in vol% of biodiesel in a diesel as to minimize the usage of fossil fuel, the more the elastomer swelling and decrease in mechanical properties.

1.3 Objective

The proposed objectives of the project are: -

i. To analyze the degradation of elastomers by measuring sample weight and volume.

ii. To determine the mechanical properties (strength, stiffness, and hardness) properties after expose to B10 and B30 palm biodiesel.

iii. To compare the degradation of elastomer after exposed to B10 and B30.

1.4 Scope of Project

The proposed scopes of project are: -

i. To prepare experimental test procedure and develop testing capability.

ii. To perform physical and mechanical properties characterization tests.

iii. To perform failure analysis study using advanced characterization methods.

iv. To generate test report and failure analysis report.

1.5 General Methodology

The overall methodology of the proposed projects is divided into four phases, and described in detail as follows: -

Phase 1: Designing apparatus to be use

In this step, the apparatus and method that will be use in this project will be defined according to customer requirements. For the specialized test equipment and jigs for tensile test are design and fabricate same with the water bath temperature control equipment.

Phase 2: Sample Preparation

All samples received will be prepared according to the test standard requirements. Elastomer samples shall be group into 2 types, which are samples that is not immersed and immersed samples. For the immersion test, pure diesel shall also be used (in addition to the B10, B20 and B30 biodiesels) to obtain the baseline data for comparison purpose. To get the average result, 5 samples prepared so that the result more valid and the error manage to be reduced.

Phase 3: Materials Characterization

In this phase, characterization activities shall involve physical and mechanical analysis. Details of the proposed activities are described as below: -

3.1 Physical property

Physical analysis can be conducted using static immersion of the samples inside the fuels (pure biodiesel, B10 and B30 palm biodiesel blend). All tests shall be performed at fix room temperature with varying immersion time of 3-7 days. Prior to immersion, all samples shall be dried by blotting with lint-free cloth followed by air drying at room temperature for 30 - 40 minutes (Haseeb *et al.*, 2011). Measurement on the changes in weight (using 4 decimal units accuracy balance) and volume (using Vernier caliper and micrometer) of the elastomer before and after immersion shall be conducted. Changes in term of sample mass and volume shall be calculated using **Eqs. (1)** and **(2)**.

$$\%\, Mass\ change = \frac{M_2 - M_1 \times 100}{M_1} \quad \textbf{(1)}$$

where M_1 and M_2 are the initial sample weight and the sample weight after immersion, respectively.

$$\%\, Volume\ change = \frac{V_2 - V_1 \times 100}{V_1} \quad \textbf{(2)}$$

where V_1 and V_2 are the initial sample volume and the sample volume after immersion, respectively.

3.2 Mechanical properties

Mechanical analysis of the performance of the samples shall be conducted using static immersion condition (immersed in pure biodiesel, B10 and B30 palm biodiesel blend). All samples shall be immersed at fix room temperature and varying immersion time of 3-7 days. The samples shall be dried using clean cloth after immersed. Later, the samples shall be subjected to tensile test and hardness test. For the tensile test, the sample will be cut into a dog bone shape. The tensile strength and tensile modulus measurement shall be conducted to American Society of Testing and Materials **(ASTM) D412-16** standard (at strain rate of 500 mm/min) using Instron Universal Testing Machine (5 kN) (Haseeb *et al.*, 2011).

Phase 4: Documentation

At the end of this project, all experimental data and findings obtained from the experiment are reported and submit the customer.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Some of the natural resources that we have now are unsustainable resources, this means that one day the resources cannot be use anymore. It is very important to take a precaution step so that the resources can be maintain and it can be used for future generation. The usage of natural resources such fossil fuel can led to pollution which it will emit harmful gas as product when burnt other than useful energy that we need and it is very dangerous for human health which can led to severe diseases (Haines *et al.*, 2006).

The fossil fuels are mainly use in transportation and industry sector where the fuel is used to move the engine. Fossil fuels accounted for 88% of the primary energy consumption with oil (35% share), coal (29%) and natural gas (24%) as major fuels, while nuclear energy and hydroelectricity account for 5% and 6% of the total primary energy consumption respectively (Brennan and Owende, 2010). Therefore, the transportation and industry such as truck and other vehicles create and important field. In order to achieve reinvestment from petroleum products, this is where the use of alternative fuels arises as a very effective, long-term alternative solution.

Besides, the effect of the emitted greenhouse gaseous will affect the ozone layer and this will cause the global warming. This is cause by the present of nitrous oxide and nitrogen dioxide that was release from burning of fossil fuel. As the main function of ozone layer is to prevent direct exposure of UV light from sun towards human, the depletion of ozone layer will cause skin cancer premature aging, eye cataract and damage or weak the immune system (Coldiron *et al.*, 1992). The effect of global warming is it will cause our global hot and rises of sea level which is cause by the melting of ice at the north pole.

Due to the demand of the fossil fuel, continuous depletion and contamination of the fossil fuel, it is now considered as an unsustainable source of energy. Many study and research were made to generate a new source that can be sustainable and can function same or nearly the same with fossil fuel such biodiesel. This study is to run the test on elastomer behavior immersed in various type of biodiesel in order to investigate the mechanical-physical properties of the elastomer as biodiesel is one of sustainable resources that tends to replace the diesel.

2.2 Biofuel

Advanced liquid biofuels are being marketed in the United States (U.S.) to achieve national energy independence and safety and reduce greenhouse gas (GHG) emissions. U.S. first generation biofuels are produced primarily from major commercial crops such as corn (Zea mays, L.)-grain ethanol and soy (Glycine mix, L.) biodiesel. (Wu, 2008). A study made for the next generation feedstocks and categorized as cellulosic components of municipal solid waste, forest residues and thinning, annual crop residues, dedicated herbaceous perennial energy crops, short-rotation woody crops and microalgae. These feedstocks may produce a various type of biofuels such ethanol, biodiesel, jet fuel, green gasoline, green diesel. There also other feedstock such Jatropha (Jatropha curcus L.), grease and cooking waste oil and animal fats (Pamela R. *et al.*, 2009).

Since a fossil fuel have a lot of negative impact towards environment and human, a biofuel was produced which will reduce those negative impact. In this project we will focus on biodiesel and the application on the usage of biodiesel in vehicle as there are a lot of heavy vehicles on the road using diesel as fuel and there also high-performance car that using diesel to get a better performance than petrol engine car.

The use of biodiesel has an effect that leads to a good potential and environmentally friendly solution to reduce over-reliance on energy imports (Giakoumis *et al.*, 2012). This biodiesel is generally known as alternative diesel fuel which is containing alkyl monoesters of fatty acids that form from the derivation of few sources such vegetable oil, animal fats or waste cooking oil. The transesterification reaction and also known as alcoholysis is the process to produce biodiesel (Srivastava and Prasad, 2000; Singh *et al.*, 2019; R. *et al.*, 2009). As the properties of biodiesel is the same with diesel fuel, its blend can be use in diesel engine directly with mixture of diesel fuel (Singh *et al.*, 2019; A. Sorate and V. Bhale, 2018; Srivastava and Prasad, 2000).

2.2.1 Production of Biodiesel

At the current level of production, biodiesel requires a subsidy to compete directly with petroleum-based fuels. The governments giving support by providing incentives to encourage the research and study on biodiesel production in order to encourage the rapid growth of the biodiesel industry (Gerpen, 2005). There are several generally accepted technologies that established to produce biodiesel fuel. Some of the oils need to be reduce in viscosity so that the properties are acceptable to be used in diesel engine. There is various type of procedures for the modification process to get a better quality of biodiesel such blending, micro-emulsions, pyrolysis of vegetable oil and transesterification.

Since 1900, the use of vegetable oils as alternative fuels already implement by the founder of diesel engine, Dr. Rudolph Diesel when he first tests his compression engine using a peanut oil. But the direct use of vegetable oils in the engine lead to a failure. After doing extensive research, crude vegetable oils need to be improve in viscosity by mixing it directly or diluted with diesel fuel for it to be use as a fuel in diesel engine (Koh *et al.*, 2011). But the direct use of this oil has generally been considered as not valid. **Table 2.1** below show the performance of vegetable oils as diesel fuel:

Table 2.1 Performance of vegetable oils as diesel fuels (Abbaszaadeh et al., 2012)

Fuel characteristics	Consequence(s)
Viscosity	High viscosity interference with injection process, poor fuel atomization, high viscosity/low volatility causes poor cold engine start-up and ignition delay. Also, caused to thickening and gelling
Cloud point, pour point, cold-filter plugging point	Fuel performance compromised under cold-temperature conditions
Cetane number	Low cetane number implies long ignition delay, high auto ignition temperature and diesel knock
Combustion	Inefficient mixing of oil with air leads to incomplete combustion
Flash point	High flash point facilitates to lower volatility characteristics
Distillation range	Presence of high-boiling components affects the degree of formation of solid combustion deposits, important to engine start-up and warm-up
Carbon residue	The limited thermal stability of partly unsaturated vegetable oils and lower volatilization characteristics lead to more deposit formation, carbonization of injector strips, coking and trumpet formation on injectors, ring sticking and lubricating oil dilution and degradation
Oxidative stability	Oxidative and thermal polymerization cause deposition on injectors
Long-term operation	Development of gumming, injector coking, ring ticking, failure of engine lubricating oil due to polymerization and serious engine deterioration

Thus, the use of vegetable oils for diesel engines requires significant engine improvements, including adjustments to pipeline and injector construction materials, otherwise the engine running times will be shortened, maintenance costs will be increased due to higher wear, and the risk of engine failure will be increased.

Micro-emulsification is the production of microemulsions (cosolvency) that are a possible solution to the problem of high viscosity in vegetable oils. Micro-emulsion-based fuels are sometimes often referred to as hybrid fuels, while combinations of standard diesel fuel with vegetable oils have also been referred to as hybrid fuels (Knothe *et al.*, 1997; Abbaszaadeh *et al.*, 2012). Microemulsions are clear, stable isotropic fluids containing three components: an oil phase, an aqueous phase, and a surfactant. In order to deal with the high viscosity of the vegetable oils, microemulsions conduct with methanol, ethanol and ionic or non-ionic amphiphiles or known as immiscible liquids have been studied. Micro-emulsion fuel including soybean oil, methanol, 2-octanol and cetane was the cheapest synthetic diesel fuel dependent on vegetable oils ever to clear the EMA examination with ratio of 52.7:13.3:33.3:1.0 (Knothe *et al.*, 1997; Abbaszaadeh *et al.*, 2012).

Pyrolysis is the transformation from one biological material to another by way of steam or water with the aid of a catalyst (Mohan *et al.*, 2006). The material use in this reaction can be vegetable oil, animal fat, natural fatty acids or methyl esters of fatty acids. Those materials composed commonly of triglycerides using thermal cracking reactions to produce biodiesel. Many researchers have reported the product obtained from pyrolysis of triglycerides suitable for usage in diesel engine. The reaction was proposed by Schwab et al. is as shown in **Figure 2.1**below:

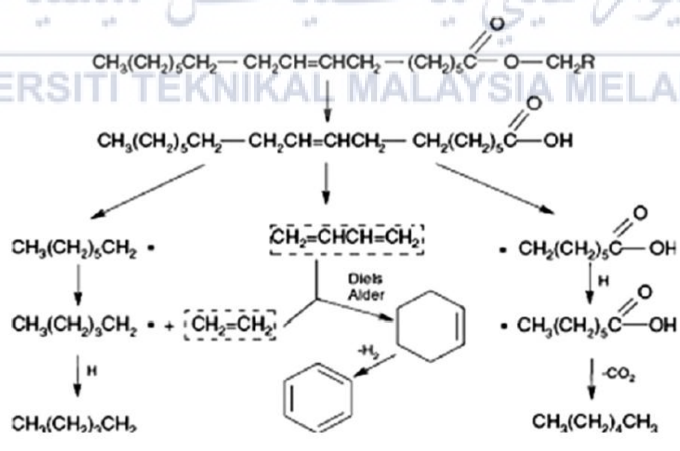


Figure 2.1 The mechanism of thermal decomposition of triglycerides

Thermal cracking and pyrolysis machinery are inefficient with small throughputs. In fact, while the goods are chemically like petroleum-derived gasoline and diesel oil, the extraction of oxygen through thermal processing often eliminates all environmental benefits from the use of oxygenated fuel. It produces some low-value materials and sometimes even more petrol than diesel fuel.

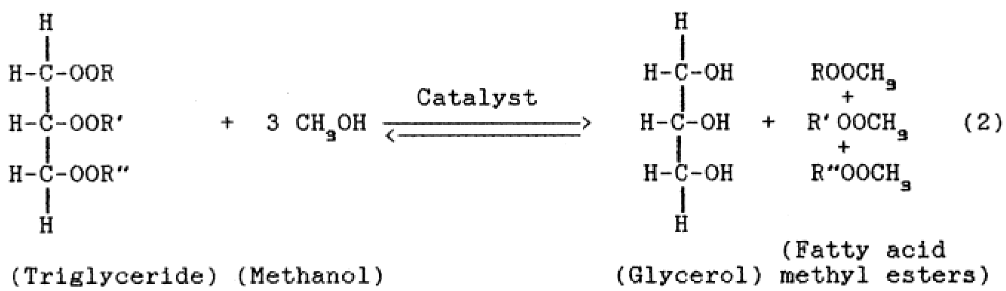
Among the four techniques, the chemical conversion (transesterification) of oil to its corresponding fatty ester is the most promising solution to the high viscosity problem. This is because the base catalyst has faster reaction speeds, higher FAME levels, and medium temperature. The most commonly used alkali catalyst are NaOH, KOH, and sodium potassium alkoxide (Taylor and Demirbas, 2009; Abbaszaadeh *et al.,* 2012).

2.2.2 Transesterification Process

The option of catalyst used for the processing of biodiesel through a transesterification reaction is defined by the quantity of free fatty acid and the quality of the feed. Acid based catalyst are preferred for the transesterification reaction when the raw materials has high free fatty acid and water content and requires a longer time to be process between 2-10h at temperature range 60-100^{o}C. In contrast to that, an alkali-based reaction is preferable (Taylor and Demirbas, 2009; Singh *et al.*, 2019). The transesterification reaction is as following equation:

$$\underset{\text{Ester}}{\mathrm{RCOOR'}} + \underset{\text{Alcohol}}{\mathrm{R''OH}} \overset{\text{Catalyst}}{\rightleftarrows} \underset{\text{Ester}}{\mathrm{RCOOR''}} + \underset{\text{Alcohol}}{\mathrm{R'OH}}$$

According to the equation, different alcohol use will result in different product. In case the alcohol use is methanol in the reaction, it is known as methanolysis. The reaction is as follows:



The reaction will give a product named methyl esters which is biodiesel that we want as alternative diesel fuels (Srivastava and Prasad, 2000; Gerpen, 2005).

2.2.3 Types of Biodiesel

There are a few types of biodiesel product available in the market. Six vegetable oil sample were commonly studied by majority of the researcher, which is waste cooking oil, soybean oil, rapeseed oil, palm oil and jatropa oil. This is because of the properties of this vegetable biodiesel are almost the same to the pure diesel. The properties of the biodiesel shown in **Table 2.2** below.

Table 2.2 Biodiesel properties of palm oil, jatropha, rapeseed and soybeans (Harsono, 2011)

Property	Palm Oil	Jatropha Curcas	Rapeseed	Soybean	Fossil Fuel	Biodiesel Standard	
Journal	(Chandran *et al.*, 2018)	(Mo *et al.*, 2013)	(Goembira *et al.*, 2012)			Value	Method
Calorific value ($MJkg^{-1}$)		39.23	36.90		42	38.3	
Pour point (^oC)		4				>18	ASTM D 2500
Flash point (^oC)	190	220	175	174	>68	>100	ASTM D 93
Density (kgm^{-3})	874	921	920		840	850-900	ASTM D 1298
Viscosity ($mm2s^{-1}$)	4.54	4.8	4.5		2.6	2.3-2.6	ASTM D 445
Cetane number	42	45	46	37.9		<51	ASTM D 613
Ash content (%)		0.20	0.01		0.17	<0.02	ASTM D 874
Water content (%)	0.02	0.075	0.075		<0.02	<0.05	ASTM D 2709
Acid value ($mgKOHg^{-1}$)	0.28				<0.08	<0.08	AOCS Cal 2-55
Carbon residue (%)					0.17	<0.30	

Remark:

1. Calorific value, heat of combustion - Heating value or heat of combustion is the sum of heating energy generated by the combustion of the unit price of the gas.
2. Pour (Melt) point - The melt or pour stage corresponds to the level at which the solid oil begins to melt or pour. For situations where the temperature drops below the melt level, the whole fuel system, including all fuel lines and fuel tanks, will need to be cooled.
3. Flash point (FP) - The flash point temperature for diesel fuel is the maximum temperature at which the fuel can spark flash when the ignition origin is applied. The flash point varies inversely with the variability of the gas. Maximum flash point temperatures are needed for proper diesel fuel protection and handling.
4. Density - Is the weight per unit volume. Oils that are denser produce more heat. Petrol and diesel fuels, for example, have equivalent weight power, but diesel is denser and therefore provides more energy per liter.
5. Viscosity - Viscosity refers to the thickness of the oil and is measured by measuring the time taken to pass through a specific size orifice for a given amount of the oil. Viscosity affects lubrication of the injector and atomization of the fuel. Low viscosity fuel may not provide appropriate lubrication for precision fit od fuel injection pumps, resulting in leakage or tear.
6. Cetane number (CN) - Is a comparative duration indicator between the fuel start of injection and auto-ignition. Just as the amount of octane determines the quality and value of gasoline (petrol). The higher the number of cetane, the smaller the interval of lag, and the greater the combustibility. Low-cetane gas results in fast ignition, vibration, and

combustion smoke. Generally, diesel engines will operate better with cetane numbers above 50 on fuels.

7. Ash percentage - Ash is an indicator of the quantity of metal in the gas. High concentrations of these materials can cause plugging of the injector tip, deposits of combustion, and wear of the injection system. For heating quality, as heating value decreases with decreased ash content, the ash content is essential.
8. Sulphur percentage - For diesel fuel used in on-road applications, the percentage by weight of Sulphur in the fuel Sulphur content is limited by law to very small percentages.

Beside of the type of raw material use to extract the biodiesel, the concentration that indicated the percentage of the biodiesel also be classes of biodiesel. This is indicated by the volume ratio of the biodiesel in the fuel. From the reaction, B0, B5, B7, B10, B20, B50 and B100 biodiesel is produce. The number in each code name of biodiesel represent the percentage by volume (%vol) of the biodiesel mix with diesel fuel. For B0, this fuel contains only diesel fuel without mixture of biodiesel and this fuel known as pure diesel fuel. On the other hand, B5 fuel has 5%vol of biodiesel in mix with pure diesel. Other than that, B7 contain 93%vol of pure diesel with 7%vol of biodiesel and the same for B10 and B20 contain 10%vol and 20%vol of biodiesel respectively. Lastly, B100 is a pure biodiesel without mixture of any pure diesel. Table 2 shows each type of biodiesel and its period of implementation in Malaysia.

Table 2.3 Planned Versus Actual/Expected Roll-out of Blending Requirements (Wahab, 2016)

Blend	Transportation Sector		Industrial Sector	
	Planned Roll-out	Actual Roll-out	Planned Roll-out	Expected Roll-out
B5	2008	2011 (Central region) 2012 (Southern region) 2013 (Northern region) 2014 Nationwide	None	
B7	January 1, 2015	January1, 2015	October 1, 2016	October 1, 2016
B10	October 1, 2015	End of 2016 (as reported) 1st quarter 2017 (realistically)	No plans	
B15	2020		No plans	

However, not all the biodiesel stated before allowed to be used in CI engine. This is because of higher concentration of biodiesel mixture lead to failure to some of the fuel delivery system (Chandran, 2019). Therefore, until recently, only fuel that has a maximum concentration level of 20 vol% of biodiesel mix with 80 vol% diesel (B20) is permitted to be used to run a CI engine.

2.2.4 Advantages of Biodiesel

There is a lot of advantages that can be achieve from biodiesel in compared to pure diesel. Biodiesel is a renewable energy source and it is sustainable, unlike petroleum-based diesel which is extracted from fossil fuel. The biodiesel also compatible with the fuel delivery system in a vehicle so that, vehicle modification or any fueling equipment didn't compulsory. By using biodiesel also help to reduce the global warming, as it is released less CO_2 as a side product, and it is also did not release harmful gas when burn. Not only give benefit to the car and its components, but it is also safe to handle because it is less toxic and easier to store to than petroleum (Firoz, 2017). Lastly, a lubricating property is one of the properties of biodiesel. This will prolong the lifetime of the engine.

2.2.5 Disadvantages of Biodiesel

Instead of having a lot of advantages, there are also some of disadvantage of biodiesel. According to the previous research, it shows that biodiesel tends to harm the elastomer hose in the car system especially the elastomer that directly contact with biodiesel such fuel feed line (Haseeb *et al.*, 2010; Tongroon *et al.*, 2017; Chandran *et al.*, 2018). It is also requiring many stages of process starting from fertilizing, harvested, collected and processed. In a long period of usage, the fuel pump tends to be clogged as the biodiesel able to cleanse the dirt that might be swept into the fuel delivery system. Lastly for the biodiesel to fully implement in diesel engine, some improvement needs to be done so that the system can run smoothly without any interference (Firoz, 2017).

2.2.6 Biodiesel Standard

Biodiesel standards are made aim to evaluate the characteristics of considerable biodiesel. There are many types of standard created such ASTM, EN, IS etc. All biodiesel produces need to follow all these specifications. Those standards set the guiding principle for measuring biodiesel fuels and identify acceptable values for consecutive use in the engine for different chemical and physical characteristics of oil. The main chemical and physical characteristics of biodiesel are referred to kinematic viscosity (mm2/s), oxidation stability, glycerin (% m/m), cetane number, sulfur content, pour point, acid number (mgKOH/goil), boiling point (°C), cloud point (°C), flash point (°C), density (kg/m3), heating value (MJ/kg) etc.

ASTM standards for biodiesel fuel (B100) and ASTM standards for biodiesel fuel blends (B6 to B20) with petroleum diesel have been established by ASTM D6751 requirements. ASTM D975 specifications are favored for B5 and lower blend rates. CEN has established biodiesel fuel (B100) requirements in EN 14,214, but these criteria are not appropriate for a mid-range blend such as B20. The CEN has established EN 590 guidelines for diesel fuel mixture enabling a combination of B7 and lower. In India, biodiesel standards are specified by IS 15607 (Hoekman *et al.*, 2012; Singh *et al.*, 2019).

The biodiesel use in this project is B10 and B30 which is fully supplied by MPOB. Both biodiesels contain a mixture of 10vol% and 30vol% of palm oil-based biodiesel respectively. The specification of both biodiesels is shown in the **Table 2.4** below:

Table 2.4 B10 and B30 specification (Ali et al., 2015)

Specification	B10	B30
Density (kg/m^3)	850	857
Acid value (mgKOH/g)	0.18	0.26
Viscosity (mm^2/s)	3.86	3.95
Heating value (MJ/kg)	44.23	43.13

2.3 Elastomer

Instead of using metallic component, there also rubber material used. There are rubber materials and metal component along the fuel line. Rubber component are also known as elastomeric component. This type of material majorly uses in the fuel delivery system. Hose and sealer component are the example of component that made up of elastomer.

2.3.1 Definition of Elastomer

Elastomer or rarely known as rubber are materials that have an elastic deformation of more than 200%. The polymer chains in elastomers consist of coil-like molecules that can reversibly stretch when a force is applied. What happen in the molecule during the elastomer being stretch is all the molecules will straighten out in the direction it is being pulled and being stretch according to the force direction. Spontaneously, when the force is released, the molecules return to their normal compact and random arrangement. As an elastomer having elasticity property, the Young's modulus of this materials is low and high in yield strain compared to other material. In ambient temperature, elastomer may exhibit as a soft and deformable materials that can be bent, stretch or compressed. Primary use of elastomer are seals, adhesives and molded flexible parts. Elastomer can be classified into two which are thermoplastics (TPE) or lightly cross-linked thermosets (McKeen, 2018).

2.3.2 Types of Elastomer

Elastomer has become a major concern due to the reaction with chemicals in fuel as it is directly contact with fuel. According to (Chandran *et al.*, 2018; A. Sorate and V. Bhale, 2018; Haseeb *et al.*, 2010; Haseeb *et al.*, 2011) the chemicals may cause the elastomer facing with degradation of their physical and mechanical properties. There are many types of elastomer that available in the market and different type of elastomer have different application and environment. The common type of elastomer that can be found in the car are nitrile rubber (NBR), hydrogenated nitrile rubber (HNBR), polyvinyl chloride (PVC), acrylic rubber, co-polymer FKM, terpolymer FKM, polychloroprene, Fluoroviton A, Buna, ethylene propylene diene monomer (EPDM), chloroprene (CR), synthetic rubber (SR) and poly tetra fluoro ethylene (PTFE) or Teflon. This material usually use in low pressure fuel lines in CI engine (A. Sorate and V. Bhale, 2018).

2.4 Physical-Mechanical Test of the Elastomer

For physical-mechanical properties of elastomer, there are a few types of test need to conduct in order to get the reaction happen while soaking it on the fuel. The test that need to be perform are mass test, volume test, tensile test and hardness test. All testing is described below with the result from previous research.

2.4.1 Mass Test

Mass test is basically conducted to verify the change in mass of the elastomer before and after being soaked in fuel respect to soaking time or temperature of fuel. According to (Haseeb *et al.*, 2010; Haseeb *et al.*, 2011; Tongroon *et al.*, 2017; Chandran *et al.*, 2018) the elastomer parts were weighted by means of four digit weight scale with an accuracy of ±1 mg. All result from the test setup shows that the mass of elastomer decreases which can be conclude that the elastomer being degrade while soaking with biodiesel. Referred to the test result conduct by (Haseeb *et al.*, 2010) using NBR, Polychloroprene and Fluoro-viton Increases in volume for NBR was increased with increasing temperature and decreased for polychloroprene while staying nearly constant for fluoro-viton.

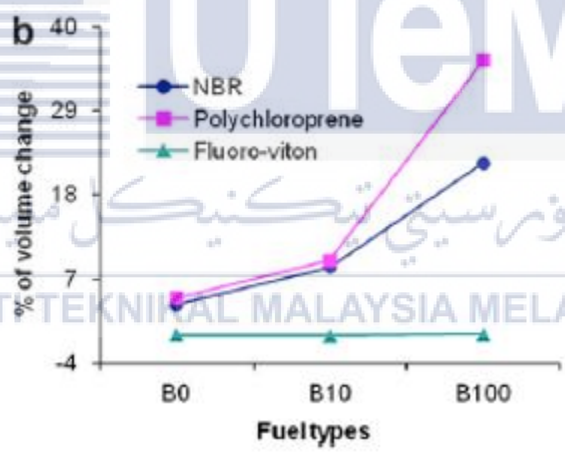


Figure 2.2 Change in volume (Haseeb et al., 2010)

2.4.2 Volume Test

The objective of this test is to make a comparison in volume of the elastomer specimen before and after immersion. The procedure for this test is measured by calculating the specimen height, width and distance. The specimen was blotted with lint-free cloth before measuring the size, followed by air drying, keeping clean areas at room temperature for 30-40 min. From the previous research result retrieve from (Haseeb *et al.*, 2010; Chandran, 2019; Chandran *et al.*, 2018; Tongroon *et al.*, 2017; Haseeb *et al.*, 2011) CR and NBR shows the greater swelling which the dimension increase from the original specimen before soak. In contrast to biodiesel and its mix, EPDM and SR swelled to a greater extent in diesel. PTFE shows a volume reduction with an increase in biodiesel concentration. Referred to this result, all researcher agree that EPDM and SR are more resistant to swelling in biodiesel than diesel and CR and NBR are less compatible under exposure to biodiesel because of the swelling rates are high.

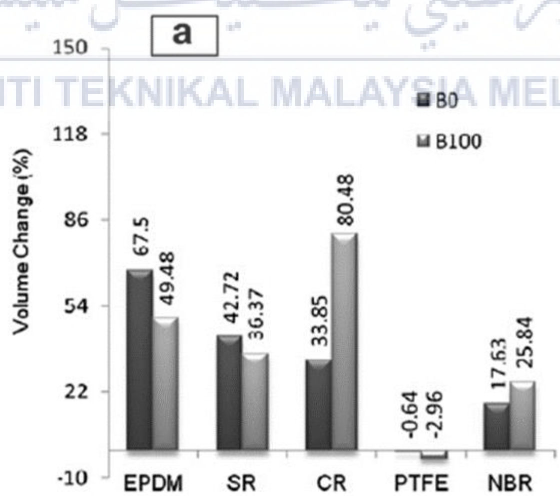


Figure 2.3 Change in volume for different elastomer after immersion at room temperature (Haseeb et al., 2011)

2.4.3 Tensile Test

A tensile test aim to test the resistance of the material to a static or slowly applied force. The output of a tensile test is a graph that consist of the load versus resulting extension of the test piece. These results depend on the material use and the dimension itself where the larger the test piece, a larger load required to give same extension. Stress and strain graph are then plotted instead of load and extension to give a normalize. From the previous research, the tensile strength level was calculated using Instron Tensile Tester (5 kN) in compliance with ASTM D412 (strain frequency of 500 mm / min) (Haseeb *et al.*, 2010; Tongroon *et al.*, 2017; Chandran *et al.*, 2018). As obtained NBR indicates a tensile strength of 10.4 MPa and an elongation of 750 percent while when applied to B100 these values are decreased to 8.7 MPa and 646% respectively. Similarly, tensile strength and elongation in polychloroprene decreased from 3.9 MPa and 225.6% to 2.3 MPa and 216.6% Likewise, tensile strength and elongation decreased from 3.9 MPa and 225.6% to 2.3 MPa and 216.6% in polychloroprene. While no major fluoro-viton shifts have been observed. The data plotted as in the figure below.

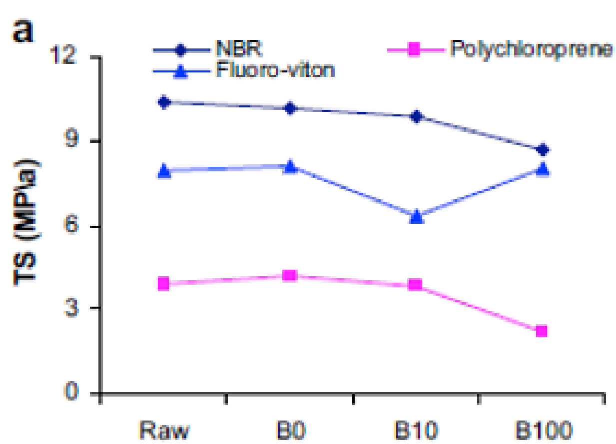


Figure 2.4 Tensile strength data obtained (Haseeb et al., 2010)

2.4.4 Hardness Test

The hardness test is basically aimed to test for the mechanical properties of the elastomer before and after soaked in biodiesel. According to (Haseeb *et al.*, 2010; Tongroon *et al.*, 2017) the hardness test was conduct by using Cogenix Dead Load Hardness Tester Model H-14 and calculate the specimen hardness value. The specimen was pressed with a 2,5 mm ball indenter and the hardness value was registered automatically (computerized). According to (Haseeb *et al.*, 2010; Chandran, 2019; Chandran *et al.*, 2018; Tongroon *et al.*, 2017; Haseeb *et al.*, 2011) results, quite similar trends have also been identified for the shift in hardness of the respective elastomers.

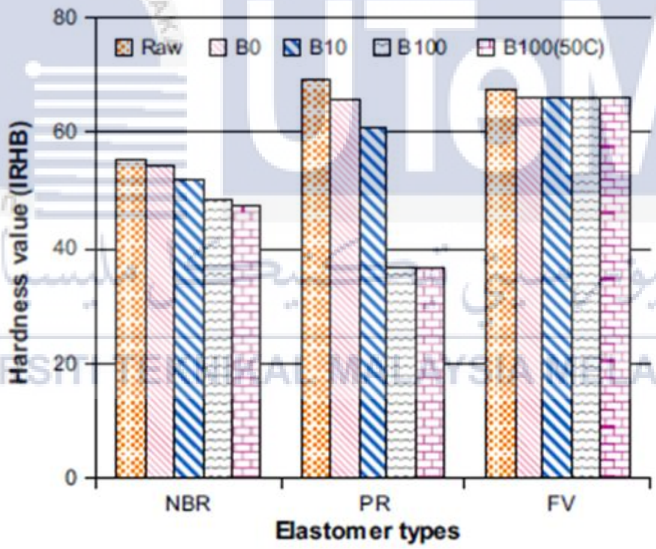


Figure 2.5 Change in hardness of elastomers in different blends after immersion (Haseeb et al., 2010)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter describes the methodology used in this project to obtain the data for mechanical and physical properties of the elastomer. This project was conduct according to the flowchart shown in Figure 3.1. According to the flowchart, this project starts with planning the test to be conducted to obtain the mechanical and physical properties of the elastomer. The planning was carried out according to the ASTM standard as guideline.

3.2 Flow Chart

To make sure that the project can run smoothly, it is very crucial to have a good planning and set a target of time that needed to complete the project according to the requirement. Figure 3.1 shows the beginning of the project in determining the objective until analyzing the result obtain from each test that was conduct.

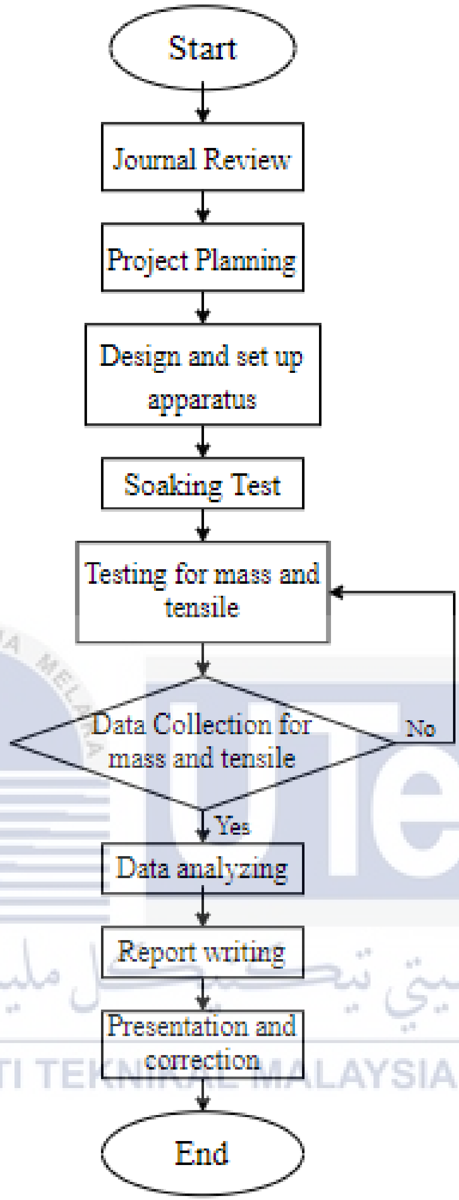


Figure 3.1 Flowchart of overall project

From **Figure 3.1**, the flowchart shows the overall process from the start of the project towards the end. Before conducting any project, a study was conduct by gathering information by doing literature review on the previous research regarding on testing that need to be done. This is because, the previous research is very helpful for us to conduct a test as their result can be set as our references. Next, the project planning was done to ensure that the project can be done according to the due date without any delay. Delay in project can led to a negative impact towards the project and will affect the quality of our result. Therefore, planning is very important to prevent a

The process then follows by design and set up the apparatus that will be used to conduct the testing. For this process, all equipment that need to be prepared as it is a custom-made equipment. Maybe some of it can be found in the market but the price is way too high and not affordable. For the materials, both biodiesel B10 and B30 was supplied by MPOB.

3.3 Equipment Preparation

The equipment to be use for testing need to prepared first to make sure that everything is organized and make our testing easier. The equipment that used in this project is water bath temperature control, jig for tensile test and some electronic equipment such data logger for controlled temperature.

3.3.1 Oil Bath Temperature Controller System

Oil bath is an apparatus use for the soaking test where all the specimen will be immersed in this bath. This apparatus can be obtained at the market easily but cannot withstand for a long period of time. To solve the problem, the oil bath needs to be fabricated. The material use for this oil bath is a glass aquarium which bigger than A4 paper because there are almost 200 specimens need to be immersed. Next is a temperature controller system with waterproof temperature sensor and heating element function to control the heating of biodiesel and other material use are wood and rubber insulator in order to prevent a lot of heat transfer to the surrounding.

The oil bath first needs to be design and draw in CAD software such Solidwork to get the 3D drawing of the system. The 3D drawing as shown in **Figure 3.2** below.

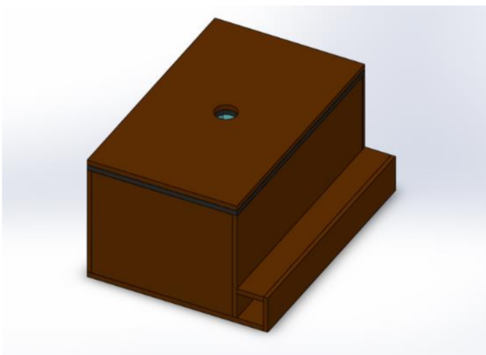


Figure 3.2 3D drawing of oil bath

3.3.2 Data Logger for Controlled Temperature

The soaking test is conduct for a long period of time, in order to monitor the temperature of biodiesel keep constant, a data logger need to be use. Before preparing other apparatus, the data logger needs to be set up first. This data logger use Arduino uno as the controller system and other electronic component that can be connect and program to the Arduino uno such DS18b20 waterproof sensor, RTC and sd card slot. A study on how to write and program the Arduino need to be done first before connecting all the circuit and use the system.

Basically, this system function is as a system that can monitor the temperature of the biodiesel by write the data in a memory card. The temperature sensor first transfers the reading of the temperature in code form and transfer to the Arduino to be convert into an actual reading of temperature in ^{o}C or ^{o}F. At the same time, the RTC send exact time and date to Arduino and all the information then transfer to the SD card slot to write into the memory card. The data will be written in the form of Microsoft excel so that it easier to read the temperature.

3.4 Elastomer Specimen Preparation

The elastomer purchase which is fuel hose that used in BMW F10 5series need to be cut into certain dimension to fulfill the requirement in standard for conducting test in elastomer. Each test has different standard need to be follow. The standard explains in **3.4.1** for mass test, **3.4.2** for tensile test and **3.4.3** for hardness test.

3.4.1 Mass Test

Referred to the ASTM D471-06 the dimension needs to be followed is rectangular in shape with dimension of 25 by 50 by 2.0 mm with ± 0.1 mm. To get the exact measurement of the specimen, apparatus such Vernier caliper, ruler, cutter and saw are used to cut. The Vernier caliper need to be used to measure to prevent the error during taking measurement compared to ruler.

3.4.2 Tensile Test

For tensile test, the standard use for the test is ASTM D412-06. The dimension for the test specimen as stated in the standard is as in the figure and table below. There are many types of dies and shape of test specimen for tensile test but for this project, die C is used which is dumbbell shape. After specimen been cut, the test carried out using Instron tensile tester with 5kN of force apply and strain rate of 500mm/min.

Table 3.1 Dimension of standard dumbbell for dies C (American Society for Testing and Materials, 2006)

Dimensions	Units	Die C
A	mm	25
B	mm	40
C	mm	115
D	mm	32
D-E	mm	13
F	mm	19
G	mm	14
H	mm	16
L	mm	33
W	mm	6
Z	mm	13

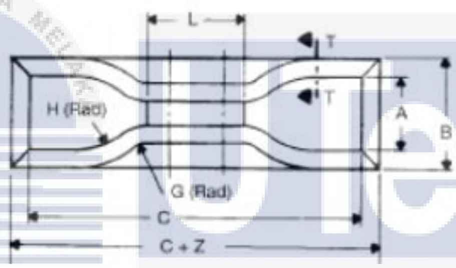


Figure 3.3 Dumbbell shape die

3.5 Soaking Test

For soaking test, the ASTM 471 is set as standards. The biodiesel use in this test is B10 and B30 blend and the other apparatus and materials use is nylon, aluminum foil and a beaker. The nylon is used to hang specimen during soaking test so that all the specimen surface is expose to the biodiesel and aluminum is to seal the beaker so that no impurities get into the biodiesel and keep the temperature constant. The setup of apparatus is shown as in **Figure 3.4**.

Figure 3.4 Apparatus Set up for Soaking test

This test conduct in a lab so that the surrounding condition such temperature and humidity can be control. According to ASTM D471, the temperature use is room temperature.

CHAPTER 4

RESULT AND DISCUSSION

This chapter discusses the result obtained from the experiment conducted as described in **Chapter 3.** The result obtained were analyzed and discussed accordingly in this chapter.

4.1 Mass Test

The mass of the sample was taken before and after the sample being soaked in both palm biodiesel (B10 and B30). The mass after soaked were taken every week until week 4. Refer to the **Table 4.1,4.2,4.3** and **4.4** the mass of as received sample is M1 and after soaked is M2. The sample is weighing 3 times and the average weight as in the table below.

Table 4.1 Mass change for Elastomer soaked in B10 at Room Temperature

Week	Sample Number	M_1 (g)	M_2 (g)	Change in Mass (%)
W2	1	10.4460	11.8725	13.66
	2	10.2787	11.9036	15.80
	3	12.0827	13.5801	12.40
	Average			**13.95**
W4	1	10.9204	12.7348	16.61
	2	11.8901	13.6300	14.63
	3	11.9900	13.9540	16.38
	Average			**15.87**
W6	1	11.1665	12.9263	15.80
	2	9.1811	10.5568	15.00
	3	11.8115	14.1672	19.94
	Average			**16.91**

Table 4.2 Mass change for Elastomer soaked in B10 at 40°C

Week	No. of Sample	M_1 (g)	M_2 (g)	Change in Mass (%)
W2	1	11.1746	11.2508	0.01
	2	11.3181	11.9626	0.06
	3	10.4983	11.6765	11.22
	Average			**3.76**
W4	1	12.0247	13.1041	0.09
	2	11.3762	13.2200	16.21
	3	10.9302	11.6252	0.06
	Average			**5.45**
W6	1	10.7414	14.8599	38.34
	2	10.9708	12.8316	16.96
	3	12.2432	13.0267	0.06
	Average			**18.45**

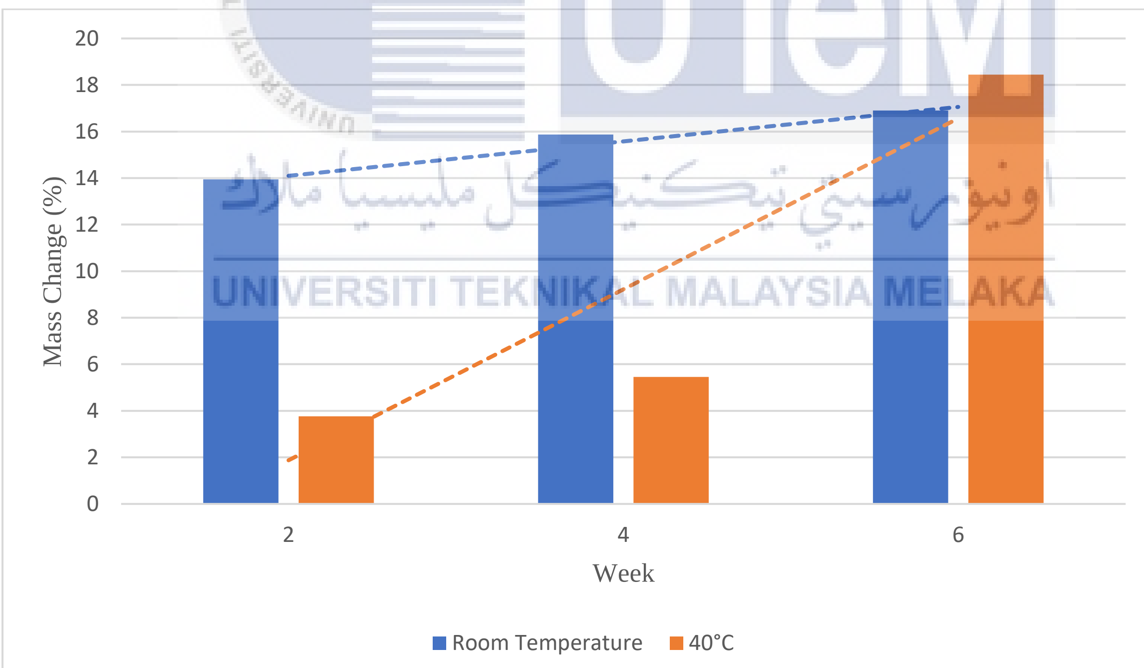


Figure 4.1 Mass Change for Sample Soaked in B10 for both conditions.

Table 4.1 and **4.2** shows the mass change for sample soaked in B10 palm biodiesel soaked in both condition which are soaked at room temperature and 40°C of biodiesel. For each week, 3 samples were prepared, and the mass was recorded as shown in the **Table 4.1** and **4.2**. The data was collected every 2 week starting from week 2 until week 6. The highest mass change (%) for room temperature and 40°C are after the elastomer soaked for 6 weeks with an average of 16.91% and 18.45% respectively.

Refer to **Figure 4.1** above, the trend of the graph is keep increasing as the soaking time is increase. The slope of the linear line of the graph for 40°C sample is steeper compared to the room temperature conditions. This shows that the elastomer that soaked in high temperature gained mass more than soaked at room temperature. According to previous study by (Chandran *et al.*, 2016) the degradation due to change of temperature is due to the adverse effect of dissolved oxygen in NBR. This is proven after conducting composition analysis in their study. Higher dissolved oxygen in the elastomer will increase the degradation of elastomer.

Table 4.3 Mass change for Elastomer soaked in B30 at Room Temperature

Week	Sample Number	M_1 (g)	M_2 (g)	Change in Mass (%)
W2	1	13.0822	15.1307	15.66
	2	12.7814	14.7296	15.24
	3	10.5396	12.0933	14.74
	Average			**15.21**
W4	1	11.1639	12.9350	15.86
	2	10.5781	12.1331	14.70
	3	12.8538	14.9755	16.51
	Average			**15.69**
W6	1	11.7211	13.6839	16.75
	2	10.7714	12.4853	15.91
	3	11.9384	13.9400	16.77
	Average			**16.48**

Table 4.4 Mass change for Elastomer soaked in B30 at 40°C

Week	Sample Number	M_1 (g)	M_2 (g) Average	Change in Mass (%)
W2	1	11.8005	12.4781	0.06
	2	11.3282	12.7820	12.83
	3	9.9877	12.3456	23.61
	Average			**12.17**
W4	1	11.4021	12.9734	13.78
	2	11.2013	12.3578	10.33
	3	10.2031	11.7452	15.12
	Average			**13.07**
W6	1	13.0341	13.7601	0.06
	2	10.0252	13.5113	34.78
	3	10.2161	12.1067	18.51
	Average			**17.78**

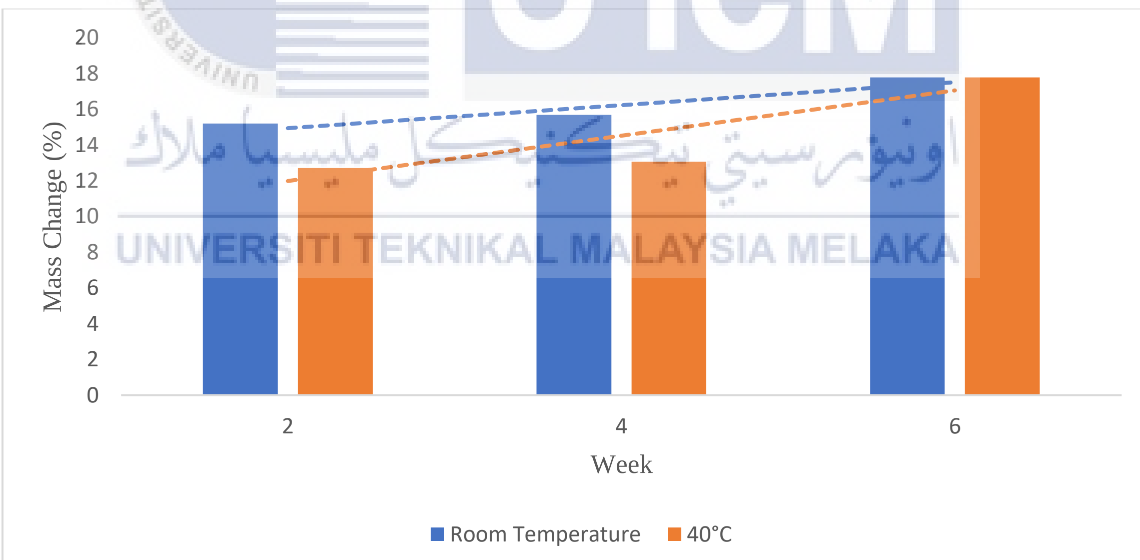


Figure 4.2 Mass change for elastomer soaked in B30 at both conditions

Table 4.3 and **4.4** above shows the mass change (%) for the sample soaked in B30 palm biodiesel at both conditions which are room temperature and 40°C of biodiesel. The highest changed is recorded during 6 weeks of soaking test for both conditions. Refer to **Figure 4.2,** both conditions still show that the mass change increase as the time increase. The slope for sample soaked at 40°C is more steep compare to the room temperature conditions. According to the graph, the higher the temperature the higher the change of mass.

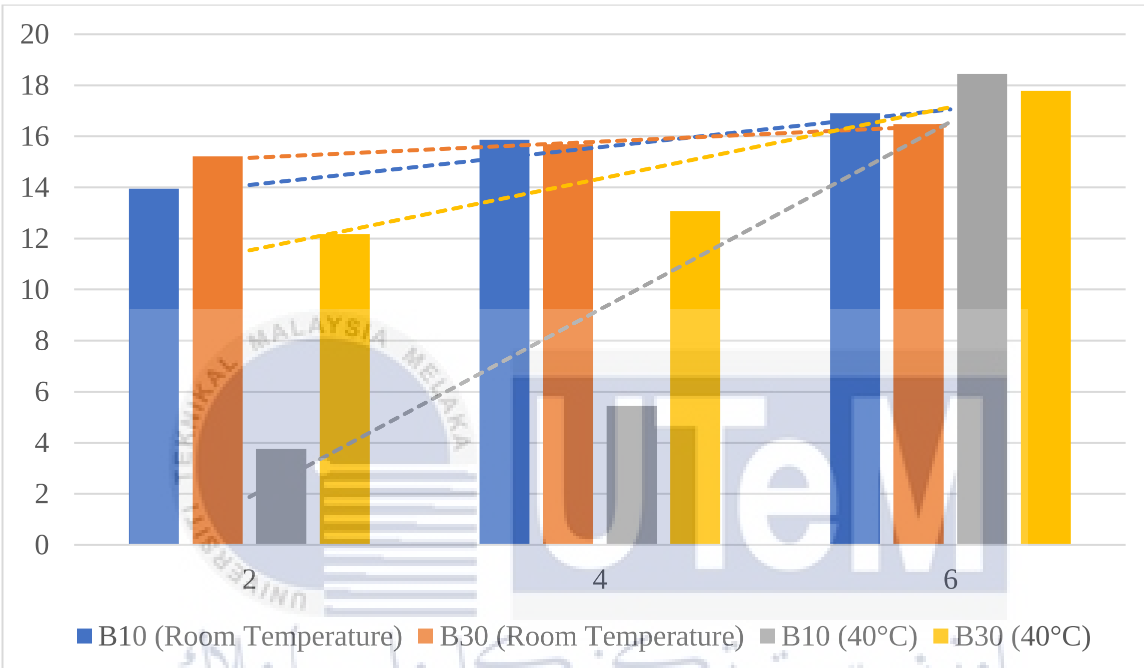


Figure 4.3 Comparison for B10 and B30 at 40°C

Figure 4.3 above aim to compare the mass change (%) for the effect of percentage of palm biodiesel in a biodiesel which in this study is to compare the elastomer effect when soaked in B10 and B30 biodiesel for both conditions. From the graph plotted, it shows that all sample mass increases as the soaking time increase. However, the gradient of the graph shows that the sample soaked in B30 at room temperature have a less steep slope, which mean that the elastomer is not gaining much mass compare to when expose to B30 at 40°C and B10 biodiesel either at room temperature or 40°C condition.

According to the previous study by (Haseeb *et al.*, 2011), NBR type of elastomer shows that the mass change (%) when soaked in B10 is higher compare to when soaked in B20 and B50. On the other hand, study by (Tongroon *et al.*, 2017) stated that the immersion period or type of biodiesel has a significant effect on the mass change (%). This hypothesis is done after the calculation using ANOVA statistical test perform by (Tongroon *et al.*, 2017) in order to determine whether the means of the independent groups have any statistically significant differences between each other. Most of the existing study reported that higher amount of biodiesel in biodiesel-diesel blends result in increase of mass of elastomer and more with increase in temperature. This is might be due to swelling of the elastomer for NBR attributed to the absorption solvent into the elastomer as reported in (Haseeb *et al.*, 2010). The degree of dipole-dipole interaction in biodiesel is higher as compared to pure diesel or a low biodiesel contain in biodiesel-diesel fuel. Its unique chemical difference arising from the increased polarity of esters turn the elastomer become swelling more in biodiesel compare to that in pure diesel (Haseeb *et al.*, 2010). Some study says that the higher viscosity of the biodiesel will lower the chance for the elastomer to swell. Due to B10 have a lower viscosity, the biodiesel was absorb more into the elastomer compared to that soaked in B30 biodiesel (Sharma *et al.*, 2018). For a long period of service, the fuel hose might be swell more and might be a blockage in fuel delivery system.

4.2 Tensile Test

The tensile test result for the soaked hose is shown in the **Figure 4.4, 4.5, 4.6** and **4.7.** All result is tabulated and analyzed in this section.

4.2.1 Tensile Test Result for Elastomer Soaked at Room Temperature

Figure 4.4 and **4.5** below shows the maximum extension of the fuel hose before the hose failed. The result taken is for the as received hose and soaked hose for week 2 up to week 6.

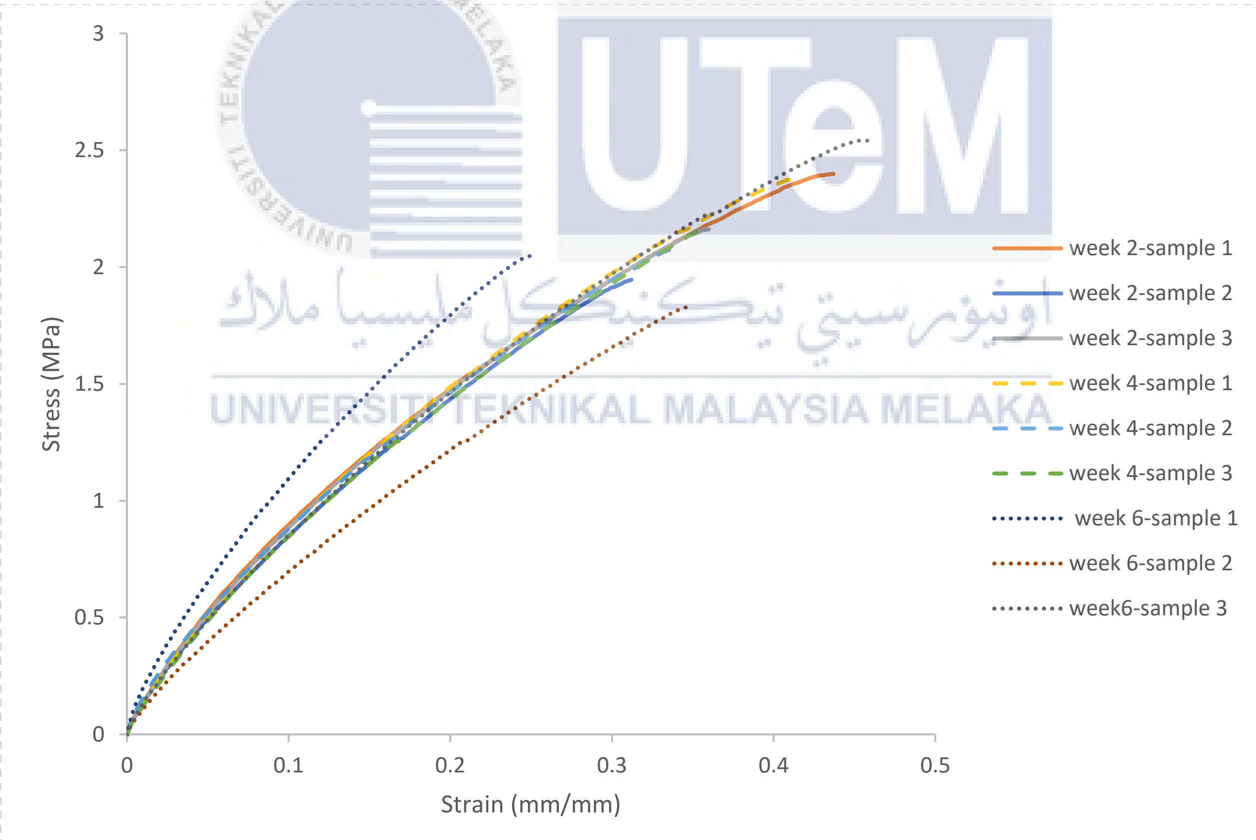


Figure 4.4 Stress-Strain Graph for Elastomer Soaked in B10 at Room Temperature

Figure 4.4 shows the plotted data for stress-strain of the B10 soaked hose at room temperature for 3 weeks (week2, week4 and week 6) and 3 sample was tested for each week. Based on the graph in **Figure 4.4**, the gradient of the graph is almost the same for all sample but different in maximum stress that the elastomer can hold. Maximum stress is the total stress that applied to the elastomer before it fractures, and these mechanical properties is important as the fuel hose operate in high internal pressure. When the elastomer cannot withstand high stress, then it easier to failed or burst. Majority of the sample maximum stress is range between 2-3 MPa. This data shows that the strength of the elastomer is not change so much. The strain of the hose decreased, as the soaking time increased. This can be seen for the result obtain for week 2 and week 6, the strain in week 6 is much lower than week 2. The strain for week 2 is range from 0.3 to 0.5, while for week 6 is range from 0.3 to 0.35.

The previous study is slightly different, (Chandran, 2019) reported that the NBR type of elastomer keep degrade with time . Thus, if the elastomer is degraded, supposedly the tensile stress also decreases. However, difference in tensile change was not significant. The different of this result is already explained by (Trakarnpruk and Porntangjitlikit, 2008b) where they stated that this may cause by the different temperature conducted during soak. This may also cause by the cross-linking of the elastomer. When the cross-linking is higher, the reaction of the biodiesel with the elastomer is limit as stated by (Tongroon *et al.*, 2017).

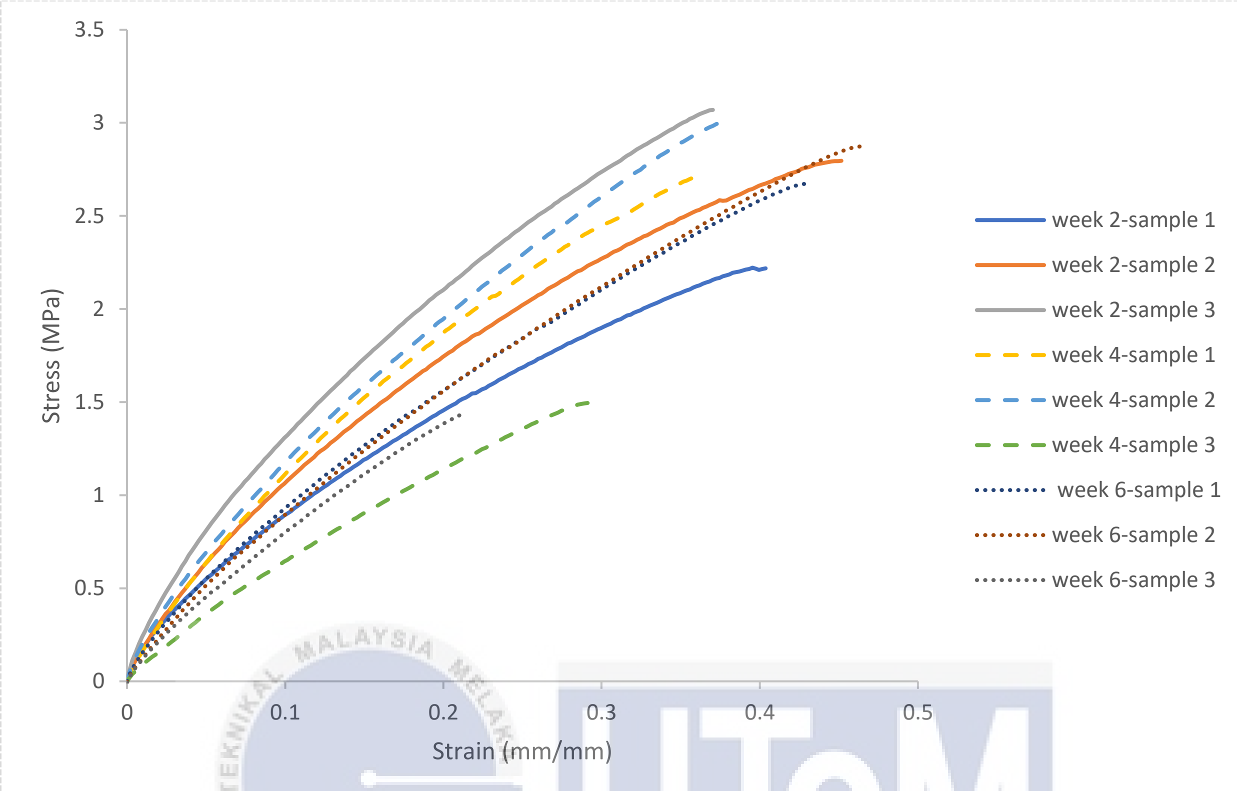


Figure 4.5 Stress-Strain Graph for Elastomer Soaked in B30 at Room Temperature

Figure 4.5 shows the plotted data for stress-strain of the B10 soaked hose at room temperature for 3 weeks (week 2, week 4 and week 6) and 3 sample was tested for each week. The graph shows that the strength of the elastomer is decreases. As for week 2 the average maximum stress is 2.7MPa decrease to 2.39MPa in week 4 and 2.33MPa in week 6. From the result, the elastomer is degraded that cause the tensile strength of elastomer to decrease with the increase of soaking time. This result is the same as the previous study where the elastomer is degrade along the soaking time as reported by (Tongroon *et al.*, 2017)

The graph shows that the sample for week 2 is range between 0.35 to 0.45. While for week 4, range of extension is between 0.2 to 0.4. Compared to week 2 sample, the week 4 sample already degrade because some of the sample cannot stretch more than week 2 sample. For the week 3 data, it lies in between of week2 and week 4 range which is between 0.35 to 0.4. Result week 3-1, the pattern of the curve is not the same as for another curve.

4.2.2 Tensile Test Result for Elastomer Soaked at 40°C

Figure 4.6 and **4.7** is the data of maximum extension for the sample that were soaked in B30 at 40°C.

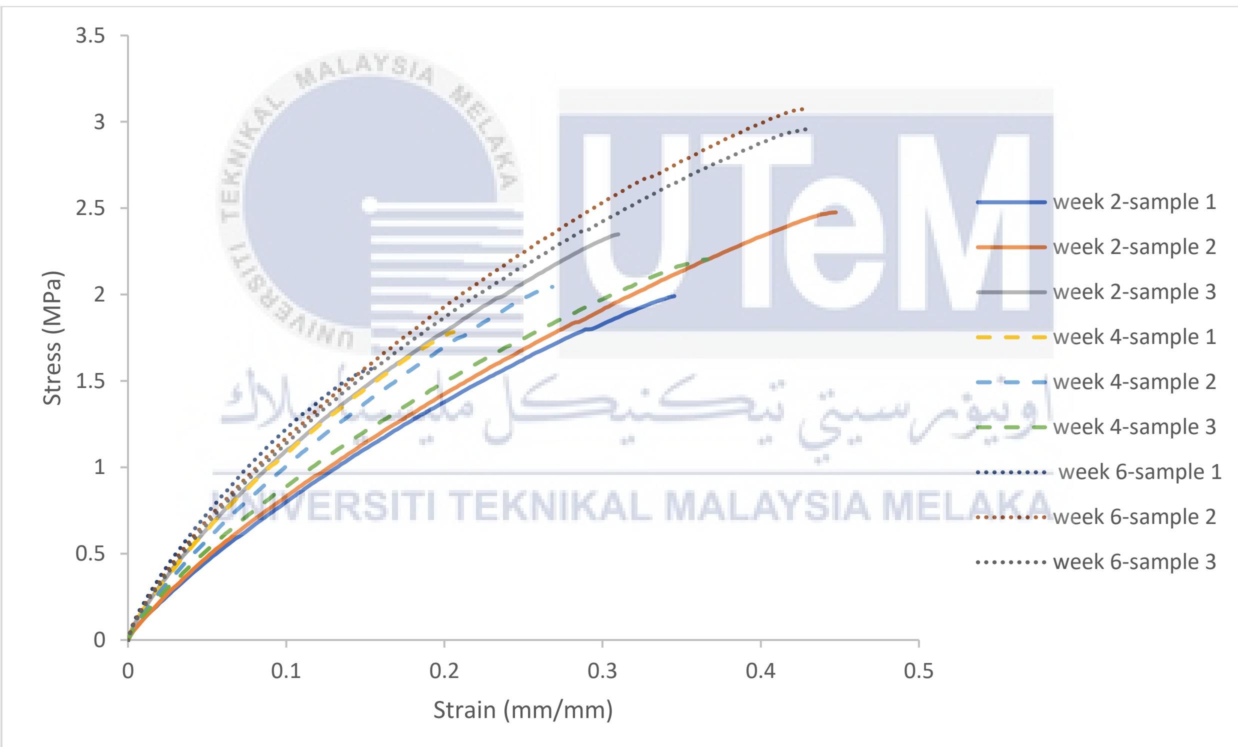


Figure 4.6 Stress-Strain Graph for Elastomer Soaked in B10 at 40°C

Figure 4.6 shows the stress-strain of hose soaked in B10 but with different condition which is controlled temperature of 40°C. The timeline is the same as before which is data taken for as received and week 2 up to week 6. Compare to the previous condition soaked at room temperature, the data for this condition is much lower where for week 2 sample. For 40^{o}C of biodiesel, the average maximum tensile stress is 2.27MPa while for room temperature condition, the maximum tensile strength is 2.7MPa. Week 4 specimens average maximum stress is 2.01MPa while for week 6 is 2.53MPa.

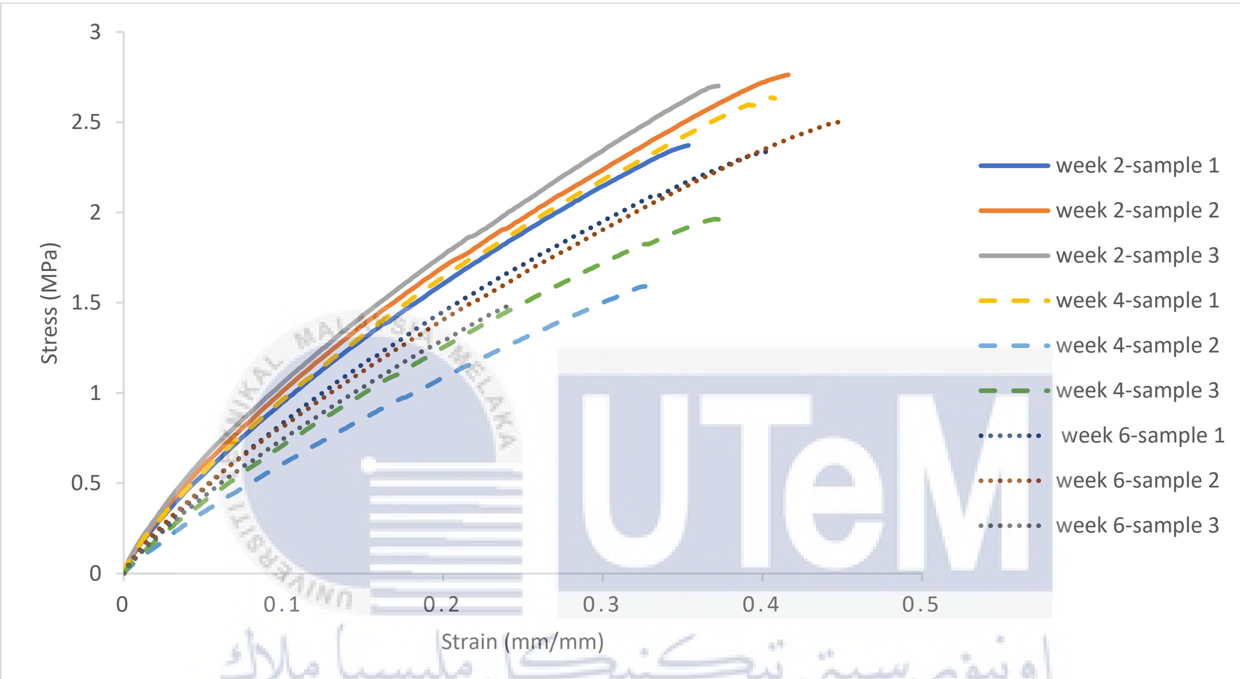


Figure 4.7 Stress-Strain Graph for Elastomer Soaked in B30 at 40^{o}C

Figure 4.7 above shows that the tensile stress of the hose is the highest for the sample that soaked for 2 weeks with average maximum stress of 2.61MPa while for specimen soaked for 4 weeks is 2.06MPa and slightly increased to 2.11MPa. This result is linear with the previous study as reported by (Haseeb *et al.*, 2010) that, as received NBR shows 10.4MPa strength and 750% elongation while upon exposure to B100 biodiesel the value is decrease to 8.7MPa and 646% of elongation. The strain of the hose decreased as the soaking time increased. In week 2 the hose tensile strain is between 0.35 to 0.45 while in week 4 the range of tensile strain is 0.25 to 0.4. This shows that the strain of the hose decreased, thus mean that the hose is easily be failed due to its poor ability to elongate.

Compare to the specimen soaked in B10 at 40°C, week 2 and week 6 specimens average maximum stress is lower than when soaked in B30 at 40°C. Refer to **Figure 4.6** and **4.7**, the average maximum stress for week 2 is 2.27MPa while for B30 is 2.61MPa. However, specimen soaked for 6 weeks in B10 is higher 2.53MPa compare to 2.11MPa in B30.

4.2.3 Average Maximum Stress (MPa) of Elastomer Soaked at Room Temperature

Table 4.5 below shows the Average Maximum Stress of the sample that soaked at room temperature for both type of biodiesel and tabulated as in **Figure 4.8** and **4.9**. This result obtained from the tensile test perform after the soaking test.

Table 4.5 Average Maximum Stress (MPa)of Elastomer Soaked at Room Temperature

Week Sample	Week 2	Week 4	Week 6
B30 (MPa)	2.70	2.39	2.33
B10 (MPa)	2.16	2.21	2.13

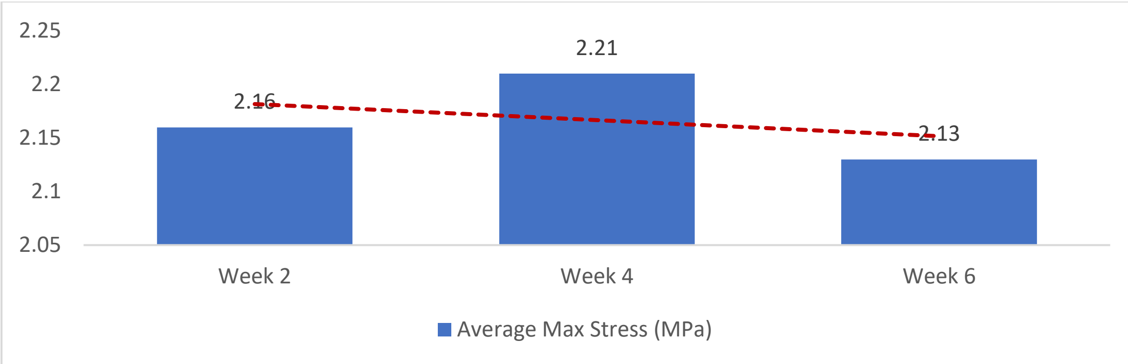


Figure 4.8 Bar Graph of Average Maximum Stress (MPa) of Elastomer soaked in B10 at Room Temperature

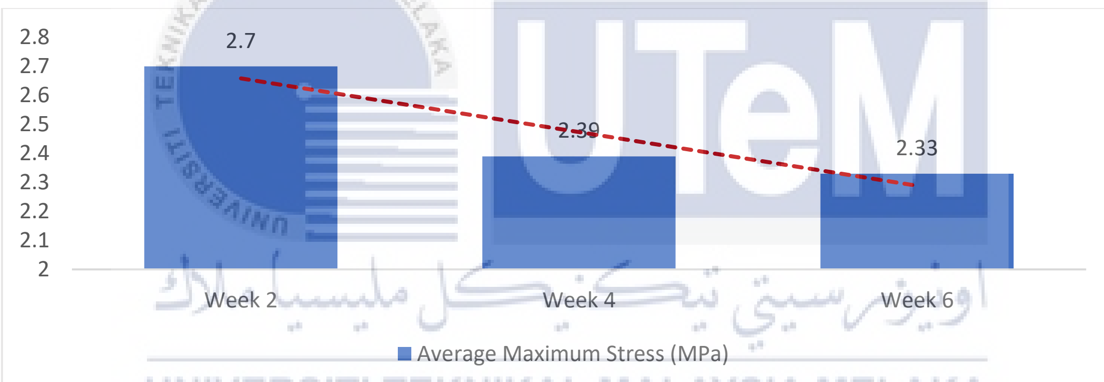


Figure 4.9 Bar Graph of Maximum Stress (MPa) of Elastomer soaked in B30 at Room Temperature

4.2.4 Average Maximum Stress (MPa) of Elastomer Soaked at 40ºC

Table 4.6 shows the Average Maximum Stress of the sample that soaked at 40ºC for both type of biodiesel and tabulated as in **Figure 4.10** and **4.11**. This result obtained from the tensile test perform after the soaking test.

Table 4.6 Average Maximum Stress (MPa) of Elastomer Soaked in B10 and B30 at 40°C

Week Sample	**Week 2**	**Week 3**	**Week 4**
B30 (MPa)	2.61	2.06	2.11
B10 (MPa)	2.27	2.01	2.53

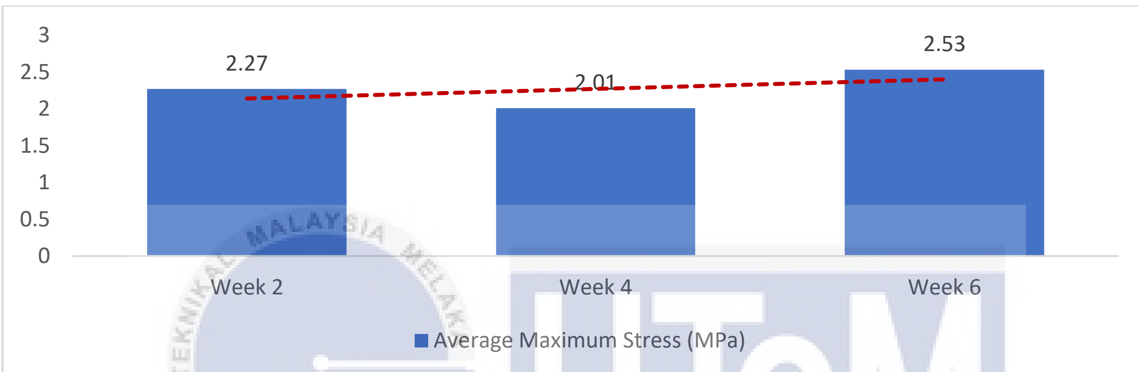


Figure 4.10 Bar Graph of Average Maximum Stress (MPa) of Elastomer soaked in B10 at 40°C

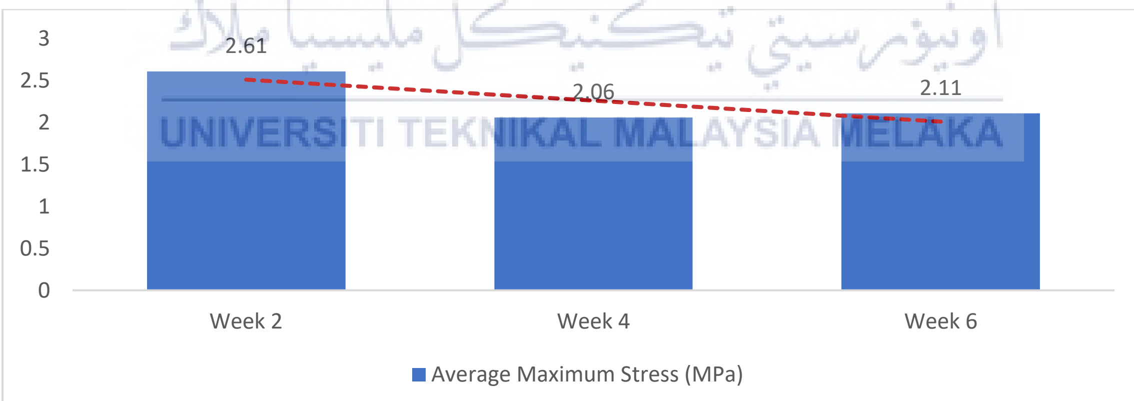


Figure 4.11 Bar Graph of Average Maximum Stress (MPa) of Elastomer soaked in B30 at 40°C

4.2.5 Correlation of Maximum Stress (MPa) with Change in Mass (%)

Figure 4.12, 4.13, 4.14 and **4.15** below shows the correlation of average maximum stress that obtained from tensile test with the mass change after the specimens were soaked for 2, 4 and 6 weeks. The aim of this graph plotted is to investigate the relationship of mass change (%) with the average maximum stress of the specimens after being soaked for 2,4 and 6 weeks.

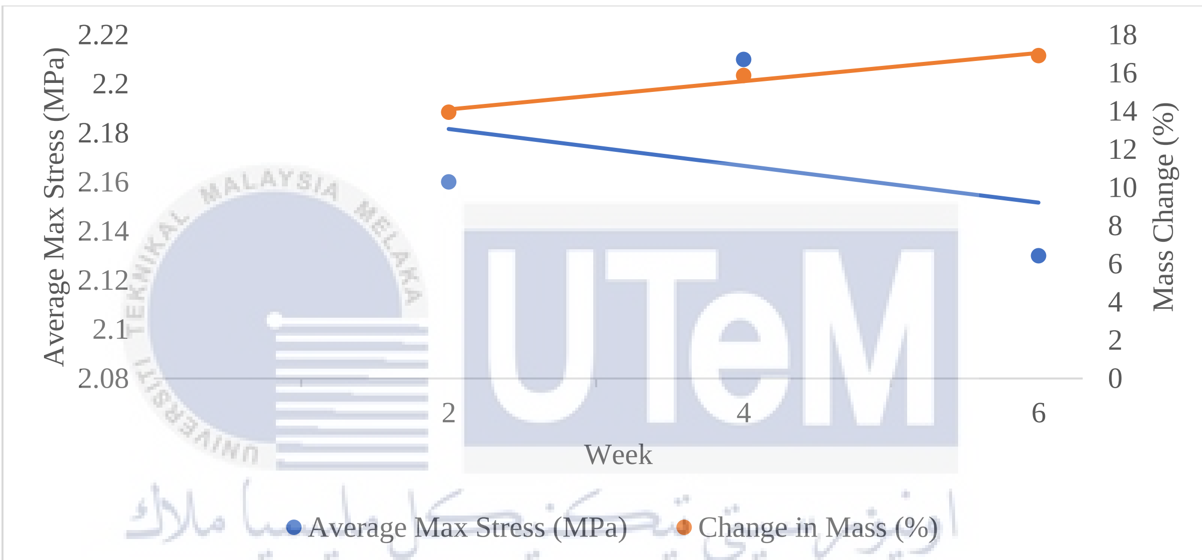


Figure 4.12 Correlation of Average Max Stress (MPa) and Change in Mass (%) for sample soaked in B10 (Room Temperature)

Table 4.7 Correlation of Average Max Stress with Change in Mass for sample soaked in B10 (Room Temperature)

	Average Max Stress (MPa)	*Change in Mass (%)*
Average Max Stress (MPa)	1	
Change in Mass (%)	-0.21	1

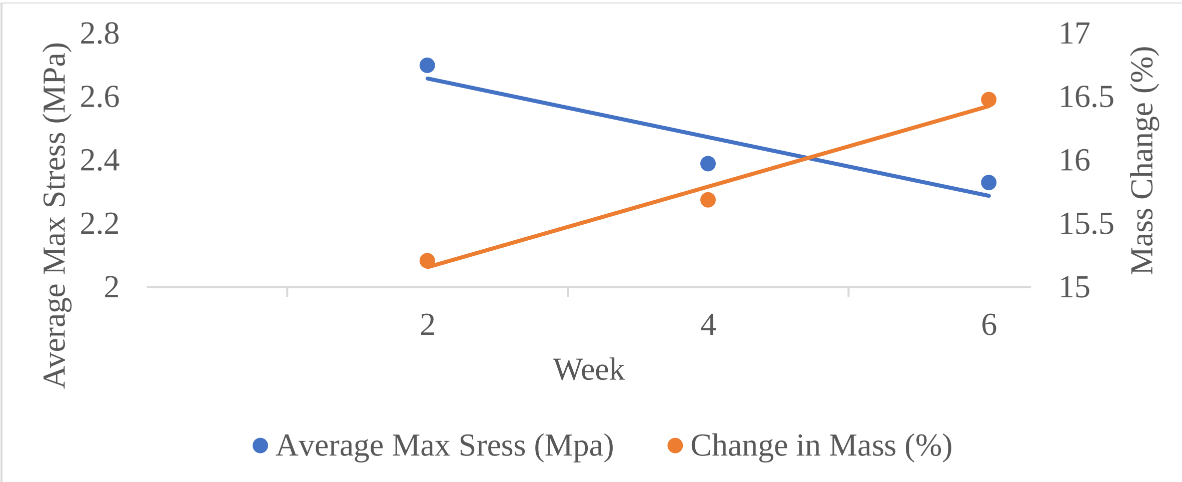


Figure 4.13 Correlation of Average Maximum Stress (MPa) and Change in Mass (%) for sample soaked in B30 (Room Temperature)

Table 4.8 Correlation of Average Max Stress with Change in Mass for sample soaked in B30 (Room Temperature)

	Average Max Sress (Mpa)	Change in Mass (%)
Average Max Sress (Mpa)	1	
Change in Mass (%)	-0.87179	1

Figure 4.14 and **4.15** below is the data obtained for the elastomer that exposed to B10 and B30 but in room temperature. This data taken is to investigate if the temperature is affecting the degradation process other than type of biodiesel.

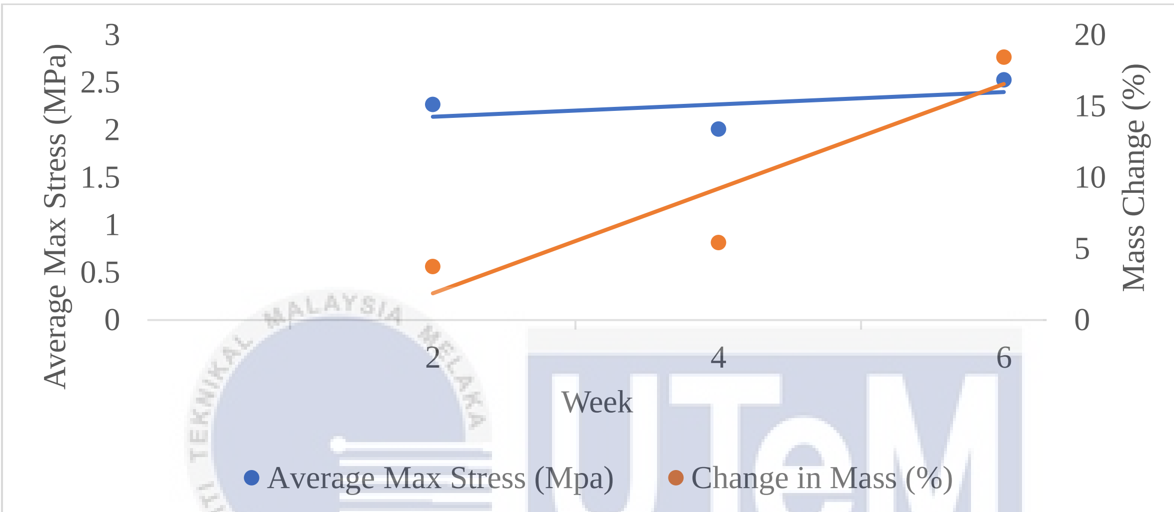


Figure 4.14 Correlation of Average Maximum Stress (MPa) and Change in Mass (%) for sample soaked in B10 (40°C)

Table 4.9 Correlation of Average Max Stress with Change in Mass for sample soaked in B10 (40°C)

	Average Max Stress (Mpa)	Change in Mass (%)
Average Max Stress (Mpa)	1	
Change in Mass (%)	0.808664	1

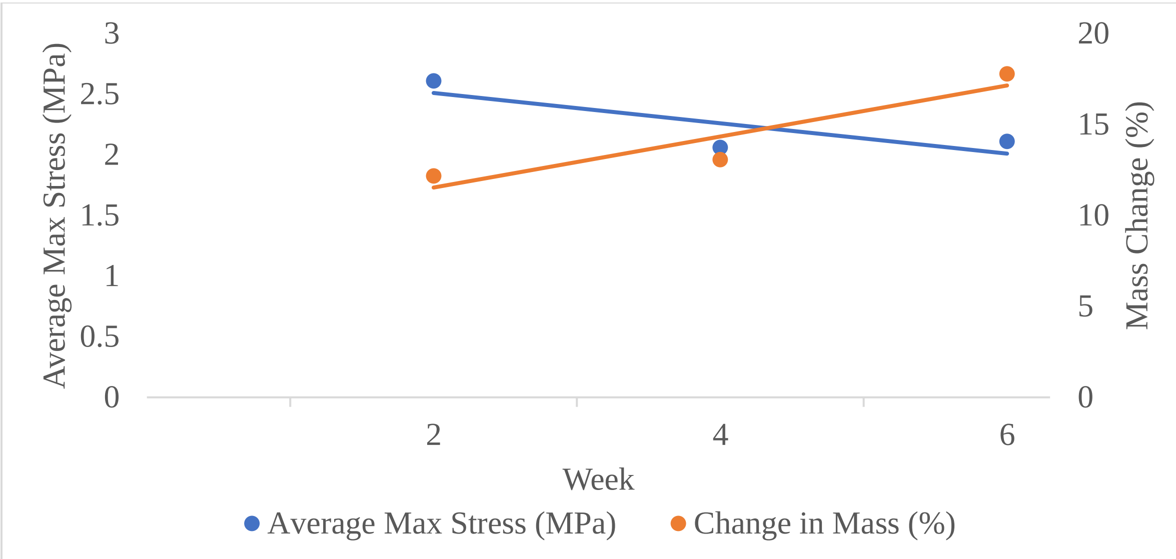


Figure 4.15 Correlation of Average Maximum Stress (MPa) and Change in Mass (%) for sample soaked in B30 (40°C)

Table 4.10 Correlation of Average Max Stress with Change in Mass for sample soaked in B30 (40°C)

	Average Max Stress (MPa)	Change in Mass (%)
Average Max Stress (MPa)	1	
Change in Mass (%)	-0.55738	1

From **Figure 4.12, 4.13, 4.14** and **4.15** above, it can be observed that the elastomer decreased in strength when the mass change increased. The gradient of the graph when compare between type of biodiesel, B30 shows that the degradation of elastomer is higher because the gradient is steeper compared to B10 graph. In room temperature, the strength of elastomer decreases when exposed with B30 and the line is decreasing slightly when exposed to B10 biodiesel. For the mass change, both graph in **Figure 4.12** and **4.14** shows that the elastomer is gaining mass, but specimen soaked in B30 gained more weight.

In terms of temperature, for B30 biodiesel shows that when the elastomer is exposed to high temperature biodiesel (40^oC), the Average Maximum Stress (MPa) line show that the strength is decreased more than elastomer exposed to the room temperature biodiesel. On the other hand, when the elastomer is exposed to B10 biodiesel at 40^oC, it shows that the strength of the elastomer increased but decreased when exposed to room temperature biodiesel.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The objective of this study is to describe the impact of degradation of elastomers by measuring sample weight and mechanical properties (strength) properties after exposed to B10 and B30 palm biodiesel and to investigate the failure mechanism of B30 palm biodiesel-immersed elastomers using tensile test method. Based on the result that already discussed in the previous chapter, B30 biodiesel shows more degradation in terms of strength compared to B10. The NBR type of elastomer is gained more weight and decreased in tensile strength when exposed to a high-volume percentage of palm biodiesel-diesel blend which is B30 compared to B10 and when the biodiesel blend was heated to 40^{o}C.

5.2 Recommendation

For the upcoming research of this project, a different type of elastomer needs to be tested as the NBR still showing degradation upon exposure to biodiesel but still can be used. Refer to the previous study material such FKM (fluoroelastomer) has a good compatibility with diesel compared to other elastomer. But the fuel hose using this type of material is not easy to find in the market. On the other hand, the hardness, FTIR and volume test should be done to verify all properties change in the elastomer. Besides, all equipment needs to be well prepared as to avoid the same error in this study to be repeated in the future work such the dog bone cutter. But I suggest that the sample should not be cut into dog bone shape as the cutting process is very critical and lead to many errors. For future work, the sample should be in rectangular shape as to reduce the error. This is because, according to what I observe on the sample after being cut is, the sample dimension is not even at the gage length. This is very critical when performing tensile test as the sample will fail at the area that have less dimension. Figure below shows the uneven dimension especially at the gage length of the sample.

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