Faculty of Mechanical Engineering

PHYSICAL – MECHANICAL PROPERTIES OF ELASTOMER DILUTED WITH B10 AND B20 BIODIESEL

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PHYSICAL – MECHANICAL PROPERTIES OF ELASTOMER DILUTED WITH B10 AND B20 BIODIESEL

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DECLARATION

I declare that this thesis entitled "Physical – mechanical properties of elastomer diluted with B10 and B20 biodiesel" is the result of my own research except as cited in references. The thesis has not been accepted for any degree and is not submitted in candidature of any other degree.

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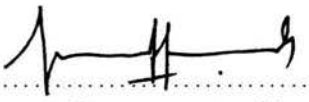
APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion, this dissertation/report is sufficient in terms of scope and quality as a partial fulfilment of Master of Mechanical Engineering (Automotive).

Signature : 

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Date : Feb 12, 2019

DEDICATION

To my beloved mother, Ruslina binti Mamat and my father, Hassan bin Samin.

ABSTRACT

Nowadays, there are a lot of heavy machineries and vehicles that uses diesel (CI) engine. Therefore, the usage of diesel in industrial application and transportation is increasing rapidly. This type of engines uses diesel as their source of fuel. However, the usage of pure diesel (B0) is very harmful and may pollute the environment due to the release of harmful exhaust gasses and a lot of soot or particulate matter. Therefore, alternative fuel is the best solution for this problem which is biodiesel. This is because the biodiesel tends to produce greener exhaust gasses and less particulate matter that reduce the pollution from the diesel engine. Though the biodiesel and pure diesel share almost the same characteristic, there are a few advantages and disadvantages of biodiesel compared to pure diesel. Biodiesel tends to have the corrosive properties when it is blended with Ultra Low Sulphur Diesel (ULSD). Therefore, usage of biodiesel will affect the elastomer which is one of the main components of the fuel delivery system. The elastomer can usually be found in the fuel lines for diesel engine and also the sealing of the engine parts. In this project, biodiesel B10 and B20 was studied. Therefore, a few tests have to be done in order to investigate the effect of B10 and B20 biodiesel on the physical – mechanical properties of the elastomer. For physical test, the mass test before and after soaking in elastomer will be done and. On the other hand, the hardness test and tensile test will be done to test for the mechanical properties of the elastomer before and after soaking in the B10 and B20 biodiesel. However, the elastomer needs to be soaked for a certain amount of time before being tested for the physical – mechanical properties. Each test was done according to the respective ASTM standards which are ASTM D471 for soaking test and mass test, ASTM D2240 for hardness test, and ASTM D412 for tensile test.

ABSTRAK

Pada masa kini, terdapat banyak jentera dan kenderaan berat yang menggunakan enjin diesel (CI). Oleh itu, penggunaan diesel dalam aplikasi perindustrian dan pengangkutan meningkat dengan pesat. Enjin jenis ini menggunakan diesel sebagai sumber bahan api mereka. Walau bagaimanapun, penggunaan diesel tulen (B0) sangat berbahaya dan boleh mencemarkan alam sekitar disebabkan pelepasan gas ekzos yang berbahaya dan banyak jelaga atau zarah. Oleh itu, bahan api alternatif adalah penyelesaian terbaik untuk masalah ini yang merupakan biodiesel. Ini adalah kerana biodiesel cenderung untuk menghasilkan gas ekzos yang lebih hijau dan kurang zarah yang mengurangkan pencemaran dari enjin diesel. Walaupun biodiesel dan diesel tulen berkongsi ciri yang hampir sama, terdapat beberapa kelebihan dan kekurangan biodiesel berbanding diesel tulen. Biodiesel cenderung untuk mempunyai sifat menghakis apabila dicampur dengan Ultra Low Sulfur Diesel (ULSD). Oleh itu, penggunaan biodiesel akan mempengaruhi elastomer yang merupakan salah satu komponen utama sistem penyaluran bahan api. Elastomer biasanya boleh didapati di saluran bahan api untuk enjin diesel dan juga pengedap bahagian enjin. Dalam projek ini, biodiesel B10 dan B20 telah diuji. Oleh itu, beberapa ujian perlu dilakukan untuk mengkaji kesan biodiesel B10 dan B20 pada sifat fizikal dan mekanik elastomer. Untuk ujian fizikal, ujian jisim sebelum dan selepas perendaman dalam elastomer akan dilakukan. Di samping itu, ujian kekerasan dan ujian tegangan akan dilakukan untuk menguji sifat-sifat mekanik elastomer sebelum dan selepas direndam dalam biodiesel B10 dan B20. Walau bagaimanapun, elastomer perlu direndam selama jagka waktu yang telah ditetapkan sebelum diuji untuk sifat fizikal - mekanikal. Setiap ujian dilakukan menurut piawaian ASTM masing-masing iaitu ASTM D471 untuk ujian rendaman dan ujian jisim, ASTM D2240 untuk ujian kekerasan dan ASTM D412 untuk ujian tegangan.

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LIST OF SYMBOLS

A	-	Ampere
C	-	Calibration constant
M_1	-	Mass of specimen in air before soaking
M_2	-	Mass of specimen in air after soaking
N	-	Newton
t	-	Time
v	-	Kinematic viscosity
W	-	Watt

CHAPTER 1

INTRODUCTION

1.1 Background

Biodiesel is widely used for diesel engine vehicle nowadays. This is a very useful alternative fuel in the global fuel market due to the factors of air pollution, depletion of natural resources and increasing price of fossil fuel. The plus side of using biodiesel is it does not need any major modification to the engine. This is because the biodiesel shares the same properties with diesel fuel. Therefore, it also can be adapted by only using minor modifications (Jeon and Park, 2018).

Chandran et al. (2016) also states that biodiesel (B100) is also known as fatty acid methyl ester (FAME). This type of biodiesel is typically produced from vegetable or animal based oil through transesterification process. This process is mainly to reduce the viscosity of the vegetable oil from 40 mm^2s^{-1} into a much lower viscosity which is approximately 5 mm^2s^{-1}. The value is said to be suitable to be used for the diesel engine.

The biodiesel focused in this research is from palm oil because Malaysia is known as one of the biggest producers and exporters of palm oil in the world. This is because Malaysia is accounting for 39% of the world's palm oils and fats production and 44% of export trade of oils and fats (*Malaysian Palm Oil Council*, 2018).

Other than sharing the same properties with diesel, there are also a lot of advantages of biodiesel. The main advantage is significantly reduces the emission of the harmful gasses. Regardless of the advantages, there are a few drawbacks for the biodiesel.

the major concern for the biodiesel is that the biodiesel may affect the elastomer which is the main components for the fuel delivery system.

Diesel engine has fuel delivery system to make sure that the fuel can be delivered through fuel lines in order to support the combustion in the engine. This fuel lines are usually made of a few types of materials which are mainly from elastomer. The most common elastomer to be used in the engine is Nitrile Rubber (NBR) (Sorate, Bhale and Dhaolakiya, 2015). The fuel delivery system in a diesel engine is as shown in **Figure 1.1**.

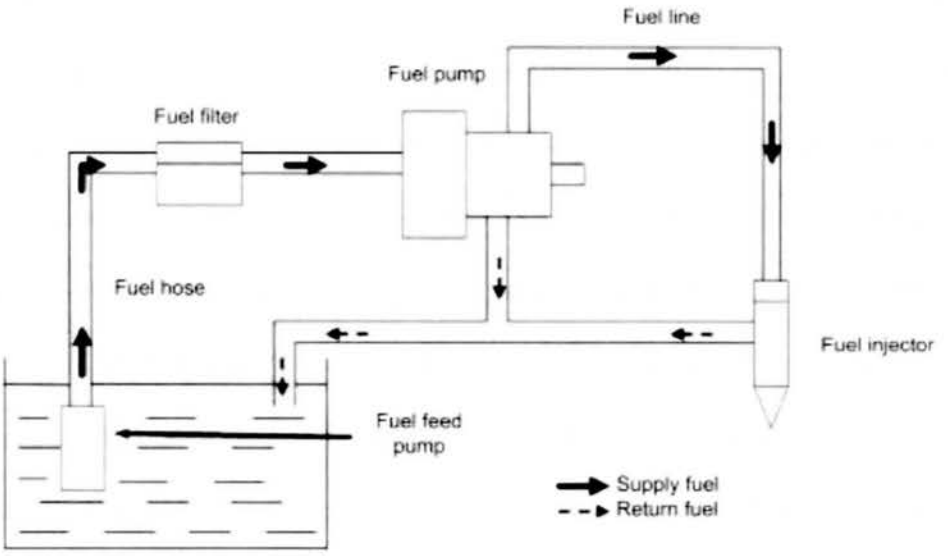

Figure 1.1: Fuel delivery system in a typical diesel engine (Chandran *et al.*, 2016)

Due to the chemical properties of the biodiesel, it will affect the elastomer and cause degradation on the elastomer. This will cause the elastomer to be further degraded as the usage time increases. In this project, the fuel hose from the tank to the fuel pump is considered as the part to be tested.

1.2 Statement of purpose

The purpose of this study is to investigate the effect of palm oil biodiesel B20 and B10 on the elastomer that is used in the fuel lines of a CI engine by soaking and running a few tests on the elastomer such as tensile test, mass, and hardness test according to the ASTM standard.

1.3 Problem statement

The usage of biodiesel blend in engine fuel and boiler fuel are becoming more common and widely used in the industry and on the road. Biodiesel tends to have corrosive properties when it is blended with Ultra Low Sulphur Diesel (ULSD). The materials used such as nitrile rubber and Viton seals will swell as being soaked in the biodiesel such as (B20, B50, and B100). The recent study also shows that the swelling increases as the concentration of the biodiesel increases. This means the higher the percentage of the biodiesel such as B20, B50, and B100, the swelling of the rubber and seals will increase. Other than that, other effect also occurs on the increasing concentration. For example, the hardness and elasticity of the materials will be affected as the concentration increases. This will cause the materials such as rubber hose and the seals to be replaced in order to avoid any leakage or blockage in the fuel lines. This will reduce the lifespan of fuel delivery components.

Biodiesel must resist aging and oxidation along the extent of storage and must not risk deterioration of storage tank as well as construction elements of transfer and blending. Therefore, fuel that has a maximum concentration level of 20vol% biodiesel with 80vol% diesel (B20) is permitted to be used until present (Chandran *et al.*, 2018).

Therefore, tests should be done in order to investigate the effect of biodiesel on the elastomer. This is mainly to test whether the existing material used for the fuel delivery system can withstand the usage of B10 and B20 in the diesel engine. This is very important because Malaysia is going to be using B10 and B20 biodiesel in the near future. If the material is not suitable to be used in the existing engine, a new material will be suggested to be used.

1.4 Objective of project

This research is done in order to determine the solution for the following problem stated in Section 1.3. The objective of this research is to investigate the effect of B10 and B20 on the physical – mechanical properties of elastomer.

1.5 Scope of work

The scope of this research is to test and compare the elastomer that is suitable for the diesel engine using biodiesel B10 and B20 to be suggested for future use. For this project, the elastomer used is Nitrile Rubber (NBR). To test the mechanical – physical properties of the elastomer, the mass test, hardness test, and tensile test were done after soaking the elastomer in the biodiesel B10 and B20. The soaking test was done for five consecutive weeks for both biodiesel B10 and B20.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, the source of natural resources such as petroleum and coal are going down and it is very important to make sure that the resources can be preserved. On the other hand, the usage of natural fossil fuel such as pure diesel can cause a lot of pollution due to the production of soot, release of harmful gasses and it is very dangerous if being used for a long time (*Truck News*, 2016). This is because the gasses produced by diesel engine using pure diesel can cause the greenhouse effect which can cause severe diseases.

One of the most prominent areas where the high demand for the petroleum-based fuel exhibits itself is the transportation and agricultural sector which in turns form not only one of the main consumer of fossil fuel which is diesel and petrol but also one of the leading contributor to the environmental pollution in the area. Therefore, the transportation and automotive industry such as trucks and off-road engines and vehicles create an important field. To achieve the diversification from petroleum products, this field is where the use of the alternative fuels emerges as a very promising, long-term alternative solution (Giakoumis *et al.*, 2012).

Another effect of greenhouse gasses is the thinning of ozone layer and this is also one of the contributions to the global warming. If ozone layer is thinning, the people living in the area will be affected and they will get dangerous diseases such as eye cataract, eye cancer, skin cancer, and many more. This may cause death to certain people living in the

area. Global warming is also very dangerous because it can cause the ice in North Pole and South Pole to melt. The melting of ice in these areas will cause the sea level to rise and also death of animals that lives there such as polar bear and penguins and they are already on the verge of extinction. Therefore, the usage of alternative fuel is very crucial to make sure that the natural resources can be preserved because the alternative fuels not only can save the natural resources but also preserve the nature due to less pollution produced.

The focus of this study is to run some test on the elastomer soaked in biodiesel to check the mechanical – physical properties of the elastomer soaked in biodiesel B10 and B20. The tests are soaking test, mass test, hardness test, and tensile test. The introduction and explanation on the apparatus and materials used in this project are discussed in this chapter.

2.2 Biofuels

There are a lot of heavy vehicles on the road such as lorry, busses, and trucks. Heavy vehicles usually uses diesel as their fuel. Since pure diesel has a lot of dangerous effects that can harm the environment and also human being, the alternative fuels have been introduced to reduce the pollution. For this project, the focus is on biofuels. Biofuels can help to improve the greenhouse gas reduction and shrink the dependency on fossil fuel (Kass *et al.*, 2018). The most established biofuels to be used is biodiesel.

Biodiesel usage has an effect that leads to a good potential and environmental friendly solution to reduce the overreliance on the energy import (Giakoumis *et al.*, 2012). Typically, biodiesel is known as alternative diesel fuel containing alkyl monoesters of fatty acids which is derived from a few sources such as vegetable oil, animal fats or waste cooking oil. This biodiesel can be obtained through transesterification reaction (Alves,

Mello and Medeiros, 2013; Sorate, Bhale and Dhaolakiya, 2015; Zhu, Cheung and Huang, 2016) Since biodiesel has the same physical properties of diesel fuel, the biodiesel and its blend can be used in the diesel engine directly when mixed with diesel (Vijay Kumar, Veeresh Babu and Ravi Kumar, 2018).

A few studies recently shows that the use of biodiesel produces lower emission of particulate matter (PM), unburned hydrocarbons, and carbon monoxide compared to diesel while engine efficiency is either unaffected or improved (Giakoumis *et al.*, 2012; Alves, Mello and Medeiros, 2013; Zhu, Cheung and Huang, 2016).

2.2.1 Production of biofuels

Biodiesel is a mixture of fatty acid methyl ester (FAME). To create biodiesel, a specific process needs to be done which is transesterification process. The purpose of this process is simply to reduce the viscosity of the vegetable oil from 40 mm^2s^{-1} into lower viscosity approximately about 5 mm^2s^{-1} which is said to be suitable for use in diesel engine (Chandran *et al.*, 2016). According to Metawea, Zewail, El-Ashtoukhy, El Gheriany, & Hamad (2018), the transesterification process had been done traditionally by using enzyme, an acid or base to improve the reaction rate and yield.

However, the process of enzymatic transesterification is very expensive due to the high cost of enzyme. On the other hand, the acid-catalysed of the transesterification is very slow and it also needs a high amount of methanol to oil molar ratio. Other than that, another disadvantage of using acid-catalysed transesterification process is the nature of the acids itself. This is because acids have corrosive nature. Some of the examples of the acids that can be used for the process are sulfuric acid, sulfonic acid, and hydrochloric acid (Demirbas, 2008).

The most suitable catalyst to be used for the process is base alkali which is known as base-catalysed transesterification process. This is because the base catalyst has faster reaction rates, higher yields of FAME, and moderate temperature. Hence, the process is more economical compared to the acid-catalysed and enzymatic transesterification process (Stamenković *et al.*, 2008). The most commonly used alkali catalyst are NaOH, KOH, and sodium potassium alkoxides (Metawea *et al.*, 2018).

2.2.2 Transesterification process

Biodiesel can be obtained from a process called transesterification. This process can be done by transesterification of triglycerides present in SVOs or animal fats on an industrial scale (Agarwal, Gupta and Dhar, 2017). This process of transesterification is actually a reaction of triglycerides present in the vegetable oils or animal fats with presence or absence of a catalyst in primary alcohols. For this process, the most basic process will produce primary esters in addition to glycerol. These esters are known as biodiesel and also is the main by-product (Agarwal, 2007).

Transesterification process is a reversible reaction in which an ester is converted into another ester. This process literally the interchange of ester groups with an alcohol while base is presence in the reaction (*Transesterification*, 2018).

2.2.3 Types of biodiesel

There are a few types of biodiesel production available in the market. Some of the biodiesel are made from waste cooking oil, soybean oil, rapeseed oil, palm oil, and jatropa oil. This is because all of the above vegetable biodiesel has almost the same properties as diesel. The properties of the vegetable biodiesel can be referred to **Table 2.1**.

Table 2.1: Biodiesel properties of palm oil, jatropa, rapeseed and soybeans (Sisbudi, 2011)

Property	Palm Oil	Jatropa curcas	Rapeseed	Soybean	Fossil fuel	Biodiesel standard	
						Value	Method
Calorific value (MJkg-1)		39.23	36.90		42	38.3	
Pour point (°C)		20				>18	ASTM D 2500
Flash point (°C)	190	135	175	174	>68	>100	ASTM D 93
Density (kgm-3)		880	920		840	850-900	ASTM D 1298
Viscosity (mm2s-1)		4.8	4.5		2.6	2.3-2.6	ASTM D 445
Cetane number	42		46	37.9		<51	ASTM D 613
Ash content (%)		0.20	0.01		0.17	<0.02	ASTM D 874
Water content (%)		0.073	0.075		<0.02	<0.05	ASTM D 2709
Acid value (mgKOHg-1)		0.40			<0.08	<0.08	AOCS Cal 2-55
Carbon residue (%)		0.20			0.17	<0.30	