EFFECT OF BIODIESEL CONCENTRATIONS ON SWELLING PROPERTIES OF POLYMER BASED O-RING

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DECLARATION

I declare that this project report entitled “Effect of Biodiesel Concentration on Swelling Properties of Polymer Based O-ring” is the result of my own work except as cited in the references

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of the Bachelor of Mechanical Engineering.

Signature : .....

Supervisor's Name : .....

Date : .....

DEDICATION

To my beloved mother and father

ABSTRACT

Nowadays, most of the industry rely on diesel to fuel heavy machineries and vehicles due to its high efficiency. However, the usage of diesel could cause harm to the environment because it releases harmful gases that can pollute air, water, soil, reduce visibility and global climate change. To reduce the usage of diesel in heavy machineries and vehicles due to its harmful properties that polluting the environment, many researches has been focusing on developing biodiesel as a substitute of conventional diesel. Biodiesel is made of reusable natural elements and emits less harmful chemical to the environment. Although biodiesel could replace diesel as fuel source, there are a few cons in using biodiesel compared to diesel. Biodiesel prone to have corrosive properties when it is mixed with Ultra Low Sulphur Diesel (ULSD). There, biodiesel could affect the elastomer part that exist in fuel delivery system. The elastomer parts present in fuel delivery system such as fuel lines, fuel tank, gasket, and O-ring. In this project, biodiesel B10 and B30 will be used to study its effect on elastomeric O-ring. Therefore, there a few tests will be done to study the effect of biodiesel concentration on swelling properties of elastomeric O-ring. Immersion test and mass test is done to study the mechanical properties of the O-ring after being soaked in biodiesel with certain duration and temperature according to ASTM D471-06. Hardness test is done to study the mechanical properties of the O-ring according to ASTM D2240-15.

ABSTRAK

Pada masa kini, sebahagian besar industri bergantung pada penggunaan diesel untuk menggerakkan mesin berat dan pengangkutan kerana kecekapannya yang tinggi. Namun, penggunaan diesel boleh membahayakan alam sekitar kerana ia melepaskan gas berbahaya yang mencemarkan udara, air, tanah, mengurangkan jarak penglihatan dan perubahan iklim global. Bagi mengurangkan penggunaan diesel dalam industri permesinan dan pengangkutan, banyak penyelidikan telah dilakukan berfokus kepada pengembangan biodiesel sebagai pengganti diesel konvensional. Biodiesel diperbuat daripada unsur semula jadi yang boleh diperbaharui dan ia mengeluarkan bahan kimia yang kurang berbahaya kepada alam sekitar. Walaupun biodiesel dapat menggantikan diesel sebagai sumber bahan bakar, terdapat beberapa kekurangan dalam menggunakan biodiesel. Biodiesel cenderung untuk mempunya sifat menghakis ketika dicampur dengan Ultra Low Sulphur Diesel (ULSD). Oleh itu, biodiesel akan mempengaruhi bahan-bahan elastomer di dalam sistem penghantaran bahan bakar di dalam kenderaan. Bahagian elastomer dalam sistem penghantaran bahan bakar adalah termasuk saluran bahan bakar, tangki bahan bakar, gasket and cincin O. Dalam projek ini, biodiesel B10 dan B30 akan digunakan untuk mengkaji tindak balasnya terhadap cicin O elastomer. Oleh itu, terdapat beberapa ujian akan dilakukan untuk mengkaji kesan kepekatan biodiesel terhadap sifat pembengkakan cincin O elastomer. Ujian rendaman dan ujian jisim akan dilakukan untuk mengkaji sifat mekanikal cincin O setelah direndam di dalam biodiesel dengan jangka masa dan suhu tertentu mengikut ASTM D471-06. Ujian kekerasan dilakukan untuk mengkaji sifat mekanikal cincin O mengikut ASTM D2240-15.

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LIST OF ABBREVIATIONS

FAME	-	Fatty Acid Methyl Ester
CPO	-	Crude Palm Oil
NBR	-	Nitrile Rubber
PTFE	-	Polytetrafluoroethylene
ULSD	-	Ultra Low Sulphur Diesel
FDS	-	Fuel Delivery System
ASTM	-	American Society for Testing and Materials
NO	-	Nitrogen Oxide
e.g	-	Example
FKM	-	Fluorocarbon
FTIR	-	Fourier Infrared Spectroscopy
ATR	-	Attenuated Total Reflection
UATR	-	Universal Attenuated Total Reflection
FEA	-	Finite Element Analysis
MPOB	-	Malaysia Palm Oil Board
PTC	-	Positive Temperature Coefficient

CHAPTER 1

INTRODUCTION

1.1 Background

Diesel is a type of fuel made of crude oil from fossil fuel. Fossil fuel were produced over a long time from the remains of plants and animals that lived millions year ago. Fossil fuel are known as non-renewable fuel sources. In 1892, Rudolf Diesel created a new fuel product that bear his name which is diesel. Diesel fuel is a reliable fuel source as it provides better fuel economy, greater torque and high energy density as compared to gasoline. Gasoline is a refined petroleum used as fuel for internal combustion engines.

However, despite providing a great fuel performance, diesel also causing more harm to the environment and health. In health issue, diesel emission contributes to the development of cancer, cardiovascular and respiratory health effect. To the environment, diesel causing harm by polluting the air, water, and soil. It also reduces the visibility and causing global climate change. Realising these implication, other alternative method should be invented to provide a greener fuel usage with minimum effect to the environment and health.

Biodiesel is a type of fuel that is combined of natural elements such as plants, vegetable, and other natural reusable materials. Biodiesel is a substitute of conventional diesel which emits less harmful chemicals to the environment from its

combustion. Started by an inventor named Martin Mittelbach. He furthered the development of the biodiesel fuel industry in 1990s. First biodiesel production was from recycled used cooking oil due to rising price of crude oil and concerns over global warming. Since it is produced from renewable resources, biodiesel has many advantages such as it can be directly used in existing diesel engines, i.e. no modification of diesel engine is needed, less greenhouse gas emission, biodegradable and nontoxic. Many research were conducted to develop vegetable oil derivatives until the same level of properties and performance of hydrocarbons-based petroleum diesel. Substituting triglycerides for diesel fuel is linked with high viscosity, low votality and polyunstaturated characters. Palm oil biodiesel was succesfully produced by various processes that can be altered in at least four ways which are *pyrolysis*, *microemulsion, dilution* and *transesterification* [1].

Pyrolisis

Pyrolisis is a method of transformation of one substance into another by mean of heat with the aid of catalyst in the absence of air or oxygen. In early finding, hydrogen is used to remove oxygen in the form of water while now, the removal of oxygen in the form of water and carbon oxides is accomplished by using the shape-selective catalysts like zeolites [2]. This process is effective, simple, wasteless and pollution free, however, it requires high temperature, expensive equipment and produce low quality of biodiesel (contain heterogeneous molecules ncluding ash and carbon residue) [3].

Microemulsion

The vegetable or animal oil were solubized in a solvent (alcohol) and surfactant until the required viscosity is obtained. It is a simple process and pollution free, however, the product has high viscosity, low stability and could led to sticking, incomplete combustion and carbon deposition [3].

Dilution

Dilution is preheated vegetable or animal oils were blended with petroleum diesel within 10-40% ration. Then the resulted oil-diesel mixture is applied into the diesel engine. This process does not required any chemical process, absunce of technical modification and easy implementation, however, the blended biodiesel has high viscosity, unstable, low votality and increase in biodiesel concentration results in improper spraying pattern, poor atomisation, imcomplete combustion and difficulty in handling by standard engines [3].

Transesterification

This is the most common process for palm oil biodiesel. The Vegetable or animal oil and fats were reacted with alcohol and catalyst. Then the mixture of biodiesel (product) and glycerol (byproduct) will undergo separation and purification steps before further usage. This process provide high conversion of biodiesel with relatively low cost, mild reaction conditions, product properties are closer to the petroleum diesel and applicable for industrial scale production, however, this process

requires low free fatty acids and content in the raw material, extensive separation and purification steps, possibilities of side reaction to occur [3].

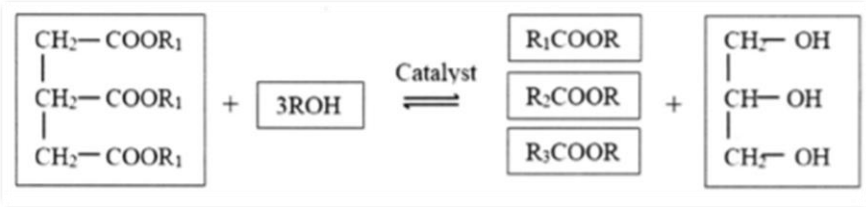

Figure 1. 1: Transesterification process of biodiesel

Biodiesel also known as fatty acid methyl ester (FAME) is produced from natural element through transesterification process as summarized in **Figure 1.1**. Vegetable oil which consist of triglycerides are converted into three mono-alkyl esters.

Table 1.1 shows the type of biodiesel according to its concentration percentage. A 100% pure biodiesel is known as B100 (*Biodiesel-100%*), where the digit indicates the percentage of biodiesel concentration in petroleum diesel. Here, B2 and B5 biodiesel are already widely used in most heavy vehicles, thanks to its lubricating properties. On recent development of biodiesel, many research works tend to produce a high-quality biodiesel to be used in diesel engine without reducing its performance and half-life of engine. Due to some challenges such as injector choking and sedimentation, only biodiesel with maximum concentration of 20% biodiesel B20 is permitted until today [4].

To increase the performance of biodiesel B40 on diesel engine, additive such as bio-polymer was proven to improve the characteristic of biodiesel such as kinematic viscosity, specific gravity, flash point and midpoint boiling temperature [5]. Biodiesel B40 incorporated with bio-polymer is strongly possible to be a substitute for petroleum

diesel in diesel engine. Another study mix the palm biodiesel B20 with oxygen containing chemical such as methanol, ethanol, diethyl ether and distilled water to an extend of 2% to reduce the Nitrogen Oxides, NO_x emission [6]. The study shows that the emission like carbon monoxide and hydrocarbon was reduced by 28% and 30% compared to petroleum diesel, however, the emission of carbon dioxide was higher compared to petroleum diesel to due the combustion characteristic.

Table 1.1: Type of biodiesel and its usage [4]

Type of biodiesel	Percentage of biodiesel concentration	Usage
B2	2% Biodiesel, 98% Diesel	Usable in standard diesel engine.
B5	5% Biodiesel, 95% Diesel	
B10	10% Biodiesel, 90% Diesel	
B20	20% Biodiesel, 80% Diesel	
B30	30% Biodiesel, 70% Diesel	Under development
B100	100% Biodiesel, 0% Diesel	Unusable in standard diesel engine due to high corrosive properties.

1.1.1 Palm Oil Biodiesel

Currently, Malaysia is ranked number two in palm oil industry in the world right behind Indonesia. Therefore, Malaysia have focused on using palm oil as raw stock for biodiesel production. The palm oil that is harvested and produced from palm trees is defined as Crude Palm Oil (CPO). The crude palm oil is transferred to palm oil refinery for refinery process. Palm oil biodiesel is created by combining refined oil with petroleum diesel. Blending petroleum diesel with certain percentage of palm oil diesel is called as Envo diesel [7]. Recently, the Primary Industries Ministry of Malaysia stated that Malaysia will fully implement B20 palm oil biodiesel to 3400 petrol stations nationwide. It is expected to consume 534,000 tonnes of palm oil annually.

1.1.2 Elastomer O-ring

An O-ring is a torus, or doughnut shaped ring generally made from an elastomer. However, O-ring also commonly made from metal, elastomer, and thermoplastic materials such as Nitrile rubber (NBR) and Polytetrafluoroethylene (PTFE), respectively. The cross-section of the O-ring can be in a form of hollow or solid. O-ring's function is primarily for sealing to prevent the loss of fluid or gas. O-ring has wide scope of sealing such as static, reciprocating, oscillating, rotary, seat, pneumatic and vacuum. The material of O-ring depends on the application, for example, NBR O-ring has good mechanical properties and high wear resistance compared to other elastomer but it is not compatible with fuel of high aromatic content, aromatic hydrocarbons (benzene) and strong acid. O-ring can be applied to various application such as medical (syringe, pump, filtration), oil and gas industrial (valves,

gas pump, storage tank), electronics (semiconductor) and food and beverage (beverage dispenser). O-ring has many advantages such as seal wide range of pressure, temperature, and tolerance. It requires a minimum maintenance, no critical torque on tightening and it is light in weight. However, O-ring could be weakened due to deterioration and corrosion. Deterioration is a term refers to chemical change of a material resulting in permanent loss of the properties of a material. While corrosion is the result of chemical action of a fluid and the elastomer compound upon the metal surface of a material.

1.2 Problem statement

Biodiesel have corrosive properties when it is blended with Ultra Low Sulphur Diesel (ULSD) [8]. In fuel delivery system (FDS) in diesel engine, O-Ring is one of the common parts in this system where it plays a crucial part in engine performance as its function is to prevent the loss of fluid and gas. Due to corrosive properties in biodiesel, the O-Ring will undergo degradation with the usage time [8]. In addition, O-ring properties is highly depends on the hardness of the material [9]. Swelling is the tendency of material to absorb moisture which occurred through the voids, pores, cracks present on and below the surface. Swelling can leads to severe degradation on the material with tendency towards surface protruding as well as cracks generation on its surface [10]. Thus, in this study, O-ring that is made of polytetrafluoroethylene (PTFE) is subjected to immersion test (ASTM D1414 - 94) of two different concentration of biodiesel, B10 and B30 in order to investigate the swelling properties of the O-Ring.

1.3 Objectives of project

This research is conducted to determine the solution for the issues stated in Section 1.2. Thus, the objectives of this research are as follows:

1. To determine the effect of different soaking time and biodiesel's temperature on swelling properties of O-ring.
2. To investigate the swelling properties of O-ring after being immersed in two different types of biodiesel, B10 and B30, respectively.

1.4 Scope of Project

The scopes of this project are:

1. Fabrication of test rig (*Temperature Controlled Bath*) for immersion test to control the temperature of the biodiesel at certain duration of time.
2. Conduct an immersion test of O-ring samples in B10 and B30 concentrated biodiesel at different temperature and duration.
3. Conduct a mass loss test of the immersed O-ring samples according to standards.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Over a long period, we have been depending on the fossil fuel as the main energy source to be used on electricity generation, industrial application, and transportation. Undeniably, fossil fuels are very important however, the usage of fossil fuel such as petroleum diesel causes numerous pollution due to the produced soot, harmful gasses and can be deadly if being utilized over a long period. In fact, based on the statistic from Intergovernmental Panel on Climate Change [11], carbon dioxide is the main product of combustion of fossil fuel. It contributes to 65% of global greenhouse gas emission in 2014.

Recently, there are numerous studies and research on fossil fuels to enhance the environment and maintain the sustainability of energy resources. The focus is attributed to biodiesel due to its sustainability and renewable characters that can lessen damage to the environment. They able to minimize emissions of contaminates gasses and particulate materials compared to diesel from fossil fuel. They also possesses biodegradable and non-toxic properties [12].

2.2 Biodiesel

As mentioned in previous chapter, a pure biodiesel B100 is a substitute of fossil fuel diesel made from natural elements. It is commonly used for transportation as fuel as it emits less greenhouse gas compared to diesel and produced by transesterification process. In the United States, the first specification standard for analysing pure biodiesel B100 has been determined which is ASTM Standard D6751-18. The standard shows specific tests that must be conducted to achieve stability in pure biodiesel B100 such as flash point, alcohol control, kinematic viscosity, and carbon residue. Meanwhile, biodiesel B5 follows the ASTM Standard D975 and biodiesel B6 up to B20 follows the ASTM Standard D7467-18a.

Pandit et. al [3] studied on the biodiesel production from *Scenedesmus armatus*, using egg shell waste as nano catalyst. They produce the biodiesel by transesterification process from the microalgal strain *Scenedesmus armatus* extracted from mangrove root and use chicken-eggshells as nano catalyst. The biodiesel produced was analysed by ^{1}H nuclear magnetic resonance spectroscopy using deuterated chloroform as solvent. They observed that the biodiesel is characterised by higher *cetane number*, CN58, due to higher saturation which improved clean up emission and higher combustion efficiency. Other properties of the *Scenedesmus armatus* derived biodiesel compared to petroleum diesel are stated in **Table 2.1**.