DEGRADATION BEHAVIOUR OF O-RING ELASTOMER SUBJECTED TO PALM BIODIESEL IMMERSION

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In fulfillment of the requirement for the degree of
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DECLARATION

I announce that this project titled "Degradation Behaviour of O-Ring Elastomer Subjected to Palm Biodiesel Immersion" is the original work, except where stated in citations.

Signature :..................................

Name :..................................

Date :……………………...

APPROVAL

I hereby recognize that I have read this project report and that this report is, in my view, appropriate in terms of reach and consistency for the award of a Bachelor of Mechanical Engineering degree. I have checked this report and the report can now be submitted to JK-PSM to be delivered back to the supervisor and the second examiner.

Signature :...................................

Name of Supervisor :...................................

Date :.................................

DEDICATION

To my beloved mother, Teo Siew Hoon, and father, Chin Kang Foh

ABSTRACT

It is common to find the use of elastomer in fuel lines of diesel automobile engines as well as a sealant for the engine parts. However, a polymer is well-known to be detrimental to elevated temperatures. In this study, two types of biodiesel sources of fuel were considered to evaluate the degradation behavior of the O-ring component based on nitrile rubber (NBR) in terms of the physical properties. The physical property is investigated in terms of the change in mass, in accordance with the ASTM D471. The weight of the samples was recorded before and after immersion. At the soaking stage, the O-ring samples were immersed up to 28 days in B10 and B30 biodiesel at the room temperature and 40℃ condition. The mass loss test results suggest that there is a decrease in mass loss with increasing biodiesel concentration for the NBR O-ring, from B10 to B30 biodiesel usage. Moreover, deterioration of elastomer is due to the increased polarity of biodiesel; these are related to carboxylic (ester) functional group in the biodiesel formation. Besides that, SEM micrographs at the cross-section show evidence of deterioration in the sample. Once immersed for up to 28 days (4 weeks) at 40℃, the O-ring sample in biodiesel B30 exhibits more holes and cracks than those in the B10 medium. It is possibly due to the absorption of biodiesel into elastomer, through which biodiesel may interfere with the cross-linking agent. These results suggest that NBR O-ring is acceptable for uses in the specified environment and biodiesel.

ABSTRAK

Elastomer merupakan satu bahan yang biasa digunakan dalam talian sistem bahan api malahan juga digunakan sebagai penyudah dalam bahagian enjin kereta. Walaupun, elastomer dikenali sebagai bahan yang mudah rosak pada sifat suhu. Dalam kajian ini, terdapat dua jenis biodiesel yang digunakan untuk mengkaji proses degradasi gelang O komponen berasaskan getah nitril (NBR) dari segi sifat fizikal. Ciri-ciri fizikal dikaji melalui perubahan jisim merujuk kepada ASTM D471. Jisim sampel sebelum dan selepas rendaman juga direkodkan. Di dalam eksperimen ini, sampel gelang O telah direndam di dalam biodiesel B10 dan B30 pada suhu bilik dan suhu 40℃ hingga 28 hari. Keputusan hasil kajian menunjukkan bahawa jisim berkurangan dengan peningkatan kepekatan biodiesel, dari B10 ke B30 yang digunakan. Tambahan pula, kemerosotan elastomer adalah disebabkan oleh peningkatan ketubuan biodiesel; ini berkaitkan dengan kumpulan berfungsi karboksilik (ester) dalam pembentukan biodiesel. Malahan, kemerosotan sampel gelang O telah dirakamkan melalui pengimejan menggunakan mesin mikroskop imbasan elektron (SEM). Apabila masa rendaman mencecah 28 hari (4 minggu), pada suhu 40℃, gelang O yang direndam di dalam biodiesel B30 menunjukkan banyak lubang dan retakan berbanding dengan sampel yang direndam di dalam biodiesel B10. Hal ini kerana penyerapan biodiesel ke dalam elastomer menyebabkan biodiesel mengganggu agen perangkaian silang. Hasil kajian ini menunjukkan bahawa gelang O yang diperbuat dari elastomer NBR ini sesuai untuk digunakan di dalam medium biodiesel dan persekitaran tertentu.

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TABLE OF CONTENTS

PAGE

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

FAME	-	Fatty acid methyl ester
MPOC	-	Malaysian Palm Oil Council
MPOB	-	Malaysian Palm Oil Board
FKM	-	Fluoroelastomer
SR	-	Silicone Rubber
NBR	-	Acrylonitrile Butadiene Rubber / Nitrile Rubber
HNBR	-	Hydrogenated NBR
CR	-	Poly Chloroprene Rubber / Neoprene
ECO	-	Epichlorohydrin
EPDM	-	Ethylene-propylene-diene Rubber
SBR	-	Styrene-Butadiene Rubber
IR	-	Polyisoprene
NR	-	Natural Rubber
ACM	-	Acrylic Rubber
ULSD	-	Ultra-Low Sulphur Diesel
NOx	-	Nitrogen Oxides
VOCs	-	Volatile Organic Compounds
SOx	-	Sulphur Oxides

N_2O	-	Nitrous Oxide
CO_2	-	Carbon Dioxide
CH_4	-	Methane
PM	-	Particulate Emissions
B0	-	Pure Diesel
B10	-	10 vol.% of the biodiesel blended with 90vol% of the diesel
B30	-	30 vol% of the biodiesel blended with 70vol% of the diesel
FFA	-	Free Fatty Acids
ASTM	-	American Society for Testing and Materials
MITC	-	Melaka International Trade Centre
DOE		Design of Experimentation
SEM		Scanning Electron Microscope

LIST OF SYMBOLS

A	-	Ampere
C	-	Calibration constant
M_1	-	Mass of sample in air before soaking
M_2	-	Mass of sample in the air after soaking
t	-	Time
ºC	-	Degree in Celsius

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Biodiesel is one type of biofuels that is regarded as a substitute to diesel partially or entirely for the past few decades. It is clean and renewable fuel energy that works better with a little reconstruction in the existing energy portfolio. Nowadays, biodiesel is widely utilized in the transportation sector, especially diesel engine vehicles. Significant concerns with diesel, such as the depletion of natural resources, effects of environmental pollution, and lack of supplication fossil fuel, have caused biodiesel to become a useful alternative fuel source in the global market. Hence, biodiesel can be regarded as a first choice to replace diesel in this application because biodiesel has similar properties with pure diesel fuel.

According to Akhlaghi et al. (2015), biofuels are typically classified based on the technology generation or the feedstock of biological sources. The variety of biofuels are produced from lipids, proteins, and carbohydrates in the feedstock (Huo *et al.*, 2011). More commonly, biodiesel is produced from lipid-based biofuel. There are two types of generation technology based on lipid-based biofuels to produce biodiesel that has hitherto been recorded. Saturated and unsaturated dietetic plant oil from oil seeds like corn, canola soybean, and sunflower while fruits like palm, coconut, and olive are the feedstock of the first generations. Besides, the second generation based on lipid-based biofuel produced from insects, oleaginous microorganisms, animal fats, and waste vegetable oils. Chandran et al. (2016) stated that pure diesel (B100) also named as a fatty acid methyl ester (FAME). The variety of biodiesel is usually manufactured from animal or vegetable through the transesterification process. The main objective of the transesterification process is used to decrease viscosity of the vegetable oil from 40mm^2 s^{-1} to the lower viscosity, which is approximately 5mm^{2}s^{-1} (Chandran et al., 2016). This value of viscosity is most suitable for the operation of diesel engines.

This work generates biodiesel from palm oil because Malaysia is well-known as one of the world's leading manufacturers and exporters of palm oil. Malaysia accounts for 11% of world production of oils and 27% of global oils and fats trade. Based on information on the Malaysian Palm Oil Council (MPOC) website, Malaysia's oil palm production uses approximately 4.49 million hectares of land. This industry can generate 2.13 million tons of palm kernel oil and 17.73million tons of palm kernel oil. More than half a million employees can be employed, and an additional one million people live in the sector (*The Oil Palm Tree – MPOC*, no date).

Biodiesel has similar mechanical properties to pure diesel fuel. Moreover, biodiesel can offer some technical benefits over traditional diesel, which include higher flashpoints, a higher number of cetane, better lubricity and decreased exhaust emission, etc. (Ferreira *et al.*, 2008; Chen *et al.*, 2010). Nonetheless, biodiesel also has several drawbacks. One of the significant disadvantages of biodiesel is that it can cause deterioration and swelling of the elastomer and rust of the metal part. Such behavior will cause some problems, including fuel pump breakdown, motor shaking, plugging of filters, deposits on engine walls, coking of injectors on pistons of engines, and excessive engine wear.

There is a huge range of interchangeable components in an automobile framework like an engine, fuel pump, exhaust system, and fuel injector. The place of several metallic and elastomer parts traditional fuel system for vehicles is as shown in **Figure 1.1** (Akhlaghi *et al.*, 2015). Among the variety of rubber parts used in automotive fuel delivery system are Fluoroelastomer (FKM), Silicone Rubber (SR), Acrylonitrile Butadiene Rubber (NBR), Hydrogenated NBR (HNBR), Poly Chloroprene Rubber (CR), Epichlorohydrin (ECO), Ethylene-propylene-diene Rubber (EPDM), Styrene-Butadiene Rubber (SBR), Acrylic Rubber (ACM) and Polyurethane. Besides, as for the metallic parts, some of the typical applications in the fuel delivery system include camshaft, lifter, head surface, timing gear, and chain, etc. Chandran et al. (2016) argued that the storage and automobile fuel supply system in an engine usually contain some components like fuel tank, fuel lines, fuel pump, fuel rail, and fuel injectors. The automobile fuel supply network for a diesel engine is, as illustrated in **Figure 1.2** (Chandran et al., 2016). **Table 1.1** shows the components used to manufacture parts for fuel storage and transmission (Chandran et al., 2016).

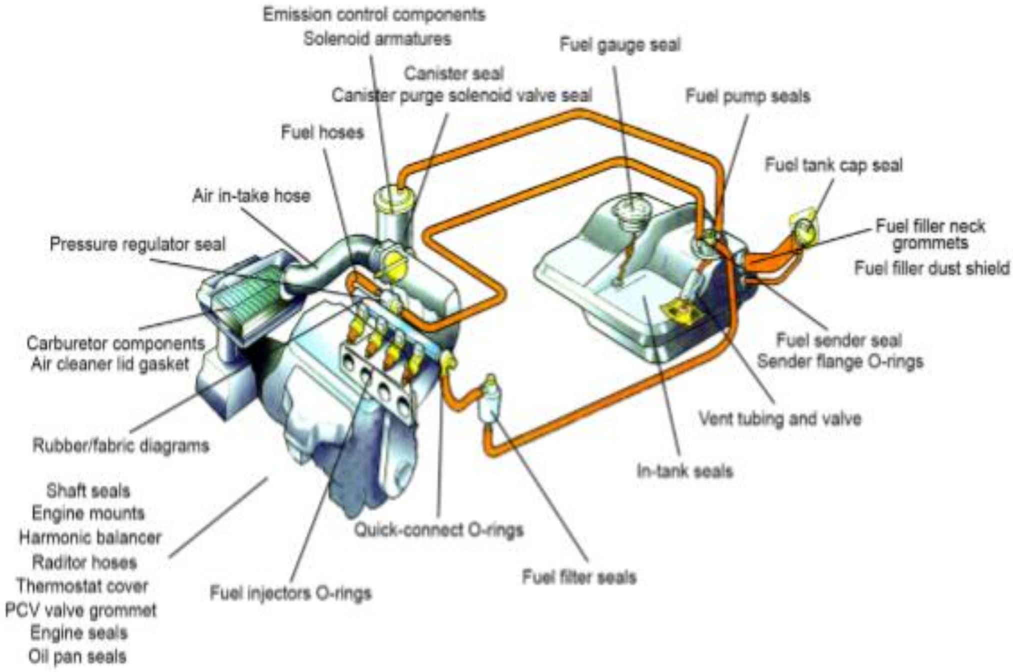

FIGURE 1.1: THE PLACE OF SEVERAL METALLIC AND ELASTOMER PARTS TRADITIONAL FUEL SYSTEM FOR VEHICLES

(Akhlaghi et al. 2015)

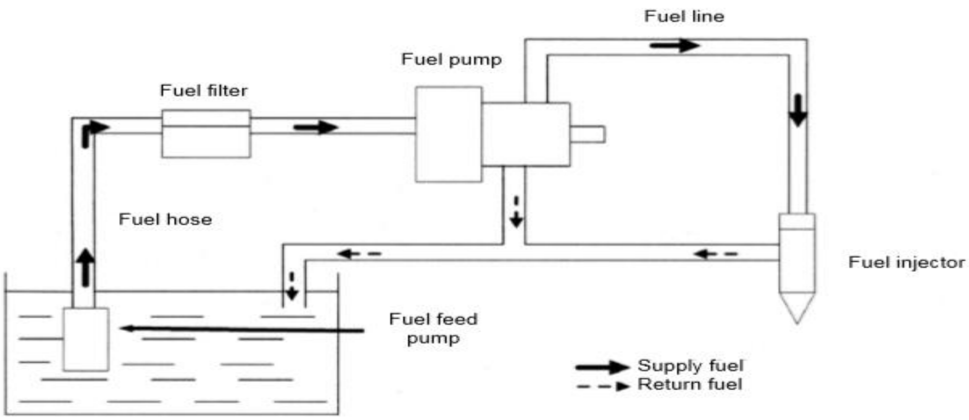

FIGURE.1.2: THE AUTOMOBILE FUEL SUPPLY NETWORK FOR THE DIESEL ENGINE

(Chandran et al., 2016)

TABLE 1.1: COMPONENTS USED TO MANUFACTURE PARTS FOR THE FUEL TANK AND TRANSMISSION

(Chandran et al. 2016)

Components	Compositions
Fuel storage	Polyethylene, steel
Pump for fuel supply	Alloy based on iron, alloy based on copper, and aluminum metal
Hoses	Polyethylene, steel, polymer
Filter of fuel	Polyethylene, aluminum, journal, resin, and document with impregnated
Pump for fuel	Alloy based on iron, alloy based on copper, and aluminum metal
Fuel injection	Inox steel
Beak	Steel
Pipe flange gasket	Polymer, journal, stopcock, and copper

From the literature, the injection system is facing various problems like swelling and deterioration in the elastomer parts of the fuel delivery system when biodiesel was utilized as a fuel in diesel engines. Since deterioration of the elastomer seal, hoses, gaskets, and O-rings have become the main problem concerning automobile material biofuel incompatibility, several works have investigated the shorter and longer-term quality of biodiesel and deterioration actions of various rubber parts used in the fuel supply system. Based on the Haseeb et al. (2011) research, swelling results of the biodiesel and its blends in the different elastomer parts compared with the swelling results of the pure diesel. It was reported that there is a significant deterioration, based on the reduction in volume, increase in the mass, decreases the tensile strength, and lowers the hardness strength with the concentration is increased (Haseeb, Jun, *et al.*, 2011). Besides that, Akhlaghi et al. (2015) also argued that when increasing concentration leads to reduce stress, meanwhile, with the change in weight, tensile strength, elongation strength, toughness strength, and stress softening are lowered.

1.2 PROBLEM STATEMENT

Biodiesel is one variety of biofuels with increasing popularity in the internal combustion engine applications because it can reduce the depletion of fossil fuels, improve greenhouse gas reduction, low-temperature operability, and stability. Nonetheless, despite the advantages mentioned earlier in this chapter, some of the issues with the use of biodiesel are that it has a corrosive property when combined with Ultra Low Sulphur Diesel (ULSD). Suchlike behavior will cause the parts used in fuel delivery systems such as Silicone Rubber (SR), Nitrile Rubber (NBR), Viton and Acrylic Rubber (ACM), etc. to swell when immersed in the biodiesel like B10, B20, B30, and B100. The results from the literature have also shown that the elastomer parts swelling in the fuel delivery process increases with rising biodiesel concentration. Hence, this results in a reduction in the tensile and hardness strength of the elastomer part in the fuel delivery system.

Consequently, the swelling rate of the elastomer and seals will be increased. Besides that, some effects on the elastomer will be apparent, which is contributing to the increase in biodiesel concentration. For instance, the elasticity of the elastomer parts used in the fuel delivery system will be affected due to the increase in the biodiesel concentration. Swelling of the elastomer parts demanded that these parts require replacement to avoid any blockage or leakage in the fuel delivery and storage system. Hence, as a result, the lifespan of the fuel delivery system will be reduced, particularly with increasing soaking time.

Biodiesel used as a transport fuel should have a higher resistance to oxidation along with the extent of storage and reduced the risk deterioration of the elastomer parts used in the fuel delivery and storage tank system as well as a construction element for mixing and transfer fuel. Therefore, biodiesel used as a transport energy source that has a peak amount of biodiesel for use in an engine, which is 20vol% of biodiesel blended to 80vol% of diesel is available to be applied (Chandran *et al.*, 2018).

According to this, further investigations are required to investigate the influence of biodiesel concentration on the performance of the type of elastomers used in the fuel supply and storage tank system. Nowadays, Malaysia is using B10 as a transport fuel, and B30 will be used as a transport fuel soon. Hence, it is essentially important to understand the existing elastomer performance and degradation behavior for uses in the fuel delivery system using both types of biodiesel, these being the B10 and B30.