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MOHD AMIR AZRIE BIN NASARUDIN

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (MAINTENANCE TECHNOLOGY) WITH HONOURS

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FRICTION AND WEAR CHARACTERISTICS OF BIODIESEL FUEL DERIVED FROM PALM OIL

Mohd Amir Azrie Bin Nasarudin

Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

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FRICTION AND WEAR CHARACTERISTICS OF BIODIESEL FUEL DERIVED FROM PALM OIL

MOHD AMIR AZRIE BIN NASARUDIN

A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

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DECLARATION

I declare that this thesis entitled “Friction And Wear Characteristics Of Biodiesel Fuel Derived From Palm Oil” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	
Name	:	Mohd Amir Azrie Bin Nasarudin
Date	:	11 January 2023

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

Signature	:	
Supervisor Name	:	Dr. Mohd Taufik Bin Taib
Date	:	11 January 2023

DEDICATION

In dedication to my family, especially my loving parents who has been very supportive towards me in completing my university studies. I am grateful for the encouragement that they have given throughout the years. This thesis is also dedicated to my supervisor, Dr. Mohd Taufik Bin Taib who helped and guided me in the completion of this thesis.

ABSTRACT

In a fuel system, an important characteristic that is rarely talked about is the lubricity of fuel. Better lubricity means lesser friction and wear. Due to the nature of biodiesel, it is important to measure the friction and wear characteristics as it flows through fuel line and injectors, especially in a pressurized system. In this thesis, the friction and wear characteristics of biofuel derived from palm oil will be analyzed. Palm oil biodiesel will be prepared in different blends of B100, B10, B20, and B30 and each of this fuel will be tested in four ball tester machine. After 3 runs, the average coefficient of friction of each oil will be compared with each other. The worn ball bearing will be observed under optical microscope, where the microstructure of worn surface will be analyzed furthur. Findings will be compared to justify the usability of palm oil biodiesel in conventional diesel engines and its effects in terms of wear and tear. This thesis will also serve to enable more research in terms of tribological properties of palm oil biodiesel.

ABSTRAK

Dalam sistem bahan api, ciri penting yang jarang diperkatakan ialah kelinciran bahan api. Kelinciran yang baik bermakna kurang geseran dan hakisan. Disebabkan sifat biodiesel itu sendiri, adalah penting untuk mengukur ciri geseran dan hakisan semasa ia mengalir melalui saluran bahan api dan penyuntik, terutamanya dalam sistem bertekanan tinggi. Dalam tesis ini, ciri-ciri geseran dan hakisan biodiesel yang diperolehi daripada minyak sawit akan dianalisis. Biodiesel minyak sawit akan disediakan dalam campuran berbeza iaitu B100, B10, B20, dan B30 dan setiap bahan api ini akan diuji dalam mesin tribologi penguji empat bola. Selepas 3 larian, purata pekali geseran setiap minyak akan dibandingkan antara satu sama lain. Galas bebola yang telah digunakan akan diperhatikan di bawah mikroskop optikal, di mana struktur mikro permukaan bebola yang terhakis akan dianalisis dengan lebih lanjut. Penemuan akan dibandingkan untuk mewajarkan kebolehgunaan biodiesel minyak sawit dalam enjin diesel konvensional dan kesannya dari segi hakisan dan geseran. Tesis ini juga akan membolehkan lebih banyak penyelidikan dari segi sifat tribologi biodiesel minyak sawit.

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In the Name of Allah, the Most Gracious, the Most Merciful

First, I would like to express my deepest appreciation to all those who provided me the possibility to complete this report. Foremost, I'm grateful to Allah the Almighty, the Creator and Sustainer, who allows me to finish up this thesis. I am thankful for everything that I'm blessed with since at birth. I also extend my gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for they have provided me guidance and platform for my research. Thank you also to the Malaysian Ministry of Higher Education (MOHE) for providing use with financial assistance.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASTM	-	American Society for Testing and Materials (Standards)
SEM	-	Scanning Electron Microscopy
mm^2/s	-	Viscosity unit, millimeter square per second
CN	-	Cetane Number
EN	-	European Norm (Standards)
DF100	-	Petroleum diesel fuel
COME20	-	20% cottonseed methyl ester, and 80% petroleum diesel by volume
POME20	-	20% palm oil methyl ester, and 80% petroleum diesel by volume
C05P15	-	5% COME, 15% POME, and 80% petroleum diesel by volume
C10P10	-	10% COME, 10% POME, and 80% petroleum diesel by volume
C15P05	-	15% COME, 5% POME, and 80% petroleum diesel by volume
B20A4	-	20% Biodiesel, 4% diethyl ether, and 76% diesel
PA	-	Polyamide
mL	-	millilitre
mm	-	millimetre
COF	-	coefficient of friction
WSD	-	wear scar diameter

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CHAPTER 1

INTRODUCTION

1.1 Background

One of the most popular choices of conventional engine is diesel engine due to its efficiency and toughness. Nowadays the demand for fossil fuel is increasing, causing the cost of running a diesel engine to rise as well. Therefore, we need to develop alternative fuels to reduce the dependency to fossil fuels (Soly et al., 2021). One of the alternatives is biodiesel made from palm oil.

In 2018, worldwide consumption of palm oil was 19.2 million tons. It is the most used vegetable oil, representing 40% of all vegetable oils production of the world. It is derived from palm tree family of the species Aracacea, specifically Elaeis Guineensis. Palm trees are very sustainable, as the fruits can be harvested after 4 years and continues to produce fruit between 40 to 50 years. One hectare of palm tree can produce ten times more oil when compared to other oil producing crops. Therefore, it is the cheapest to produce vegetable oil from palm trees. Referring to figure 1.1, currently Malaysia is one of the largest producers of palm oil, accounting for 29% of the world's production.

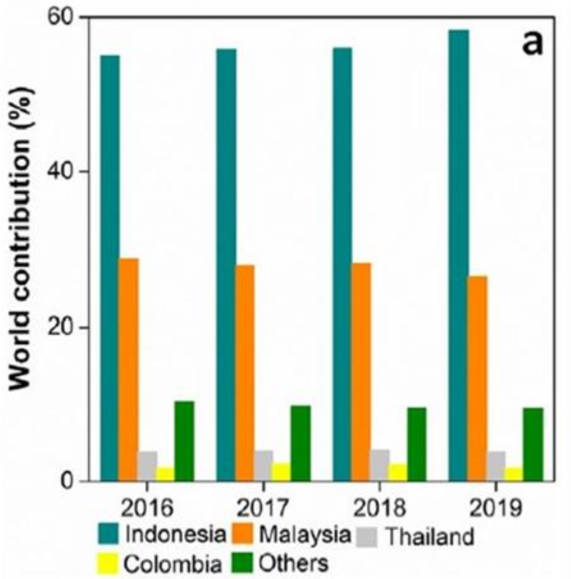

Figure 1.1 Largest global producer of palm oil from 2016 to 2019 (Dandu & Nanthagopal, 2021)

Palm oil is used in edible products, mainly as cooking oil for foods such as cookies, chocolate, and ice-creams. In the other hand, palm oil can also be used to produce inedible products such as cosmetics, fuel, and lubricant. The main interest of palm oil is its capability to produce biodiesel and biolubricant that is sustainable and biodegradable, as opposed to traditional mineral oils that causes environmental harm when disposed improperly (Durango, Zapata, Santa, & Sierra, 2022).

Biodiesel is a type of fuel that is processed from biomass sources such as vegetable oil and animal fats. It is renewable, less toxic, biodegradable, and environmentally friendly. The vegetable oil and animal fats are treated before it is used as feed stock. To produce palm oil biodiesel, treated palm oil is made to be under chemical reaction with alcohol and presence of catalyst to produce esters and glycerol. This process is called transesterification, with the basic materials consists of crude palm oil as feedstock, methanol alcohol, and potassium hydroxide as the catalyst (Suthisripok & Semsamran, 2018; Soly et al., 2021). There are many other processes that can produce biodiesel such as esterification/transesterification, epoxidation, hydrogenation, and estolides formation. Each process has its own advantages and disadvantage in terms of product characteristics and quality (Durango, Zapata, Santa, & Sierra, 2022; Dandu & Nanthagopal, 2021; Soly et al., 2021).

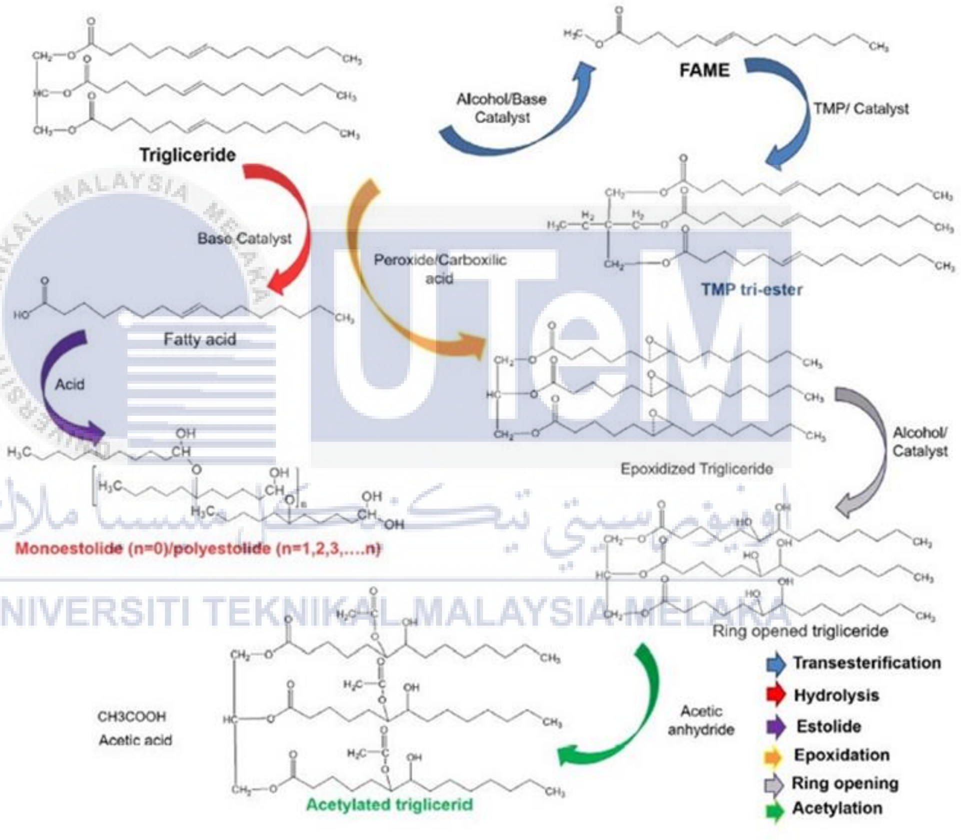

Figure 1.2 Different process of producing biodiesel (Durango, Zapata, Santa, & Sierra, 2022)

Biodiesel is a good alternative because of its similar properties to conventional diesel. Two of the most important properties of fuel for diesel engine are the cetane number and viscosity of the fuel. Cetane number represents the ignition quality while viscosity is the resistance to flow. Higher cetane number shows that the fuel has short ignition delay, giving performance increase to the engine. Viscosity of fuel is important as diesel engine are compression ignition engines. Using pressure, fuel is delivered to where it is needed. If the viscosity of the oil if too high, it will cause deposits in the engine especially around the piston rings. The advantage of using biodiesel is that it has better cetane number than diesel, but the viscosity is slightly higher. The argument is that biodiesel is also a solvent, therefore it could cause deposit formation inside the fuel system. In the other hand, using biodiesel reduces soot, suggesting less particulate matter reduction and good lubricity, which reduces wear on contacting metal surfaces (Suthisripok & Semsamran, 2018; Ayetor, Sunnu, & Parbey, 2015). Besides the fuel system, there are also many sliding contacts in engine. Therefore, we can investigate the wear and tear of engine when using biodiesel as fuel. This can help future researchers to assess the overall performance of using biodiesel in diesel engine.

1.2 Problem Statement

Fossil fuel has been the primary source to power engines for generations. It is a non-renewable source as it is made from petroleum and the demands for it is ever rising. Due to the extensive extraction from its reserves, fossil fuel is rapidly declining (Abomohra et al., 2020). The price of fossil fuel is heavily affected by supply and demand. When demand is greater than supply, the prices rises (Patton, 2022). In addition to this, the activities of acquiring fossil fuel also pollutes the environment (Borunda, 2020; Kibe, 2021). We can replace the use of fossil fuel to mitigate the fuel problems of today. There are many alternatives to using fossil fuel, one of it being biodiesel that is made from palm oil. Eventhough palm oil biodiesel has been researched, our understanding of the effects of using palm oil biodiesel as fuel in engine is still primitive. The effects of using palm oil biodiesel in terms of wear and friction is also not conclusive due to contradicting past research results. To help the research, the wear and frictional characteristics of palm oil biodiesel must be studied furthur. The study is based on:

i) Assessing the frictional and wear characteristics of different palm oil biodiesel fuel blends.

ii) To compare the coefficient of friction between each blend of biodiesel.

iii) The wear scar observation for surface microstructure investigation.

1.3 Research Objective

i) To produce different biodiesel blends.

ii) To determine and comparing the friction coefficient of biodiesel blends under sliding contact.

iii) To analyze the surface and scar formation on steel ball bearing lubricated with biodiesel blends.

1.4 Scope of Research

i) Obtaining biodiesel blends of B10, B20, and B30 from palm oil biodiesel (B100).

ii) Obtaining the friction coefficient of biodiesel blends by performing 4-ball test method following ASTM D4172 standard test parameters.

iii) Worn ball bearing surface observation using optical microscope.

CHAPTER 2

LITERATURE REVIEW

2.1 Palm Oil

Malaysia in the second largest producer of palm oil in the world between the leader Indonesia, and Thailand (Suthisripok & Semsamran, 2018). Palm oil is one of vegetable oils that represents 40% of all types of vegetable oil produced worldwide and it is the most widely used vegetable oil. It is also the cheapest source of edible oil among many others like corn oil, soybean oil and rapeseed oil. It is documented that the common characteristics of palm oil is it is biodegradable, has good lubricating properties, has high viscosity, not very volatile, and has high flash point (Durango, Zapata, Santa, & Sierra, 2022). Palm oil has excellent oxidative stability compared to oils from other sources but has poor low temperature properties (Singh et al., 2020).

In recent years, the global demand for palm oil for the food industry and for consumer goods such as soaps, cosmetics and detergents has skyrocketed. However, this growth was accompanied by great concerns about the land use of palm oil crops. This is primarily related to the expansion of palm plantations, deforestation, biodiversity loss and land conflicts. Therefore, such expansion must be accompanied by policies to protect food security and the environment to produce sustainable development (Durango, Zapata, Santa, & Sierra, 2022).

In a study that investigates the biodegradability of palm oil, it is reported that palm oil degrades more than 60% after 28 days. The biodegradability of palm oil can be explained by the presence of ester linkage in an ester group, which provides a site for microorganism to start the biodegradation process (Durango, Zapata, Santa, & Sierra, 2022).

One of elements in tribology is the viscosity of fluid. Viscosity is the resistance of a substance against flow. The effect of temperature to viscosity is indicated by viscosity index. High value shows that the viscosity change is small in wide temperature range. In case of palm oil, it is reported that it possesses viscosity index between 159 to 188 (Durango, Zapata, Santa, & Sierra, 2022).

Table 2.1 The amount of fatty acids and its chemical structure in palm oil (Singh et al., 2020)

Name	Structure	Chemical formula	Chemical name	Amount (%w/w)
Lauric acid	C_{12}	$C_{12}H_{24}O_2$	*Dodecanoic acid*	0.2
Myristic acid	C_{14}	$C_{14}H_{28}O_2$	*Tetradecanoic acid*	1.1
Palmitic acid	C_{16}	$C_{16}H_{32}O_2$ {$CH_3(CH_2)_{14}COOH$}	*Hexadecanoic acid*	44.0
Palmitolic acid	$C_{16:1}$	$C_{16}H_{30}O_2$ {$CH_3(CH_2)_5CH_5CH\text{–}(CH_2)_7\text{–}COOH$}	*Cis-9-hexadecanoic acid*	0.1
Stearic acid	C_{18}	$C_{18}H_{38}O_2$ {$CH_3(CH_2)_{16}COOH$}	*Octadecanoic acid*	4.5
Oleic acid	$C_{18:1}$	$C_{18}H_{34}O_2$ {$CH_3(CH_2)_7CH_5CH(CH_2)_7COOH$}	*Cis-9-octadecanoic acid*	39.2
Linoleic acid	$C_{18:2}$	$C_{18}H_{32}O_2$ {$CH_3(CH_2)_4CH_5CH\text{–}CH_2\text{–}CH_5CH\text{–}(CH_2)_7COOH$}	*Cis-9-cis-12-octadecadeneoic acid*	10.1
Linolenic acid	$C_{18:3}$	$C_{18}H_{30}O_2$ {$CH_3(CH_2)_4$ $CH_5CH\text{–}CH_2\text{–}CH_5CH\text{–}CH_2\text{–}CH_5CH(CH_2)_4COOH$}	*Cis-6-cis-9-cis-12-octadecatrienoic acid*	0.4
Arachidice acid	C_{20}	$C_{20}H_{40}O_2$ {$CH_3\text{–}(CH_2)_{18}COOH$}	*Eicosanoic acid*	0.4

Palm oil has similar amount of saturated and unsaturated fatty acids. Table 2.1 describes the different fatty acid profiles of palm oil (Singh et al., 2020). The saturation of fatty acids in palm oil is high at about 40% to 50%, which is higher than sunflower oil and olive oil. When used as lubricant, palm oil improves the protection against wear because of this high fatty acid content. Palmitic acid and oleic acid in the palm oil