INVESTIGATING THE OXIDATION STABILITY OF PALM OIL BY USING DIFFERENT TYPE OF ANTIOXIDANT ADDITIVE

ING WAI MING

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This report submitted
In fulfillment of the requirements for the degree of
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DECLARATION

I declare that this project report entitled "Investigating the Oxidation Stability of Palm Oil by Using Different Type of Antioxidant Additive" 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 Bachelor of Mechanical Engineering with Honours.

Signature : .....

Supervisor's Name : .....

Date : .....

DEDICATION

To my beloved mother and father

ABSTRACT

Palm oil is a vegetable oil derived from the natural source, and its outstanding properties have got the attention of many researchers to investigate the usability for the machinery lubrication. Unlike petroleum-based oil, palm oil is renewable, environmental-friendly, biodegradable, and non-toxicity. However, poor oxidation stability, low thermal stability, and low viscosity index have limited its application as machinery lubricants. In this study, the focus will be on the oxidation stability of palm oil by adding a few either natural or synthetic antioxidant additive into the oil sample. The oxidation stability will be studied by using the trend of the graph, which shows the reducing rate of antioxidant addictive in the oil sample. A different oxidation testing method, such as Fourier-transform infrared spectroscopy will be carried out to determine the antioxidant performance. Also, the viscosity, total acid number (TAN), and water content are the parameters that should take into account to validate the experiment as the oxidation process is mainly caused by the acidic product, sludge, and insoluble compound.

ABSTRAK

Kelapa sawit adalah minyak sayuran yang berasal dari sumber semula jadi, dan khasiatnya yang luar biasa telah mendapat perhatian banyak penyelidik untuk mengaji kebolehgunaan pelinciran mesin. Tidak seperti minyak berasas oleh petroleum, minyak sawit boleh diperbaharui, mesra alam, biodegradasi, dan tidak beracun. Walau bagaimanapun, kestabilan pengoksidaan yang rendah, kestabilan haba yang rendah, dan indeks kelikatan yang rendah telah membatasi penggunaannya sebagai pelincir mesin. Dalam kajian ini, tumpuan akan diberikan kepada kestabilan pengoksidaan minyak sawit dengan menambahkan sedikit aditif antioksidan semula jadi atau sintetik ke dalam sampel minyak. Kestabilan pengoksidaan akan dikaji dengan menggunakan tren grafik, yang menunjukkan penurunan kadar ketagihan antioksidan dalam sampel minyak. Kaedah pengujian pengoksidaan yang berbeza, seperti spektroskopi FTIR akan dilakukan untuk menentukan prestasi antioksidan. Juga, kelikatan, jumlah asid total (TAN), dan kandungan air adalah parameter yang harus dipertimbangkan untuk mengesahkan eksperimen kerana proses pengoksidaan disebabkan terutamanya oleh produk berasid, enapcemar, dan sebatian tidak larut.

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FTIR	Fourier-transform infrared spectroscopy
ZDDP	Zinc dialkyldithiophosphates
BHT	Butylated hydroxytoluene
CPO	Crude Palm Oil
PKO	Palm kernel oil
SAE	Society of Automotive Engineering
PAI	Peak Area Increase
TAN	Total Acid Number
CBM	Condition-based Maintenance
IR	Infrared
RDE	Rotating Disc Electrode
OES	Optical Emission Spectroscopy
SWG	Standard wire gauge

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

1.1.1 Vegetable Oil as Lubricant

Most vegetable-based oils are consisting of primary triacylglycerides, which are categorized as triglycerides. Triglyceride chemical structure gives the outstanding of machinery lubrication properties as base oil. Its long and polar fatty acid chain provides a secure lubrication layer that can work efficiently by decreasing wear and friction. Food processing industries is possible one the sector that will employ this kind of vegetable-based oil in their machinery as it is free of toxic. According to Gawrilow, (2004), the lubricant market in this food processing market will reach 700 million tons per year and table 1 shows the application and volume of market demand in one year, as reported in 2004 in Oleochemical.

Table 1.1 Potential Use of Lubricant per annum

No. 1	Potential Application	Volume (MT)
1	Two-cycle engine oils	50-70,000 MT
2	Hydraulic fluids	350,000 MT
3	Gear Oil lubricants	50,000 MT
4	Textile lubricants	45,000 MT
5	Metalworking lubricants	540,000 MT
6	Grease base fluids	1 million MT
7	Chain bar lubricant	45,000 MT

However, its drawbacks are also one of the most significant concerns that make many manufacturers avoid using it as their mainstream product in machinery lubrication. The intermolecular interaction which built the lubricant layer will lead to the poor thermal properties of the oil, and unsaturated double bonds in fatty acid are very reactive to some process, which the most we concerned – oxidation (Fox and Stachowiak, 2007).

The poor thermal and oxidation stability causes the lubricant oil to form more sludge and deposit, which significantly reduces the service life and increases the machine's downtime for the lubricant oil replacement or filtration. (Quinchia *et al.*, 2011)

1.1.2 Oxidation Mechanism in Lubricant

Oxidation process in lubricant is always the undesired process that cannot be avoided but reduced by using the antioxidant addictive. The heat generated, oxygen, copper, or iron from wear particles are the main factors that fasten the rate of oxidation process in the lubricant. The oxidation process in lubricant will lead to the formation of sludge, varnish and deposits which can affect the physical and chemical properties of the lubricant such as viscosity, total acid number (TAN) and depletion of the additives.

Oxidation involves three stages which are initiation, chain propagation, and termination. In the initiation stage, an oxidizing agent such as iron metal will bring to the formation of free radical (R) which is very reactive with oxygen. The free radical will then form as peroxide radical at the propagation stage, and these peroxide radicals are the component that will react with the element in the lubricant, which led to the formation of the hydroperoxide and another free radical (R). These hydroperoxides will decompose into another compound, such as polymetric and epoxide. The radical formed during the initial and propagation stage will then combine and build a new stable organic compound until the

end changes the lubricant's physical and chemical properties. (Majid Soleimani, Leila Dehabadi and Tabil, 2018)

1.2 PROBLEM STATEMENT

Generally, lubricant oil in the market is formulated from petroleum-based oil and it has been widely used in many fields for a very long period due to its outstanding performance and properties in lubrication. However, the undesirable cost and environment unfriendly make many researchers look for alternative base oil to make up this drawback. The high production rate of vegetable oil in many countries and non-toxic properties successfully attracts researchers from worldwide to study its characteristic.

The outperform of the vegetable-based oil in friction and wear properties surprise the researcher and gives more attraction to this study. However, the oxidation stability and thermal degradation of this oil have become the most significant challenge. In this study, the concentration will be put on the oxidation behaviour of the vegetable oil when it exposed to several conditions of the scenario that would speed up the oxidation process. Different antioxidant additive from the natural and synthetic source is prepared to blend into the lubricant which temporarily ignores the synergism effect of other additives until getting the desire information of the additive performance.

1.3 OBJECTIVE

The objectives of this report are as follows:

- Identify the suitable antioxidant that can be used in the vegetable-based oil.
- Investigate the oxidation stability of palm oil using different types of antioxidant additive in a fixed portion.

1.4 SCOPE OF WORK

- This project will use the palm oil as the base oil and antioxidant additive will be added.
- The experiment will focus only on the oxidation stability of 3 different antioxidants where the synergism factor will be temporarily ignored.
- Oil sample preparation will be deteriorated by using water and copper as a catalyst to achieve the real condition of oxidation.
- Data and trend of the graph from the viscosity, total acid number, and value of FTIR will be used to study the oxidation stability.

CHAPTER 2

LITERATURE REVIEW

This chapter will discuss the fundamental theory of the base oil, classification of an additive according to their chemical reaction mechanism, the simple introduction of 3 additive used (BHT, L-Ascorbic acid, and ZDDP), chemical and physical change due to oxidation process interpretation of viscosity and acidity number to the chemical degradation for the oxidation process.

2.1 PALM OIL AS THE BIO LUBRICANT

Palm oil is a tropical plant that originated in West Africa and Malaysia is one of the biggest export countries on palm oil production. Simultaneously, the overall production rate of palm oil is ten times higher than other oilseed cultivation which greatly increases the value of research to investigate it as bio-lubricant. In comparing the price to other vegetable oil, it shows the superior value due to its production rate. Palm oil is extracted from the fruit where crude palm oil (CPO) is from mesocarp and palm kernel oil (PKO) from the kernel.

Surprisingly, palm oil has an almost balanced composition of unsaturated and saturated fatty acid compared to other vegetable oil and this outstanding content able palm oil been used in many applications in food industries. The long and polar acid chain provide the strong lubrication film to avoid the direct contact between two surfaces and strong intermolecular bond allow palm oil to have a good viscosity index (Yahayaa *et al.*, 2019).

However, like any other vegetable oil, the triglyceride and unsaturated double bond in a fatty acid is very reactive and bring to the oxidation instability. Many factors that we should consider including the fluidity, viscosity, temperature stability, oxidation, reaction, density and other if we want to bring the palm oil as the bio-lubricant in machinery purposes (Yahayaa *et al.*, 2019).

2.2 ANTIOXIDANT ADDICTIVE CLASSIFICATION

Oxidation of a lubricant can be described as a continuous process involving initiation, propagation, branching and termination. If the process of the cycle not broken or terminated, the oxidation process will continue until the lubricant is out of the performance. There are various antioxidant addictive either natural or synthetic that can find in the market, but how we determine it is the best synergistic effect for particular lubricants in specific purposes is what we need to study. There are three types of antioxidants where generally, we classify them into primary antioxidants, secondary antioxidants, and metal deactivators.

The primary antioxidant also is known as radical scavengers, which represent the compounds such as aromatic amines, phosphorus, phenolic, and sulphur that can end the chain propagation of free radicals by donating the hydrogen atoms to react with peroxide or alkyl radical to form new radical that are more stable. As for the second antioxidant, such as organosulfur and organophosphorus, it will react with hydroperoxides which are often present as the lubricating oil reacts with oxygen to the non-radical derivative. These antioxidants are capable of stopping the cycle and preventing branching and further propagation.

Metal deactivators are one of the antioxidants that prevent the catalytic effect between the lubricant and the metal to be oxidized. It is divided into two types which are