STUDY ON THE EXTREME PRESSURE (EP) PROPERTIES OF TREATED WCO WITH ADDITION OF ZDDP VS HBN NANOPARTICLES

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2022

Faculty of Mechanical and Manufacturing Engineering Technology

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

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2022

DECLARATION

I declare that this project entitled "Study on the extreme pressure (EP) properties of treated WCO with addition of ZDDP vs hBN Nanoparticles" 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 : ALIZA NADIRA BINTI ROSLI

Date : 5 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 degree of Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours

Signature :

Supervisor Name : Dr. Muhammad Ilman Hakimi Chua Bin Abdullah

Date : 9 JANUARY 2023

DEDICATION

I dedicate this works to my beloved parents and my supervisor Dr. Muhammad Ilman Hakimi Chua Bin Abdullah, who offered unconditional love and support and have always been there for me. Thank you so much for giving me the strength to finish my Final Year Project.

ABSTRACT

Nowadays, many studies have exploited waste cooking oil into other materials that can be reused. Waste Cooking Oil (WCO) or edible waste oil has become a common term, especially for Malaysians who love fried foods. Malaysia is one of the largest cooking oil (CO) producers which will affect the amount of WCO produced. Lack of WCO management and lack of community knowledge cause environmental damage where WCO can pollute the environment. However, WCO can still be reused to make other products such as biodiesel production and soap making. This thesis examined the waste cooking oil follow by utilizing the nanoparticles that used as additives to obtain an excellent tribology properties that can improve bio-based lubricants. This research showed nanoparticles that fulfil the fundamental requirement types and concentrations, then examined and determined the most appropriate nanoparticles that can improve wear protection and reduce friction. Hence, Zinc dialkyldithiophosphates (ZDDP) and Hexagonal boron nitride (hBN) nanoparticles in place of lubricant additive was added into the waste cooking oil to improve its physical and tribology properties. The WCO filtration process carried out based on ASTM D 7317. After the filtration process, WCO blended with ZDDP and hBN nanoparticles using an ultrasonic homogenizer. The process carried out is to homogenize the composition of different nanoparticles against zero friction properties. ASTM D 2783 four ball method is used to obtain the friction and wear scar diameter result. Then, using the SEM method, the wear mechanism on the bearing ball surface analyzed by scanning the wear surface image. As a results, ZDDP and hBN nanoparticles improved the physical properties along with the good anti-wear and anti-friction characteristics of the lubricant mixtures. Waste cooking oil meets the fundamental criteria for a bio-based lubricant and can replace mineral oil as a new advanced renewable bio-based lubricant for industrial operations that are environmentally conscious and cost-effective.

ABSTRAK

Pada masa kini, banyak kajian telah mengeksploitasi sisa minyak masak kepada bahan lain yang boleh digunakan semula. Sisa minyak masak atau minyak buangan boleh dimakan sudah menjadi istilah biasa terutama bagi rakyat Malaysia yang menggemari makanan bergoreng. Malaysia merupakan antara pengeluar minyak masak terbesar yang akan menjejaskan jumlah sisa minyak masak yang dihasilkan. Kekurangan pengurusan sisa minyak masak dan kekurangan pengetahuan masyarakat menyebabkan kerosakan alam sekitar di mana sisa minyak masak boleh mencemarkan alam sekitar. Walau bagaimanapun, sisa minyak masak masih boleh digunakan semula untuk membuat produk lain seperti pengeluaran biodiesel dan pembuatan sabun. Tesis ini mengkaji sisa minyak masak susulan dengan menggunakan zarah nano yang digunakan sebagai bahan tambahan untuk mendapatkan sifat tribologi yang sangat baik yang boleh menambah baik pelincir berasaskan bio. Penyelidikan ini menunjukkan nanopartikel yang memenuhi jenis keperluan asas dan kepekatan, kemudian diperiksa dan menentukan nanopartikel yang paling sesuai yang boleh meningkatkan perlindungan haus dan mengurangkan geseran. Oleh itu, Zinc dialkyldithiophosphates (ZDDP) dan heksagon nanopartikel Boron Nitrida (hBN) sebagai ganti bahan tambahan pelincir telah ditambah ke dalam sisa minyak masak untuk memperbaiki sifat fizikal dan tribologinya. Proses penapisan sisa minyak masak dijalankan berdasarkan ASTM D 7317. Selepas proses penapisan, sisa minyak masak diadun dengan nanopartikel ZDDP dan hBN menggunakan homogenizer ultrasonik. Proses yang dijalankan adalah untuk menghomogenkan komposisi zarah nano yang berbeza terhadap sifat geseran sifar. Kaedah empat bola ASTM D 2783 digunakan untuk mendapatkan hasil diameter geseran dan haus. Kemudian, menggunakan kaedah SEM, mekanisme haus pada permukaan bebola galas dianalisis dengan mengimbas imej permukaan haus. Hasilnya, nanopartikel ZDDP dan hBN meningkatkan sifat fizikal bersama-sama dengan ciri anti haus dan anti geseran yang baik bagi campuran pelincir. Minyak masak sisa memenuhi kriteria asas untuk pelincir berasaskan bio dan boleh menggantikan minyak mineral sebagai pelincir berasaskan bio boleh diperbaharui termaju baharu untuk operasi industri yang mementingkan alam sekitar dan menjimatkan kos.

ACKNOWLEDGEMENT

Firstly, praise to Allah S.W.T., the Almighty on whom ultimately, we depend for substance. For the strength and blessing needed to complete this Project Sarjana Muda. I would like to express my sincere appreciation towards my supervisor, Dr. Muhammad Ilman Hakimi Chua bin Abdullah whose guidance, constructive comments, and useful advice were very valuable to me.

Next, a sincere thank you to the Faculty of Mechanical and Manufacturing Engineering Technology, UTeM for giving me this valuable opportunity to do this research and providing me with a complete infrastructure for me to complete my degree in Bachelor of Mechanical Engineering Technology (Maintenance Technology). To all the lecturers that have taught me throughout these four years of degree life, thank you very much for your love, kindness and patience in teaching me.

In particular, I would also like to express my deepest gratitude to my beloved family especially to my parents for their endless love and support in every way physically, mentally, and financially. Not to forget my brother and sister for continuously cheering me on.

Sincere thanks to my friends especially the close friends and course mates, who always support me in whatever I do and encourage me to be a better person. And very thankful to my classmates for always helping me with completing all assignments and giving words of encouragement to finish these 4 years of learning. Finally, thank you to all my friends and everyone around me who directly and indirectly contributed to completing my project.

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LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Material
ISO	-	International Standardization Organization
EP	-	Extreme Pressure
WCO	-	Waste Cooking Oil
ZDDP	-	Zinc Dialkyl Dithiophosphate
CoF	-	Coefficient of Friction
hBN	-	Hexagonal Boron Nitride
PTFE	-	Polytetrafluoroethylene
FFA	-	Free Fatty Acids
VOL.	-	Volume
Temp.	-	Temperature
SEM	-	Scanning Electron Microscope
RPM	-	Rotation per minute
WSD	-	Wear Scar Diameter
WP	-	Wear Preventive

CHAPTER 1

INTRODUCTION

1.1 Background

Tribology is a new term derived from the Greek word tribos, which means "rubbing". It is often used to describe the growing science of friction, wear, and lubrication at moving contacts. Mechanical, chemical, and material technologies are all included in their vast scope. In tribology, typical duties include reducing friction and wear to save energy, allowing for quicker and more accurate motions, better productivity, and lower maintenance. Lubricant formulation, industrial processes, aircraft and transportation equipment, material shaping and machining, computers and electronic devices, power generation and practically all stages of life where motion is encountered today have a fundamental interest in tribology. In addition, the fundamentals are used to apply the concepts of tribology to several other machine parts. (Khonsari et al., 2017).

For boundary lubrication, extreme pressure (EP) additives are required. Therefore, EP additives were looked into to fill in specific gaps in theoretical and practical applications. Because of the heat interaction with metal to generate film properties, compounds including chlorine, sulphur, and phosphorus elements were initially utilised in boundary lubrication. However, EP additives are not eco-friendly, yet nanoparticle EP additives are a great alternative. (Zhang et al., 2022).

Waste cooking oil (WCO) is so close to the daily lives of Malaysians. In recent years, there has been growing concern about WCO, which leads to improper disposal and the intake for biodiesel production (Yacob et al., 2015). Collecting the recycling of used or unrecovered products has been growing in recent years as the increase in the awareness of society toward environmental view (Ramos et al., 2013). An organised collection of WCO in large quantities is mainly used to produce biodiesel. Although most researchers concentrate on the generation of biodiesel from WCO, there is also another application which is significant and needs attention WCO are collected and can be used in the production of biofuel or reused in the chemical industry to make soap, detergents, lubricants, paint, and grease (Ramos et al., 2013).

One of the most popular antiwear commercially available motor lubricants is zinc dialkyl dithiophosphate (ZDDP). Another is that the nanoparticle is usually defined as a particle of matter between 1 and 100 nanometres (nm) in diameter. The absorption of solar radiation is much higher in materials composed of nanoparticles than in thin films of continuous sheets of material. For more than six decades, antiwear additives comprising phosphorus and sulphur have been widely utilised in automobile and aviation lubricants. The capacity of these compounds to generate tightly adherent tribofilms that can tolerate high pressure and severe temperatures is the key to their effectiveness. The additives are necessary for reducing wear at sliding asperity contacts; however, they are associated with several environmental issues. Alternatives that are less harmful to the environment are actively pursued, and nanoparticles have much promise. They are being researched both on their own and in conjunction with traditional additives to improve tribological performance while reducing the environmental effect. This study will look at the basic mechanics of tribofilm production for zinc dialkyl dithiophosphate (ZDDP), both alone and in combination with nanoparticle additions. (Biplav et al., 2022).

1.2 Problem Statement

Since the commencement of cooking oil, waste cooking oil (WCO) has been a problem. The WCO is manufactured on a massive scale across the world, which has resulted in significant waste management issues (Panadare & Rathod, 2015). In addition, the lack of a standardised method for disposing of WCO has resulted in various waste management approaches (Mazlini et al., 2019). In recent years, a substantial quantity of WCO has been created and discharged into the environment in several nations throughout the world, according to (Kabir et al., 2014).

The issue of cooking oil waste collection has sparked heated controversy, as unregulated disposal has detrimental environmental consequences. WCO is meant to be tossed so that they do not hurt people or the environment. Unfortunately, consumers dispose of it in sinks, garbage bins, drainage systems, toilets, or straight into water bodies or lands (Kabir et al., 2014). WCO cannot be poured down drains because it clogs them and pollutes the water, posing a threat to animals (Peng, 2016).

Nanoparticles made of transition metal dichalcogenides are thought to have much potential as a boundary lubricating additive/material for reducing friction and wear on functional engineering surfaces. On the other hand, Nanoparticles cannot give complete surface protection against oxidation, corrosion, or sludge management. As a result, current lubricant developments may rely on traditional additives like zinc dialkyl dithiophosphate (ZDDP). It is critical to understand how nanoparticles interact with such additives to investigate how its could be commercially used in fully formulated lubricants. The findings reveal that, while nanoparticles can reduce friction in all circumstances, the composition and shape of the resultant tribofilms and their lubricating processes varied substantially. MoS2 nanoparticles and nanotubes have a good synergy with ZDDP and tribofilms made from nanoparticles have better friction and wear characteristics than ZDDP-based tribofilms (Tomala, 2015).

Based on the problems and ideas stated above, it is essential to design a waste cooking oil as a clean based oil as it can save the environment and reduce uncontrolled waste of used oil.

1.3 Objectives

The objectives of the analysis are as follows;

1. To filter waste cooking oil as clean based oil for WCO based lubricant development.
2. To determine the suitable type and composition of nanoparticles to be bland as an additive.
3. To test the extreme pressure for the developed lubricant on the wear mechanisms.

1.4 Scope of Research

The attain the objectives, the scopes of this research are as follows:

1. Filtering the waste cooking oil as clean based oil according to ASTM D 7317.
2. Determine the suitable composition for HBN and ZDDP nanoparticles amount to be bland using an ultrasonic homogeniser.
3. Testing EP of the developed semple according to ASTM.
4. D 2783 and validating the wear mechanisms occurs.

CHAPTER 2

LITERATURE REVIEW

2.0 Literature Review

Lubricants play a vital part in the growth of industry and the economy. Lubricant acts as a friction reducer and antiwear mechanism on mechanical contact and improves tribological performance. Oils and greases are the most frequent lubricants used in the automobile industry.

2.1 Classification of lubricant

Three varieties of lubricants can be categorised based on their physical qualities and performance: solid, semi-solid, and liquid. Lubricant is frequently employed in industries such as manufacturing and transmission, and it may also work as a coolant since it decreases heat and corrosion and offers a smooth operation between two moving components. Lubricants have several fascinating residential applications in addition to industrial applications. Lubricants, for example, are utilised as oils in cooking and baking. They are also employed in medical procedures such as ultrasonic treatment.

2.1.1 Liquid lubricant

Lubrication technology is of great significance in improving the tribological properties and reducing friction pairs wear. In addition, lubricants have the functions of cleaning wear debris, sealing clearances, dissipating heat, and resisting corrosion or rust (Gunde Guo et. al 2020). These can be defined as the lubricants that exist in the liquid state and are more frequently used for the purpose of lubrication. Generally, lubricants do tend to contain 90% base oils and approximately less than 10% of the additives. Usually vegetable or synthetic oils like hydrogenated polyolefins, esters, silicones, fluorocarbons etc. are used as base oils.

2.1.1.1 Mineral-based oil

The mineral lubricant is obtained from crude oil through a refineries process. Mineral oil is classified into three types: paraffinic oil, naphthenic oil, and aromatic oil. The most prevalent use for lubricating oil products is paraffin oil incorporating paraffin wax. This oil has greater oxidation resistance, a higher viscosity index, low point drops, and minimal fluctuations. According to Euro TechCon (2018) they require the inclusion of addicts to reduce the pour point. Naphthenic mineral oils contain aromatic compounds which remain fluid at comparatively low temperatures such as -40°C. However, there is no sharp distinction between these two types of oil, but rather a sliding scale that ranges from the very paraffinic to the very naphthenic. For example, suppose the paraffinic structure in oil is below 50%. The oil is regarded as naphthenic. From 50%-56%, oil is considered an intermediate between paraffinic and naphthenic. Figure 2.1 shows the structure of ester linkage, synthetic and natural ester, and basic carbon structures in mineral oil molecules.

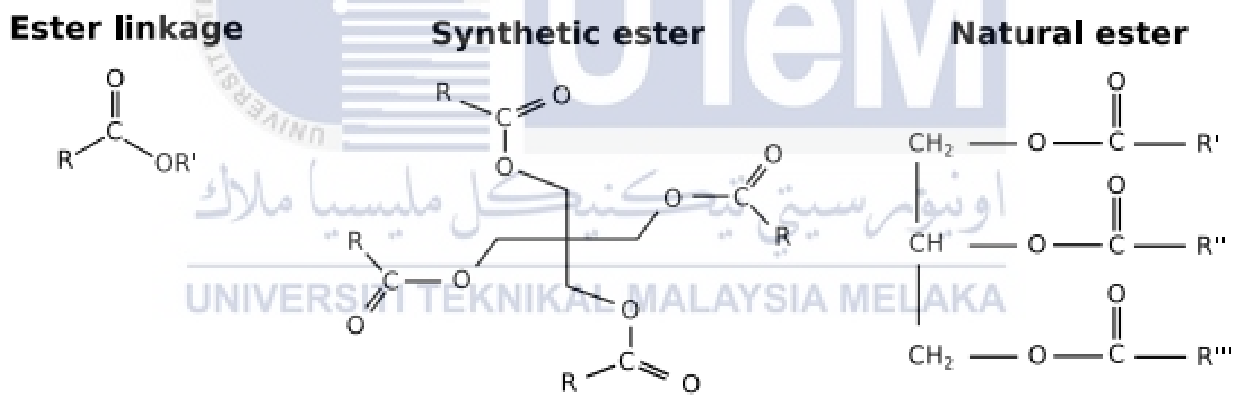

Figure 2.1: Structure of ester linkage, synthetic and natural ester (Mladen et al., 2018)

A completed lubricant's foundation is the formulated lubricant. A complete lubricant is a mixture of base oil and additives. The qualities of the mineral base oil will be altered by the additives incorporated. A refinery's primary duty is to split crude oil into usable components while removing the elements of undesired materials. Kerosene or jet fuel, diesel fuel, base oil, waxes, and asphalt or bitumen are the lightest or smallest hydrocarbon components, followed by gasoline, kerosene or jet fuel, diesel fuel, base oil, waxes, and asphalt or bitumen, which sequences substance is the heaviest and thickest. The following series of procedures are used to make base oils from crude oils, and they all work to some extent. Table 2.1 below shows the results in a mineral base oil classified into three different groups.

Table 2.1: Breakdown of each of the three mineral groups (source: www.twinoils.com)

Base oil categories	**Sulfur (%)**		**Saturates (%)**	**Viscosity index**
Group I (solvent refined)	>0.03	And/or	<90	80 to 120
Group II (hydrotreated)	<0.03	And	>90	80 to 120
Group III (hydrocracked)	<0.03	And	>90	>120

2.1.1.2 Vegetable oil

The greater affordability of renewable goods based on vegetable and animal raw materials than biodegradable materials has prompted study into using biological feedstock lubricants. According to experts, using vegetable oils is an up-and-coming option. Olive, corn, sunflower, rapeseed oils, and mineral oil I-20 have their fundamental tribo-technical qualities described. Vegetable oils have a lower freezing temperature and a more excellent flash point than mineral oils. Their load-carrying capacity meets or exceeds 60%, antiwear rates are 1.3-2.3 times more effective, and load wear index is 2.3 times higher. The oils are ordered from best to worst in terms of tribological characteristics: sunflower, olive, corn, rapeseed, and rapeseed (Andrei et al., 2017)

Table 2.2 Characteristics of lubricants

Oil	Density at 20^oC, g/sm^3	Kinematic viscosity at 40^oC, mm^2/sec	Flashpoint temperature in an open cup, °C, not lower than	Freezing temperature, °C	Embrittlement temperature, °C
Olive	0.911	41.7	232	-3…-5	-
Corn	0.918	60.6	316	-25…-27	-37
Sunflower	0.923	35.5	234	-16…-19	-35
Rapeseed	0.918	42.1	306	-19…-20	-54
I-20	0.900	64.3	220	-15	-38

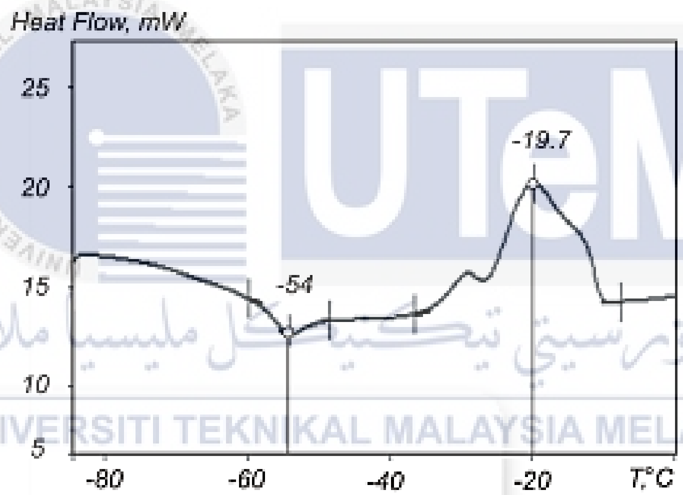

Figure 2.2 Colorimetric data on rape oil cooling

2.1.2 Solid lubricant

Solid lubricants have recently attained significant importance. Graphite and molybdenum disulphide (MoS^2) are predominantly used as solid lubricants. They are used under high temperatures and high load (pressure). According to Kopeliovich, ND can lower the coefficient of friction and wear between two contact surfaces by retaining the direct contact in a rubbing state under high loads. Graphite and molybdenum disulphide components are often found in the form of a dusty powder. The lamellar structure, in which the lamellas orient parallel to the surface in the direction of motion, demonstrates that these materials function well as lubricant additives.

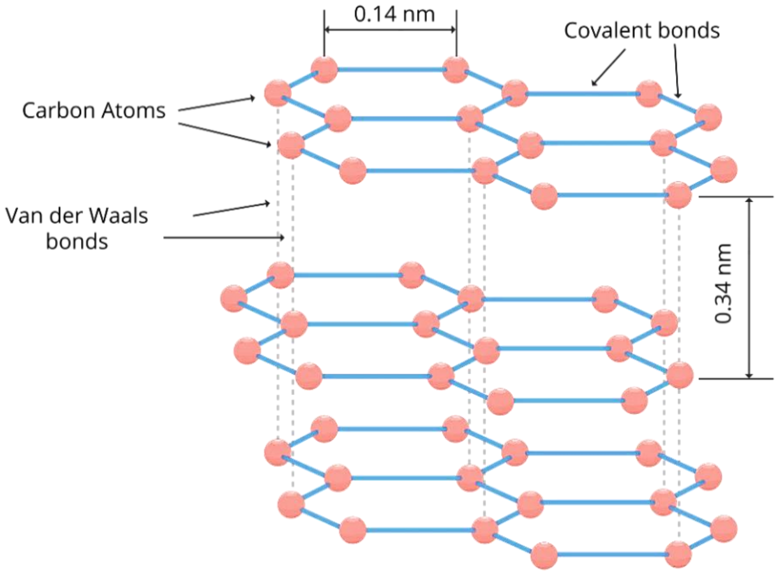

Figure 2.3 Graphite structure (Source: www.tribology-abc.com)

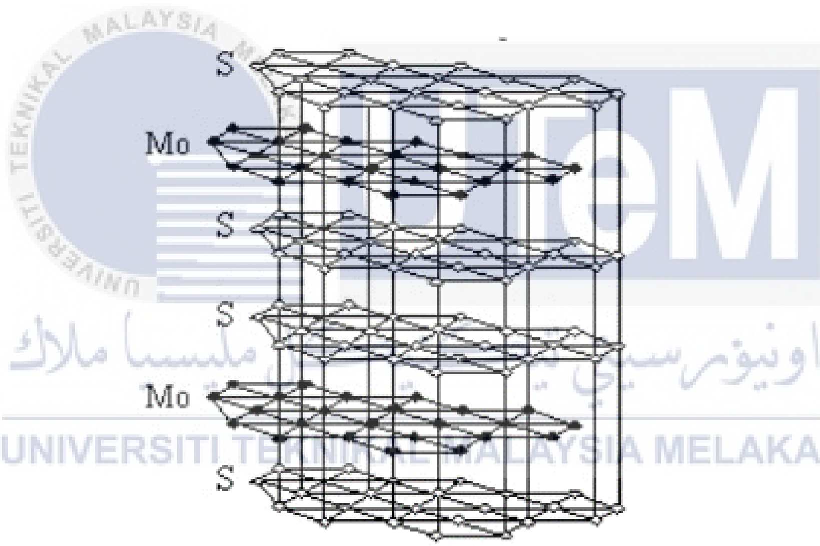

Figure 2.4 Molybdenum disulphide structure (Source: www.tribology-abc.com)

Solid lubricants such as PTFE, graphite, MoS2, and other anti-friction and antiwear additives are frequently included in polymers and sintered materials. For example, MoS2 is used in sleeve bearings, elastomers O-rings, carbon brushes, and other materials. Plastics are mixed with solid lubricants to create a "Self-lubricating" or "Internally lubricated" thermoplastic composite. They are compounding PTFE particles in plastic. For example, it forms a PTFE layer across the mating surface, reducing friction and wear. Wear, friction, and stick-slip are reduced when MoS2 is mixed with Nylon. It also serves as a nucleating agent, causing an extremely thin crystalline structure to form. The most common use for graphite-lubricated thermoplastics is in aquatic conditions.