ANTI-WEAR PERFORMANCE OF PALM-BASED OIL MIXED WITH GREEN ADDITIVE

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DECLARATION

I declare that the contents of this PSM report with title “Anti-wear performance of palm-based oil mixed with green additive” are all my own work except the articles and researches as cited are for reference purposes.

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.

Signature : ....

Name of Supervisor : ....

Date : ....

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ABSTRACT

The wide uses of mineral lubricants in several industries have raise the environmental issues due to the accidental leakage to environment during the operation. Therefore, researches about bio-based lubricants have been promoted to substitute mineral lubricants due to its environment friendly properties. Nevertheless, bio-lubricants exhibits inferior oxidation, thermal stability and poor fluid flow behavior compared to mineral lubricants. Hence, additive becomes one of the solutions to improve the properties of the bio-lubricants. In this article, the anti-wear performance of palm-based oil blended with hexagonal boron nitride (hBN) is examined from the perspective of Coefficient of Friction and Wear Scar Diameter. Moreover, the outcomes obtained will be utilized to compare with the results of previous studies. The tribological performance of all the samples were tested by four-ball tester machine in accordance with standard of ASTM D4172. There are several combinations of samples used in comparison such as bio-based lubricant with green additive, bio-based lubricant with ordinary additive, ordinary lubricant with green additive, refined bio-based lubricant and pure bio-based lubricant only. As a result, sample of Trimethylolpropane3 (TMP3) illustrate the best anti wear performance in both COF and WSD. It achieved the lowest value with 0.051 in COF and 0.27mm in WSD. This can be explained that the lubricant film formed by the mixture of ordinary lubricant and palm oil-based TMP ester can effectively improve the anti-wear performance than other samples did.

ABSTRAK

Penggunaan pelincir mineral yang meluas dalam industri telah menimbulkan masalah persekitaran kerana kebocoran secara tidak sengaja ke persekitaran semasa operasi. Oleh itu, penyelidikan mengenai pelincir bio telah dipromosikan untuk menggantikan pelincir mineral kerana sifatnya yang mesra alam. Walaupun begitu, pelincir bio menunjukkan pengoksidaan rendah, kestabilan terma dan kelakuan aliran bendalir yang buruk berbanding dengan pelincir mineral. Oleh itu, bahan tambahan menjadi salah satu penyelesaian untuk meningkatkan sifat pelincir bio. Dalam artikel ini, prestasi anti-haus minyak sawit yang diadun dengan boron nitrida heksagon (hBN) dikaji dari perspektif Pekali Geseran dan Diameter Wear Scar. Lebih-lebih lagi, hasil yang diperoleh akan digunakan untuk membandingkan dengan hasil kajian sebelumnya. Prestasi tribologi semua sampel diuji oleh mesin penguji empat bola sesuai dengan standard ASTM D4172. Terdapat beberapa kombinasi sampel yang digunakan sebagai perbandingan seperti pelincir bio dengan bahan tambahan hijau, pelincir bio dengan bahan tambahan biasa, pelincir biasa dengan bahan tambahan hijau, pelincir bio halus dan hanya pelincir bio sahaja. Hasilnya, sampel Trimethylolpropane3 (TMP3) menggambarkan prestasi anti haus terbaik dalam kedua-dua COF dan WSD. Ia mencapai nilai terendah dengan 0.051 di COF dan 0.27mm di WSD. Ini dapat dijelaskan bahawa filem pelincir yang dibentuk oleh campuran pelumas biasa dan ester TMP berasaskan minyak sawit dapat meningkatkan prestasi anti-haus secara berkesan daripada sampel lain.

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LIST OF ABBREVIATIONS

Abbreviation	Meaning
hBN	Hexagonal Boron Nitride
COF	Coefficient of Friction
WSD	Wear Scar Diameter
ASTM	American Society for Testing and Materials
EHL	ElastoHydrodynamic Lubrication
AISI	American Iron and Steel Institute
SEM-EDS	Scanning Electron Microscopy-Energy Dispersive Spectroscopy
SAE	Society of Automotive Engineers
TMP	Trimethylolpropane
OL	Ordinary Lubricant
VO	Vegetable Oil
G	Graphene
AW/EP	Anti-Wear/Extreme Pressure
RBD	Refined Bleached and Deodorized

CHAPTER 1

1.0 INTRODUCTION

1.1 Background

Lubricants oils are substances used to reduce friction and corrosion between interacting surfaces of a machine or device in order to improve the anti-wear performance. According to the records, olive oil was used as lubricating oils to move the building materials likes woods and stones in ancient Egypt, while animal fats were used to lubricate the wheels of trams. In the Middle Ages, introduction of many lubricating oils likes sperm oil, castor oil, peanut oil, rape oil were used for operation of complicated machines. In the nineteen century, human discovered that the mixture of crude oil and sperm oil would extend the lifetime of machines to more than ten years. The mineral based lubricants products were then widely used in industry.

Up to the present time, mineral based lubricating oils are still the most commonly used lubricants because of the low cost required to refine the oils. However, the used mineral lubricating oils that emitted into the environment bring harmful impacts to environment and health of living creatures. Although there are many rules and regulations to control the emission of mineral lubricating oils into the environment, but these actions are merely treating the symptoms but not the root causes. The key issues of the harmful impact are the properties of mineral lubricants such as their biodegradability and toxicity. To solve these issues effectively, we must start from the ingredients of lubricants. The lubricants that potentially discharged to environment should made of biodegradable and harmless materials to get rid of the negative effects.

As a potential substitutes for mineral-based lubricants, bio-based lubricants with better biodegradability have received a huge growing because they are able to overcome the environmental issues. Other than higher biodegradability and lower toxicity, bio-based oil are also own some advantages like good lubricity, provide high strength lubricant film, high polarity, high viscosity index, and the most importantly, they have high efficiency over a wide temperature range. However, some of the bio-based oils show imperfect oxidation and thermal stability as well as poor fluid flow behavior in comparison with mineral lubricants. Therefore, bio-based oils are mixed with some additives to overcome the above problems. Green additive such as hexagonal boron nitride (hBN) is selected to be mixed with bio-based oils to study their tribological performance. The combination of bio-based oils and green additives are expected to become the substitutes for mineral lubricants with its higher biodegradability and excellent lubricating properties.

1.2 Problem Statement

Mineral lubricants are produced during the crude oil processing. Therefore, the mineral based lubricating oils is containing some harmful components and they bring negative effects to environments and health. The widely used of mineral lubricants have led to the growth of environmental issues and it begins to draw the attention of public. Other than enhancement of laws and regulations, the researchers and scientist are investigating the alternative lubricants which has higher biodegradability, low toxicity and environment friendly to minimize the uses of mineral-based lubricants. Thus, this paper will serve a purpose to find out the most suitable alternative lubricant to replace mineral-based oils.

1.3 Objective

The objectives of this research are

1.) To evaluate the difference in frictional wear properties of palm oil mixed with different concentrations of hexagonal boron nitride (hBN) additives.
2.) To compare the tribological performance and justify the results with previous researches.

1.4 Scope of Study

The primary concern of this study is to figure out the bio-based lubricants with best tribological performance. The anterior part of the study is to examine the anti-wear performance of palm oil mixed with hexagonal boron nitride (hBN) additives. After the anti-wear performance test, the results obtained will be used to compare with previous researches which study about the tribological performance of bio-based lubricants. The bio-based lubricants that exhibits the best anti-wear performance has a great potential to become substitute for mineral-based lubricants.

CHAPTER 2

2.0 LITERATURE REVIEW

In this chapter, various of researches and materials related to title of this study have been referred. Refer to these articles is very important because it allows me to have a better understanding on the field of lubricating oils. There are many types of lubricating oils available on markets, it can be synthetic, bio-based, mineral based or a combination of them. For this study, we focus on the palm-based oil and the green additives, hexagonal boron nitride (hBN). However, I have referred to many materials about other lubricants and additives to improve my knowledges about lubricants' industries.

2.1 Tribology

(Affatato et al., 2013) stated that tribology is to study the relative motion of two contacting surfaces from the perspective of science and engineering. The application of the lubrication and wear as well as the principle of friction are also included. The term 'tribology' was originated from Greek term tribos with meaning of rubbing and Jost first used it in 2006. Leonardo da Vinci, an Italian polymath of the High Renaissance was the first to explain the two laws of friction control the motion of a rectangular block moving over a flat surface, however his works had not developed much until the 20th century. The knowledge regarding to tribology had received a huge growth followed by the development of industry sectors.

Lubrication, bio-tribology, wear and surface engineering, high temperature tribology as well as computational tribology are examined to discover the future improvements or progress of these aspects. However, there are presence of limitations in this review. This is because study of tribology is a highly interdisciplinary field, and there can be oversights. Besides, only some weighty topics such as lubrication, bio-tribology, wear and surface engineering, high temperature tribology as well as computational tribology discussed in this review. Tribology researches have seen rapid growth in past few years and it is increasing beyond the conventional domains. (Meng et al., 2020)

According to (Jabbarzadeh, 2018), interfacial molecular films appertain to self-built, take in or functionally grafted molecular structures that construct via physical and chemical processes. Researches about molecular origins of friction and the tribological properties of the molecular system are called molecular tribology. Interfacial molecular films act as last layer to prevent the corrosion occurs with their boundary lubrication regime. Self-assembled monolayers, a type of interfacial molecular films is used as a lubricant in some micro and nanoscale devices which could not be done with mass fluid lubrication. To restrain the friction and wear at the boundary lubricants regime, the comprehension towards the molecular origins of tribological behaviors of interfacial films is very important.

2.2 Lubrication Regimes

There are four types of lubrication regimes that would be encountered during the operation of machines which were boundary lubrication, mixed lubrication, hydrodynamic lubrication and elastohydrodynamic lubrication (EHL). For boundary lubrication, it typically happens at low speeds or nearly overloaded condition. The contacting surfaces rub with each other with little or no oil films between them. This issues can be prevented by providing the lubricant with appropriate lubricant viscosity. On the other hand, hydrodynamic lubrication happens at high speed where moving surfaces are operating with a thick film between them. This is due to the pressure produced by high speed of moving surfaces draw the lubricants and separate the surfaces. For mixed lubrication, it usually happens during the sliding speed of surfaces varying from low to high speed. The highest asperities of surfaces may close contact with each other occasionally. Last but not least, elastohydrodynamic lubrication will happen when rolling motion is involved as moving elements. In this condition, there is a close contact zone between the rubbing surfaces and induce rising of contact pressure in that zone. The high pressure will gradually deform the rolling elements. (Noria Corporation, 2017)

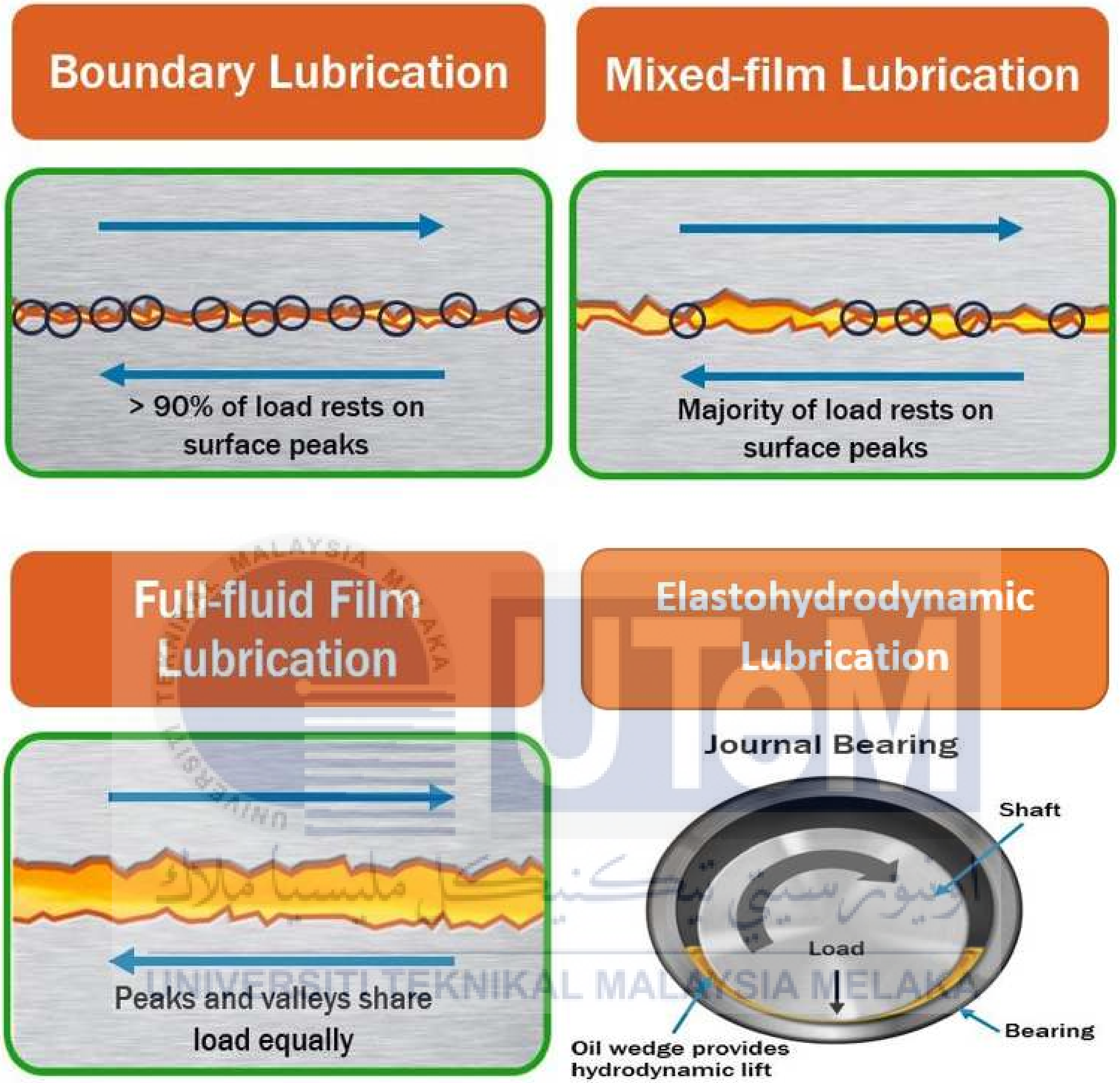

Figure 2.1 – Diagram of 4 different types of Lubrication Regimes

2.3 Wear Mechanism

Wear is defined as the removal of material from a solid body's surface as a result of counterbody's mechanical action. During friction between two opposing materials, wear can combine the impacts of several physical and chemical processes. For example, plastic deformation, cracking, fracture, melting, micro-cutting, micro-ploughing as well as chemical interaction. There are several types of mechanisms of wear.

Table 2.1 – Mechanisms of Wear

Wear Mechanisms	Characteristics
Abrasive wear	❖ Happens when a tougher object rubs against a softer object **Two Body Abrasive Wear -** Involved two contacting parts and the wear of the softer surface is caused by the tougher surface **Three Body Abrasive Wear -** The wear occurs because of a hard object trapped between two contacting surfaces
Adhesive wear	❖ Happens when two surfaces collide with enough force and parts from the less wear-resistant surface is removed
Fatigue wear	❖ The cyclic loading causes gradual and localized structural deterioration to the surface and wear occurs when applied load exceeds the fatigue strength of the surface
Corrosive wear	❖ A kind of material deterioration that includes both wear and corrosion wear processes. ❖ Both wear and corrosion can cause extensive damage or material losses.

Erosive wear	❖ Due to particles' impingement (solid, liquid, or gaseous) that removes material fragments from the surface because of momentum effect.

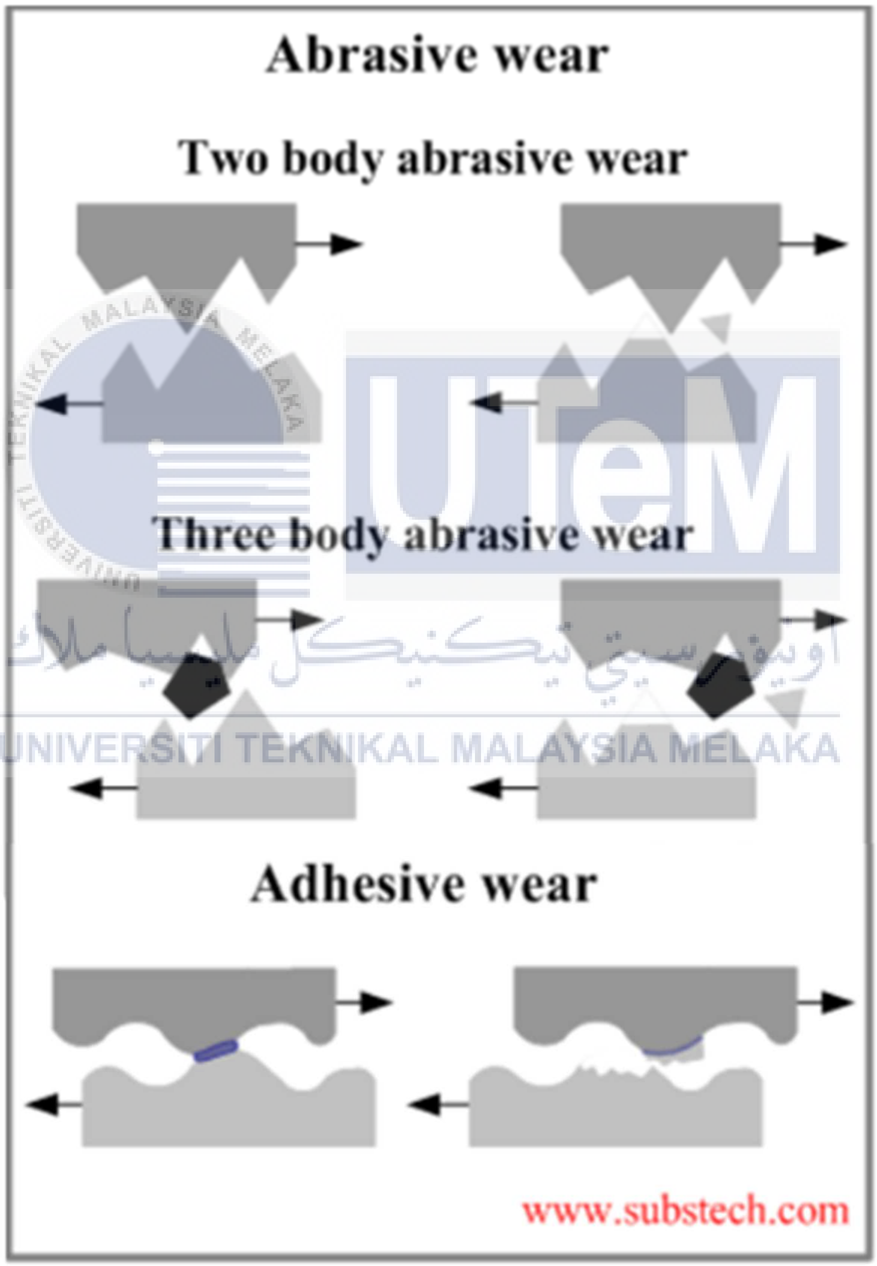

Figure 2.2 – Abrasive and Adhesive Wear (Dmitri, 2020)

Figure 2.3 – Fatigue Wear (Dmitri, 2020)

2.4 Solid Lubricants

The utilization of conventional cutting fluid has been reduced along with the developments in sustainable manufacturing. Appropriate lubrication is needed for difficult-to-machine materials when bulk cutting fluid is not applicable. Without lubricants, the heat generation due to high friction during machining will shorten the tools life as well as the workpiece surface quality. Hence, solid lubricants are added into cutting fluid to improve their tribological and thermal properties. Molybdenum disulphide or graphite will be a wide choice as it provides greater lubrication in severe condition, has better performance in contact pressure and temperatures compared to conventional oils. Their exclusive structure able to provide lower friction coefficient, hence it solves the problem of high heat generation and extend the lifetime of machines. (Sterle et al., 2018) concentrates on the tribological performance evaluation of solid lubricant, molybdenum disulphide. Tribometer is used to determine the coefficient of friction between uncoated carbide tool and AISI 1045 workpiece in the condition of high contact pressures and high sliding speeds. The data are then compared with the samples which made with dry, flooding, Minimum Quantity Lubrication (MQL), cryogenic and synthesis of MQL and cryogenic to test the performance of molybdenum disulphide. Molybdenum disulphide exhibits awesome tribological performance in the given condition and it outperforms the conventional lubricants.

Due to the restriction of some lubricants might not function over a wide range of temperatures, polymer composite coatings have been used to replace the liquid lubrication. The advanced high-bearing aromatic thermosetting polyester (ATSP) coating filled with solid lubricants, polytetrafluoroethylene (PTFE) and graphene nanoplatelets (GNPs) were tested to value their tribological performance. Nanoindentation and dynamic mechanical analysis were employed to determine the mechanical and thermo-mechanical properties of the samples while flat pin-on-disk used to test the tribological performance under the conditions of dry sliding in room temperature to 300 °C. The addition of GNPs and PTFE were proved that could performed superiorly than ATSP coating in friction and anti-wear tests. Moreover, both GNPs and PTFE exhibited excellent tribological performance in elevated temperature. However, GNPs was the best lubricants as it reduced the friction and wear by 53% and 69% in asperity condition of 300 °C. (Bashandeh et al., 2019)