TRIBOLOGICAL PROPERTIES OF PALM OIL MIXED WITH HEXAGONAL BORON NITRIDE (HBN) NANOPARTICLES

ARINA DAYANA BINTI JAMALLULIL

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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ARINA DAYANA BINTI JAMALLULIL

This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering with Honours

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MAY 2019

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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Taman Purnama

45300 Sungai Besar

Selangor

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APPROVAL

This report is submitted to the Faculty of Mechanical Engineering of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering with Honours. The member of the supervisory is as follow:

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ABSTRACT

Friction and wear are unavoidable in engineering applications. One of the common solutions to overcome these problems is by using a lubricant. Vegetable oils have been considered as potential candidates in recent years of lubrication development to improve overall tribological performance compared to mineral oils. The purpose of this study is to investigate the effect of different hexagonal boron nitride nanoparticles compositions on the tribological properties of palm oil. These palm oil were blended with various concentrations of hBN nanoparticles, ranging from 0.1 vol.% to 0.5 vol.%. Tribological testing was performed using a four-ball tester according to the standard of ASTM D4172 procedures. It was observed that addition of nanoparticle additives in palm oil showed better lubricating characteristics than pure oil. A further improvement on the addition of nanoparticles was also obtained, wherein it was observed that 0.5 vol.% concentration of nanoparticles exhibit minimum wear rate. The wear rate value of concentration 0.1 vol.% hBN reduced by approximately 10%, in comparison to the pure oil. However, increase percentage concentration of hBN resulted in higher coefficient of friction due to the agglomeration effect of hBN nanoparticles in palm oil. SEM analysis of the worn out samples was carried out to examine the topography of worn surface and EDX elemental mapping shows the elements distribution of boron and nitrogen on the worn surface. 0.5 vol.% hBN has higher distribution for both main element in boron nitride compared to 0.3 vol.% hBN, thus exhibit agglomeration effect.

ABSTRAK

Geseran dan haus tidak dapat dielakkan dalam aplikasi kejuruteraan. Salah satu penyelesaian umum untuk mengatasi masalah ini adalah dengan menggunakan pelincir. Minyak sayuran telah dianggap sebagai calon berpotensi dalam pembangunan pelinciran tahun-tahun kebelakangan untuk meningkatkan prestasi tribologi secara keseluruhan berbanding dengan minyak mineral. Tujuan kajian ini adalah untuk mengkaji kesan komposisi nanopartikel boron nitrida yang berbeza pada sifat-sifat tribologi minyak kelapa sawit. Minyak kelapa sawit ini dicampur dengan pelbagai kepekatan nanopartikel hBN, dari 0.1 vol.% hingga 0.5 vol.%. Ujian tribologi dilakukan dengan menggunakan penguji empat bola mengikut piawaian prosedur ASTM D4172. Telah diperhatikan bahawa penambahan nanopartikel aditif pada minyak kelapa sawit menunjukkan ciri pelincir yang lebih baik daripada minyak tulen. Penambahbaikan lanjut terhadap penambahan nanopartikel juga diperolehi, di mana ia mendapati bahawa kepekatan nanopartikel 0.5vol.% mempamerkan kadar haus minimum. Nilai kadar haus kepekatan 0.1 vol.% HBN dikurangkan dengan kira-kira 10%, berbanding dengan minyak tulen. Walau bagaimanapun, peningkatan kepekatan peratus hBN menghasilkan koefisien geseran yang lebih tinggi disebabkan oleh kesan aglomerasi nanopartikel hBN dalam minyak kelapa sawit. Analisis SEM sampel yang telah dipakai dilakukan untuk memeriksa topografi permukaan yang haus dan pemetaan unsur EDX menunjukkan pengagihan unsur-unsur boron dan nitrogen pada permukaan yang haus. 0.5 vol.% hBN mempunyai pengagihan yang lebih tinggi untuk kedua-dua elemen utama dalam boron nitride berbanding dengan 0.3 vol.% hBN, dengan itu mempamerkan kesan aglomerasi.

DEDICATION

This project and thesis are wholeheartedly dedicated to our beloved parents, who have been our source of inspiration and gave us strength who continually provide their moral, spiritual, emotional, and financial support. To my siblings and supervisor who shared their words of advice and encouragement to finish this study. And lastly, we dedicated this study to ALLAH SWT, thank you for the guidance, strength, power of mind, protection and skills and for giving us a healthy life.

ACKNOWLEDGEMENT

All praise belongs to Allah SWT. Without the health, strength and perseverance that He gave, I would not able to complete this project thesis. I have taken efforts in this project and spend time wisely to complete this thesis. I pay my deep sense of gratitude to my project supervisor, Prof. Madya Dr. Mohd Fadzli bin Abdollah to encourage me to the highest peak and provide me the opportunity to prepare the project. Thank you for their expert suggestions and a constructive advice for this project and my studies. I am immensely obliging to my fellow project partner and my friends for their elevating inspiration, encouraging guidance and kind supervision in the completion of my project. Besides that, I would like to thank Universiti Teknikal Malaysia Melaka (UTeM) for giving me a great opportunity for this past year. Last but not the least, my parents are also an important inspiration for me. So, with due regards, I express my gratitude to them.

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LIST OF ABBREVIATIONS

HC	Hydrocarbon
CO	Carbon Monoxide
AW	Anti-wear
hBN	Hexagonal Boron Nitride
COF	Coefficient of Friction
WSD	Wear Scar Diameter
SEM	Scanning Electron Microscopy
EDX	Energy-dispersive X-ray Spectroscopy

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, wear and friction are inevitable in engineering applications. One among the common solutions to beat these problems is by using lubricant which may scale back this friction and wear to a minimum level for promising a far better efficiency. Vegetable oil lubricants provide a renewable supply of environmentally friendly lubricants, regarding to the lubricant's capability to biodegrade into harmless products. Recently there has been an augmented concern in enhancing the utilization of biodegradable vegetable oils in lubricants, especially by environmental likewise as health and issues of safety, emerging due to changes in economic and provide factors. The use of vegetable oils and their derivatives as lubricant base oils are systematically increasing owing to sustainability issues and with regards to preservation of nature as they are biodegradable and environmentally friendly. Moreover, vegetable oil such as palm oil are sometimes a great deal more cost-effective than ester-based oils and thus offer additional potential for the flourishing implementation as lubricants in base oil (Krishna et al., 2014).

However, there was a systematic study showed that absence of additives caused an increase in wear once vegetable oil alone was used as lubricant; subsequent addition of antiwear agent reduced the wear substantially (Jayadas et al., 2006). Stachowiak et al. (2014) reported that to boost the wear resistance characteristic of contacting surfaces is by adding antiwear agents in lubricants. Antiwear agents form a protecting layer to prevent the contact

of metal-to-metal by adsorption of their molecules on the substrate surface by physical adsorption or chemical adsorption processes.

In this study, nanoparticle additive, hexagonal boron nitride (hBN) was added and mixed with the palm oil so as to enhance the lubrication properties. The hBN are safe to handle, non-toxic and don't have any limitations on their operational use due to the particles that formed extraordinarily stable compounds (Reeves et al., 2013). These compounds showed an effective lubricating substance additive property with their anti- wear ability. Notably, Talib and Rahim (2018) reported that hBN offered good anti-wear and anti-friction ability that resulted in low coefficient of friction, reduced wear and improved surface roughness. Four-ball tester machine was used and the experiment was conducted by following the ASTM D4172 standard. The result analysis was focusing on coefficient of friction and also the wear scar diameter.

1.2 Problem Statement

Nowadays, environmental concerns have increased interest in lubricants that are biodegradable. As we aware, most of lubricating oils used these days are primarily based on mineral oil that being extracted from petroleum oil. Since vegetable oils such as palm oil are a lot biodegradable than mineral oils, it caused numerous lubricating substance makers reconsider vegetable oils as base stocks. Furthermore, palm oil-based lubricant was a lot effective in diminishing the emission levels of carbon monoxide gas and hydrocarbon that indirectly will save the environment. It even have a potential to be develop commercially as a result of it give vital benefits as an alternative lubricants for industrial and maintenance applications, thanks to their superior inherent qualities.

However, due to the several weakness of palm oil such as it is low oxidative stability and weakness in term of viscosities, it cannot be used directly as a lubricant. In order to

improve palm oil to have satisfactory lubricant performance, nanoparticle additives, hexagonal boron nitride (hBN) can be added and blend together. It normally gives positive feedback as the coefficient of friction are slightly reduced due to the rolling effects between the rubbing surfaces and contribute to the wear prevention (Wu et al., 2007). By adding nanoparticles agent as an additive, it is believed that the vegetable oil such as palm oil can be improved as a new lubricant.

1.3 Objective

The objective of this project is:

1. To investigate the effect of different hexagonal boron nitride nanoparticles compositions on the tribological properties of palm oil.

1.4 Scope of Project

The scopes of this project are:

1. Test were conducted by a four-ball friction and wear tester equipment according to the ASTM D4172 standard.
2. The palm oil were blended with various concentrations of hexagonal boron nitride particles, ranging from 0.1 vol.% to 0.5 vol.%.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Tribology concept was articulated in a report of the UK Department of Education and Science in 1966. It includes the knowledge domain science and technology of cooperating surfaces in relative movement and related subjects and practices. It encompasses elements of chemistry, physics, solid mechanics, materials science, reliability, lubricant natural philosophy, heat transfer and performance. The constituent elements of tribology enveloping friction and wear are as old as history, despite of the fact that the name tribology is new (Dongare & Gite, 2014).

Conservation of materials and energy is becoming an awfully necessary issue. The main explanation for energy loss in a mechanical system is that the friction but this can be reduced by using a lubricant. Thus, it is very important to boost the lubrication properties. Many recent studies on bio-lubricants focused on modifying vegetable oils to create a better base. This can be done by formulating vegetable oils with additives that can enhance some base oil properties or present a new oil property (Reeves et al.,2012). A good combination between oil base and additives is the key to improve this process. Wear is one of the major causes of metal loss in industrial processes. Enhancement of lubricants has been shown to cut back the friction and wear of mechanical parts, that may save billions of dollars (Tung and McMillan 2004; de Barros' Bouchet, Martin et al. 2005).

2.2 Lubricant

Lubricant is extremely important to reduce wear and friction in tribological performance. The researchers need to investigate and study the reaction and fluid between the moving surfaces to better understand the characteristic effect of wear and friction between two moving surfaces. A sufficient protective lubricant film on the rubbing surfaces plays a key role in the construction of the lubricant film layer and in the control of the wear behavior of the test system under limited lubrication conditions (T.C. Ing et al., 2012). Lubrication is simply the use of material to improve the smoothness of movement of one surface over another, and the material, that is used during this manner known as a lubricant (Lansdown, 1982).

Nowadays, lubricant plays a very important role in engines and machines which are essentially used to lessen the friction and wear between two surfaces in contact. It can performs a variety of functions such as flushes out contaminants, acts as a heat transfer agent, protect metal surfaces against corrosion, absorbs shock and act as a seal against dust, water and dirt. By giving a defensive film between two sliding solid bodies, it can decrease the amount of wear, frictional force, and the degree of surface adhesion (Arif & Syahrullail, 2017). Lubricant is being produced dependent on their properties as well as requires the parameters such as temperature, speeds, and load for the researcher to explore the modification that happens on bulk material once the surface of material contact and moving comparatively to one another. Aiman et al. (2017) stated that lubricants also are normally utilized in minimising and reducing the friction and wear of interacting surface in mechanical system with the goal that the system can operate easily and running in long amount of time.

There a many main function of lubrication. Firstly, is to reduce heat loss and wear that cause from the contact of surfaces in motion, thus lessen the coefficient of friction between two interacting surfaces. Secondly, is to diminish oxidation and prevent rust. While thirdly, is to act as a dielectric in electrical device applications and lastly, is to act as a seal against dust, water and dirt. Lubrication happens when two surfaces are isolated by a film of lubricant. It is accessible in liquid, solid, and gaseous forms. A decent lubricant displays the accompanying attributes which is low freezing point, thermal stability, corrosion prevention capability, high boiling point, and high protection from oxidation (Mobarak, et al., 2014).

Generally, global environmental awareness has encouraged the production of environmentally-friendly lubricants. Due to developing regard for the environmental issues, the industry has been attempting to formulate biodegradable lubricants which can be utilized to substitute the usage of petroleum-based oils or gasoline as lubricants. Based on the study of White JJ et al. (1997), it has shown reduced carbon monoxide by the maximum amount as 38 % by using this biodegradable lubricant. To date, biolubricants are as yet not broadly being utilized on account of the difficulties and troubles regarding their performance.