Faculty of Mechanical Engineering

TRIBOLOGICAL STUDIES OF BIO-LUBRICANT UNDER HIGH LOADING CAPACITY

Hayder Saad Oleiwi Al-Nasrawi

Master of Mechanical Engineering
(Applied Mechanics)

2016

TRIBOLOGICAL STUDIES OF BIO-LUBRICANT UNDER HIGH LOADING CAPACITY

HAYDER SAAD OLEIWI AL-NASRAWI

A Dissertation submitted
In fulfillment of the requirements for the degree of Master of Mechanical Engineering (Applied Mechanics)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

DECLARATION

I declare that this dissertation entitled "Tribological studies of bio-lubricant under high loading capacity" is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : Ha..

Name : Hayder Saad Oleiwi Al-Nasrawi

Date : 30/9/2016...

APPROVAL

I hereby declare that I have read this dissertation and in my opinion this dissertation is sufficient in terms of scope and quality for the award of Master of Mechanical Engineering (Applied Mechanics).

Signature : ....

Supervisor Name : Dr. Nor Azmmi Bin Masripan

Date : 30/9/2016

DR. NOR AZMMI BIN MASRIPAN
KETUA JABATAN (STRUKTUR & BAHAN)
FAKULTI KEJURUTERAAN MEKANIKAL
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEDICATION

In the name of Allah, The most Gracious, The most Merciful

All of praise for Allah, glorified and exalted be he. Praise the God for abundant blessings which given to me, and the determination that he gave me to complete this study.

To the great teacher and educator, My Prophet Mohammad (Allah blessings and peace be upon him and his family), which is the light and guidance for the world.

To my lovely parents, the most great and most sacrifice;

To my dear father, who has never spared any effort in our way, I aspire to make him proud of me as much as I am proud of him for his generosity. My beloved mother, which is my gates to paradise, that illuminating with her duaa and love, she removes all my worries by her smiles. Her love and sacrifice cannot be described by words, I did not get to what I am now without their love and sacrifices and their care, and I will not be able to rewarding to them favors in all duration of my live, but I pray for almighty God to protect and save them and bless them paradise.

To my dearest brothers and sisters: Their love, support, duaa and encouragement are meant a lot to me, I ask the God to care and save all for you.

To my lovely wife, dear, and a companion of my life: For her patience and support, and its continuous assist for me. My beloved daughters, they are the privilege of my eyes (Zainab and Ghadeer). I ask and pray to the God to keep and save both of them for me.

For every person who was care of me, even without to be related to me. For your motivation and duaa for me I would like to say: Thank you all.

ABSTRACT

Increased severity in operating conditions coupled with the environmental and toxicity issues related with using conventional lubricants. In addition to, depletion of petroleum reserves and high prices of fossil fuels, have led to exploration of new kind of natural additives as a bio-lubricant. BP as an agricultural wastes are potential to be developed as bio-oils that to replace the petroleum products, due to their environmentally friendly characteristics, being biodegradable, nontoxic and renewable. The purpose of this study are to produce crude oil from BP as a bio additives in paraffin oil, as well as to determine their physical and tribological properties as bio-lubricant under severe operation conditions to identify their ability for lubrication. In this study, ultrasonic homogenizer had been used to mix the lubricants. Brookfield viscometer had been used to determine viscosity of lubricants under various temperatures, while viscosity index had been determined according to ASTM D2270. Tribological performance of BP as a bio-lubricant was tested using a four-ball test machine under extreme pressure conditions, according to ASTM D2783-03. Various lubricating oils (PO and PO+5%, 20%, 50% of banana peel) were tested. The experiments were run for 30 minutes under 500-1750N range of load. The temperatures were set at 27, 80, 100 °C and the sliding speed was set to 1000 RPM. The wear scar and surface roughness were measured using digital microscope and surface roughness tester, respectively. Statistical approach had been used in this the results analyzed was to identify the ability of BP for lubrication. The results focused on density, viscosity, VI, coefficient of friction, wear scar, wear volume losses, Extreme Pressure (EP) Anti-Wear (AW) properties, welding load and surface roughness, which are the basis of comparison between bio-lubricant and paraffin oil. Experimental results showed significant improvement in overall performance with increased BP content compared with paraffin oil through all parameters mentioned above. The results showed that at 100 °C, 50%BP had achieved a highest rate improved compared with paraffin oil in terms of dynamic and kinematic viscosity at rates 250.3% and 229.7% respectively and VI at rate 310.2%. Meanwhile, at 100 °C, lower value of COF at welding point was 0.086 for 50%BP followed by 20%BP, 5%BP and 100%PO at values 0.089, 0.456 and 0.595 respectively. For AW and EP properties, where rates are increase in mean wear scar diameter and welding load at 100 °C of 50%BP compared with paraffin oil was 67.36% and 44.62% respectively. Values of welding loads at 100 °C were 1625 N, 1575 N, 1475 N and 900 N for 50%BP, 20%BP, 5%BP and 100%PO respectively. The results showed that best performance was achieved by mix a 50% of BP in the mineral oil, where COF and WSD could reach their lowest value in extreme operation conditions. As a results, banana peel as EP and AW additives has proven itself able for use in lubrication applications for gears and as engine oils.

ABSTRAK

Peningkatan tahap dalam keadaan operasi yang ditambah pula dengan isu-isu alam sekitar dan ketoksikan yang berkaitan dengan menggunakan pelincir konvensional. Selain, pengurangan rizab petroleum dan harga yang tinggi bahan api fosil, telah membawa kepada penerokaan jenis baru bahan tambahan semulajadi sebagai bio-pelincir. BP sebagai sisa pertanian yang berpotensi untuk dibangunkan sebagai bio-minyak yang untuk menggantikan produk petroleum, kerana ciri-ciri mesra alam mereka, yang mesra alam, tanpa toksik dan boleh diperbaharui. Tujuan kajian ini adalah untuk mengeluarkan minyak mentah dari BP sebagai bahan tambahan bio dalam minyak parafin, dan juga untuk menentukan ciri-ciri fizikal dan tribological mereka sebagai bio-minyak pelincir di bawah keadaan operasi yang teruk untuk mengenal pasti keupayaan mereka untuk pelinciran. Dalam kajian ini, homogenizer ultrasonik telah digunakan untuk campuran pelincir. Brookfield meter kelikatan telah digunakan untuk menentukan kelikatan minyak pelincir di bawah pelbagai suhu, manakala indeks kelikatan telah dipilih mengikut ASTM D2270. prestasi Tribological BP sebagai bio-minyak pelincir telah diuji menggunakan mesin ujian empat bola di bawah keadaan tekanan yang melampau, menurut ASTM D2783-03. Pelbagai minyak pelincir (PO dan PO + 5%, 20%, 50% daripada kulit pisang) telah diuji. Kajian ini telah berjalan selama 30 minit di bawah 500-1750N pelbagai beban. Suhu telah ditetapkan pada 27, 80, 100 ° C dan kelajuan gelongsor ditetapkan kepada 1000 RPM. Memakai parut dan kekasaran permukaan diukur menggunakan digital mikroskop dan permukaan roughness tester, masing-masing. pendekatan statistik telah digunakan dalam hal ini keputusan dianalisis adalah untuk mengenal pasti keupayaan BP untuk pelinciran. Keputusan tertumpu kepada ketumpatan, kelikatan, VI, pekali geseran, memakai parut, memakai kerugian jumlah, tekanan melampau (EP) Anti-Wear (AW) Hartanah, beban kimpalan dan kekasaran permukaan, yang merupakan asas perbandingan antara bio-pelincir dan minyak kuat. Keputusan eksperimen menunjukkan peningkatan yang ketara dalam prestasi keseluruhan dengan peningkatan kandungan BP berbanding dengan minyak kuat melalui semua parameter yang dinyatakan di atas. Hasil kajian menunjukkan bahawa pada 100 ° C, 50% BP telah mencapai kadar yang tertinggi bertambah baik berbanding dengan minyak kuat dari segi kelikatan dinamik dan kinematik pada kadar 250,3% dan 229.7% masing-masing dan VI pada kadar 310,2%. Sementara itu, pada 100 ° C, nilai yang lebih rendah daripada COF pada titik kimpalan adalah 0.086 50% BP diikuti oleh 20% BP, 5% BP dan 100% PO pada nilai 0,089, 0,456 dan 0,595 masing-masing. Bagi hartanah AW dan EP, di mana kadar adalah peningkatan dalam min diameter memakai parut dan beban kimpalan pada 100 ° C 50% BP berbanding dengan minyak kuat adalah masing-masing 67,36% dan 44,62%. Nilai-nilai beban kimpalan pada 100 ° C masing-masing 5% BP dan 100% PO ialah 1625 N, 1575 N, 1475 N dan 900 N 50% BP, 20% BP,. Hasil kajian menunjukkan bahawa prestasi terbaik dicapai dengan campuran 50% daripada BP dalam minyak mineral, di mana COF dan WSD boleh mencapai nilai terendah dalam keadaan operasi yang melampau. Dengan itu, kulit pisang sebagai EP dan bahan tambahan AW telah membuktikan dirinya mampu untuk digunakan dalam aplikasi pelinciran untuk gear dan sebagai minyak enjin.

ACKNOWLEDGMENTS

First my praise is to the Almighty "Allah", on whom we ultimately depend. Then, I would like to sincerely thank to my supervisor Dr. Nor Azmmi Bin Masripan for his guidance, advices, and support. Without his valuable assistance, this work would not have been completed. My acknowledgment also goes to Universiti Teknikal Malaysia Melaka (UTeM), and especially Faculty of Mechanical Engineering. My acknowledgment also to Mr. Azrul Syafiq Mazlan who is willing to provide an assistance at tribology laboratory. I am also indebted to my friends (Raed Mohammad, Omar Abdul Hasan, Ahmed Ismail, Ahmed Dawood and Amer Adil) for their contributions.

My acknowledgment and thanks for teachers who guarantee me during my study. Most importantly, I am forever grateful my family who understands the importance of this work, none of this would have been possible without their patience and help.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

Abbreviation	Specification
AAA	Authentication, Authorization and Accounting
AO	Antioxidant
AR	Average Readings of three ball
ASE	Automotive Society of Engineers
ASTM	American Society for Testing and Materials
AW	Anti-Wear
BL	Boundary Lubrication
BP	Banana Peel
CEC-L-33-A-94	Coordinating European Council
CMFO	Commercial Metal Forming Oil
COF	Coefficient Of Friction
DV	Dynamic Viscosity
EHL	Elastohydrodynamic Lubrication
EP	Extreme Pressure
F.B.E.P.O.T.M	Four Ball Extreme Pressure Oil Testing Machine
HL	Hydrodynamic Lubrication
HR	Horizontal Reading of three ball
IMSR	Immediate Seizure Region

IP	International Protection Marking
ISR	Initial Seizure Region
JBWR	Just Before Weld Region
KV	Kinematic Viscosity
LaF3-DDP	Lanthanum Trifluoride
LNSR	Last Non Seizure Region
MARDI	Malaysian Agricultural Research and Development Institute
ML	Mixed Lubrication
MWSD	Mean Wear Scar Diameter
PFAD	Palm Fatty Acid Distillate
PO	Paraffin Oil
R&D	Research and Development
RPM	Revolution Per Minute
SBO	Soybean Oil
SKF	Svenska kullagerfabriken
TPC	Total Phenolic Content
VI	Viscosity Index
VR	Vertical Reading of three ball
WL	Weld Load
ZDDP	Zinc dithiodiphosphate

LIST OF SYMBOLS

Symbol	Specification
Ra	Surface roughness
cP	Centipoise
cSt m2s-1(cSt· 106)	Centistoke
C%v/v	Volume/volume percentage
V substance	Volume of substance
V solution	Volume of solution
ρ	Density
ν	Kinematic viscosity
μ	Dynamic viscosity
μ	Coefficient of friction
W	Load
R	Distance
V	Volume losses
d	Wear scar diameter
R	Radius of ball bearing
RPM	Revolution per minute

CHAPTER 1

INTRODUCTION

1.1 Research background

The term "tribology" was derived from the Greek word "τριβος", which means rubbing or abrasion (Sharma and Mishra, 2015). Tribology can be defined as the science and technology of interacting surfaces in relative motion which are present in various machine elements (Nosonovsky and Bhushan, 2010). In almost every aspect of our daily lives, we meet some appearances of tribology such as sliding, brushing, gripping, holding, machinery works, friction between skin and clothes, movement of artificial hip joints etc (Mattei et al., 2011). Friction is the force resisting the relative motion of solid surfaces, fluid layers and material elements sliding against each other. There are many types of friction like, lubricated friction, fluid friction and dry friction. An important consequence of many types of friction is wear, which may lead to decline in performance and/or damage to components. Wear can be defined as undesired removal of material due to mechanical action (Golshokouh, S. and Ani, 2014). Friction and wear are not material properties but, system properties, depending on the materials used and on the operational (contact) conditions (Cabanettes and Rosén, 2014).

Lubrication is the process or technique employed to reduce friction between two surfaces and wear of one of them or both. As the load increases on the contacting surfaces three clearly positions can be observed with respect to the mode of lubrication, which are called regimes of lubrication.

These regions can be described by the Stribeck curve. Most friction and wear are created during start-up and shutdown of engines, whereas Boundary Lubrication (BL) occurs at low speeds and thin films (Tuszynski, 2006). The major reasons of using lubricants in engines are to control friction properties, reduce wear, enable power generation and to improve the efficiency. Other reasons are for cooling, sealing, load balancing, cleaning and rust prevention. Engine oils consist of the base oil and additives. Mineral based-oil is used in most applications to increase effectiveness in lubrication of various industrial parts fixed and mobile. Although this oil is very useful, it is also an environmental hazard, poses damage on human, has high price and is non-renewable sources (Pettersson et al., 2008; Shi, Huang and Wu, 2015).

In recent years, great development in engines and requirements of the environment is observed. This has led to high efficiency and improvement on load carrying capacity of new and environmentally friendly sources (agricultural waste) especially at severe operating conditions. Vegetable oils as additive have several properties which can achieve this purpose comparable to mineral oils, such as high lubricity, low volatility, high viscosity index, environmental friendly, more biodegradability, low Coefficient Of Friction (COF) and low wear scar (Waara, 2006).

In this study, Banana Peels (BP) had been investigated as an additive in lubrication system. This is a novel attempt to use banana peels (banana skin) in lubrication system. Hence, it is very important and necessary to evaluate the characteristics of BP as a lubricant additive to show their effect on tribological properties at severe condition and to test their validity in industry applications.

1.2 Problem statement

Lubricant oils are one of the main productions from mineral oils as around 90% of lubricant oil derived from mineral oil. Annually more than 35 million tons lubricant oils are used in the world. More than 17 million tons of lubricants are nonrenewable. In addition to, more than 2400 kilo tons of this amount is waste oil; around 72% of waste oil is collected, while more than 674 kilo tons of waste oil uncollected and is enters into environment (Golshokouh et al., 2014). The worldwide governments are concerned over the health-related and environmental effects of petroleum oil, thus requiring environmental laws and need for a highly-efficient, environmentally friendly, biodegradable and renewable lubricants (Lawal, 2013). The molecular structure of vegetable oils has desirable qualities as a lubricant, such as long, polar fatty acid chains which provide high strength lubricant films that interact strongly with metallic surfaces, reducing both friction and wear.

Vegetable oils are particularly effective as boundary lubricants due to high polarity of the entire base components which allows strong interactions with the lubricated surfaces compared with the mineral oil (Ing et al., 2012a; Fox and Stachowiak, 2007). Moreover, in recent days, depletion of non-renewable energy resources, high price and poor performance of conventional mineral-based lubricants have stimulated the use of vegetable oils, especially in severe operating conditions, to be compatible with the great development of engines and requirements of environment. Banana is a tropical fruit grown in over 122 countries worldwide (Ehiowemwenguan et al., 2014). The increasing production of banana has led to increase of agricultural waste generated from its peels (Abbas et al., 2014).

According to scientists, approximately one tons of wastes are produced by every ten tons of bananas (Sharma and Mishra, 2015). To avoid wastage, these banana wastes can be turned into a new energy source (Sharma and Mishra, 2015). There is no study related in tribological properties and ability of banana peel on lubrication in severe loading conditions.