UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION OF LOAD BEARING CAPACITY ON DIFFERENT BIO-LUBRICANT ENHANCE BY NANOPARTICLES USING EXTREME PRESSURE METHOD

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

by

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DECLARATION

I hereby, declared this report entitled “Investigation of Load Bearing Capacity on Different Bio-Lubricant Enhance by Nanoparticles Using Extreme Pressure Method” is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.
The supervisory is as follow:

………………………………………………………………

(DR. MUHAMMAD ILMAN HAKIMI CHUA BIN ABDULLAH)

ABSTRAK

Nanopartikel kini memainkan peranan penting dalam mengurangkan haus enjin dengan menggunakan bahan tambah dalam pelinciran. Zirkonia oxida (ZrO_2) dan grafit telah digunakan sebagai aditif dalam kajian ini. Oleh itu, kajian ini memberi tumpuan kepada kajian mekanisme pakai dan geseran pada galas bola yang diuji oleh pelincir bio menggunakan tekanan melampau. Tujuan kajian ini adalah untuk menentukan nanopartikel yang sesuai untuk digunakan dalam bio-pelincir sebagai tambahan. Seterusnya, objektifnya ialah untuk menyiasat keupayaan beban pada pelincir bio yang dipertingkatkan oleh nanopartikel menggunakan kaedah tekanan ekstrem. Beberapa ujian dijalankan pada tekanan yang melampau untuk galas bola yang dilincirkan oleh pelincir bio dan ujian mengikut piawaian kaedah ujian ASTM D2783 untuk pengukuran ciri-ciri tekanan melincirkan cecair (Kaedah Empat Bola) untuk pelincir. Hasil mekanisme yang haus telah dibandingkan berdasarkan jenis nanopartikel aditif yang digunakan dalam bio-pelumas yang terjadi pada galas bebola telah diselidik. Tambahan lagi, mekanisme haus yang berlaku pada galas bebola disiasat dengan menggunakan mikroskop atau mikroskop elektron imbasan (SEM). Hasilnya menunjukkan dengan penambahan zirkonia oksida dan grafit nanopartikel dalam sisa minyak masak telah meningkatkan keupayaan membawa beban dalam minyak pelincir. grafit nanopartikel memberikan pekali geseran yang lebih rendah berbanding dengan yang lain. Sementara itu, zirkonia oksida menunjukkan bahan tambah anti-haus yang baik dengan memberikan kadar haus yang lebih kecil berbanding nanopartikel yang lain. Oleh itu, nano-minyak dapat memberikan prestasi yang lebih baik terutama ketika berada di bawah tekanan yang melampau.

ABSTRACT

Nanoparticles currently play an important role in reducing engine wear by using an additive in lubricant. Zirconia oxide (ZrO_2) and graphite have been used as an additive in this study. Thus, this study focuses on the investigation of wear and friction mechanism on the ball bearing tested by bio-lubricant using extreme pressure. This is due to the performance of an engine is declining because of the presence of wear in the engine part like a piston ring. The purpose of this study is to determine the suitable nanoparticle to be used in bio-lubricant as an additive. Next, the objective is to investigate of load-bearing capacity on different bio-lubricant enhanced by nanoparticles using extreme pressure method. Several testing was conducted on the extreme pressure for ball bearing lubricated by bio-lubricant and the testing accordance to ASTM D2783-Standard Test Method for Measurement of Extreme-Pressure Properties of Lubricating Fluid (Four-Ball Method) for lubricant. The wear mechanism result has been compared based on different types of nanoparticles additive used in bio-lubricant that occurs on the ball bearing was investigated. Furthermore, the wear mechanism that occurs on the ball bearing was investigated by using microscope or scanning electron microscope (SEM). The result shows that with the addition of zirconia oxide and graphite nanoparticle in waste cooking oil was improved the load-carrying ability of lubricating oil. Graphite nanoparticle gives the lower coefficient of friction compared to other. Meanwhile, zirconia oxide shows a good in anti-wear additive give smaller wear rate compared to another nanoparticle. Thus, the nano-oil can give better performance especially when under extreme pressure.

DEDICATION

To my beloved parents, Mr Abdul Gaffar Bin Esa and

Madam Masturah Binti Manab and siblings.

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Alhamdulillah, all thanks should be praise to Allah as He help and ease me so much to complete this project successfully. This research project won't be complete without people surrounding me who give a lot support and help.

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Thank you.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AC	-	Alternating Current
Al_2O_3	-	Alumina
API	-	American Petroleum Institute
ASTM	-	American Society for Testing and Materials
AW	-	Anti-Wear
COF	-	Coefficient of Friction
cSt	-	centistokes
Cu	-	Copper
CuO	-	Copper Oxide
EP	-	Extreme Pressure
Fe	-	Iron
hBN	-	Hexagonal Boron Nitride
IL	-	Ionic Liquid
ISL	-	Initial Seizure Load
ISO	-	International Standardization Organization
m	-	Mass
OA	-	Oleic Acid
PAO	-	Polyalphaolefins
SEM	-	Scanning Electron Microscope

EDX	-	Energy dispersive X-ray spectroscope
TEM	-	Transmission electron microscopy
SiO_2	-	Silicon Dioxide
TiO_2	-	Titanium Dioxide
v	-	Volume
WP	-	Wear Preventive
WSD	-	Wear Scar Diameter
ZnO	-	Zinc Oxide
ZrO_2	-	Zirconium Dioxide
ρ	-	Density
%	-	Percentage
Rpm	-	Rotation per minute

CHAPTER 1

INTRODUCTION

1.1 Introduction

Today, most of the mechanical components have been applied by lubricants with various properties were formulated and synthesized. According to Bart et al., (2013), to facilitate the relative motion of solid bodies, lubricant was used as substance to minimize friction and wear between interacting surfaces. Wear usually not desirable in any application. A lubricant is important to reduce wear and friction between two surfaces or reduce metal to metal contact. According to Li et al., (2011) it is important to predict and assess the performance of lubricants loaded bearings within respect to friction, wear and load bearing capacity over a wide-ranging of dynamic operating circumstances. Furthermore, industrial of lubricant already taken step to recover the quality of the component life over decreased material wear rate and surface friction (Siniawski, 2007). According to Patil et al., (2014) found that when the system operating with the overload pressure, the lubricant itself fails to perform as lubricating properties. However, the surfaces in mechanical contact and slide between multiplex sets of microscopic interactions will be caused by friction and wear.

Numerous researchers have tried to improve the tribological lubrication properties at lubricant to reduce the coefficient of friction and wear rates. In recent years, there are many investigation related to numerous nanoparticles used as oil additives. To reduce wear and friction with effectively, addition of nanoparticles to lubricant that a large number of papers have been reported. According to Hernández Battez et al., (2008) the tribological properties and the lubricating mechanisms of CuO as a nanoparticles in the lubricant. CuO suspensions showed the highest coefficient of friction and bottommost wear per nanoparticle and the anti-wear mechanism of nanoparticulate additive was produced by tribo-sintering. So, friction and wear will be reduced effectively with low hardness and elastic modulus from the result showed that the CuO nanoparticles as additive can form a copper protective film.

Furthermore, according to Patil et al., (2014) the characteristics of nanoparticles, such as size, shape, and concentration are dependent on the friction decrease and anti-wear behaviours. The water-based nanofluids with 50% particle concentration of ZnO and Al_2O_3 are used as lubricants water-based nanofluids with 50% particle concentration were used as lubricants. The average particle size for ZnO particles is 70 nm and for Al_2O_3 particles it is 45 nm. According to Gara & Zou, (2012), work investigated the friction and wear characteristics of ZnO and Al_2O_3 water-based nanolubricants. Outstanding to the film and bearing effects of particles, nanoparticles will be acted as abrasive wear and will produce wear on the surface that will they found it.

Therefore, friction and anti-wear properties of the metal oxide composite nanoparticle, nano-carbon materials and boron-based nanoparticle additives in oil or grease lubricants were carried out. Friction and surface damage caused by such situations can be reduced by an additives and applying extreme pressure (EP). However, these type of nanoparticle additive has limited studies on the extreme pressure (EP) properties. So, the load bearing capability by using extreme pressure testing of graphite and zirconia oxide (ZrO_2) as an additive be investigated.

1.2 Problem Statement

To keep on the newest technological level, lubricants can be an important thing as form element or engineering fluid because of the tribological system (Bart et al., 2013). According to Laad, (2016) different mechanical systems need a variety of functional lubricants significantly to moderate the total energy disbursed by mechanical systems and also to reduction the friction and wear of contacting surfaces as well as. The enhancement of lubricant oil properties are of great importance in the context of protecting machinery from highly probable damages and decrease energy consumption. However, numerous researchers have recently developed various methods to support the desirable physical, chemical or mechanical properties of base lubricants, and to enhance the lubrication properties of raw oil which several additives with unique properties are added (Choi et al., 2009).

In Malaysia, the used oil has been disposed as scheduled waste oil. According to Li, (2017) unreasonable discharging on waste cooking oil can cause environmental pollution and reclaiming waste cooking oil in food will extinguish human body. Waste cooking oil needs to be managed correctly and carefully because if it is handled properly, it can be affect to the public health and the environment. However, the oil has been normally used in several aspects for in the era of mechanization. Therefore, to reuse waste cooking in some useful ways oil is a great idea that have been taken.

To satisfy this issue, lubricants usually used in industry and manufacturing units to prevent products and tools from wear and maintain their respective surface quality (Shahnazar, 2016). The lubrication mechanism is that a self-laminating protective film is formed on the friction surface and the wear behavior changes from sliding friction to rolling friction (Luo, 2014). However, a current lubricant cannot sustain an extreme load. Therefore, the new additive was applied is nano size particle such as graphite and zirconia oxide (ZrO_2) to overcome this problem.

1.3 Objective

Based on the problem statement are discussed above, the objectives of this study are listed below:

1. To determine suitable nanoparticle to be used in bio-lubricant as an additive.
2. To investigate load bearing capacity that occurs with a different type of nanoparticles additive.
3. To investigate wear mechanism that causes ball bearing surface failure.

1.4 Scope of work

In order to achieve the objective, the scopes of the research are:

1. Determine the suitable nanoparticle to be used in bio-lubricant as an additive.
2. Investigating the load bearing capacity on different nanoparticles additives used in bio-lubricant by using ASTM D2783-Standard Test Method for Measurement of Extreme-Pressure properties of Lubricating Fluid (Four-Ball Method).
3. Investigating the wear mechanism that causes ball bearing surface failure using microscope/ Scanning Microscope Electron (SEM).

CHAPTER 2

LITERATURE REVIEW

2.1 Liquid as a Lubricant

Lubricants use to protect products and tools from wear and friction for maintaining their respective surface quality. Lubricant normally used in industry and manufacturing area. Friction and wear are minimized with a lubricant that uses to facilitate relative motion of solid bodies. According to (Shahnazar, 2015), the most importance to ensure the machineries will be protected from highly probable damages and decrease energy consumption by the enhancement of lubricant oil properties. Thus, the maintenance cost will be reduced. The other function of lubricant are required to control friction in metal forming processes in order, to limit tool and work piece overheating and to protect work piece surfaces and tools.

Lubricant can be classified into three types which are a solid lubricant, semi-solid lubricant, and liquid lubricant. Solid lubricants are generally used to solve lubrication problems with liquid lubricants and can requisite a work under extreme conditions of temperature, loads and speeds with thin film formation. According to Gunda, (2016), the key factors to this performance is the layered lattice structure of molybdenum disulphide are will be lower friction coefficient.

The combination lubricating oil with thickening agents is termed as grease known as a semi-solid lubricant (Darbyshire, 2007). The third type of lubricant is liquid lubricant. This lubricant also known as oil lubricant that are form a low friction liquid film based on sliding interfaces by physical or chemical interface. Furthermore, due to the low thermal-stability and lower viscosity of conventional lubricating oil in association with large amount of friction heat that will be more challenge when the friction occurs in extremely high load without cooling system (Wu et al., 2016). Therefore, a liquid lubricant can be categorized into three group. There are mineral oil, vegetable oil, and Poly Alpha Olefins (PAO) oil. All this liquid lubricant have a variation properties and their usage.

2.1.1 Mineral Oil

Currently, the increment of industrialization, modernization, and development, petroleum demand is high due (Syahrullail, 2013). Some of the petroleum is used in mineral oil-based fluids for metal working applications where it can increase productivity. It also acting as a coolant for high-quality manufacturing operations and as a lubricant for metal cutting and forming processes. Furthermore, mineral oil is very commonly used for transformer fluid and has been used for more than a century in industrial applications as manufacturing lubricants petroleum. For example, small units used in limited areas like shopping complex may use fire resistance fluids such as silicone, high-temperature mineral oil and synthetic ester fluids. Therefore, to identify and quantitatively determine groups of parts with almost similar chemical character or also to help their technical properties there are always a goal to describe the physically of mineral oil.

In addition, the mineral oil contains three basic chemical form which is paraffinic, naphthenic and aromatic. According to Stachowiak & Batchelor (1993), the first type of mineral oil are paraffinic oils. The structure of paraffinic chemical form that contain straight and branched. Structure for paraffinic oil has non-ring long-structure. Furthermore, paraffinic oil is relatively viscous and also it is resistant to oxidation. So, the paraffinic oil is main factor is being used in an industrial lubricant, manufacturing engine oils and processing oils like textile, rubber, and paper industries. Figure 2.1 show the paraffinic structure.

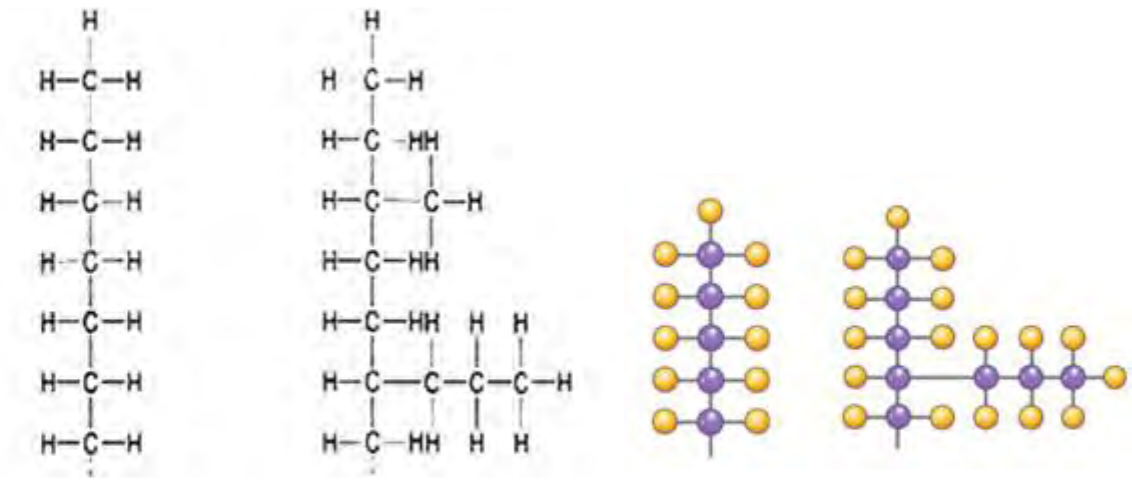

Figure 2.1: Structure of paraffinic (Stachowiak & Batchelor, 1993)

The second type of mineral oil is naphthenic oil. The naphthenic oils being produced from the distillation of mineral based oil while the structure of naphthenic oil have a saturated to the ring structure. The naphthenic oils also have is low pour point, flash point, viscosity and also low resistance to oxidation. Thus, it being used in metal working fluids, moderate temperature application and mainly for manufacturing. Figure 2.2 shows the naphthenic structure.

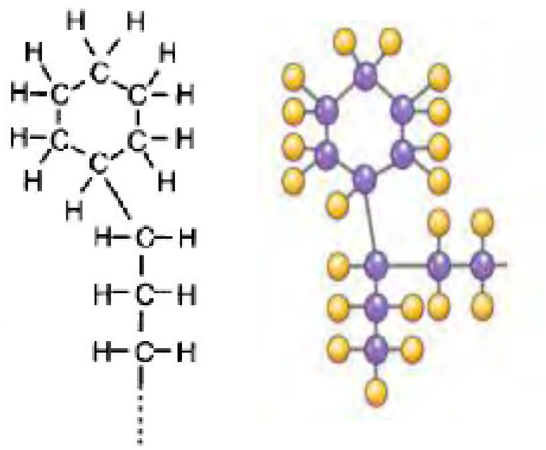

Figure 2.2: Structure of naphthenic (Stachowiak & Batchelor, 1993)

The last type of mineral oil is aromatic oil. The process of refining in the manufacture of 7 paraffinic oils will produce aromatic oils. The structure of aromatic oil is non-saturated ring structure. Difference with other type of mineral oil, the aromatic oil is dark and its flash point is higher. While the aromatic oil is used for adhesives, manufacturing seal compounds and as plasticizers in asphalt and rubber production. Figure 2.3 shows the aromatic structure.

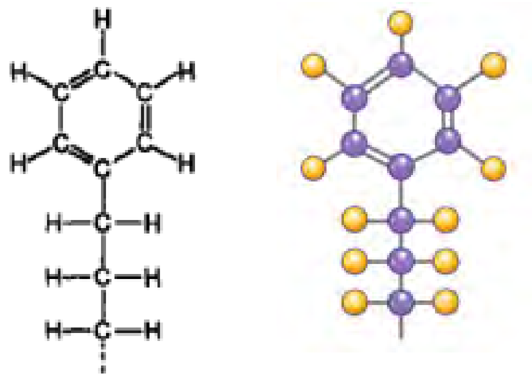

Figure 2.3: Structure of aromatic (Stachowiak & Batchelor, 1993)

2.1.2 Poly Alpha Olefins (PAO) Oil

Synthetics hydrocarbons are almost the same using composition to those found in which basic carbon and hydrogen compound are combined (Speight, 2014). To formulate lubricants with optimal rheological–tribological, the properties for diverse applications of the development of synthetic lubricants in recent decades has been the result of concerted efforts. However, the currently available lubricants range from natural and petroleum-derived hydrocarbons (mineral oils) to synthetic hydrocarbon- and silicone-based polymers (Zolper et al., 2012).There are a lot of types of synthetic base oil. The popular synthetics base oil is poly-alpha-olefins (PAO).

According to Xue et al., (2016) poly-alpha-olefin (PAO) pour point depressant is a sticky liquid polymer primarily derived from the polymerization of alpha-olefin at definite temperatures, pressures and viscosity modifier in the presence of catalysts. To become an effective cold flow improver and it has been proven, which is used primarily in lubricating oil. PAO also have a greater consistency in molecular structure and molecular mass distribution resulting in more consistent lubrication properties than their mineral oil counterparts. PAO commonly have greater viscosity indices and vapor pressure than the mineral oils in current use. Table 2 show the physical characteristics of the PAO.

Table 2.0: Physical characteristics of the PAO (Zhang, 2009)

Properties	PAO
Dynamic viscosity 100ºC (mm^2/s)	10
Dynamic viscosity 40ºC (mm^2/s)	66
Dynamic viscosity -40ºC (mm^2/s)	39000
Viscosity index (VI)	137
Chrominance (number) Color, ASTM	<0.5
Pour point (ºC)	-48
Open flash point (ºC)	266
Total acid number (TAN), (mg KOH/g)	<0.05
Appearance (B&C = bright and clear)	B&C