UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OPTIMIZATION OF TRIBOLOGICAL PERFORMANCE FOR PURIFY ENGINE-OIL ENHANCE BY NANOPARTICLES

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

by

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APPROVAL

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

……………………………………………………….

(Project Supervisor)

ABSTRAK

Pada masa kini, pelincir sangat penting dalam kehidupan seharian manusia. Biasanya, selepas pelincir digunakan, ia akan dibuang. Walaubagaimanapun, pengurangan sumber pelincir menyebabkan kajian semula menggunakan pelincir yang digunakan. Kajian mendapati bahawa penggunaan nanopartikel boleh menjadi salah satu penyelesaian dalam menggunakan semula pelincir yang digunakan. Nanopartikel digunakan sebagai bahan tambahan untuk meningkatkan prestasi pelincir yang digunakan. Oleh itu, kajian ini dijalankan untuk menyiasat pengoptimuman prestasi tribological untuk membersihkan enjin minyak meningkatkan oleh nanopartikel. Kemudian, reka bentuk percubaan (DOE) dibangunkan dengan keadaan pelinciran sempadan berbanding dengan bahan tambahan lain menggunakan kaedah Taguchi, yang terdiri daripada susunan L9 orthogonal. Setiap pensampelan data dianalisis menggunakan kaedah Taguchi. Parameter hasil bagi setiap sampel diperoleh dan ujian tribologi dibina dengan ujian empat bola mengikut prosedur ASTM D4172. Untuk mendapatkan kesan koefisien geseran dan memakai diameter haus sampel isyarat-to-noise (SN) dan Means signal-to-noise graf nisbah dihasilkan dan dianalisis. Di mana, ZrO2 0.5%, Grafit 0.3% dan NaCl 0.5% menunjukkan hasil sampel optimum parameter. Selain itu, ia menunjukkan nilai terendah bagi pekali geseran (CoF) dan memakai haus diameter (WSD) berbanding komposisi lain. Akhir sekali, kajian ini menentukan mekanisme haus pada permukaan yang dipakai bagi tiga bebola galas sampel, parameter optimum, baik dan lebih buruk telah dikaji menggunakan imej SEM. Hasilnya menemui beberapa ciri-ciri di atas permukaan galas bebola seperti arah geser, kawah, dan alur. Ini kerana pelekat memakai berlaku pengambil alih di atas permukaan galas bola yang dipakai.

ABSTRACT

Nowadays, the lubricant is very important in human life and become a high demand especially in the heavy industrial sector. Normally, after the lubricant has been used, it will be discarded. However, the decrement of the lubricant resources leads to the study of re-using the used lubricant. The studies found that the used of nanoparticles can become one of the solutions in re-using the used lubricant. The nanoparticles are used as the additive in order to enhance the used lubricant performance. Thus, this study is conducted to investigate the optimization of tribological performance for purify engine-oil enhance by nanoparticles. By using Taguchi method, an optimal composition (0.5 vol%) of zirconia, graphite, and sodium chloride nanoparticles separately dispersed in engine oil SAE 0W – 20 is used in order to achieve the purpose of this study. Later, the design of experiment (DOE) is developed by under boundary lubrication condition compared with other additives using the Taguchi method, which consists of L9 orthogonal arrays. Each data sampling is analyzed using Taguchi method. The result parameters for every sample obtain and the tribological testing was constructed with four-ball tester according to ASTM D4172 procedures. In order to obtain the effect of the coefficient of friction and wear scar diameter of the samples the signal-to-noise (SN) and Means signal-to-noise ratio graph is generated and analyzed. In which, ZrO_2 0.5%, Graphite 0.3%, and NaCl 0.5% shows the optimum parameter result of the samples. The ZrO_2 0.5%, Graphite 0.3%, and NaCl 0.5% composition not only shows the lowest value of the coefficient of friction (CoF) and the wear scar diameter (WSD) but also a better image of the worn surface compared to the other compositions tested using SEM images. Moreover, by using SEM images, it is found that some of the features on the worn surface of the ball bearing are actually caused by sticker usage that takes place on the ball bearing surface.

DEDICATION

To my beloved family and supervisor.

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Alhamdulillah, all praise to Allah, for give me a strength and patience to finish this thesis successfully. I would like to express my deepest gratitude to Dr. Muhammad Ilman Hakimi Chua Bin Abbdullah as my supervisor, for not giving up to provide guidance and the guidance from the start until the finish. Not only that, thank for taking the time to give the advice even in busy for criticism, comment, and correction of all parts of the chapter. For all that is given, I really appreciate and make it as experience.

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LIST OF ABBREVIATION, SYMBOLS AND NOMENCLATURE

%	-	Percent
API	-	American Petroleum Institute
AW	-	Anti-Wear
cm	-	Centimetre
CoF	-	Coefficient Of Friction
DOE	-	Design of Experiment
EP	-	Extreme Pressure
g	-	Gram
hBN	-	Hexagonal Boron Nitrite
m	-	Mass
ml	-	Millilitre
NaCl	-	Sodium Chloride
PAOs	-	Polyalphaolefins
SAE	-	Petroleum Lubricant Society of Automotive Engineers
SEM	-	Scanning Electron Microscope
TAN	-	Total acid number
TBN	-	Total base number
Vol.	-	Volume
WSD	-	Wear Scar Diameter

ZDDP	-	Zinc Dialkyl Dithiophoshate
ZrO_2	-	Zirconia Oxide
ρ	-	Density
L_9	-	Orthogonal Array
nm	-	Nanometer
r/min	-	Revolutions per minute
°F	-	Farad
N	-	Newton’s
ft.lb	-	Foot-pound force

CHAPTER 1

INTRODUCTION

1.1 Introduction

Motor oil usually been used as a smooth operation on a lubricant to provide a machine running smoothly, to reduce wear on moving parts, cleans moving parts from sludge and so on. However, performance of motor oil as the lubricant is not last longer. This is due to some characteristics changes of oil such as total base number (TBN), total acid number (TAN), kinematic viscosity, viscosity index, and etc.

Waste engine oil normally been thrown away or disposed. Actually waste engine oil can be recycled and re-used as second-class oil. Therefore, many usages that can be derived from used oil. The existence of recycling used oil it help prevented from contaminating soil and water, wherein the usage base stock that a basic stock from crude oil can be reduced. According to Habibullah et al. (2015b), the demand for biofuel is remarkable because of environmental factors and the reduction of crude oil reserves. As example, the industry sectors that used a lot of lubricant oil will cause the demand for crude oil production higher.

In this study, the used oil will be filter and homogenize with nanoparticles as an additive. As environmentally friendly additive will be choose which are not affect any risk to the environment. After the sample has done filtration and homogenizes process, the sample will be tested with four-ball tester according to ASTM D4172. The aims using four-ball tester is to determine the wear protection properties of a lubricant. Besides that, using the four-ball tester, wear scar will be produced, and it can be measured and recorded. After that, the coefficient of friction (COF) will be recorded and evaluated by using L9 Orthogonal Array by Taguchi method. This method, parameters can be determined for each sample. For the average wear scar smaller, is the better the wear protection provided by the lubricant. The worn surface of the ball bearing will be analyse using Scanning electron microscope (SEM).

1.2 Problem Statement

Nowadays, most of conventional engine oil which are already in the market was re-improved using a lot of additives, but most of the consumer did not know that the conventional additives contain a lot of poisons element to the environment. The concern for the content of heavy metal zinc and phosphorus as environmental contaminants has resulted in efforts to find more environmentally not dangerous replacements for industrial applications (Cardis et. al. 1989). Some additives such as ZDDP, sulphur substance and containing phosphorus, can poison the catalytic converter which results to the failure of the emission system (Li et. al., 2011). Several research on the capability of vegetable oil as a replacement to the convention oil has been extensively carried out, but due to the depletion of current petroleum oil, industries and engineering cannot wait for the new bio-lubricant. Hence, the development of new improved engine oil from the waste engine oil become one of the fast solutions to a current problem.

Therefore, the purpose of the study is to develop an improve engine oil from the recycle engine-oil. Because there are some industries that require a lot of lubricant to meet a higher demand to maintain machine operation every day. Not only that, with the new-lubricant, it can prevent the depletion of raw materials and high raw material burning. Directly recycling used oil can prevent for pollution of soil and water. For example, motor oil is not too much uses for wear out and used motor oil not very dirt, so if it can be recycled it can be save the raw material as natural resource.

1.3 Objective

The objective for this project are;

1) To optimize on the tribological performance of new develop engine oil enhance by zirconia, graphite and sodium chloride nanoparticles.
2) To investigate the effect of different composition of nanoparticles towards friction properties.
3) To determine wear mechanism occur on the worn surface of ball bearing.

1.4 Scope of Work

In order to achieve the objective, the scopes are prepared as shown below:

1) Optimizing on the tribological performance to developing of new develop engine-oil using L9 Orthogonal arrays from Taguchi Method.
2) Investigating the effect of different composition of nanoparticle towards friction properties by using Four-Ball tester according to the ASTM D4172.
3) Determine the wear mechanism on worn surface of ball bearing by using SEM.

CHAPTER 2

LITERATURE REVIEW

2.0 Literature Review

This chapter will cover all the aspect introduction to lubricant, liquid as a lubricant, petroleum lubricant society of automotive engineers (SAE) standard which includes the SAE, SJ and SN grade of all. Furthermore, this chapter may also include the use of nanoparticles as an additive in the lubricant.

2.1 Introduction to Lubricant

Nowadays, the lubricant so widely and became an important material in the automotive industry or sector. A lubricant as the application which uses oil or grease substance in order to diminish friction.

Fluid film lubrication is the most desirable form of lubrication because, during normal operation, the film is thick enough to completely separate the load-carrying surfaces. Fluid films are formed in three ways: 1) Hydrodynamic and elastohydrodynamic films are formed by the motion of lubricated in the surfaces through a convergent zone such that sufficient pressure is developed in the film to maintain separation of the surfaces. 2) The hydrostatic film is formed by pumping fluid under pressure between the surface that may or may not is moving with respect to each other. 3) Squeeze films are formed by the movement of lubricated surfaces toward each other (Pirro and Wessol, 2001).

Lubricant film can help prevent corrosion by protecting the surface from water and other corrosive substances. There is three categories regimes type of lubrication it is hydrodynamic lubrication (fluid film lubrication), boundary lubrication (boundary film lubrication) and mixed lubrication. Hydrodynamic lubrication occurs when two surfaces in sliding motion that relative to each other are fully separated by a film of fluid. Boundary lubrication occurs when the two surfaces are contacting in such a way that only extreme-pressure (EP) or anti-wear (AW) layer is all that is protecting them. Mixed lubrication is a cross between the boundary and hydrodynamic lubrication. While the bulk of the surfaces are separated by a lubricating layer, the asperities still make contact with each other.

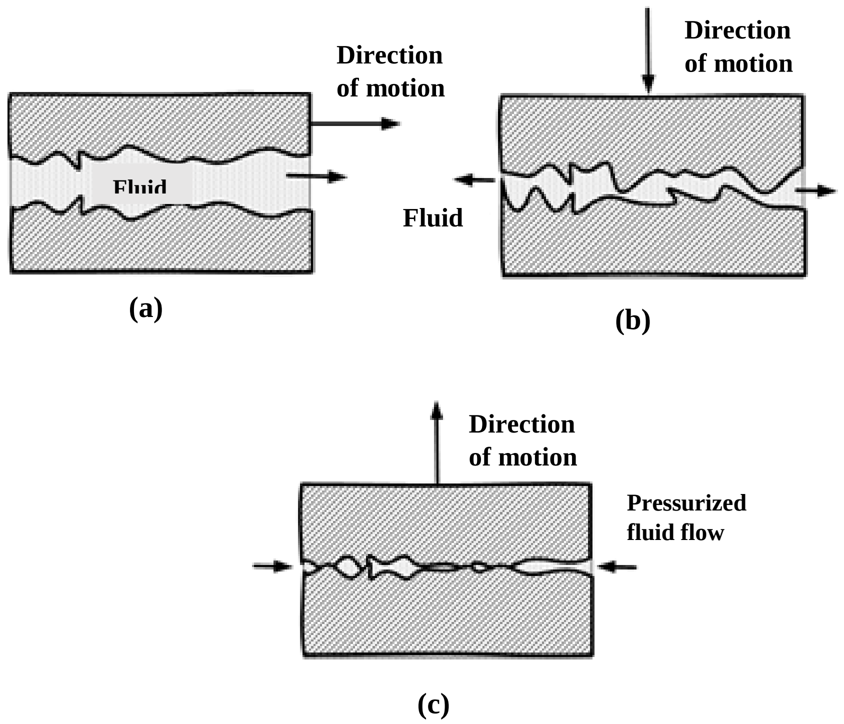

Figure 2.1: Regimes type of lubrication (a) hydrodynamic lubrication, (b) boundary lubrication, and (c) mixed lubrication.
(Source: http://nptel.ac.in/courses/112103024/module3/lec2/1.html)

2.1.1 Function of Lubricant

The lubricant is a substance, solid, liquid or gases that can be used to reduce the friction between two moving surfaces that is in contact. While lubricity is the property of a lubricant's ability to reduce friction. Lubricant not only can reduce friction between two contact surfaces, but it also can improve the frequency of a device or machine and reduces wear. Currently, almost every type of machinery and also sectors such as agriculture, transport, construction and sometime even at home using lubricant.

2.1.2 Type of Lubricant

There has three type of lubricant which are solid, semi-solid and liquid. The solid lubricant is considered a solid material that reduces friction and mechanical interaction between the surfaces in motion relative to the load action. Solid lubricants, provide better lubrication for different types of applications and used as a dry film or as additives in liquids. Like gear lubrication, it also benefits from solid lubricants, when applications relating low sliding speeds and high contact loads. According to Leslie, 2009, when used with a low-viscosity base oil lubricant especially capable, solid lubricant efficiently provides the necessary wear protection and the load performance required of the gear oil. Liquid lubricants can lower the temperature of the action along the surface and remove the contaminants, while they can be brought into the interaction that accumulate due to rotation and pressure generation between the bodies. Liquid lubricants can be mixed with other chemicals to provide additional properties such as corrosion resistance and surface active layers.

2.1.2.1 Petroleum Based Oil

Based stock oil usually 80 to 95 percent of total grease mass; it is the largest component in a grease formulation (Bonner, 1954). The lubricant oil which has been recycled should be high quality, the proper viscosity and pour point for the intended application. The base oil selected for grease formulation should have the same qualities as if the equipment was to be lubricated with oil solely. The lubricating oil used in grease formulation may be a natural material oil or a synthetic oil such as diester oil, silicon oil, fluorocarbon oil. In general for petroleum oil, naphthenic oils are the best selected than paraffinic oils because of their better solubility characteristics for metallic soaps and additives. The property of any grease is determined by the properties of the base oil. The best suited for low-temperature and high-speed applications, whereas greases made from a high-temperature, low-load, and high-speed applications are whereby grease with a low-viscosity base oil. According to Parkash, 2010, a high-viscosity oil is used for low-temperature, low-speed, and heavy-duty applications.

Lubricants are synthesized from three different base oils; mineral, synthetic and biological, all showing dissimilar assets and suitable for diverse applications. In the industry, the most commonly used lubricant is mineral oil. Which required temperatures to be moderate petroleum-based liquids and are used for machinery is mineral oils. Usually, biological lubricants are used in the food or pharmacological industry, such as oven or oven, where the risk of pollution should be minimized. Vegetables and animals are a source of biological oils. By selecting the appropriate base stock for the lubricant formulation, various properties and performance of final products can be assessed and predicted (Shahnazar et. al., 2015).

2.2 Liquid as Lubricant

Synthetic lubricants are chemically engineered to form pure lubricants. They contain no contaminants or molecules that do not intend a designed determination. The synthetic is flexibility and pure, uniform molecular structures impart properties that provide better friction-reduction, optimum fuel efficiency, maximum film strength and extreme-temperature performance which conventional lubricants cannot be reached. At high temperatures, a big portion of synthetic oils has additional lubricants that increase the ability of the oil to keep engine parts slick. Synthetic oil can reduces wear over the long term and may make the engine last longer. Besides that, synthetic oil is better stability, there are specially engineered to maintain their viscosity (thickness) at higher temperatures and within the longer duration of time. They also can help avoid engine wear in some ways, allows the oil to "stick" to engine parts more easily, providing better wear protection, and better occupation protecting the engine from dry starts.

2.2.1 Mineral Based

According to Nynas, 2009, mineral oil are primarily made of hydrocarbon, namely the carbon atoms and hydrogen bonded together to form different molecular structures. Mineral oil can be divide into distinct group which are paraffinic and naphthenic oils. In addition to the paraffinic and naphthenic structures, these molecules could be aromatic or polycyclic aromatic. Mineral oils consist of straight and branched chain paraffinic, naphthenic, and aromatic hydrocarbons with 15 or more carbon in a complex mixture. Generally, the physical properties of mineral oils be certain of their composition in terms of carbon number distribution, and this is defined by the source of crude oil (Aluyor and Ori-jesu, 2009). The characteristic fractional part of the material oil, whether crude oil or lubricant-based oil fractions, using ordinary chemical practices to determine the exact structure is unlikely without significant expenditure. Crude oil generally contains a thousand components and this is shown in the processing of each fraction. It is therefore objective to describe the fraction of mineral oil with the relatively simple benefits to determine their technical properties or to identify and quantitatively determine a group of components with similar chemical characteristics (Mang and Dresel, 2001).

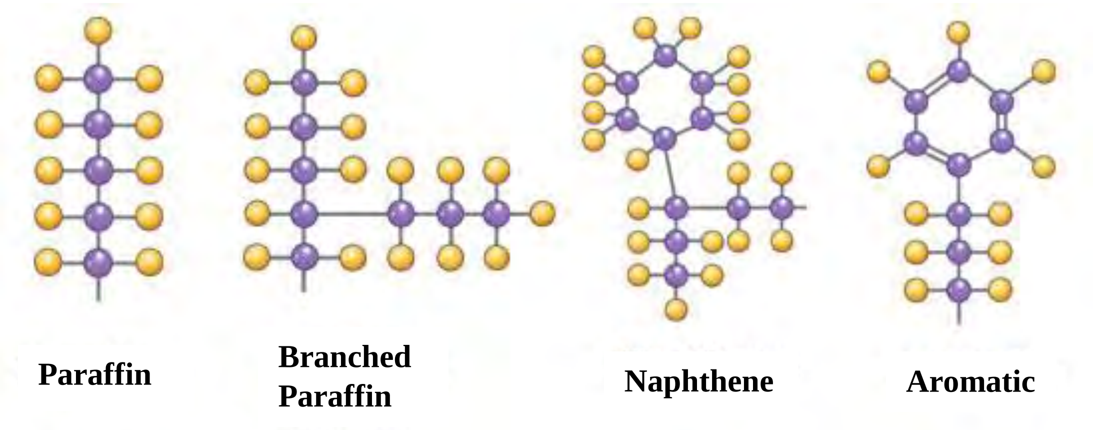

Figure 2.2.1: Common Mineral Oil Molecules
(Source: http://machinerylubrication.com/Read/28960/mineral-oil-refining)

Table 2.2.1: API Base Oil Categories
(Source: http://www.kewengineering.co.uk/Auto_oils/mineral_or_synthetic_oil.htm)

Group	Saturates		Sulphur Weight %	Viscosity Index	Process
I	< 90 %	And /or	> 0.03	80 – 119	Solvent refined
II	> 90	And	< 0.03	80 – 119	Hydro-processed
II+	"> 90%"	And	< 0.03	100 – 119	"Hyrdo-cracked"
III	> 90%	And	< 0.03	> 120	Severe "Hydro-cracked"
IV	Polyalphaolefins (PAO's)				Chemical reaction
Group V – all other synthetic					