UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OPTIMIZATION OF TRIBOLOGICAL PERFORMANCE FOR FILTRATION WASTE COOKING 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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I hereby, declared this report entitled “Optimization of Tribological Performance for Filtration Waste Cooking Oil Enhance by Nanoparticles” 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 a partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours. The member of the supervisory is as follow:

………………………………

(Dr. Muhammad Ilman Hakimi Chua Bin Abdullah)

ABSTRAK

Pada masa kini, minyak sayuran memperolehi populariti yang tinggi dalam industri minyak pelincir. Ia adalah pelincir yang boleh dibiodegradasi kerana ciri-cirinya yang mesra alam sekitar, boleh diperbaharui dan kurang toksik. Minyak sayuran berpotensi menjadi pengganti minyak petroleum. Kajian ini dijalankan untuk menghasilkan pelincir baru sebagai sumber gantian kepada minyak pelincir berasaskan petroleum. Dalam kajian ini, sisa minyak masak dicampurkan dengan grafit dan ZrO_2 *nanopartikel, dan ditambah dengan asid oleic sebagai ejen surfaktan. Proses penapisan sisa minyak masak dijalankan berdasarkan ASTM D7317. Selepas proses penapisan, sampel dicampurkan dengan nanopartikel dan surfaktan dengan menggunakan ultrasonik homogenizer. Kajian ini bertujuan untuk mengesan komposisi nanopartikel yang berbeza terhadap sifat-sifat geseran. Dengan menggunakan kaedah empat bola berdasarkan ASTM D4172 nilai geseran dan saiz pada permukaan di bola galas diperolehi. Mekanisme haus pada permukaan di bola galas dianalisis menggunakan kaedah SEM dengan mengimbas imej permukaan haus tersebut. Selepas semua data telah dikumpulkan, data akan dianalisis. Hasil keputusan dari analisis ini mendapati nilai purata yang optimum bagi pekali geseran adalah 0.05407. Sample 2 memperoleh diameter paling kecil bagi kesan haus pada permukaan bola galas dengan purata 575.0 μm, dan berkait dengan purata pekali geseran yang rendah, 0.0507. Sebagai tambahan, apabila purata pekali geseran makin rendah, diameter kesan haus pada permukaan semakin kecil, dimana geseran mempengaruhi kerosakan dan haus pada permukaan. Kesimpulannya, komposisi sisa minyak masak dan nanopartikel mempunyai berpotensi sebagai pelincir baru.*

ABSTRACT

Nowadays, vegetable oils gain popularity in lubricant industry. It is due to biodegradable lubricants which have been promoted because of the environmentally friendly characteristics. Vegetable oil is potentially being used as a substitute for petroleum oil. They are environmentally friendly, renewable and less toxic. This study was conducted to produce a new lubricant as a replacement source for a current petroleum-based lubricant. In this study, waste cooking oil was mixed with graphite and ZrO2 nanoparticles, and the oleic acid as surfactant agent. The filtration process of waste cooking oil was done according to ASTM D7317. After the filtration process, the sample was blended with nanoparticle and surfactant by using Ultrasonic Homogenizer. Ultrasonic homogenizer to investigate the effect of the different composition of nanoparticle towards friction properties. Four-ball method according to ASTM D4172 was carried out to obtained the wear and friction results. By using SEM, it scanning the image of worn surface of the ball bearing and the wear mechanism can be determined. After all the data have been collected, the results were analysed. The optimum results show that the coefficient of friction achieves an average of 0.05407. Sample 2 obtained the smallest wear scar diameter with an average 576.0 μm and coherence with coefficient of friction with a lowest average of 0.0507. In addition, when the average coefficient of friction low, the wear scar diameter smaller, where the friction can causes the wear and surface damage. As a conclusion, the composition of waste cooking oil and nanoparticles have a potential as a new lubricant.

DEDICATION

To my beloved parents

ACKNOWLEDGEMENT

All praise belong to Allah SWT. I am really grateful to Allah SWT for giving me opportunities to complete my thesis Final Year Project. I would like to express my deepest thanks to Dr. Muhammad Ilman Hakimi Chua bin Abdullah, Senior Lecturer at Faculty of Engineering Technology UTeM as my supervisor who had given me full of commitment, always support me and give advice to not give up. I extremely grateful for your assistance and suggestion throughout my final year project. All the guide, advice and all the knowledge from Dr, I will remember and applied in future. To my beloved family, thank you for always supports me up and down, and pray the best for me always and every day, you all have a top places in my heart now and ever. To my friends for helping in service all the stress from this year and not letting me give up. To my teammate, special thanks, and appreciation for an advisor, support, patience and understanding for pushing me further than I expected. Furthermore, I would like to acknowledge with my appreciation to staff of UTeM, especially technicians in FTK laboratory, who gave a permission and teach to use all equipment and the necessary materials to complete my final year project. Finally, special thanks to all lecturers, technicians, my classmates and anyone who involved directly or indirectly to support me until this research to be completed.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURES

ASTM	American Society for Testing and Materials
COF	Coefficient of Friction
DOE	Design of Experiment
DOF	Degree of Freedom
hBN	Hexagonal Boron Nitride
PAO	Poly Alpha Olefins
SEM	Scanning Electron Microscopy
S/N ratio	Signal Noise Ratio
V.I	Viscosity Index
WSD	Wear Scar Diameter
WCO	Waste Cooking Oil
ZrO_2	Zirconia

CHAPTER 1

INTRODUCTION

1.1 Introduction

The increase of ecological concern inspire current researcher to go for renewable sources as a new raw material in lubricant industry. Waste cooking oil is one of the raw materials that can be produced as a new renewable source due to huge quantities of this oils and animal fats that are available throughout the world. The main issues for waste cooking oil is the disposal problem due slow degradation, and possibly contamination occur on water and land resources. According to Panadare, 2015, some refinery and modification process on waste cooking oil can be used as a multi-purpose lubricant. Currently, vegetable oil gains popularity in lubricant industry because it has a potential to be used as a lubricant. The significant advantages of vegetable oil to an environment such as ecological and possessed acceptable performance in a variation of utilization help researchers to study the potential of vegetable oil as a new lubricant (Gawrilow, 2003).

Furthermore, vegetable oil obtains high lubricity, high flash point, great viscosity index, great bio-degradability, low toxicity and low evaporative loss. However, there are several weaknesses of vegetable oil since it is oxidative, low thermal and hydrolytic stabilities. By adding nanoparticles agent as an additive, it is believed that the vegetable oil can be improved as a new lubricant. Nanoparticles agents that normally used are zirconia, ZrO_2 and graphite, while the surfactant agent is oleic acid. Nanoparticles currently are among the most demanded and promising additives, where low concentration between 0.2 vol.% and 3 vol.% are added into lubricating oil that can improve the tribological performance (Abdullah et al, 2014). According to Habereder et al. (2009), lubricants with environmentally friendly have a high biodegradability and can reduce the pollution. Triglycerides of vegetable oil are a natural ester that derived from glycerol and three fatty acids. According to Suarez et al. (2010), there are more polar in triglycerides of vegetable oils and have more inclination to metal. Stachowiak et al. (2005), point out in their study, oils with higher polar group can provide boundary lubrication effects, easily react and adsorb with metal surface. The lubricating film with strong bond to the surface acts efficiently as a reducer to the friction and the amount of wear.

1.2 Problem statement

Currently, the petroleum oil facing huge implementation due to the heavy usage in most of the industries related to a great number of human needs. As a fact, most of the conventional lubricants give effect to the environment which obtained high toxicity that can affect to the living thing (Abdullah, et al.,2014). According to Shahabuddin et al. (2012a), regarding the use of petroleum based lubricant, factors such as unknown petroleum reserve, environmental pollution and increase in consumption has raise a concern thus it has become important to find the alternative lubricant to meet the demand in the future. Approximately 12 million tons of lubricant waste are damped to the sea has been reported yearly (Tottea et al., 2003)

According to Quinchia et al. (2014), the vegetable oil seems to potentially be a substitute for petroleum oil. They are suitable because of their renewability, less toxic content, environmentally friendly and contains lubricating properties such as high lubricity, high viscosity index and low volatility (Nizam, 2009). However, it is very difficult disintegrate the mineral lubricant in petroleum oil due to its non-biodegradable nature. Same as waste cooking oil, the way of disposing is done incorrectly by disposing in drain and sinks that can cause the environmental pollution and plumbing system damaged. Since the vegetable oil have an oxidative, low thermal, and hydrolytic stabilities characteristics, it can be improved as a new lubricant by adding ZrO_2 and graphic nanoparticles as an additive.

1.3 Objective

The objectives of this proposal project:

1. To optimize the tribological performance of the new develop bio-lubricant.
2. To investigate the effect of the different composition of nanoparticles, e.g ZrO_2 and graphite, and surfactant agent, e.g Oleic acid, towards friction properties.
3. To determine the wear mechanism, occur on the worn surface of the ball bearing.

1.4 Scope of work

In order to achieve the objectives, several scopes have been determined:

1. Optimizing of the tribological performance of the new develop bio-lubricant using L9 Orthogonal arrays from Taguchi Method.
2. Investigating the effect of the different composition of nanoparticles, e.g ZrO_2 and graphite, and surfactant agent (Oleic acid), towards friction properties by using Four-Ball tester according to the ASTM D4172.
3. Determine the wear mechanism on worn surface of the ball bearing by using SEM.

CHAPTER 2

LITERATURE REVIEW

2.0 Literature Review

Lubricant has an important role in industrial and economic development. Lubricant works as a friction reduction and anti-wear mechanism on mechanical contact plus to boost the tribological performance. Normally, oils and greases are the common type of lubricants that used in automotive industry. The oil functions is the surface becomes smooth when the sliding surface was filling by surface cavities and it can reduce the friction. It is also used as transmitting forces, transporting foreign particles, cooling or heating the surfaces. Modern methods of refining process is done by removing and/or modify the structure of the molecules to boost the properties of the lubricant, however they are restricted in their capability to directly changes the structure of oil to optimize the overall of hydrocarbon structures and content (Kodali et al., 2001).

2.1 Classification of Lubricant

Based on their physical properties and it performance, there are three types of lubricant can be distribute which are solid, semi-solid and liquid. The application of lubricant is widely used such as in industrial and transmission, it also can react as a coolant because it reduces the heat, corrosion and provides a smooth operation between two moving parts.

2.1.1 Solid Lubricant

According to Kopeliovich, ND, solid lubricant capable to reduces the coefficient of friction and wear between two contact surfaces, by keeping the direct contact have a rubbing part in condition under high loads. There are two types of solid lubricant usually used which are graphite and molybdenum disulphide. These materials usually found in dusty powder. Due to lamellar structure, which in the direction of motion the lamellas orient parallel to the surface, and shows that these materials have a good performance as additives for lubricant.

Particle orientation after initial sliding

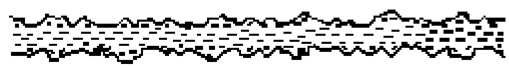

Figure 2.1 Particle orientation after initial sliding (Source: www.tribology-abc.com)

Figure 2.1 shows in the direction of lamellas, the low friction can easily cause the shear to each other. At low speed, smooth particle on the relatively polished surface, meanwhile, at higher rate of motion, large particles good performs on the relatively rough surface. Other substances besides graphite and molybdenum disulfide that are useful in solid lubricant are polytetrafluoroethylene (PTFE) and boron nitride. Based on the Table 2.1 shows that the solid lubricant selection comparison and rating according to the different criteria and different substance of solid lubricant.

Table 2.1 Solid lubricant selection comparison and rating (Source: Randolph, 2003)

Criteria	Graphite	M_oS_2	PTFE	BN
Normal atmospheres	1	1	1	1
Vacuum atmospheres	3	1	1	1
Ambient temperature	1	1	1	1
Continuous service temperature to 260°C in air	1	1	1	1
Continuous service temperature to 400°C in air	1	3	N/A	1
Continuous service temperature to 450°C in air	2	3	N/A	1
Burnishing capability	1	1	3	2
Hydrolytic stability	1	2	1	1
Thermal conductivity	2	3	3	1
Load-carrying lubrication	2	1	1	2
Friction reduction	2	2	1	3
Dispersibility	1	1	3	2
Color	Black	Gray	White	White
Relative cost	1	2	2	3

1 = best

2.1.2 Semi-solid Lubricant

According to Abdulbari et al. (2011), dispersing thickening agent into carrying lubricant in a controlled mixing temperature will produce a new type of lubricant that is called as grease. The thickener is a soft dispersed solid that has been thickened the lubricant grease that consists the oil with low viscosity. It consists of base oils approximately 75 to 95%, additives by 0 to 5% and minute thickener fibers by 5 to 20% (Mangala, 2013). The liquid portion of the grease is from mineral or synthetic oil and any fluid that has lubricating properties. In the automotive and industrial application, grease from mineral oil have a high attention that provides the good performance (Pirro, 2001).

Figure 2.2 Semi solid lubricant (Source: nptel.ac.in/courses/112102015/22)

The earliest grease was made with calcium soaps, and later soaps such as aluminum, clay, lithium and polyuria. According to Pirro D. M. (2001), low-cost grease has several disadvantages which it has restricted temperature achievement, but have a good water resistance, good for low-temperature application and improved the shear stability.

2.1.3 Liquid Lubricant

There are several natural organics which in categories liquid lubricant, it consists of animal fat, part of mineral oil (petroleum), vegetable oils, synthetic organics and combination between two or more of the mentioned materials. According to Gunderson et. al., (1962), by adding the mixture of additives, it can improve the particular characteristics of the lubricant. Liquid lubricants shows low electrical conductivity, and unacceptable in some nanotechnology appliance. Table 2.2 shows the type of the natural and synthetic organic compound.

Table 2.2 Types of liquid lubricants (oils) (Source: Bhushan, 2013)

Natural Organics	Synthetic Organics
Animal fat	Synthetic hydrocarbons (polybutene)
Shark oil	Chlorinated hydrocarbons
Whale oil	Chlorofluorocarbons
Vegetable oils	Esters
Mineral (petroleum) oils	Organic acid
Paraffinic	Fatty acid
Naphthenic	Dibasic acid (di)
Aromatic	Neopentyl polyol
	Polyglycol ethers
	Fluoro
	Phospate
	Silicate
	Disiloxane
	Silicone
	Dimethyl
	Phenyl methyl
	Chlorophenyl methyl
	Alkyl methyl
	Fluoro
	Silanes
	Polyphenyl ethers
	Perfluoropolyethers

2.1.3.1 Mineral Based Oil

Base oils are the one of the lubricants that important. According to Mang (2001), the weighted average more than 95% of the lubricant formulation for all. Some of the mineral oils are used in commercial applications which contain 10-25% of substances as known as an additive. The function of additive is very important part of the composition of mineral oil which can act as an anti-wear additives, corrosion, to prevent severe surface damage under severe loading and oxidation stability. Besides that, the composition of mineral oils can improve the viscosity index, prevent from any deformers, pour point depressants (Aluyor, 2009). According to Jackson (1987), mineral oil that derived