UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION ON FRICTION CHARACTERISTICS OF SAE 15 W40 CONVENTIONAL ENGINE OIL WITH NANO ADDITIVE

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

by

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DECLARATION

I hereby, declared this report entitled "Investigation on Friction Characteristics of SAE 15W40 Conventional Engine Oil with Nano Additive" 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) with Honours. The member of the supervisory is as follow:

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(EN AZRIN BIN AHMAD)

ABSTRAK

Tujuan kajian ini adalah menentukan komposisi minyak enjin yang sesuai dengan nano-aditif dan untuk menguji dan mencirikan kelikatan dan diameter parut campuran zirconia dioksida (ZrO_2) nanopartikel, yang tersebar dalam minyak enjin konvensional (SAE 15W40). Ujian tribologi dilakukan dengan menggunakan penguji empat bola mengikut prosedur standard ASTM D4172. Selain itu, ujian kelikatan juga dilakukan menggunakan kelikatan yang dipanaskan pada 40˚C. Menurut analisis, COF dan diameter parut haus hanya meningkat sedikit dengan menyebarkan beberapa kepekatan nanopartikel ZrO_2 dalam minyak enjin konvensional, berbanding tanpa bahan tambahan nanopartikel. Sumbangan 0.1 vol.% daripada ZrO_2 dapat menjadi campuran optimun bahan tambahan dalam minyak enjin konvensional, untuk mendapatkan COF yang lebih rendah. Sebaliknya, keputusan kelikatan kinematik menunjukkan bahawa pada 0.2 vol.% mempunyai nilai kelikatan yang terbaik.

ABSTRACT

The purpose of this study is to determine the suitable composition of engine oil mixed with nano-additive and to test and characterize viscosity and scar diameter the mixture of zirconia dioxide (ZrO_2) nanoparticles, dispersed in conventional engine oil (SAE 15W40). Tribological testing was conducted using a four-ball tester according to ASTM standard D4172 procedures. Besides, viscosity testing also conducted using heated viscosity at 40˚C. According to the analysis, COF and wear scar diameter only increased slightly by dispersing several concentrations of ZrO_2 nanoparticles in conventional engine oil, compared to without nanoparticles additive. Contribution of 0.1 vol.% of ZrO_2 can be an optimal composition additive in conventional engine oil, to obtain a lower COF. On the other hand, the results of kinematic viscosity show that at 0.2 vol.% has the best value of viscosity.

DEDICATION

To my beloved parent

To my dedicated supervisor

To my dedicated co-supervisor

To all my friends and teammate

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LIST OF ABBREVIATIONS, SYMBOL AND NOMENCLATURE

3D	-	Three-dimensional
Al_2O_3	-	Aluminium oxide/ Alumina
ASTM	-	American Standard Testing Material
ATF	-	Automatic Transmission Fluid
CA	-	Cholanic acid
CeO_2	-	Cerium dioxide
COF	-	Coefficient of friction
cSt	-	Centistokes
FTK	-	Faculty of Engineering Technology
HB	-	Heptybenzoic acid
MoS_2	-	Molybdenum disulphide
PCA	-	Pentylcyclohexane carboxylic acid
PTFE	-	Polytetrafluoroethylene
SAE	-	Society of Automotive Engineers
SEM	-	Scanning Electron Microscopy
TAN	-	Total Acid Number
TiO_2	-	Titanium dioxide
VI	-	Viscosity Index
ZrO_2	-	Zirconia

CHAPTER 1
INTRODUCTION

1.0 Introduction

Different sorts of oils are available everywhere throughout the world including mineral oils, synthetic oils, re-refined oils, and vegetable oils. Materials that lubricate moving parts are important to starts a machines. Lubricant is any substance that can reduce the friction and wear between two contacting surfaces. The lubrication process occurs by forming a thin film between the moving parts. Lubrication can also acts as cleansing agents, electrical insulators, preventing corrosion and improve the performance of the engines (Boyde, 2002). Lubricants exists in three stage which are solid, liquid and semi-solid. The characteristic for lubricant is it contains a substance that can diminish the erosion and wear between two moving surfaces. Therefore, the advantage of using the conventional engine oil with Nano-Additive can helps to reduce the friction and wear.

Nouveau, (1900) reported that earliest man likely saw how much effort it was to pull logs that had been stripped of bark in view of the lubrication gave by sap overflowing from the wood. Other prehistoric lubricants were mud or pounded reeds set under dragged sledges for pulling amusement or timbers and rocks for building development. More broad utilization of lubricant was required with the innovation of the barter system. The primary trucks were made with unrefined wooden axles and bearings. In the end, individuals found that spreading a piece of creature fat on the dry and squeaking parts made the wheel run discreetly and easily. One of the most punctual references to unrefined petroleum utilized as a lubricant is from a cotton turning factory in Pittsburgh, Pennsylvania, in 1845.

The expansion of inorganic nanoparticles into lubricating oils has pulled in broad consideration both in the scientific group and in the lubrication industry due to its viability in decreasing wear and friction. Assortments of inorganic nanomaterials including metal nanoparticles, metal oxide nanoparticles, carbon nanomaterials, and metal nanostructures have been used in oil media to move forward the counter wear and friction decrease properties (Sotres & Arnebrant, 2013). Among the inorganic nanoparticles used in lubricating oils, metal oxide nanoparticles have points of interest such as cheap, generally high solidity, and simplicity of controlling the molecule measure and morphology, making them a great contender for commercial applications in lubricating oils (Li, Xie, Yong, & Sun, 2017).

1.1 Problem Statement

Engine oil is the main usage in the lubrication for engine system. Conventional lubricant additives play a prime part in gear lubrication and cutting lubrication (Zhang, Simionesie, & Schaschke, 2014). The engine needs a high level efficiency to deliver high performance during operation. Even so, wear and friction occurs on mechanical parts due to the tribology effect in long terms. In addition, the lubricant is an ideal way to decrease the corrosion, wear, and friction in the engines. Furthermore, the research regarding the role of zirconium oxide in tribology act is quite interesting due to its potential which can give impact to the lubricant industries.

The utilization of energy effective conventional engine oil with appropriate zirconia additives are commend for the execution, environmental friendliness, and sustainability. This is because the zirconia as additive in engine oil can reduce the wear diameter and friction in the engine system. Moreover, the properties of the zirconia itself can help to improve the thermal conductivity in the engine to lessen the excess of heat that cause wear and friction in the engine.

1.2 Objectives

From the background and the problem statement that have been stated, the objectives of this research are:

i. To determine the suitable composition of mineral oil mixed with Nano-Additive.
ii. To blend concentration of the mineral oil with Nano-Additive.
iii. To test and characterize viscosity and scar diameter the mixture of mineral oil with ZrO_2.

1.3 Scope

In order to achieve the objectives of the research study, several scopes have been drawn:

i. Determining the composition of engine oil (SAE 15W40) mixed with ZrO_2 to form a lubricant.
ii. Blending engine oil with different composition of ZrO_2 by using ultrasonic homogenizer.
iii. Testing the tribological performance of the develop oil by using 4-ball tester according to D4172.
iv. Characterizing the viscosity of engine oil mixed with ZrO_2 using viscometer.
v. Characterizing the scar diameter using Scanning Electron Microscopy (SEM).

CHAPTER 2

LITERATURE REVIEW

2.0 Lubricant

Lubricants play vital roles in industries, especially when it comes to the use of machinery to operate and transmission application. These lubricants are used to keep the operating parts from failure and allow the freely of operation. There are some functions of lubricants which can be used to reduce friction, reduce wear, acts as a coolant to reduce heat that produced between two moving parts, and increases the efficiency of the machine by reducing the loss of energy. On top of that, lubrication also will make the operating parts move smoothly without any wear or noises.

Lubricant can be classified into three types based on their physical appearance which are solid, semi-solid and liquid. Each of the lubricant has their own specific performance. Lubricant is widely used in various applications such as in industrial and transmission lubrication. Lubricant can act as coolant because it reduces the production of heat, corrosion and the smoothness between two moving parts and reduce noise. In addition, it can reduce the wear and produce a high efficiency of the machine.

Solid lubricant can be found in dry powder which contains graphite and molybdenum disulphide as basic materials. This lubrication can be applied by rubbing at the surface which can self-lubricate cages in ball bearing with a correct technique (Roberts 1990). Semi-solid lubricant is a combination of lubricants oil with thickening agents which called grease. Usually grease is used as anti-friction of roller bearings and another industrial machine (Srivastava & Sahai 2013). In addition, grease seemly used for low load application and low speed because it does not operate well and has a relatively poor coolant. Liquid lubricants are any kind of categories of fluid such as vegetable oil, mineral oil and others. The most important of lubrication is to ensure all the machinery and engines operate effectively. Without them, all the operating parts cannot operate well and breakdown will happen.

In addition, a good characteristic of a lubricant is prevention of corrosion, high viscosity index, high boiling point and low freezing point. In lubricating, oil has been improved with the use of additives. This is because the additive will protect the lubricant in service by limiting the chemical change and deterioration and to protect the mechanism from harmful combustion products and malfunctioning lubricating oil. Additive also will improve existing physical properties and to prepare new characteristics in the oil. The most important of additives are anti-oxidant that will reduce the rate of degradation, extreme pressure is usually used in gear lubricants and detergent or dispersion used in engine oils to prevent carbon deposits.

According to Roberts (1990), there are many types of lubricant that depend on the gearing, operating speed and load, temperature and the method of lubricating application. The characteristics of the lubricant in gearbox include transferring heat generated and lubricate the teeth from the gear working. Moreover, it is important to find suitable properties of lubricant which have a good reliability to provide slip away power transmission at higher mechanical efficiency with low maintainability and long term service life. Surface failure occurs when the lubricant film on the gear wheel teeth in insufficient to protect the surfaces from the stress, resulting in pitting forming in the contact region. If the lubricant film is not well maintained, a scratch might happen. Thus, the temperature will increase and may causing distress and wear of the material surface. By choosing the lubricant with a low viscosity, the reducing friction and churning can be minimizing. If the lubricant is too viscous, the excessive heat is generated.

Three examples were apparently arranged as follow: (1) Test A - normal lubricant of SAE 40 grade. It can be expressed that specimen A is the reference lubricant, (2) Test B - comprises of test A with 0.5% Amine phosphate added substance, and (3) Test C - comprises of test A with 0.5% Octylated/butylated diphenylamine additive. It can be expressed that specimen B and test C are arranged with two distinct sorts of anti-wear additives. Test D and test E can be referred to as base lubricants with respect to contaminated lubricant by waste palm oil, from 1% to 5%. Points of lubricant compositions are appeared in Table 2.

Table 2.1: Lubricant sample compositions (Kalam et al. 2011)

Samples	Lubricant compositions
A	Normal lubricant as SAE 40 grade
B	Sample A with 0.5% Amine phosphate additive
C	Sample A with 0.5% Octylated/butylated diphenylamine additive
D	Sample B with 1% to 5% waste palm oil with base lubricant
E	Sample C with 1% to 5% waste palm oil with base lubricant

2.1 State of lubricant

2.1.1 Solid

Solid lubrication is made up from graphite and molybdenum disulphide (MoS_2). These material can be found in dry powders that have an effective lubrication. Add an additive due to their fine layer that is alternating between different materials. The lubricants need to place in parallel on the surface between the directions of motion. Boron nitride, polytetrafluoroethylene (PTFE), cerium fluoride, talc, calcium fluoride and tungsten disulphide are the other substances that are useful in solid lubrication.

In addition, solid lubricants can be used in condition when conventional lubricants are insufficient. A typical application usually uses are in reciprocating motion, ceramics, high temperature and extreme contact pressures. Solid lubrication will act when the operating conditions needs to have a higher demand of advancing technology and a good performance to avoid a severe damage of the coating, even though liquid lubricants and grease are required to control the friction in gear application. In addition, due to the working condition, the solid lubrication are required to improve the coating performance in a variety of situations such as corrosion, wear, friction, lubrication, extreme temperatures and many other involve in operating conditions (Abere et al. 2014).

2.1.2 Semi-solid

Greases, vaseline, wax and other similar compound are semi-solid lubricants used to reduce friction between two moving surfaces. According to Abdulbari et al. (2011), by dispersing thickening agent into carrying lubricant in a controlled mixing temperature will produce a new type of lubricant that called grease. Grease can be divided into several types based on the application that is clay greases, multi-purpose greases, asphaltic-type greases, extreme-pressure greases, soap-thickened mineral oils, and others.

Lubricating grease has been used for a lot of application that involving machinery and moving part for efficiency and to prolong the lifetime of the machinery. Generally, grease is widely used in bearings and gear systems. On top of that, grease also can be operated under high-speed and lightly-loaded condition whereby, lubricant will be enough to maintain fully flooded lubrication. The performance of using grease are much better than using the liquid lubricant because of grease can act as a seal, to provide protection against corrosion and the same time being able to reduce noise and shock. Therefore, grease is mainly applied to bearings and gears that working at high temperature. Moreover, lubricating grease will produce an environmental friendly and will find it way as materials for grease formulation.

Nowadays, practiced greases formulation is made from petroleum and it derivatives. In addition, the application of grease from natural sources is more preferable. The usage of wastes from natural resources will increase an efficiency of these natural resources. Furthermore, environmental concern and regulation has increased the need of renewable from the remaining of the world petroleum resources.

2.1.3 Liquid

There have many different kinds of properties that used in lubricant categories such as vegetable oil and mineral oil. All the liquid lubricants have a variation properties and usage. Vegetables oils come from oil that containing seeds, fruits or nuts by the different mixture and pressing methods. There are various type of vegetable oil such as jatropha oil, corn oil, canola oil, groundnut oil, palm oil and olive oil (Aluyor et al. 2009). Apart of that, mineral oil that comes from petroleum derivative usually has been used as a lubrication of an engine. The most familiar type of lubricant is base oil. The purpose usages of liquid lubricant are to transfer heat, minimize friction and wear between mechanical parts which are in contact with each other.

In gear application, using a liquid lubrication plays an important role as a lubricant by lubricating moving parts such as between the gear and a bearing. It also cleans, inhibits corrosion, improves sealing and acts as a coolant by carrying heat away. However, leakage, human error, and blown pipes may occur, and disposal of engine oil may damage the ecosystem due to its toxicity. High concerns of usage petroleum based products have produced the opportunity to get an environmentally friendly lubricant from biodegradable.

The limitation of using lubricant also plays an important role which are can give effect on our environment, health issue and cost are all relevant while in considering the choice of lubricant and application method. However, the minimum quantity of lubrication should be considered when the operation of parts is still running. The performance of these lubricants depends on the process of transmission, materials and surface (Tang & Li 2014).

2.2 Type of liquid lubricant

2.2.1 Mineral oil

According to (Dinesh et al. 2016), Engine oil goes about as lubricant by lessening wear between sliding parts of the engine. They likewise work as coolant by diverting excessive heat from the moving parts of the engine. Typically, heat put away in bulk of the engine oil is higher than its thermal conductivity which brings about the arrangement of oil sludge inside the engine at extraordinary conditions and builds the changes of the engine oil getting burnt along these lines creating a lot of smoke. Also, when the engine oil is subjected to elevated temperature its viscosity decreases and thickness of the lubricating layer eventually shrivels thereby causing high wear and tear between the rubbing surfaces. This reduces the lifetime of the engine body. Recent trends in the field of nanotechnology includes usage of nanoparticles as new generation additives in the engine oil because of their tendency to improve its tribological and heat transfer properties.

Mineral oil is used in a various kind of industrial or mechanical applications as an automotive and industrial gear oils, engine oils, transmission fluids, machine oils, bearing oils and hydraulic oil. Some of the mineral oils are used in commercial applications which are contains 10-25% of substances as known as additive. These additive a very important part of the composition of mineral oil which can acts as an anti-wear additive, corrosion, to prevent severe surface damage under severe loading and oxidation stability. Moreover, this composition of mineral oils can improve the viscosity index, prevent from any deformers, pour point depressants (Ori-Jesu & Ori-jesu 2009).

2.2.2 Vegetable oils

In recent year, people noticed that vegetable oil has been used as a lubricant a long time ago since a serious concern of the remaining the world petroleum resources. The majority of vegetable oils consist primarily of triacylglycerides. Vegetable oils can be classified as a renewable resource, environmentally friendly and biodegradable lubricants for industrial and transportation applications according to (Srivastava & Sahai 2013).

According to Srivastava & Sahai (2013), Four main vegetable oils dominate the industry accounting for about 82 to 85% of worldwide vegetable oil production. Soybean oil is 31 to 35%, palm oil 28 to 30%, rapeseed oil 14 to 15% and sunflower oil is 8 to 10% of global production. A large portion of vegetable oil production is in developing countries. According to (Abere et al. 2014) classify that vegetable oils are come from oil that containing fruits nuts or seeds by different combination and pressing methods. There are various type of vegetable oil likes groundnut oil, canola oil, olive oil, palm oil, corn oil and jatropha oil. Each of vegetable oils falls under their original compositions and by the growth of their chemical and physical properties to control their utility in many types of applications (Aluyor et al. 2009).

Bio lubricants are nothing but the mixture or compositions with additives will make the lubricants in biodegradability and low toxicity as a deliberate and primary intention. In addition, biodegradable lubricants show less emission because of a higher boiling temperature range of esters. Moreover, they are totally free aromatics and oil mist reduction lead to less inhalation of oil mist into the lung (Srivastava & Sahai 2013).

Vegetable oils normally show better than mineral oils in term of viscosity index. Usually, viscosity index is used to measure a fluids change of viscosity in relation to temperature. The higher the viscosity index, the smaller the relative change in viscosity with temperature. In addition, the other properties it may be mixing with some additive. Besides, low temperature and low resistance to oxidative degradation are the main issues for the vegetable oil. It proved that methylene will interrupt