UNIVERSITI TEKNIKAL MALAYSIA MELAKA

TRIBOLOGY ANALYSIS OF POLYOL AS LUBRICANT ADDITIVE

This report submitted in accordance with the requirement of the University Technical Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honour

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This report is submitted to the Faculty of Technology Engineering Mechanical and Manufacturing of UTeM as partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours. The member of the supervisory is as follow:

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ABSTRAK

Keperluan pelincir mesra alam telah menjadi kebimbangan hari ini sebagai alternative kepada pelincir berasaskan mineral kerana kesannya kepada alam sekitar. Ini adalah kerana daya impak bumi oleh minyak berasaskan mineral menjadikan kesan penggantian menjadi asas. Kajian ini memberi tumpuan kepada polyol yang dihasilkan sebagai pelincir tambahan kepada pelincir hidraulik. Untuk mengetuai analisis ini, kesan poliol kepada indeks kelikatan meningkatkan kelikatan pelincir menggunakan (Viscometer) mengikut (ASTM D445). Selepas itu, mengetahui TAN menggunakan Titrasi Asid nombor mengikut (ASTM D664). Kemudian, kualiti pelincir haus dan pencegahan diperoleh dengan menggunakan penguji empat bola mengikut (ASTM D4172) dengan beban dan kelajuan yang sama. Lebar pakai bola yang menggunakan SEM menurut (ASTM E986) dianggarkan menggunakan lensa kanta pembesar optik dan komponen haus juga telah dipertimbangkan. Apabila analisis telah dilakukan, sampel nombor 3 adalah hasil optimum iaitu 7.5% polyol kerana indeks kelikatan yang baik, jumlah asid total, dan pekali geseran berbanding dengan sampel yang lain. Ia menunjukkan bahawa poliol sebagai pelincir aditif berpotensi digunakan dalam penghantaran. Ini kerana pekali geseran polyol sebagai tambahan pelincir adalah dalam rejim pelinciran sempadan dan ciri pencegahan haus menunjukkan prestasi yang baik untuk menahan beban dan kelajuan.

ABSTRACT

The requirements of ecofriendly lubricants has become a concern today as alternatives to the mineral-based lubricant due to its effect to the environment. This is because of the earth impact forces by mineral-based oil making the impact of substitution to be fundamental. This study is focused on created polyol as lubricant additives to hydraulic lubricants. To lead this analysis, the effect of polyol to viscosity index increases the viscosity of lubricant using Viscometer according to (ASTM D445). After that, to know the TAN using Titration Acid Number according to (ASTM D664). Then, the wear and preventive quality of the lubricant were obtained by utilizing a four-ball tester according to (ASTM D4172) with the same loads and speeds. The wear scar breadth of the balls using SEM according to (ASTM E986) was estimated utilizing an optical magnifying lens and the wear component additionally had been considered. When the analysis had been done, sample number 3 is the optimum result which is 7.5% polyol because of the good viscosity index, total acid number, and coefficient of friction compared to another sample. It shows that the polyol as lubricant additives is potentially being used in transmission. This is because of the coefficient of friction of the polyol as lubricant additives are in boundary lubrication regime and the wear preventive characteristic shows good performance to withstand the load and speed.

DEDICATION

To my beloved parents that always supported and motivated me.

To all my friends that give me the moral supported.

To my supervisor and co-supervisor who always guides me.

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LIST OF ABBREVIATIONS

PAO	-	Polyalphaolefines
TMP	-	Trimethyl propane
ASTM	-	American Standard for Testing and Material
%	-	Percentage
cSt	-	Centistokes
mm	-	Millimeter
PAG	-	Polyglycol
POE	-	Polyol Ester
NOPs	-	Natural Oil Polyols
FA	-	Fatty Acid
TG	-	Triglycerides
MG	-	Monoglycerides
DG	-	Diglycerides
SOP	-	Standard of Procedure
g	-	gram
WSD	-	Wear Scar Diameter
COF	-	Coefficient of Friction
VI	-	Viscosity Index
RPM	-	Rotation Per Minute
N	-	Newton
^{o}C	-	Degree Celsius
ZDDP	-	Zinc dialkyldthiophosphates

CHAPTER 1:

INTRODUCTION

1.1 Background of Study

A few years ago, the mostly industrial application used the animal and plant oils as a lubricant. Plants oil-based lubricants show the good lubrication because of the majority used in the industry. This is because of alternative for mineral oils are used in liquid-based lubricants for coolant metalworking and hydraulic fluid. It's just remembered the fatty acid was manufactured from animal and plants as the primary source of lubricants since the nineteenth century when the mineral oil becomes a high quantity. Time by time, fatty acid and mineral oil were trending used until now the trend had been concerning in lubricants and functional fluid. Nowadays, the industry is focused on non-polluting or environmentally aware to make a renewable nature. (Wilson & Wilson, 1998) In other words, oil-based lubricant resources will be used up very limited time by time.

1.2 Problem Statement

Nowadays, lubricant oils were created utilizing mineral oil as a base liquid because of its lower cost and durability. Furthermore, mineral oil can produce good tribology performance. The issues caused by mineral oil are tough to dispose of and it can cause pollution to the environment (Willing, 2001). The most worrying issue is the limited resource of mineral oil. As the solution to this problem, vegetable oils-based lubricant was produced. Vegetable oils as lubricants liked palm oils were used because of their biodegradability and good properties for lubricants. Besides

that, waste cooking oil also shares the same properties as vegetable oil and its advantages are it can reduce the waste cooking oil from being thrown away without any benefits.

There are two essential methodologies for managing environmental safety concerning two lubricants. The first to discover approaches to kill the transfer of oils into the earth. The second is to utilize the ecologically safe item in condition delicate, for example, agribusiness, ranger service, districts, mining, marine, and so forth. (Kumar, 2012)

'polyol' is an oligomeric backbone having two or more hydroxyl groups (Sonenshein, 2011). This material typically used to manufacture polyurethane. since this material can be synthesized from vegetable oil, it is believing this material still possess lubrication properties of vegetable oil. Therefore, the study on the tribological properties of polyol should be performed.

In this research, the potential of polyol was investigated and evaluated because of the environmental factor of the mineral-based lubricant used.

1.3 Objective

1. To investigate effect of polyol addition to friction and wear properties of hydraulic oil.
2. To investigate effect of polyol addition to physical and chemical properties of hydraulic oil.

1.4 Project Scope

1. To measure viscosity (kinematic viscosity) by using fuel & lube testing heated viscometer according to the ASTM standard test method.
2. To measure the flash point according to the ASTM standard test method.
3. To measure the Acid number according to the ASTM standard test method.
4. Investigating the tribology properties (friction & wear) of polyol by using four-ball testers according to the ASTM D 4172 standard test method.
5. Study the wear mechanism on the worn surface of the ball bearing by using SEM.

CHAPTER 2:

LITERATURE REVIEW

2.1 Introduction of Lubricant

Lubricant is an element used to reduce friction and wear when the two surfaces are contacted. According to (Syahrullail, M.Hariz, Abdul Hamid, & Abu Bakar, 2013) high quality of lubricant must have the characteristics like a maximum of boiling point, small freezing point, good viscosity index, maximum thermal stability, hydraulic stability, prevent the corrosion and good resistance to reduce the oxidation. The lubricant also used to separate the moving parts in a system. So that it will decrease the roughness and surface simultaneously to reduces the heat generation, vibration, and operational sound. Other than that lubricant can reduce the expansion by transferring the heat and can act as a coolant and it also can function like transporting foreign particles. In a commercial lubricant, usually, there are 90% of oil and the other 10% is additives. The additives work as friction and wear modifier, produce stable viscosity, give better viscosity index, avoid corrosion and oxidation, the slow aging process, avoid contaminants, etc. (Jeffrey, 2007).

Lubricants can be divided into few categories such as a liquid, semi-solid, and solid. Solid lubricant is the solid material that acts as a layer that is collected as an organic or inorganic compound such as graphite, molybdenum disulfide, and cadmium disulfide. The next one is semi-solid lubricant which is liquid are blended in a form of thickener and additives, like grease. Petroleum oil, vegetable oil, and synthetic oils are the example of liquid. Each of these has different base oil resources, for example, natural oils that are derived from animal fats and

vegetable oil. Lastly, product reaction is the liquid lubricant that is tailored per requirements such as ester, silicones, and polyalphaolefines (Munack et al., 2001).

2.1.1 Solid Lubricant

In serious administration conditions, for example, high temperature or solidifying, vacuum, radiation, and high burden, strong greases are utilized to control grinding and wear. The advantages of solid lubricants are it has excellent tribology characteristics for metal lubricants but less performance for most inorganic. It can stand high pressure besides good wear preventive characteristics at slow speeds. Solid lubricants can be utilized in any condition to achieve grating and wear under high burden as well as high temperatures (Erdemir et. al., 2000). At sliding surfaces, solid lubricants penance itself to lessen the contact and wear. Solid lubricant properties are shear effectively to decrease contact and to stay away from wear between the two moving surfaces. Examples of inorganic solid lubricants are molybdenum disulfide, graphite, and hexagonal boron nitride. Besides that, a soft metal such as lead, gold, silver, copper, indium, and zinc also used as a solid lubricant.

2.1.2 Semi-Solid Lubricant

Semi-solid lubricant is made of calcium, sodium or lithium cleanser base emulsified with mineral or vegetable oils is known as oil. It is utilized in a high burden place and in a condition where fluid lubricants can't wait. Oils are shear-diminishing which experience a decrease in viscosity under shear Oils are utilized at substantial weights where oil trickle is bothersome and place where reaching surfaces that are irregular and hard to put lubricant oil at it. The advantages of oil are its stick at application place and have great attaching to surface, useful for

slanted/vertical shafts drag out the life of worn parts, give a decent mechanical grease safeguard in extraordinary conditions, for example, stun stacking, turning around tasks, low speeds and high loads next to than diminish commotion and vibration

2.1.3 Liquid Lubricant

Liquid lubricant comprises of a blend of base oil and added substances which are mixed to consistency and it is intended to meet the execution needs of administration. Liquid lubricants are generally composed of 90% of oil and 10% of additives to maximize the performance. The type of lubricant is based on the type of oil, the based oil was produced to give the performance required for lubrication oil. The addition of additives is made to adapt the friction and wear, to get better viscosity, good quality viscosity index, to prevent the corrosion and reduce the oxidation. The performances of liquid lubricants typically determined by the boiling point and cold point, the good viscosity index, thermal stability, prevent corrosion and resistance to reduce the oxidation (Syahrullail et al., 2013).

Various types of lubricants are produced such as synthetic oil, mineral oil, and vegetable oil. A standout amongst the most significant factors in choosing base oil is the fluid's viscosity at different temperatures. Besides that, the viscosity and coefficient of friction is the important thing to be considered. Nowadays biodegradability being a significant thing to be considered because lubrication oil causes most of the environment problems (Syahrullail et al., 2013).

The mineral oil and synthetic oil are highly toxicity, and biodegradability is low because did not disappear totally after 180 days, These factors will affect the environment and most important are losses to the soil, water, and contaminant that will threat plant, animal and human life (Sallimon et.al, 2010). The strong awareness of environmental and pollution encourage need

of new renewable sources and biodegradable lubricant that are environmentally friendly. For the past century, mineral oil has taken place in lubricant production and nowadays the greenhouse effect causes worries because mineral and synthetic oil are hard to dispose of. Other than that, the mineral oil-based lubricant is discharged into the earth amid use, spills, and transfer which cause the pollution (Schneider, 2006).

2.1.3.1 Mineral Oil

Nowadays, mineral base oils are chemical substances prepared from crude petroleum oil by using chemically process. This is endangered the environment because petroleum oil is not environmentally friendly, non-biodegradable and it also toxicity.

Mineral-based oil which is derived from crude petroleum is has been widely used. Nevertheless, since there are issues on the environmental effect of mineral oil such as the contamination of soil and water from the event of spillage will result from a serious catastrophic disaster on the environment due to the presence of non-biodegradable lubricants. Most of the current lubricant is mineral based which is harmful to the earth and hard to dispose of (Petran et al., 2008).

Mineral-based oil can offer focal points, for example, better solvency with additives, an improved similarity with seals, and lower cost. The mineral oils also operate at high operating temperatures and low operating temperatures. There are other potential advantages, such as better energy consumption due to better heat dissipation, strong oil film, prolong lifetime of equipment, more viscous viscosity index and in some mineral oil, it can resist fire. The disadvantages of these products are due to poor oxidation stability, high pour point, and non-biodegradable resources.

Mineral-based oil as a liquid can be arranged into three kinds which are paraffinic, naphthenic and aromatic. The paraffinic oil that can be created through either hydrocracking or dissolvable extraction process (Kroschwitz et. Al., 2004). It also possesses a high boiling point, lower pour point, relatively viscous and the most important are resistant to oxidation (Kroschwitz et. Al., 2004). Besides that, the hydrocarbon molecules in paraffinic oils contain long-chain structure. The naphthenic oil was distillate from crude oil and the properties are differing from paraffinic oil which has poor in oxidation, lower pour point, lower flash point and lower viscosity (Barnes et. Al, 2001).

The other products that can be made are aromatic oil that is used as adhesive, seal compounds and others. This oil can be made through process refining the mineral oil, the Properties of this oil are the same as paraffinic oil from which has a high boiling point and the molecules of aromatic are no saturated ring structure and dark in color. Furthermore, mineral oil base stocks have bad debris such as Sulphur, metal contaminant and carbon leftover which affect the performance and shorten the life of the lubricant oils. Table 2.1 below shows the characteristic of mineral oil product and Figure 2.5.1 show the structure of the mineral oil known as chemical form.

Table 2 1: The Characteristic of Mineral Oil Product (Petran et al., 2008)

Naphthenic	**Aromatic**	**Paraffinic**
Moderately good aging behavior	Poor stability	good oxidation stability
Good pour point	Varied pour point	Good pour point
Low viscosity	Lowest viscosity index	High viscosity index

Low volatility (high flash point)	Varied volatility	Low volatility (high boiling point)
High specific gravities	High specific gravities	Lower specific gravities
Outstanding solubility	Excellent solvency	Poor solvency

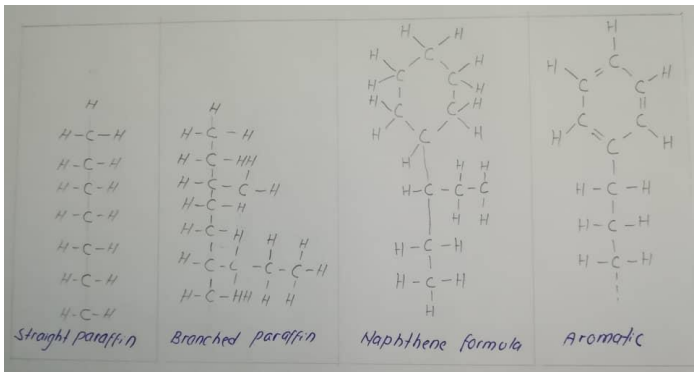

Figure 2 1: Mineral Oil Chemical structure.

2.1.3.2 Synthetic Oil

Synthetic based oil is made by blending low molecular weight materials using compound response into higher molecular weight materials. Commonly synthetic-based oil has numerous good properties that add to their quickly developing use for an assortment of modern applications. They have a low pour point, low instability, hydrolytic strength, and great common lubricity. Most synthetic-based lubricants are blended with additives but, some synthetics require newly developed additives. Many kinds of synthetic-based oils used to deliver synthetic oils with favorable circumstances over regular mineral oil-based items, for example, low pour point, low instability, low danger, high viscosity list, high oxidation soundness, high glimmer, and flame focuses (Syahrullail et al., 2013)

There are many types of synthetic oil such as polyalphaolefines (PAO), polyglycols (PAG), ester oil, silicones, etc. PAO's biochemical structure and belongings are used widely in

nowadays lubrication production. Polyalphaolefines are formulated by polymerization of hydrocarbon molecules (alphaoleins). Polyalphaolefines are commonly used as fully synthetic and as a blend with mineral oils. The procedure happens in the response of ethylene gas within the sight of a metallic impetus. Polyalphaolefines or PAO are recommended to use in automotive gear lubricant, automotive hydraulic and transmission fluids. Figure 2.2 shows the structure of polyalphaolefines (PAO).

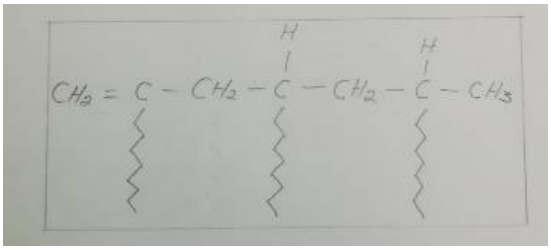

Figure 2 2: Structure of Polyalphaolefines

2.1.3.3 Vegetable Oil

Vegetable oil can assume a fundamental job to supplant the oil ointment as it has different focal points. The best piece of the vegetable oil are triglycerides which contain three hydroxyl gatherings and a long chain of free unsaturated fats that connected at the hydroxyl bunch by the ester linkage acids (Erhan, Sharma, & Perez, 2006). These triglycerides will give the high quality of the oil movie that interfaces straightforwardly with the metallic surface and decreases contact and wears. The solid intermolecular response will give a versatile to the vegetable oil to change in temperature and give increasingly stable thickness.

Vegetable oil from feedstock, rapeseed and soybean oils is most usually utilized. Soybean oil alone representing around 90% of all fuel stocks which can be gotten from field pennycress and Jatropha different harvests, for example, mustard, flax, sunflower, canola, palm oil, hemp, and Jatropha. The good side of using vegetable-based oils, it does not overburden the environment with emissions, less energy use in production and simpler processing technology.