UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION OF WEAR BEHAVIOUR BY DIFFERENT NANOPARTICLES IN CONVENTIONAL OIL ON THE BALL BEARING TESTED USING EXTREME PRESSURE

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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APPROVAL

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

DR. MUHAMMAD ILMAN HAKIMI CHUA BIN ABDULLAH

(Project Supervisor)

ABSTRAK

Nanopartikel telah dikaji sebagai bahan tambahan kepada minyak pelincir bagi meningkatkan ciri-ciri tribologi minyak pelincir sekaligus mengurangkan geseran dan haus. Haus ialah proses kemerosotan atau penyingkiran bahan diantara dua permukaan disebabkan gelongsoran atau kesan gulingan. Bagaimanapun, haus tidak boleh disingkirkan tetapi hanya boleh dikurangkan dengan menggunakan minyak pelincir. Pada waktu sekarang, keupayaan pelincir tidak boleh bertahan dalam tekanan tinggi. Oleh itu, penggunaan nanopartikel baru sebagai bahan tambahan untuk mengurangkan haus dan meningkatkan kecekapan minyak enjin adalah diperlukan. Tujuan kajian ini adalah untuk menentukan beban maksimum nanopartikel sebelum kerosakan berlaku menggunakan *Four Ball Tester Method* berdasarkan ASTM D2783 dan untuk mengkaji jenis haus dan mekanisma yang berlaku pada permukaan bola galas menggunakan mikroskop/SEM. Tiga jenis nanopartikel yang akan digunakan dalam ujikaji ialah *Graphite, Alumina* (Al_2O_3) *dan Zirconia* (ZrO_2). Sampel minyak diuji menggunakan *Four Ball Tester* berdasarkan ASTM D2783 untuk pengukuran sifat-sifat tekanan melincir fluida (kaedah empat bola) untuk pelincir. Kemudian, minyak dan bahan aditif dicampurkan bersama menggunakan *ultrasonic homogenizer* dan dimasukkan dalam *Four Ball Tester* untuk mengukur mekanisma haus pada tekanan lampau; kelakuan geseran dan aplikasi logam gelangsar dengan mencegah sifat-sifat pelincir. Kemudian mekanisma haus terhasil pada bola galas dianalisis menggunakan SEM. Hasilnya menunjukkan dengan penambahan nanopartikel Alumina dan Zirkonia dalam minyak enjin telah meningkatkan keupayaan minyak dan mampu bertahan pada tekanan lampau. Nanopartikel Grafit memberikan pekali geseran lebih rendah berbanding nanopartikel Zirkonia dan Alumina. Oleh itu, nano-oil boleh memberikan prestasi lebih baik terutamanya berada di bawah tekanan lampau.

ABSTRACT

Nanoparticles have been studied as an additive in lubrication oils for improves the tribological properties of lubricant oil to reduce friction and wear. Wear is a process of deterioration or removal material between two surfaces due to sliding or rolling effect. However, wear cannot be eliminated but only can be reduce using a lubricant. Nowadays, lubricant cannot sustain it properties in extreme pressure. Therefore, it is necessary to apply nanoparticles as a new additive in lubricant to reduce wear and improve engine oil efficiency. The purpose of this study is to determine the maximum load of nanoparticle before the failure occur using Four Ball Tester Method according to ASTM D2783 and to investigate the wear types and it's mechanism that occur on the ball bearing worn surface using a microscope/SEM. Three types of nanoparticle were used in this experiment are Graphite, Alumina (Al_2O_3) and Zirconia (ZrO_2). The oil sample was tested using four ball testers according to ASTM D2783- Standard Test Method for Measurement of Extreme Pressure for Lubricating Fluids (Four Ball Method). Next, oil and additives mixed together using ultrasonic homogenizer and added in four ball tester to determine wear mechanism in Extreme Pressure (EP) properties; friction behavior and sliding metal application by prevent properties of lubricating fluids. Then, wear mechanism occur on the ball tester was analysis using SEM. The result shows that with the addition of Alumina (Al_2O_3) and Zirconia (ZrO_2) nanoparticle in SN 0W-20 was improved the lubrication properties and sustain at extreme pressure. Graphite nanoparticle shows a lower coefficient of friction compared to Zirconia and Alumina. Thus, nano-oil can give better performance especially when under extreme pressure.

DEDICATION

To my beloved family.

ACKNOWLEDGEMENT

Bismillahirrahmanirrahim.

Alhamdulillah. Thanks to Allah SWT, whom with His willing giving me the opportunity to complete this Final Year Project report. This Final Year Project report was prepared to complete the undergraduate program that leads to the Degree of Bachelor of Mechanical Engineering Technology in Maintenance, University Technical Malaysia Melaka (UTeM).

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Lubricant is one of agent used to reduce friction between two surface contacts moving together. It also functioning as a transportation to remove contaminant and others particle from moving part to prevent the damage becomes worse. The efficiency of machine or engine can be improved by protects them from wear and corrosion by using lubricant (Duzcukoglu et al., 2010; Imran et al., 2013 and Quinchia et al., 2014). There are three type of lubricant form which is solid, semi-solid and liquid. A good lubricant could be reduce friction, good thermal stability, high viscosity index, low freezing point and high boiling point, corrosion retardation and resistance to oxidize. A lubricant can be prevents by rubbing the surfaces to reduces wear.

There are many types of substances that used to lubricate the moving part. The most commonly used are oil, graphite and grease. Grease also functioning as a thickening agent to obtain the part becomes more consistence while oil is used as a lubrication agent to reduce friction. The other type of substances is dry lubrication and gases. Dry lubrication typically include of any lubricant used in solid form, loose powder or sometimes may in bulky solids while gases is usually used in gas bearing is air or any type of gases as long as it not damage the bearings.

1.1 Problem statement

Anti-wear mechanism is the new technologies that have looked many related automotive studies to improve engine performance and efficiency in recent years (Abdullah et al. 2014). Wear and friction between two sliding surfaces can be reducing when engine in started condition by giving a useful lubricants to protect the engine (Abdullah et al. 2013). Calhoun, (2016) also agree that to keep the surface of two metal, lubricant will used to reduce friction and prevent wear. However, current lubricant cannot sustain an extreme load. In addition, new additive was applied in nano size particle such as hBN, Al_2O_3 and ZrO_2 to solve the problem. Hence, to maintain the properties of lubricant, researchers and scientist are looking from for environment friendly additives it has an ability to enhance, (Abdullah, 2014).

1.2 Objective

The objectives of this project are:

i. To determine the maximum load of nano-oil before failure occur using ASTM D2783.
ii. To investigate the wear type and it mechanism that occur on the ball bearing worn surface using microscope/ SEM.

1.3 Scope of the project

The present work is to test on the extreme pressure for ball bearing lubricated by nano-oil using ASTM D2783-Standard Test Method for Measurement of Extreme-Pressure properties of Lubricating Fluid (Four-Ball Method) for nano-oil. For this purpose, three types of nanoparticle was used which is Graphite, Alumina (Al_2O_3) and Zirconia (ZrO_2).

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

i. Determining the extreme pressure using ball bearing lubricated with nano-oil using ASTM D2783- Standard Test Method for Measurement of Extreme-Pressure properties of Lubricating Fluid (Four Ball Method) for different type of nanoparticles.
ii. Investigating the wear type and wear mechanism on ball bearing worn surface using microscope or SEM.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

Movements between two contacts surfaces can be improve using lubricant. Lubricant can be classified into three types which are solid lubricant, semi-solid lubricant, liquids and gases. In order to reduce friction, lubricant also helps to reduce wear, prevent corrosion and overheating at movement part. It also helps to prevent the damage caused by abrasion and adhesion as well as uneven expansion of the part or components due to heat. Nowadays, there are wide variety used of lubricant depending upon on the application and requirement. The most commonly used in industry are grease, graphite, oils and etc. According to Duzcukoglu et al. (2010), wear and corrosion can reduce efficiency of machine or engine. Hence, lubricant can help to improve the efficiency by protect from wear and corrosion.

2.1 Background

This chapter focused on previous published literature which has been done by many researchers in the past. It can be as a guideline for report writing and helps to give a better understanding and information about the topic. Main focus of the study is on lubricant performance and the use of Al_2O_3, ZrO_2 and Graphite as additives.

2.1.1 General engine lubricant

Since the Roman era, many liquids including water have been used as lubricants in order to reduce friction, heat and wear occur between mechanical moving parts. Today, lubricant oil most commonly used as lubricant because of its wide range of applications in industry. According to Stachowiak (2005), lubricant not only use as lubricant, it also help to control wear and friction because of the present it complex structure. Typically, lubricant oil consist 95% of base stock and 5% of additives. There are two basic categories of lube oil which are mineral oil and synthetic oil. Mineral oils are sieve naturally from petroleum, or crude oil while synthetic oils are occurring from Polyalphaolefin, which are hydrocarbon-based polyglycols or ester oils.

The most commonly used are mineral oils even there are many types of lube oils to choose from. Crude oil is not expensive; moreover, it already exists for used. Mineral-based oil also can be produced in a wide range of viscosities. The low viscosity oil consist of chains hydrogen-carbon with molecular weights of around 200 atomic mass units (amu), and high viscosity has molecular weights around 1000 amu. Mineral-based oils can be blended together to improve their performance based on its application. For example, 10W-30 of motor oil is a blend of low viscous oil (for easy starting at low temperatures) and highly viscous oil (for better motor performance).

Synthetics oil mostly used at high extreme operating temperatures are encountered or where the lube oil must be fire resistant. Lube oils occur from raw petroleum, which emerges from an oil well as a yellow-to-black, flammable, liquid mixture of thousands of hydrocarbons (only carbon and hydrogen atoms). From 400 million years ago, petroleum deposits were formed by the decomposition of tiny plants and animals that lived about. Due to climatic and geographical changes occurring at that time in the Earth's history, the breakdown of these organisms varied from region to region.

Physical properties of lube oil can be change by add some additives with the refined oil it depending on the application. The common additives improve the lube oil ability to prevent from galling and scoring when the metal surfaces come in contact under extreme high pressures including metals such as lead or metal sulphide. Another common additive is polymeric where they enhance the viscosity index, counteracting the tendency of oils to thin at high temperatures. Nitrosomines will use as antioxidants and anti-corrosion because they neutralize the acids and form thin films on metal surfaces.

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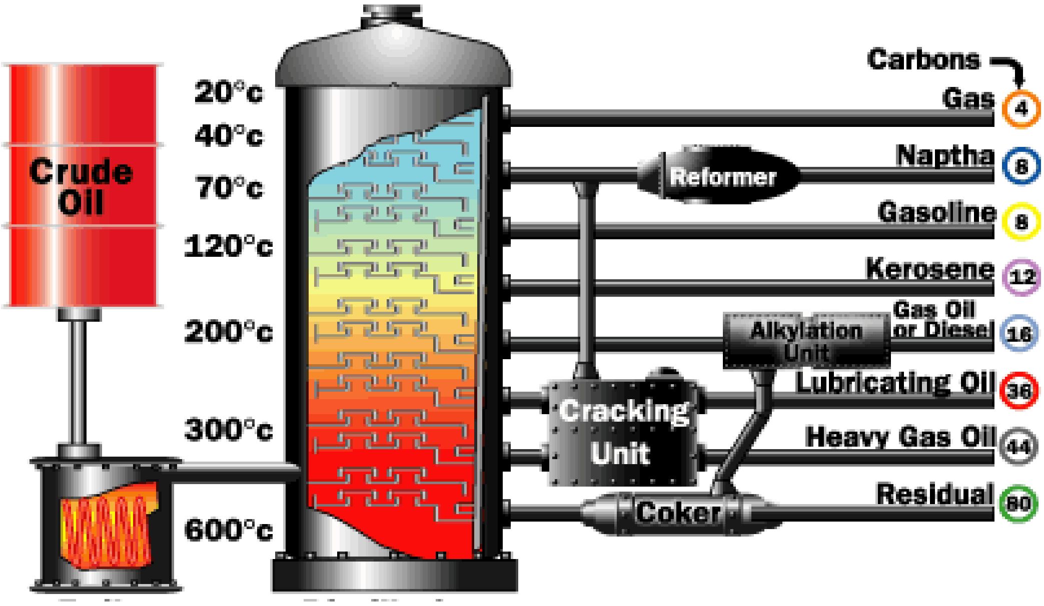


Boiler **Distillation Colum**

(Super-heated steam)

Figure 2.1: Lubricating oil refined from crude oil (source: www.howstuffworks.com)

Raw oil is extract from petroleum or crude oil, which passing a sedimentation process before it is transfer into fractionating towers. A fractionating tower has been constructed from high grade steels to resist the corrosive compounds present in crude oils; inside, fit with an ascending series of condensate collecting trays. Fractional distillation is process where hydrocarbons in crude oil are separated from each other through the tower. Their respective boiling points can be determine when the vapours rise up through the tower, the various fractions cool, condense, and return to liquid form at different rates. First liquid reach its boiling point is natural gas, followed by gasoline, kerosene, fuel oil, lubricants, and lastly tars. These fraction obtained by ascending order based on their boiling points (Stachowiak, 2005).

Next, the crude oil will through sedimentation process. In this process, the crude oil is transfer to the refinery by pipeline or tanker ship. At this phase, any water and solid contaminants, will removed before the crude oil is pumped into large holding tanks, where the water and oil are allowed to separate and the contaminants remove from the oil. After that, the crude oil is heated up to 700 degrees Fahrenheit to breakdown into a mixture of hot vapour and pumped into the bottom of the first of two fractionating towers. At this phase, hot hydrocarbon vapours will float upward and start to condense and different trays installed at different levels in the tower will collect in. Continuously a normal atmospheric pressure is maintained about 80 percent of the crude oil is vaporizes while the remaining 20 percent of the oil heated again and pumped into a second tower, wherein to made it vaporize at a lower temperature by lower the residual oil's boiling point of vacuum pressure. Compounds with higher boiling points, such as tar and the inorganic compounds, remain behind for next process.

The lube oil that has been collected in the two fractionating towers is passed through several ultrafine filters after the unwanted compounds removed. Contaminant such aromatics, contain six-carbon rings would affect the oil viscosity if they weren't removed in a process called solvent extraction. This is because aromatics are soluble in the solvent than the lube oil. The aromatics dissolve when the lube oil is treated with the solvent. The aromatics can be recovered if the solvent remove. Aromatic compound rapidly oxidize because it is anti-oxidants, hence an over-refined oil (Stachowiak, 2005).

Finally, oil is mixed with an additive to give it the desired physical properties such as the ability to survive at low temperatures. At this point, the lube oil is going through a quality control tests that assess its viscosity, specific gravity, colour, flash, and fire points. If the oil is passes the quality standards then it can be packaged for sale and distribution.

2.2 Lubricant

Engine performance can be maintain by adequate the lubrication. Lubricant helps to reduce wear, friction, clean the internal component, enhance compression, keep engine cool and form a tight seal between piston and cylinder wall. If metal-to-metal contact can be preventing, friction, wear and heat can be reducing greatly.

2.2.1 Types of lubricant

There are many type of lubricant used in industry. For example; base oil, synthetic oil, solid lubricant, aqueous lubricant, and bio lubricant. Base oil is derives from crude oil. Synthetic oil is derived from synthetic hydrocarbons include of PAO, phosphate esters, silicate esters, ionic fluids, polyalkylene glycols (PAG), synthetic esters and multiply alkylated cyclopentanes. However, solid lubricant is dry lubricant such as grease or oils include of PTFE, inorganic solids (graphite, boron, molybdenum disulfide, tungsten disulfide), and metal/alloy. Bio lubricant is derived from vegetable oils and other renewable source. According to Chandrakar (2014), bio lubricant has a potential to be new renewable oil in future.

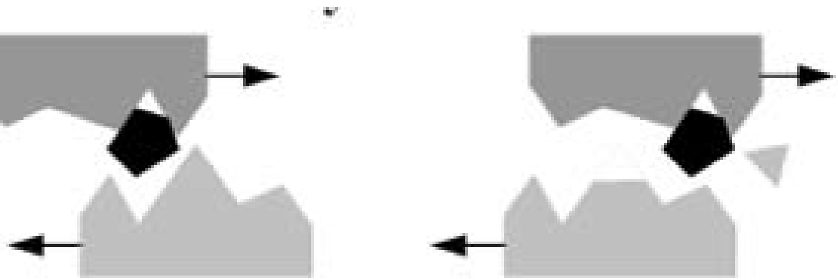
2.2.1.1 Solid Lubricant

Solid lubricant or dry lubricant mostly used as additive in oils or grease because of its high-performance of anti-seize pastes and anti-frictions. The most common additive used is graphite, molybdenum disulfide, boron nitride, and Polytetrafluoroethylene (PTFE). It may be in present of dispersed particle forms or surface films. Solid lubricant will applied by coating part surface, powder forms used by rubbing the part surface and as an additives in grease or lubricating oils. Solid lubricant has low shear strength in sliding direction, high compression strength and good in adhesion to substrate surface. Solid lubricant can work under high loads, has thermal stability and diverse the applications form. According to Schraf (2013), friction coefficient will decrease with increasing of contact stress.

Sliding direction

(a)

Sliding direction



(b)

Figure 2.2 shows type of abrasion wear (a) two body contact (b) three body contact (source: www.subtech.com)

2.2.1.1.1 Graphite

Graphite comes from Greek word *graphein* means to write. It has structure composed by hexagonal layers arranged by carbon atoms; within layers which is each carbon atom bonded to three coplanar neighbor atoms by strong covalent bonds. Each bonding has difference distance of carbon atoms between planes is longer or weaker. The weaker bonding electron called as *Van Der Waals*. Graphite contains of carbonaceous material that form by metamorphosis of sediments by reaction between hydrothermal and carbon compound.

Graphite structure

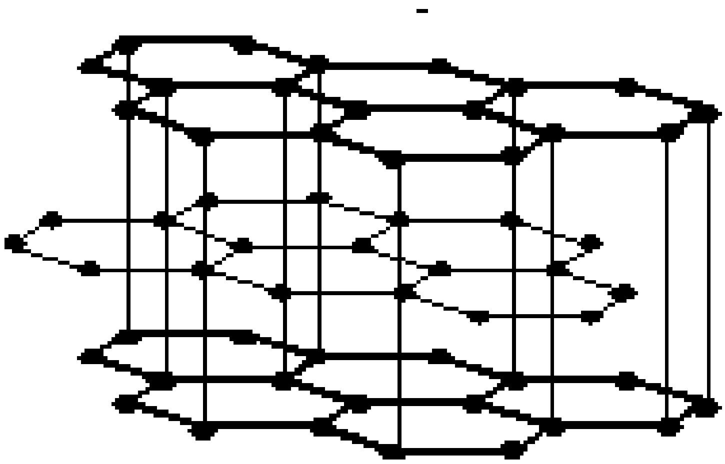


Figure 2.3: The structure of crystalline graphite (source: www.encyclopedia.com)

Graphite is best lubrication used as additive. The bonding energy between hexagonal planes is at lower level than adhesion can be reducing by adsorption of water. However, graphite is not suitable in vacuum even water vapor is required for lubrication. It can be classified into two main groups; synthetic and natural. Natural graphite is occurred from mining process. It is contain of carbon, sulfur, SiO_2 and Ash. Moreover, it has high carbon content and degree of graphitization; it also has a good resistance and better lubricity to oxidize. Synthetic graphite has high purity of carbon and high temperature for sintered product. Hence, it has good lubricity of natural graphite. Hwang et al. synthesized that graphite can be used as additive to improve friction-reducing and anti-wear properties of pure oil using disc-on-disc tribotester.

2.2.1.1.2 Molybdenum Disulfide

Molybdenum Disulfide (MoS_2) also known as mineral molybdenite and found in the thin veins within granite and highly refined in order to achieve suitable purity for lubricants. MoS_2 has a hexagonal crystal structure like graphite with the intrinsic property of easy shear. The performance often exceeds than graphite and is effective in vacuum as well whereas graphite does not. Temperature of MoS_2 can be exceeding until 400ºC restricted by oxidation. There are important parameter should be take care which is particle size and film thickness should be matched to the surface roughness of the substrate. According to Stachowiak (2005), MoS_2 has strong chemical bonds between atoms form planes of high strength while it bonding relatively weak at normal direction because the atoms are far apart. Large particles can cause excessive wear by abrasion caused by impurities in the MoS_2, while small particles can make accelerated oxidation. However, MoS_2 is more efficient compound to reduce friction although it not soluble in organic media and only used in form of fine dispersions (Rastogi and Yadav, 2002).

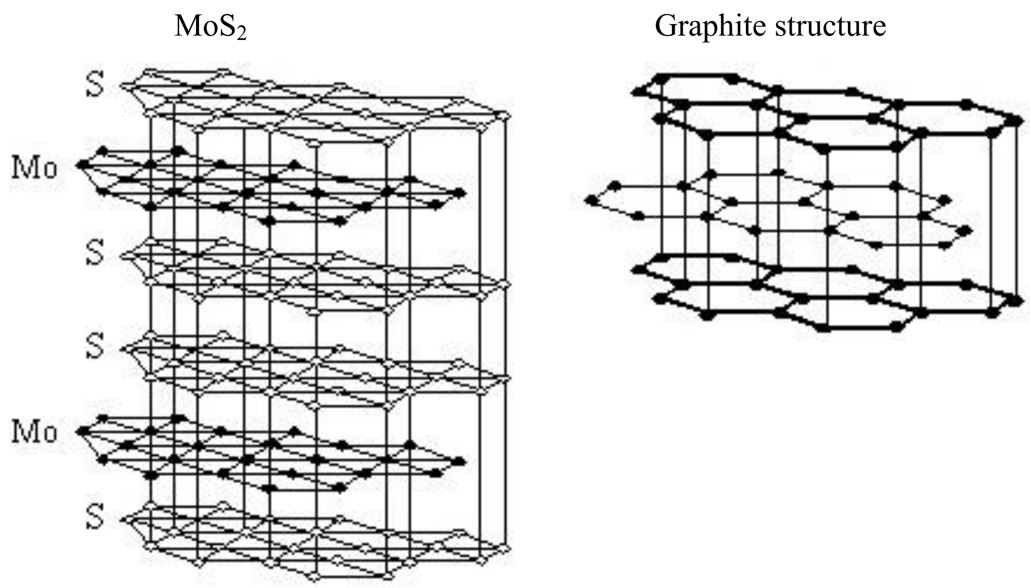


Figure 2.4: MoS_2 crystalline structure (source: www.ktzmy-us.com)

2.2.1.1.3 Boron Nitride

Hexagonal Boron Nitride (hBN) is white in colour and has a similar with graphite lamellar structure which is black, but considered as less effective than other solid lubricants except for high-temperature applications. For hBN lamellar structures, the bonding between layers is determined by weak van der Waals forces while the bonding among the molecules within each layer is covalent. The measured lattice parameters, density for graphite (2.290 g/cm3 for h-BN and 2.265 g/cm3) and Mohs hardness for graphite is (1.65–1.78 for h-BN and 1.85–1.95), are very close to graphite; however, the compositions of Cu-based friction are different. According to