UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION OF WEAR MECHANISM ON THE BALL BEARING TESTED BY NANO-OIL USING EXTREME PRESSURE METHOD

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology Bachelor of 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 fulfillment 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:

…………………………………

(DR. MUHAMMAD ILMAN HAKIMI CHUA BIN ABDULLAH)

ABSTRAK

Nano-teknologi kini telah memainkan peranan yang penting dalam mengurangkan haus dalam enjin dengan menggunakan bahan tambahan dalam minyak enjin. Hexagonal boron nitrida (hBN), alumina (Al_2O_3) dan grafit telah digunakan sebagai bahan tambahan dalam kajian ini. Oleh itu, kajian ini memberi tumpuan kepada penyiasatan mekanisme haus pada galas bola diuji oleh minyak nano menggunakan tekanan yang melampau. Hal ini disebabakan prestasi enjin menurun kerana kehadiran haus di bahagian enjin seperti cincin omboh. Tujuan kajian ini adalah untuk menentukan muatan maksimum minyak nano sebelum kegagalan berlaku menggunakan ASTM D2783. Beberapa ujian telah dijalankan melalui tekanan lampau untuk galas bola dilincirkan oleh minyak nano. Ujian ini telah dijalankan mengikut standard ujian kaedah untuk pengukuran sifat tekanan melampau minyak pelincir (kaedah empat bola), ASTM D2783. Objektif kedua kajian ini adalah untuk menyiasat mekanisma haus yang berlaku pada galas bola permukaan dipakai. Mekanisma haus yang berlaku pada galas bola akan dikaji dengan menggunakan mikroskop atau mikroskop pengimbasan elektron (SEM). Hasil kajian menunjukkan bahawa dengan tambahan hBN, Al_2O_3 dan grafit nanopartikel dalam SAE 15w40 telah meningkatkan keupayaan menanggung beban minyak pelincir. Grafit nanoparticle memberikan COF lebih rendah berbanding dengan yang lain. Sementara itu, hBN menunjukkan yang baik dalam anti-haus tambahan dengan memberikan kadar haus kecil berbanding nanopartikel lain. Oleh itu, minyak mampu memberikan prestasi yang lebih baik terutamanya apabila berada di bawah tekanan yang melampau.

ABSTRACT

Nano-technology currently has plays an important role in reducing engine wear by using an additive in the engine oil. Hexagonal boron nitride (hBN), alumina (Al_2O_3) and graphite were used as additive in this study. Thus, this study focuses on investigation of wear mechanism on the ball bearing tested by nano-oil using extreme pressure. This is due to the performance of an engine is declining because of the presence of wear in the engine part like piston ring. The purpose of this study is to determine the maximum loading of nano-oil before failure occur using ASTM D2783. A several testing were conduct on the extreme pressure for ball bearing lubricated by nano-oil. This testing was followed according to ASTM D2783-Standard Test Method for Measurement of Extreme-Pressure properties of Lubricating Fluid (Four-Ball Method) for nano-oil. Another objective of this study is to investigate wear mechanism that occurs on the ball bearing worn surface. The wear mechanism that occurs on the ball bearing was investigated by using microscope or scanning electron microscope (SEM). The result show that with the addition of hBN, Al_2O_3 and graphite nanoparticle in SAE 15w40 was improved the load-carrying ability of lubricating oil. Graphite nanoparticle give lower COF compared to other. Meanwhile, hBN shows a good in anti-wear additive by giving smaller wear rate compare to another nanoparticle. Thus, the nano-oil can give better performance especially when in extreme pressure.

DEDICATION

To my beloved parents and siblings.

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Alhamdulillah, all thanks should be praise to Allah as He help and ease me so much to complete this project successfully. This research project won't be complete without people surrounding me who give support and help.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AC	-	Alternating Current
Al_2O_3	-	Alumina
API	-	American Petroleum Institute
ASTM	-	American Society for Testing and Materials
BAuA	-	Brazilian American United Association
BSI	-	British Standards Institution
Co	-	Carbon Monoxide
COF	-	Coefficient of Friction
cSt	-	centistokes
Cu	-	Copper
CuO	-	Copper Oxide
EP	-	Extreme Pressure
Fe	-	Iron
hBN	-	Hexagonal Boron Nitride
IL	-	Ionic Liquid
ISL	-	Initial Seizure Load
ISO	-	International Standardization Organization
LWI	-	Load-wear Index
m	-	mass
MACs	-	multialkylated cyclopentanes
NIOSH	-	National Institute for Occupational Safety and Health
PAO	-	Polyalphaolefins
PIB	-	Polyisobutanes
R&D	-	Research and Development
Rpm	-	Revolution per Minute
SAE	-	Society of Automotive Engineers

SCCP	-	Signalling Connection Control Part
SEM	-	Scanning Electron Microscope
SiO_2	-	Silicon Dioxide
Sn	-	Tin
TiO_2	-	Titanium Dioxide
v	-	Volume
WL	-	Weld Load
WP	-	Wear Preventive
WSD	-	Wear Scar Diameter
$ZnAl_2O_4$	-	Zinc Aluminate
ZnO	-	Zinc Oxide
ZrO_2	-	Zirconium Dioxide
ρ	-	Density

CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, the lubricant is widely used in most moveable component and all machinery. Lubricant is used because it has the ability to reduce the friction between two surfaces or reduce metal to metal contact. Furthermore, lubricant also has the ability to protect the component in the machine from wear and corrosion. As a result, the efficiency of the machine or engine will improve hence prolong their life (Duzcukoglu and Sahin, 2010; Imran et al., 2013; Quinchia et al., 2014). A good quality of the lubricant contributes to the performance of the engine. This is because a good quality of lubricant will protect the parts of the engine.

The research fields nowadays have been attracted in nanotechnology because of their special chemical and physical properties (Imran et al. 2013). Therefore, nano-additive has been explored in order to create a nano-lubricant. Ming et al. (2009) was used Cu nanoparticle as oil additive in his study. The anti-wear, load-carrying and friction reduction performance of SJ 15W/40 has been improved by the Cu nanoparticle. The load applied on the SJ is about 400N, shows that about 90 per cent of wear being reduced by SJ containing 0.5 wt% Cu nanoparticle. Meanwhile, Cu nanoparticle in the SJ increase the load-carrying performance from 500 to 700 N. Furthermore, the SJ contains 0.5 wt% Cu nanoparticle has lower friction coefficient and more stable compare than SJ.

The tribological effect of the metal oxide composite nanoparticle, nano-carbon materials and boron-based nanoparticle additives in oil or grease lubricants has been studied. ZrO_2 and SiO_2 composite nanoparticle was used as additive in lubricating oil by Li et al. (2011). The nanoparticle is used because to identify the lubricating properties with this addition of nanoparticle. Furthermore, Berman et al. (2014) and Joly-Pottuz et al. (2008) use graphene in their studies. This graphene shows anti-wear and friction properties. However, the evaluation of tribological properties of graphene has only a few number are devoted to it. The load-carrying capacity has been improved by used tri(hydroxymethyl)propane esters containing boron and nitrogen as lubricant additives in rapeseed oil (RO). However, when high load condition, this additive cannot provide a good friction-reducing effect.

Furthermore, several studies were carried about friction and anti-wear properties of the metal oxide composite nanoparticle, nano-carbon materials and boron-based nanoparticle additives in oil or grease lubricants have been observed. However, these type of nanoparticle additive has limited studies on the extreme pressure (EP) properties. Therefore, the extreme pressure properties of hexagonal boron nitride (hBN), alumina (Al_2O_3) and graphite nanoparticles as an additive for diesel engine oil were investigated in this study.

1.2 Problem Statement

The way in improving engine performance and efficiency has been studied in recent years. According to Sahin et.al. (2016) improving the friction and wear behavior of material became an engineering problem. Piston rings, cylinders, bearing and cam lobes are the place where usually wear occur in the engine. However, piston rings of an engine often cause wear (Watson et al. 1955). This happens due to the higher load is applied at the parts of the engine. Thus, will affect the failure of an engine. Shizu and ping (2012), mention that piston/cylinder, swash plates, journal bearings, gears, cams and rolling element bearings are one of the components that are usually affected by abrasive wear. This problem will cause the performance of the engine will drop.

To cater this issue, lubricant was used as a problem solving. Shahnazar et al. (2016), to protect products and tools from wear, lubricant are broadly used in industries unit. Lubricant also maintains product respective surface quality. Calhoun (1960), also agree that to minimize friction and avoiding wear, the lubricant is used as to keep two metal surface wet. In order to protect wear and corrosion on the machine or engine, lubricant was used hence it can improve the efficiency and maximizes machine and engine life (Duzcukoglu and Sahin, 2010). This supported by Farhanah and Bahak (2015), to protect and prolong the engine life is important by use lubricant to lubricate parts in an internal combustion engine. However, the current lubricant cannot sustain an extreme load. Therefore, the new additive was applied is nano size particle such as hBN, graphite, and Al_2O_3 to overcome this problem.

1.3 Objective

Based on the problem statement are discussed above, the objectives of this study are listed below:

1. To determine the maximum loading of nano-oil before failure occur using ASTM D2783
2. To investigate wear mechanism that occurs on the ball bearing worn surface.

1.4 Scope

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

1. Testing 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.
2. Investigating the type of wear and wear mechanism on the ball bearing worn surface using microscope/SEM.

CHAPTER 2

LITERATURE REVIEW

2.1 Liquid as a Lubricant

Lubricant is a substance that been introduced between two moving or sliding surface that is to reduce the friction between each other. According to Calhoun (1960), the main function of the lubricant is to keep two metal surface wet. Thus, the friction and wear on the metal can be minimized. The other function of the lubricant is to reduce expansion of metal due to frictional heat and destruction of material. Furthermore, unsmooth relative motion can be avoided by the lubricant. Thus, maintenance cost will be reduced. Lubricant can be classified into three group which is a solid lubricant, semi-solid lubricant, and liquid lubricant.

Any solid material that reduced friction and mechanical interaction between surfaces in relative motion against the action of a load is considered as a solid lubricant (Rudnick, 2009). The solid lubricant is used either in dry powder or with binders to make them stick firmly to the metal surface while in use. The other class of lubricant is a semi-solid lubricant. According to the Darbyshire (2007), combination lubricating oil with thickening agents is termed as grease known as a semi-solid lubricant. Lastly, the group of lubricant is a liquid lubricant. The liquid lubricant also is known as lubricating oil. The liquid lubricant has the ability to absorb heat and operating temperature can be minimized (Bruce, 2012). A liquid lubricant can be categorized into three group which is mineral oil, synthetic oil, and vegetable oil.

2.1.1 Mineral Oil

Mineral oils are one of the lubricants that are usually used. Crude oil which is mined in various parts of the world is the source of mineral oil. Nowadays, synthetic oils, solid lubricants, and wear resistant polymers show the rapid development compare to the mineral oils. However, mineral oil still being used in many industries because of mineral oil cost is low compared to other. Furthermore, the origins of mineral oils are the fossil fuel theory which is the hypothesis accepted generally. From that theory, decomposition of animal and plant matter in salt water is the origin of mineral oils. The river that dumped silt into the sea is the place that contains dead plant and animal. They were collected by using the sedimentary basin. The dead animal and plant was buried and compressed for very long time. Kerogen is like tar molecule. Organic matter will transform into tar-like molecule under this condition. The kerogen will be transformed into the complex hydrocarbon as the temperature and pressure increase. This is a basic constituent of crude oil.

From the analysis, crude oil contains about 125 different compounds. However, only 45 compounds are being analyzed in detail (Kimura and Okabe, 1982). The mineral oil contains three basic chemical form which is paraffinic, naphthenic and aromatic. Figure 2.1 show the paraffinic structure. They contain straight and branched paraffinic. The process of hydrocracking or solvent extraction will form paraffinic oils. Structure for most hydrocarbon molecules has non-ring long-structure. Furthermore, paraffinic oil is relatively viscous and also it is resistant to oxidation. The pour point and flash point of paraffinic oil also high. Thus, paraffinic oil is being used in an industrial lubricant, manufacturing engine oils and processing oils in textile, rubber, and paper industries.

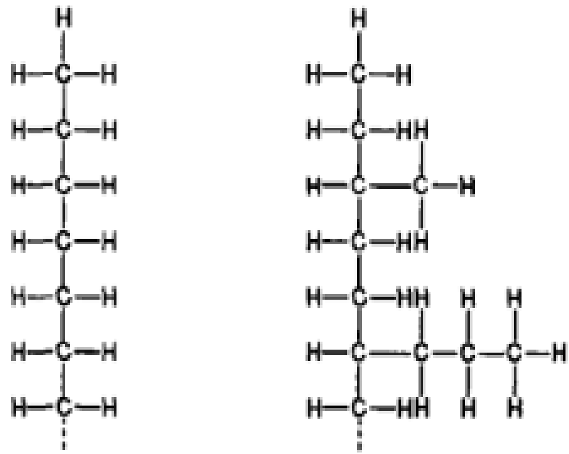

Figure 2.1: Structure of paraffinic (Stachowiak & Batchelor, 1993)

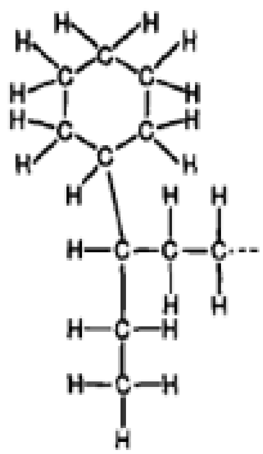

Figure 2.2: Structure of naphthenic (Stachowiak & Batchelor, 1993)

The other type of mineral oils is naphthenic oils. Figure 2.2 shows the naphthenic structure. The naphthenic oil being produced from the distillation of crude oil. The naphthenic oils have a saturated ring structure. The naphthenic oils have a low in pour point, flash point, viscosity and also low resistance to oxidation. Thus, it being used in metal working fluids, moderate temperature application and mainly for manufacturing. The last type of mineral oil is aromatic oil. The process of refining in the manufacture of paraffinic oils will produce aromatic oils. From Figure 2.3 shows how is the aromatic structure. The structure of aromatic oil is non-saturated ring structure. Aromatic oil is dark and its flash point is higher. Thus, aromatic oil is used for adhesives, manufacturing seal compounds and as plasticizers in asphalt and rubber production.

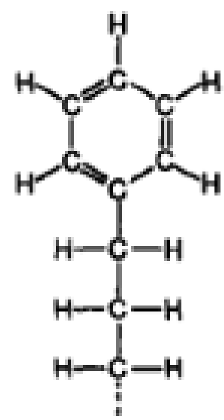

Figure 2.3: Structure of aromatic (Stachowiak & Batchelor, 1993)

2.1.2 Polyalphaolefins (PAO)

There are a lot of types of synthetic base oil. Nowadays, the famous synthetics base oil is polyalphaolefins (PAO). PAO is the polymer that been stabilize because of it create by polymerization of higher olefins like decane, C_{10} then followed by hydrogen to remove the double bond. According to the Hodges (1996), PAO has high viscosity index and low-temperature flow properties because of the isoparaffinic structure. Furthermore, an excellent oxidation stability and the addition of oxidation inhibitors is respond by PAO. This can be achieved by choosing the suitable additive. In certain aviation application like military specification MIL-H-83282 is used polyalphaolefin base oil as suitable materials for the formulation of fire-resistant hydraulic fluids. The critical systems on the sub-sea oil installations also used specialized polyalphaolefin-based hydraulic fluids.