FRICTIONAL BEHAVIOR OF SK11 IN ENGINE OIL AND NANOPARTICLES-ENHANCED ENGINE OIL

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this report entitled “Frictional Behavior of SK11 in Engine Oil and Nanoparticles-Enhanced Engine Oil” is the result of my own research except as cited in the references.

Signature : ……………………………..

Name : ……………………………..

Date : ……………………………..

APPROVAL

I hereby declare that I have read this report entitled and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Automotive).

Signature	:	……………………………..
Name of Supervisor	:	……………………………..
Date	:	……………………………..

DEDICATION

This final report is dedicated to my loving parents who are the most amazing people that could not be replaced with any other things. To my father, thank you for being the man that you are, for being my pillar of strength and fountain of wisdom. To my mother, thank you for teaching me the true meaning of hard work and shows me that I have to give it my all if I want to succeed. To both of you, thank you for endlessly showering me with your support, guidance and love ever since I was born until forever. Truly, words can never express the gratitude that I have and I thank Allah for giving me such a great gift in my life; which is both of you.

ABSTRACT

This final report describes the purpose of the study which to investigate the frictional behavior of SK11 ball bearing in lubricating oil. The frictional behavior was investigated using Four-ball Tester according to the standard test ASTM D4172 as reference. The ball bearings were immersed in two different lubricant condition; engine oil and nanoparticle-enhanced engine oil. Each tests were conducted under varying load and speed, with 100, 300, 500 N and 100, 300, 500 rpm respectively. The tests were undergone under different temperatures which are 27, 50, and 100˚C and the running time was approximately 60 minutes. The investigation was carried under different parameters in order to study which lubricant conditions give significant effects to frictional behavior of SK11 ball bearing and to see the effectiveness of additives when parameters were varied. The nano oil was prepared by dispersing a mixture of approximately composition 0.5 vol.% of 70nm hexagonal boron nitride, hBn with SAE 15W-40 engine oil as base oil. The mixing method used was sonication technique. Based on the results obtained, the varied parameters are compared in term of coefficient of friction and it was then analyzed to see which lubricant conditions possess a better value in coefficient of friction.

ABSTRAK

Laporan akhir ini menerangkan tujuan kajian yang dijalankan untuk menyiasat kelakuan geseran bola *bearing* SK11 dalam minyak pelincir. Kelakuan geseran disiasat menggunakan kaedah *Four-ball Tester* mengikut standard pengujian ASTM D4172 sebagai rujukan. Bola *bearing* telah diletakkan di dalam dua keadaan pelincir yang berbeza; minyak enjin dan minyak enjin yang dipertingkatkan dengan partikel nano. Setiap ujian telah dijalankan di bawah beban dan kelajuan yang berbeza dengan 100, 300, 500 N dan 100, 300, 500 rpm mewakili nilai masing-masing. Sesi pengujian juga dijalankan di bawah suhu yang berbeza iaitu 27, 50, dan 100˚C dan tempoh pengujian dijalankan adalah kira-kira 60 minit. Siasatan telah dijalankan di bawah parameter yang berbeza untuk mengkaji keadaan pelincir yang mana memberi kesan yang penting kepada tingkah laku geseran bola *bearing* SK11 dan untuk melihat keberkesanan bahan tambahan apabila parameter berubah-ubah. Minyak nano telah disediakan melalui campuran kira-kira 0.5 vol.% 70nm komposisi heksagonal boron nitrida, hBN dengan minyak enjin SAE 15W-40 sebagai minyak asas. Kaedah pencampuran yang digunakan adalah melalui teknik *sonication*. Berdasarkan keputusan yang diperolehi, parameter yang berubah-ubah dibandingkan dari segi pekali geseran dan kemudianya dianalisis untuk melihat kondisi pelinciran mana menghasilkan nilai yang lebih baik untuk pekali geseran.

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Praise to Allah SWT the Most Merciful and the Most Gracious; I have successfully completed my research for my final year project. Throughout the completion process, I have taken efforts; however, the preparation of this Final Report would not have been completed without the support, hard work and endless efforts of a large number of individuals and institutions. Therefore, I would like to take this opportunity to express my deepest gratitude and special thanks to all those people who gave me the possibility to complete this report successfully.

First of all, I would like to thank to my family for their never ending support. Besides that, I also would like to extend my thankfulness to my Supervisor; Associate Professor Dr Mohd Fadzli bin Abdollah for the reprimand, guidance and constant supervision during my practice, as well as for providing necessary information in completing this Technical report. And not to forget to my panels, thank you for giving such bold comments and constructive criticisms.

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Thank you.

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ρ	-	density	(kg/m^3)
m	-	mass	(kg)
ν	-	volume	(m^3)
μ	-	coefficient of friction	
T	-	frictional torque	(kg.mm)
W	-	normal load applied	(kg)
r	-	rotation radius from rotation axis	(mm)

LIST OF ABBREVIATIONS

COF	Coefficient of Friction
hBN	Hexagonal Boron Nitride
EP	Extreme Pressure
AW	Anti Wear
ICE	Internal Combustion Engine
PTFE	Polytetrafluorethylene

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Lubrication is one of the powerful process or technique to reduce wear on surfaces in close proximity, and moving relative to each another. Besides, it also can act as a cleaning agent and transport debris away from interface, other than provides cooling for a system. Lubricant is essential to lubricate the machine component to reduce friction, wear, and seizure of the bearings. Nowadays, there are different types of substances that can be used to lubricate two contacting surfaces, which normally can be found in machine components. Oil and grease are the most common. Oils can be synthetic, vegetable or mineral-based as well as combination of both of these, while grease is composed of oil and a thickening agent to obtain its consistency.

Ever since in the early developments, friction leads to major issues, one includes it effects to engine performance. Thus, current study conducted is mainly focusing on resolving issues related to engine oil and its effective performance. Reducing friction is a key objective of lubrication. Corrosion prevention is one of lubricating film function as it protects the surface from water and other corrosive substances.

Therefore, study suggested that the usage of engine oil with additive of nanoparticle possessed a better and excellent performance compared to base engine oil. In recent studies, results showed that nano-lubricant is efficient in reducing friction and wear. Besides that, lubricants containing additive are said have significant effects to improve its lubricating properties. In this study, the coefficient of friction (COF) between engine oil and nanoparticles engine oil are to be compared to determine which condition produces low coefficient of friction. Hence, Hexagonal Boron Nitride (hBN) as shown in Figure 1.1 is chosen to be lubricant additive. It comes in powder, which makes it can be dispersed into any oil, grease, or water. Based on (Gao et. al., 2011), hBN possesses unique characteristics; therefore it is suitable as an additive to be dispersed in high temperature lubricant or to be used on high friction contact surface.

Figure 1.1 Hexagonal Boron Nitride (hBN)

(Source: http://www.reade.com/products/boron-nitride-powder-bn-boron-nitride-spray)

1.1 PROBLEM STATEMENT

Since friction effects efficiency and engine performances, the presence of lubricants may reduce the amount of frictional force acting inside the engine. An addition of nanoparticles in engine oil is to be said as one of best way to reduce wear and friction effects thus help to increase efficiency and engine performances.

Based on several studies that have been conducted, it was found out that the percentage of volume concentration affected hBN nanoparticles performance. A lower concentration of nanoparticles helps in reducing of friction coefficient and resistance to wear, plus it exhibited better tribological properties. For this project, two different tests will be carried out in order to study the effect of hBN nanoparticles in engine oil. Comparison is to be made between ball bearings which are immersed in engine oil and nanoparticles-enhanced engine oil. The tests are done to evaluate which test condition provides lower value of friction coefficient.

Therefore, a Four-ball Tester experiment is proposed in order to study the frictional behavior of SK11 in engine oil and additional of nanoparticles in engine oil. The friction coefficient is calculated and needed to be averaged to average the friction coefficient value for all tests.

1.2 OBJECTIVE

i. To compare the coefficient of friction (COF) of SK11 in engine oil and nanoparticles-enhanced engine oil.

1.3 SCOPE OF PROJECT

The scopes of this project are:

i. Conduct an experiment in order to study the effect of nanoparticles as additives. The experiment is carry out by using Four-ball Tester and the ball bearings will be tested under varying speed, load and temperature.

ii. Recording data in data processing system and calculate the average coefficient of friction (COF) for all tested specimens.

iii. Compare experimental results between ball bearings that are immersed in engine oil and nanoparticles as additives in engine oil.

1.4 REPORT LAYOUT

This project was carried out in order to compare frictional behaviour of SK11 ball bearing while being immersed in two different types of lubricants; engine oil and nanoparticles-enhanced engine oil. The method chosen to investigate frictional behaviour was Four-ball Tester and the project layout consists of five chapters, which presented in this report.

Through this report, Chapter 1 can be said as the beginning where this section explains introduction of lubrication, friction, as well as additives and the flow continued to problem statement, objective until it reached scope of project.

While in Chapter 2, this is the section where review of literature related to the project was comprehensively explained and summarized. The findings and information gathered from various sources will be beneficial in order to give a clear view to the project.

As for Chapter 3, it encompasses the method chosen to carry out experimental procedures by using Four-ball Tester. Proceeding to Chapter 4, this section presents complete results obtained from the project. The findings were interpreted and discussed clearly in this section.

Last but not least, the final chapter which a clear and concise conclusion was made. The conclusion summarized the findings of this project and determined the significant of the findings related to the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature review is essential when it comes to writing a research or thesis. For this project, this chapter includes brief explanation on the related published researches, paper works and the studies that have been investigated. On top of that, there are wide ranges of resources and references which can be found not only in a thesis, but in articles, journals, or even text books. Therefore, once all findings and information have been gathered, it was then implemented in this project in order to complete the project with accordance of time given.

2.2 Lubricants

Lubrication is the process or technique employed to reduce wear on surfaces. Lubrication helps in reducing frictional resistance, reduce wear on surfaces as well as reducing noise from the moving component of a machine. Besides that, lubrication helps in carrying excessive heat away from two contacting parts and one of the examples of lubricant is engine oil. Somehow, lubricant may act as ‘cleaning’ agent where it helps to remove debris or particles and additionally produces a seal between two parts to prevent contamination in parts, machines or engines. Despite its purposes in reducing friction, lubricant may influence friction in concentrated contact.

2.2.1. Classifications of Lubrication

There are some classifications of lubrication based on its physical properties.

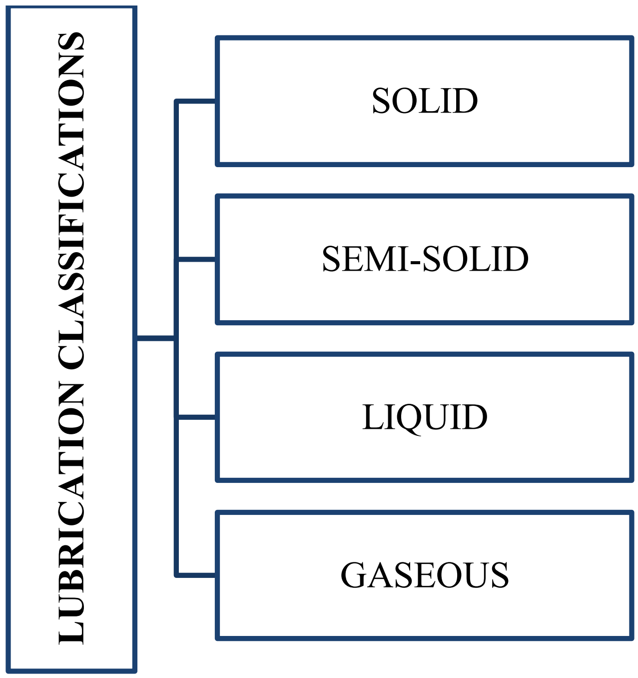

Figure 2.1: Lubrication classifications

2.2.1.1 Solid Lubricant

Solid lubricant comes as solid materials. Under high loads, it reduces coefficient of friction and wear between two contacting parts while preventing direct contact between both surfaces. Besides its ability to work under high loads, solid lubricant possesses high thermal stability which makes it suitable to be used as additives mainly in oils and greases. Particles such as graphite and molybdenum disulfide are common solid lubricant, while boron nitride and polytetrafluorethylene (PTFE) are some other types of solid lubricant normally used.

2.2.1.2 Semi-solid Lubricant

Semi-solid lubricant comes in form of grease which purposely used in bearings as lubrication. Grease mainly contains lubricating oils, which usually has quite low viscosity that has been thickened by finely dispersed solids called thickeners. Normally, it carries up to 75% to 95% base oil, 0% to 5% additives and 5% to 20% minute thickener fibers. Other than providing a better mechanical lubrication cushion in extreme conditions, it is also water resistant and beneficial in reducing oil vapor problems.

2.2.1.3 Liquid Lubricant

One of many purposes of liquid lubricant is it acts as liquid films while bearings are floating on them. These liquid films exist between two surfaces and there is resistance to abrasion contained in the liquid. Vegetable oils, animal fats and mineral oils are some classifications of liquid lubricant. Liquid lubricant is used to help in cleaning of a bearing by transporting debris or particles and cooling it by carrying excess heat away.

2.2.1.4 Gas Lubricant

Normally, gas lubricant is used when there is a separation or an ultra-thin film thickness presence between tribo-pairs. Some examples of gas lubricant are Helium, Nitrogen and Air. Gas lubricant has low viscosity hence making it as an ultra-low friction lubricant. Besides, there is no seal needed when gas lubricant is used as lubrication.

2.2.2. Types of Lubrication

There are three types of lubrication, namely boundary, mixed and full film. Full-film lubrication may be broken down into two parts which are hydrodynamic and elastohydrodynamic. Hydrodynamic lubrication is said to occur when there is two surfaces in sliding motion. These surfaces are fully separated by a film of fluid. As for elastohydrodynamic lubrication, it is quite similar to hydrodynamic but it occurs when the surfaces are in a rolling motion. However, the film layer produced in elastohydrodynamic conditions is much thinner than that of hydrodynamic lubrication while the pressure on the film is greater.

Irregularities are still present even when the surfaces are smooth and polished. They stick out of the surface forming peaks and valleys at a microscopic level. Somehow, these peaks are called as asperities. For a full-film condition, the lubricating film must be thicker than the length of the asperities. This type of lubrication is said to be the most effective in protecting surfaces.

While in boundary lubrication, conditions such as frequent starts and stops, and shock-loading are usually found in it. As full film cannot protect surfaces due to speed, load or other factors, some oils have extreme-pressure (EP) or anti-wear (AW) additives. These additives cling to metal surfaces and form a sacrificial layer that protects the metal from wear. Hence, when EP or AW layer protecting two contacting surface, boundary lubrication is said to occur. However, itis not ideal, as it causes high friction, heat and other undesirable effects.

Mixed lubrication is a mixture between boundary and hydrodynamic lubrication. As the bulk of the surfaces are separated by a lubricating layer, the asperities still make contact