WEAR CHARACTERISTICS OF SK11 IN ENGINE OIL AND NANOPARTICLES-ENHANCED ENGINE OIL

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A report submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this project entitled "Wear Characteristics of SK11 in Engine Oil and Nanoparticles-Enhanced Engine Oil" is the result of my own work except as cited in the references.

Signature : ………………………………

Name : KASMIAH BINTI LASUNU

Date : ………………………………

APPROVAL

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

Signature : ………………………………………………..

Name of Supervisor : ……………………………………………….

Date : ………………………………………………..

DEDICATION

To my lovely beloved mother, family and friends.

ABSTRACT

An experiment investigation was carried out to distinguish the wear characteristics of SK11 ball bearing in SAE 15W-40 diesel engine oil and enhance with 0.5 vol. % of hBN nanoparticles. In this project, the lubricant used were the conventional SAE 15W-40 diesel engine oil and the SAE 15W-40 diesel engine oil dispersed with 0.5 vol. % of hBN nanoparticles using the sonication technique. The tribological test using the Four Ball Tester were performed. The total sample were 27 for each lubricant. The WSD were analyzed using the MPS-3080 digital microscope. It was observed from the result that the wear rate of the SK11 ball bearing reduced at speed of 300 rpm at low temperature after added with the nanoparticles. Meanwhile, there are also at 100°C, there are no significant reduction in wear rate even after added with nanoparticles additive.

ABSTRAK

Satu experimen telah di jalankan untuk mengkaji ciri-ciri kehausan pada bola SK11 dalam minyak enjin diesel SAE 15W-40 dan dalam minyak enjin diesel SAE 15W-40 di tambahbaik dengan 0.5 vol. % nanopartikel hBN. Dalam projek ini, bahan pelincir yang di gunakan ialah minyak enjin diesel SAE 15W-40 dan minyak enjin diesel yang di tambah baik dengan 0.5 vol. % nanopartikel hBN menggunakan teknik sonifikasi. Ujikaji tribologi telah dijalankan denagn menggunakan penguji tribo empat-bola. Sebanyak 27 sampel telah di uji mengguna kan kedua-dua pelincir. Penurunan diameter telah di analisis menggunakan mikroskop digital iaitu MPS-3080. Daripada pemerhatian, kadar kehausan bola SK11 telah berkurang pada kelajuan 300 rpm di suhu yang rendah iaitu 27°C selepas minyak pelincir di tambah dengan nanopartikel hBN. Pada suhu 100° C tiada perubahan yang ketara pada kadar kehausan walaupun selepas di tambah dengan nanopartikel.

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VI	-	Viscosity Index
WSD	-	Wear Scar Diameter
hBN	-	hexagonal Boron Nitride
FBT	-	Four Ball Tester
COF	-	Coefficient of Friction
SN	-	Signal to Noise
TAN	-	Total Acid Number
TBN	-	Total Base Number
SEM	-	Scanning Electron Microscope
SWCNT	-	Single Walled Carbon Nanotubes
MWNTs	-	Multi Walled Nanotubes
Sn	-	Tin
Fe	-	Iron
Cu	-	Copper
Ag	-	Silver
Ti	-	Titanium
Ni	-	Nickel
Co	-	Cobalt
Pd	-	Palladium
Au	-	Gold
ZrO2	-	Zirconium dioxide
TiO2	-	Titanium dioxide
Fe3O4	-	Iron (II, III) oxide
Al2O3	-	Aluminium oxide
ZnO	-	Zinc oxide
CuO	-	Copper oxide
WS2	-	Tungsten sulphide
CuS	-	Copper sulphide

MoS_2	-	Molybdenite
LaF_3	-	Lanthanum fluoride
CeO_2	-	Cerium (IV) oxide
$La(OH)_3$	-	Lanthanum hydroxide
Y_2O_3	-	Yttrium (III) oxide
$CeBO_3$	-	Cerium Boride
SiO_2	-	Silicone dioxide
$CaCO_3$	-	Calcium carbonate
PTFE	-	Polyetrafluoroethylene

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Tribology is the study of something that is rub to each other and it was not a new field. It includes the friction, wear and lubrication. (Ludema, K.C. 2012). The focus for the project is about wear. Wear is a surface damage that occur due to the removal of material during sliding contact of two surfaces. Wear can occur because of several mechanisms which includes abrasion and adhesion. (Girard. L. et al., 2015).

It is an avoidable to have friction and wear in every mechanical system and this is where the lubricant play an important part as it assists in reducing wear and friction under the boundary condition. Lubricant usually consists of two main components which are 90% base oil and 10% additives. Additives are chemical compound added to the lubricant to improve the lubricant performance and one of it was nanoparticles additives.

Until recently, nanoparticles have become the most promising additives as it helps increase tribological properties of a lubricating oil only just in a small amount of concentration between 0.2% and 3% vol into the lubrication oil. (Abdullah et al., 2014[c]). Ilie. F., et al found that the optimum concentration for TiO_2 under new process (NP) is 0.4 wt% and under traditional process (TP) is 0.5 wt% for their anti-wear abilities. They also proved that even in NP and TP, both TiO_2 nanoparticles show greater anti-wear abilities compare to only with the base oil. It is also proven that larger wear scar diameter of steel ball that lubricated with RBD palm olein compared with the ones that lubricated with paraffinic mineral oil. However, both lubricant indicates abrasive wear occurred on all worn surfaces and suggested that it was due to the formation of tribochemical films between the rubbing surface and the cooling effect of the lubricants which reduce the adhesion. (Syahrullail.S et al., 2013).

Girard. L. et al run a wear test that demonstrate that the scar size of bearing lubricated with engine oil was a lot smaller compared with the scar size of bearing lubricated with mineral oil. There are also studies showed that the dispersing of nanoparticles into an engine oil could increase the anti-wear abilities of the engine oil. For example, a 15W40 diesel engine oil added with 0.5 vol % of hBN nanoparticles as additives result in low wear rate by

58% which was in good quantitative agreement with the coefficient of friction. The worn surfaces obtain also showed a smoother surface ($R_a = 0.043$ µm) of ball when lubricated with 15W40 diesel engine oil with 0.5 vol % of hBN nanoparticles compared to conventional diesel engine oil. (Abdullah et al., 2014[a]).

Other research showed that the worn surface of a ball bearing that was lubricated with SAE 15W40 diesel engine oil had severe adhesive wear due to not enough support at the high-pressure contract area and result in plastic deformation. (Abdullah M. I. H. C. et al., 2016). Wu Y.Y. et al showed that a smoother worn surface when CuO nanoparticles was added to the standard oil compared when the standard oil without any nanoparticles where the trace of worn surfaces was formed by wear debris. The worn surfaces on the ball bearing have the characteristics of adhesive wear and some abrasive wear when lubricated with conventional diesel engine oil and showed only a slight of adhesive wear when the engine oil added with nanoparticles as an additive. (Abdullah M.I.H.C et al., 2016).

Other than that, when the unmodified CuO + paraffin oil to well modified CuO + paraffin oil showed a reduction on wear scar diameter (WSD) from 1200mm to 600mm. This shows that the paraffin oil + CuO with modified suspensions have well wear behavior like shown in Figure 1.1. (Asrul, M. et al., 2013)

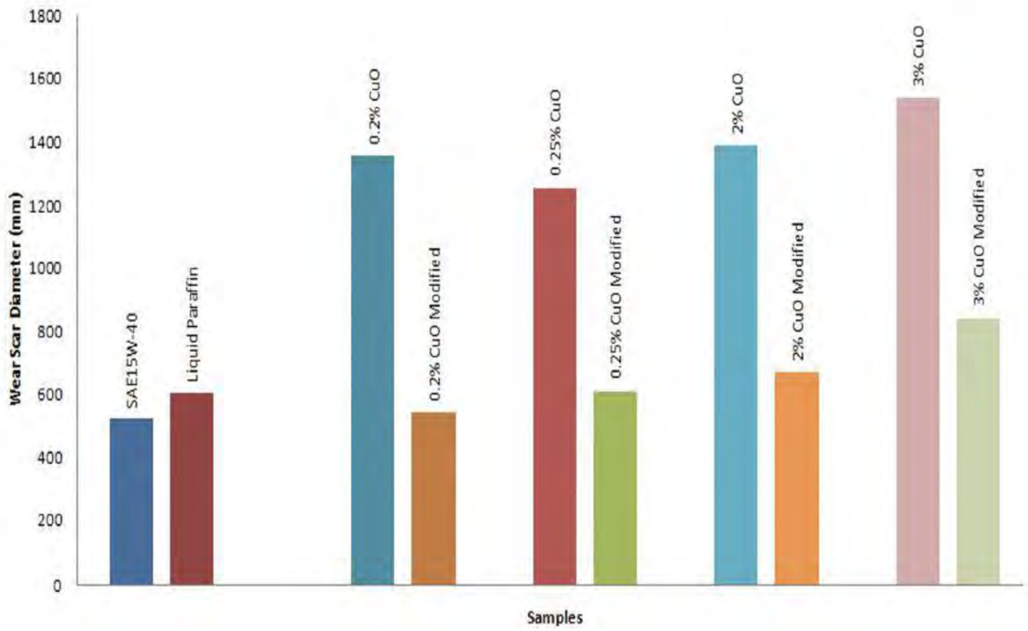

Figure 1.1 Wear scar diameter (mm) as a function sample (Asrul, M. et al., 2013)

1.2 PROBLEM STATEMENT

In general, as observed from previous research, there were a lot of studies that focusing on tribological properties of the engine oil when added with nanoparticles. Other than that, there are also studies that investigated more on the friction and wear characteristics about other nanoparticles such as Ni, CuO, TiO_2 and less studies on hBN nanoparticles. Hence, the goal of this project is to find out the wear characteristics of SK11 ball bearing in SAE 15W-40 diesel engine oil and enhance SAE 15W-40 diesel engine oil with hBN nanoparticles as an additive.

1.3 OBJECTIVE

The objective of this project is as follow:

1. To distinguish the wear characteristics of SK11 ball bearing in SAE 15W-40 diesel engine oil enhanced with and without hBN nanoparticles as an additive.

1.4 SCOPE OF PROJECT

The scopes of this project are:

1. Conduct the experiment using Four Ball Tester with two different lubricants which are SAE 15W-40 diesel engine oil and nanoparticles-enhanced engine oil using hBN nanoparticle.
2. An analysis will be done to differentiate the wear characteristics of the ball bearing after taken out from the Four Ball Tester machine by using the Inverted microscope.

1.5 GENERAL METHODOLOGY

The actions that need to be carried out to achieve the objectives in this project are listed below.

1. Literature review

   Journals, articles, or any materials regarding the project will be reviewed.

2. Preparation of sample.

   The lubricants needed are diesel engine oil SAE 15W-40 and 0.5% nanoparticles-enhanced engine oil.

3. Experiment.

   The experiment will be conducted by using the Four Ball Tester to distinguish the wear characteristics on the ball bearing. The experiment will be conducted by using the Standard Test Method with different load, speed and temperature.

4. Analysis.

   Analysis will be presented to differentiate wear of the ball bearing.

5. Report writing

   A report on this research will be written at the end of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Lubricants and Lubrication

Principle of bearing a sliding load on a friction reducing film can be said as a lubrication. (Nehal et al., 2011). Whereas the substance composed by the film is called a lubricant, and to apply it called lubricate. Lubricant play an important role in decreasing the negative effect of tribological process related to friction and wear and increase in temperature in tribomechanical system. (Sreten et al., 2013). Other than that, more critical function also carried out by lubricant such as cooling, cleaning and suspending, and shield metal surface against corrosive damage.

Lubricant consists of base oil fluid and an additives package. Base oil function as a fluid for lubricant to separate a surface of moving parts by providing fluid films. Besides minimizing friction, it also eliminates heat and wear particles from the system. An additive on the other hand, are added to enhance the lubricant characteristics. (Nehal et al., 2011).

Base oil in lubricant mainly synthesized from three different types of base oil such as mineral oil, synthetic oil and biological oil and most widely used in industry is mineral oil. It is majorly used in industry due to their substances which are petroleum based fluids and utilized for machineries which requires its temperature be moderated. For synthetic oils, used to lubricate at high or low temperatures. Finally, biological oil are types of lubricant oil typically utilized in food or pharmacological industry where the risk of contamination need to be minimized. (Shahnazar et al., 2015).

As important the roles of base oil in lubricant, however, the important of additives also cannot be neglected because only suitable additives can be added to the base oil to enhance certain properties for example oxidation stability, anti-corrosion and anti-wear as well as stability against biological degradation. However, a lot of recent studies on lubricant added with nanoparticles and many have proven their research. (Shahnazar et al., 2015).

2.1.1 Lubricant Regimes

Typically, lubrication regimes consist of three main parts that are:

- Boundary lubrication
- Mixed lubrication
- Hydrodynamics lubrication

First is boundary lubrication happened when a solid surface is so closed or in direct contact which result in high coefficient of friction and thus resulting in high wear. Second regimes that are mixed lubrication occur when a surface in irregular contact at medium speeds and load and only a few sharp surfaces are brought in contact. Lastly was the hydrodynamics lubrication which either occurs at high speed or at light loads. The friction and wear does not exist because the two surface were separated by a film of lubrication. The Stribeck curved below showed the lubrication regimes and its relation between friction coefficients. The symbols indicate (μ) the friction coefficient versus the dimensionless parameter (η V/L), where η is the fluids dynamic viscosity, L is the normal load applied and V is the relative sliding speed. (G. Les et al., 2015).

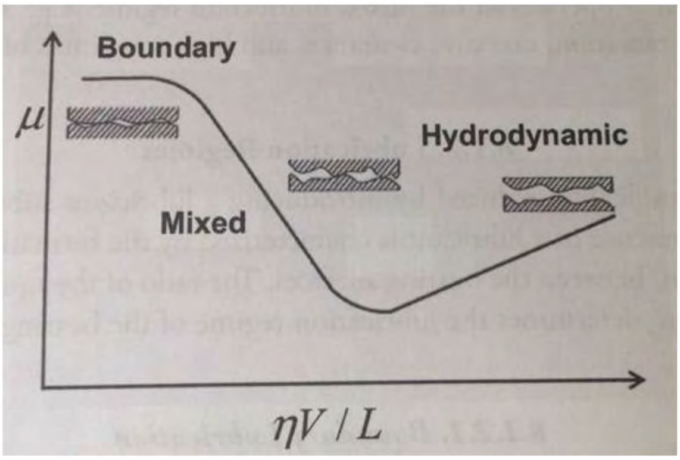

Figure 2.1 Stribeck curve with lubrication regimes and relationship between friction coefficients.

2.2 Nanoparticles as Additives in Engine Oil.

Nano lubrication is one of the most advanced lubrication technologies besides thin film coating and gas lubricant. Nano lubricants have been a main choice in industry because they are relatively insensitive to temperature and that their reaction to tribochemical are limited compared to the conventional additives. Only a low concentration of nanoparticles between 0.2% and 0.3% vol into lubricating oil are enough to improve the tribological properties. (Abdullah et al., 2015). Nanoparticles also has a potential in emission reduction as well as improving fuel economy. Their particle size also a merit for them because it allow them to enter the contact region easily for load bearing and lubricating. It also showed that some nanoparticles like $CaCO_3$, it exhibits optimal performance under high frequency for bigger sizes whereas smaller ones more suitable for higher load and lower frequency. Morphology of nanoparticles also played an important role on friction reduction but also has a subtle effect on antiwear performance. (Dai et al., 2016). Even past studies have shown that nanoparticles have powerful tribological properties than conventional solid lubricant additives. (Shahnazar et al., 2015). The tribological properties of paraffin oil and biolubricant added with TiO_2 nanoparticles additives were investigated by (Zulkifli et al., 2013) and their result showed adding TiO_2 in (trimethylolpropane) TMP ester good friction-reduction and wear scar diameter reduced by 11%. The same results also showed when the tribological properties of an API-SF engine oil and base oil with CuO and TiO_2 and nano-diamond nanoparticles used as an additives. (Wu et al., 2007).

There are a lot of research about nanoparticles additives which basically aim to improve the tribological performance of the lubricating oils. For an instances, load-carrying capacity and wear reduction of liquid paraffin were enhanced when surface-modified TiO_2 nanoparticles were added. (Xue et al., 1997). (Zhou et al., 2001) stated there are formation of film on the surface when they investigated the tribological behaviour of LaF3 nanoparticles as an oil additives.

(W. Dai et al., 2016) has classified nanoparticles into seven types according to their chemical elements that is carbon and it derivatives, metal oxide, metals, sulphides, rare earth compounds, nanocomposites and others. Table 2 below are the detailed information about each category that have been listed.

Table 2.1 A summary of nanoparticles as lubricant additives

Types	Nanoparticles
Carbon and its deravatives	Graphene, diamond, SWCNT, MWNTs
Metals	Sn, Fe, Cu, Ag, Ti, Ni, Co, Pd, Au
Metal oxide	ZrO_2, TiO_2, Fe_3O_4, Al_2O_3, ZnO, CuO
Sulfides	WS_2, CuS, MoS_2, $NiMoO_2S_2$
Rare earth compound	LaF_3, CeO_2, $La(OH)_3$, Y_2O_3, $CeBO_3$
Nanocomposite	Cu/SiO_2, Cu/ graphene oxide, Al_2O_3/SiO_2, serpentine/$La(OH)_3$, Al_2O_3/TiO_2
Others	$CaCO_3$, $ZnAl_2O_4$, Zeolite, ZrP, SiO_2, PTFE, Hydroxide, BN, serpentine

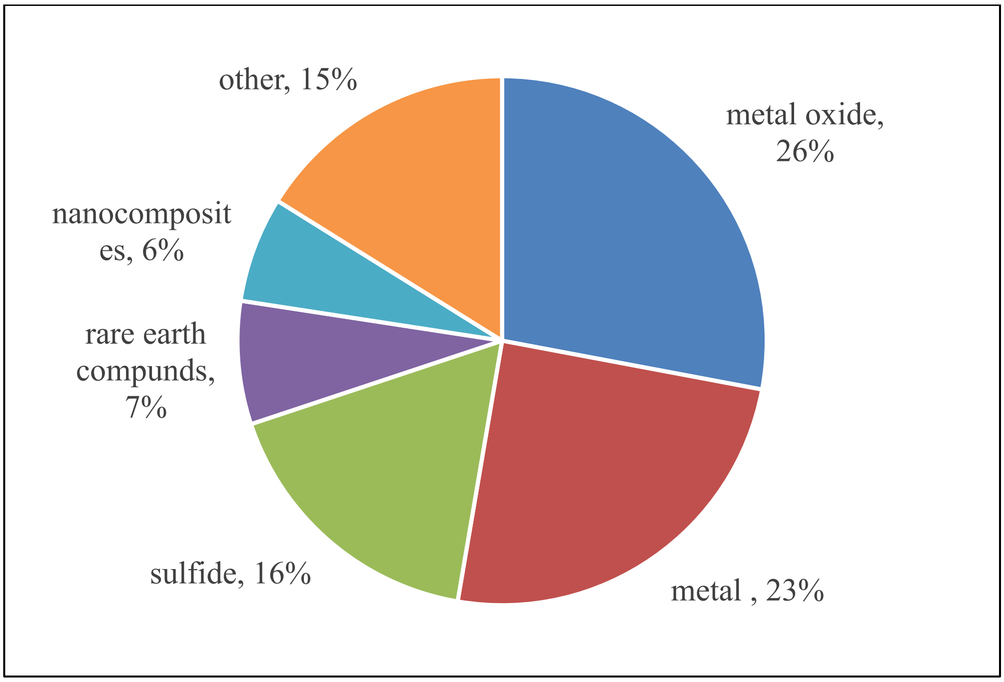

Figure 2.2 Statistics of nanoparticles worked as lubricant additives.

2.3 Hexagonal Boron Nitrate (hBN) Nanoparticles

Boron-based nanoparticles have been under a spotlight due to its load carrying and anti-wear behaviour. It also been a favourite and best candidate to be used as a lubricant oil additives because they were thermally stable and environmental friendly. (Shahnazar et al., 2016).

Table 2.2 Physical properties of hBN nanoparticles (Abdullah et al., 2016)

[a]Properties	hBN nanoparticles
Appearance	White powder
Average diameter particle size (nm)	70
Density ($kg.m^{-3}$)	2.3
Maximum use temperature in air (°C)	1800
Thermal conductivity ($W.m^{-1}.K^{-1}$)	27
Thermal expansion coefficient @25 °C-1000 °C	1×10^{-6}/°C (parallel to press air)

[a]From manufacturer.

With its ultra-flat surface, the hexagonal boron nitrate (hBN) with less than 2% lattice mismatch with graphite could be great additives. It is also show its low friction behaviour to not only layered structures but also to contact interface between layered even when single-layered without even sliding. (Shahnazar et al., 2016).

2.3.1 Effect of hBN nanoparticles on the Coefficient of Friction (COF) and as a Friction Modifier.

(Abdullah et al., 2014[a]), has studied the effect of hBN/Al_2O_3 nanoparticles additives on the tribological performance of engine oil and the result showed that engine oil with hBN nanoparticles has lower COF compared to engine oil with Al_2O_3 nanoparticles even though it shows greater influence in signal-to-noise (SN) ratio.