SEVERE SLIDING WEAR CONDITION OF A BALL BEARING IN ENGINE OIL AND NANO-BIO-LUBRICANT

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A report submitted

in fulfillment of the requirement for the degree of

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DECLARATION

I declare that this project report entitled “Severe Sliding Wear Condition of a Ball Bearing in Engine oil and Nano-Bio-Lubricant” is the result of my own work except as cited in reference.

Signature : ....

Name : ....

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 Engineering.

Signature : ………………………………………….

Name : ......……………………………..………..

Date : ………………………………………….

DEDICATION

To my beloved father and mother.

ABSTRACT

A new green technology to replace conventional engine lubricant is arrived. The original engine lubricant usually is refined which sourced from natural source. It contains hydrocarbon substance that will cause several of side effects to human being and environment. Furthermore, massive use of natural source brings energy crisis too. Therefore, expanded worries about the harm brought by conventional oil-based lubricants have made an improvement by replace it to bio-lubricant with nanoparticle additives. This report describes severe sliding wear condition of a ball bearing in engine oil and nano-bio-lubricant by evaluate the coefficient of friction and wear scar diameter and make a comparative study from journals which using bio-lubricant blended with nanoparticle additive. For instance, SAE 10W-40 engine oil (MO), palm kernel oil (PKO), palm kernel oil blended with nanoparticle copper oxide (PKO+CuO), palm oil (PO), palm oil added with hexagonal boron nitride (PO+hBN) and soybean oil (SO) are used to be discuss in this report. Four ball tester is used to obtain the data by following parameter which are applied load of 20 and 30kg, spindle speed of 1500,1750, 2000RPM and 100℃ working temperature. The results analysis was focused on trending of friction coefficient and wear scar diameter and friction coefficient of lubricant under the most severe sliding wear condition. It was found that the trending of friction coefficient and wear scar diameter of MO is increasing when the parameter value increased. PKO and PKO+CuO showed decreasing trend in COF but increasing in wear scar diameter. PO and PKO had lower COF compared to engine oil with decrement percentage of COF about 39.3% and 45.1% respectively. In aspect of additive, CuO additive reduce COF about 3.15% whereas hBN increased by 5.71%.

ABSTRAK

Satu teknologi hijau baru untuk mengantikan pelincir enjin konvensional sudah tiba. Pelincir enjin asal yang biasa digunakan adalah diperhalusi yang bersumber dari sumber semula jadi. Pelincir enjin tersebut mengandungi bahan hidrokarbon yang menyebabkan beberapa kesan negatif kepada manusia dan alam sekitar. Tambahan pula, penggunaan sumber semula jadi secara besar-besaran juga memyumbang krisis tenaga. Oleh hal yang demikian, kebimbangan tersebut iaitu bahaya disebabkan oleh pelincir berasaskan minyak konvensional telah membuat peningkatan dengan menggantikan kepada pelicir berasaskan biologik dengan bahan tambahan nano-partikel. Laporan ini menerangkan keadaan haus gelangsaran yang teruk pada minyak enjin dan pelincir nano-bio dengan menilai pekali geseran dan diameter parut haus dan membuat kajian perbandingan dari jurnal yang menggunakan pelincir bio yang dicampurkan dengan bahan tambahan nanopartikel. Contohnya, minyak enjin SAE 10W-40 (MO), minyak biji sawit (PKO), minyak biji sawit campur dengan nanopartikel tembaga oksida (PKO+CuO), minyak sawit (PO), minyak sawit ditambah dengan boron nitrida heksagon (PO+hBN) dan minyak kacang soya (SO) digunakan untuk dibincangkan dalam laporan ini. Penguji empat bola digunakan untuk memperoleh data dengan mengikuti parameter yang dikekalkan beban 20 dan 30kg, kecepatan pengumpar 1500,1750, 2000RPM dan suhu kerja 100℃. Analisis keputusan difokuskan pada tren pekali geseran dan diameter parut haus dan pekali geseran pelincir dalam keadaan haus gelangsaran yang paling teruk. Didapati bahawa tren pekali geseran dan diameter parut haus MO meningkat apabila nilai parameter meningkat. PKO dan PKO + CuO menunjukkan kecenderungan penurunan COF tetapi peningkatan dalam diameter parut haus. PO dan PKO mempunyai COF yang lebih rendah berbanding dengan minyak enjin dengan peratusan penurunan COF masing-masing sekitar 39.3% dan 45.1%. Dalam aspek bahan tambahan, bahan tambahan CuO mengurangkan COF sekitar 3.15% sedangkan hBN meningkat sebanyak 5.71%.

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bpd	Barrels per day
COF	Coefficient of friction
CI	Compression ignition
CuO	Copper oxide
ZDDP	Dialkyldithiophosphates
MO	Engine oil
hBN	Hexagonal Boron Nitride
PKO	Palm kernel oil
PO	Palm oil
POD	Pin-On-Disc
SCR	Selective Catalytic Reduction
SO	Soybean oil
WR	Wear rate

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CHAPTER 1

INTRODUCTION

1.1 Background

Crude oil is a complex mixture, mainly organic hydrocarbon compound with several different kind of chemical components. The Pengerang Refining development said that part of Petronas' $27 billion Pengerang Integrated Complex consists of 300000 barrels-per-day (bpd) oil refinery and a petrochemaical process with a capacity of output about 7.7 million tonnes every year in the southern Malaysian state of Johor. Fueling is made the increase in demand from which gasoline and demand for more offshore drilling, more fracking, extraction of oil from ground to transfer crude oil to refineries. All of these have their own connected impacts and risks to our environmental. As many people rely on using of car in the world, the oil supply may not be able to sustain and increasing the potential for future military issues (Carley 2019). Refining is performed to remove unwanted chemical bond and structure from the crude oil to lower the tendency of oil to age and also enhance and improve the temperature characteristics and viscosity of oil. Majority molecules of various sizes and structures are refined from crude oil according to different temperature working process such as gasoline, kerosene, bitumen, diesel, lubricating oil and others. Lubricating oil relates to hydrocarbon molecules of a particular size which within 26 to 40 carbons. Normally, lubricating oil have large and heavy molecules that can be refined in little silos. There are several processes of refinery which are categorised those molecules relying on size and weight, eliminates impurities and allowing each of the crude oil products to be used.

In automotive industry, crude oil is used to refine as lubricant which apply on machine and engine to prevent wear of part in the engine. For example, the piston with the piston ring is allocated in the cylinder which need lubricant to reduce friction stress between the wall of cylinder and ring. In a high speed reciprocating motion of piston, it creates higher friction from direct close contact and also leads overheat of the components causing the piston ring break. Thus, lubricant act as important role to provide a protect layer on the piston ring and wall so that both component would not have scratch or wear based on the viscosity of lubricating oil and the working temperature.

Recent development is trying to improve the efficiency of engine and less consumption of fuel oil as well as the emission of unwanted gas to the environment by reduce the friction losses on lubricated surface. In internal combustion engine, models have been developed the rate of piston ring in the boundary of cylinder and mixed lubricant regimes. Piston ring provide a sliding seal, preventing the leakage of fuel oil and the air mixture from intake valve during compression and power stroke. Furthermore, piston ring is able to maintain the oil in the sump from leaking to the combustion chamber that will burn and waste of fuel. Due to the reciprocating motion, there would be a surface interaction occurring between piston, piston ring and the wall of cylinder which cause the friction and wear of cylinder bore. Thus, lubricant acts important role to reduce the friction during the high speed of revolution. If the piston ring is worn out, piston ring will provide a gap at the cylinder bore and lose it function, unable to seal the combustion chamber and the pressure will released. Hence, the vehicle loses power and lead to increase of fuel consumption.

A very interesting experiment is conducted which is replacement of engine oil by using palm-based oil. The original palm oil is unable to achieve the performance of petroleum-based lubricant which is maintain lubricity in high working temperature. Hence, the substance of nano-lubricant-oil is using palm oil as based and mixing with hexagonal boron nitride (hBN) nano additive. Generally, hBN is layered material isostructural to graphite and has similar exotic properties as graphite. hBN has unique characteristics that make it superior performance in order to enhance the wear properties compared to inorganic solid lubricants such as graphite and molybdenum disulphide (MoS_2). In fact, hBN is a covalent bond compound of boron (B) atom and nitrogen (N) atom by weak van der Waals forces. The performance of lubricating of hBN arises from the east shearing along is its crystalline structure. A number of researches state that nano additive of hBN can be inferred to be an effective lubricant and also it is able to reduce wear significantly.

Among the gasoline engine, a piston ring with an excellent wear resistance and low cylinder running surface wear are required significantly compared to compression ignition (CI) engine and turbocharging already have a very smooth cylinder running surface. In order to meet these requirements, also known as low friction in high wear resistance, a good lubricant with palm-based oil and proper composition is compulsory to apply on it to smoothen piston ring and cylinder as reduce friction as low as possible. This is the best condition for engine and combustion chamber to unleash almost 100% efficiency and less emission of unwanted gas such as carbon dioxide (CO_2). Although the based material of lubricant changes from petroleum-based to palm-based oil, but it can be trusted that palm-based oil with nano additive to improve the properties that original lubricant is able to replace the petroleum-based lubricant.

In this experiment, ball bearing is used as material to carry out by using 4 ball tribometer tester. This could study the friction force on surface of ball bearing when contacted with the fast speed revolution, high temperature and heavy load. During the testing, lubricant will dip on the ball bearing continuously to ensure the ball bearing lubricated. The ball bearing will undergo severe sliding on 4 ball tribometer tester. The wear on the ball bearing will be observed.

1.2 Problem statement

The mineral-based oil and lubricant are heavily refined oil which sourced from natural source. Nowadays, regular oil, synthetic oil and semi-synthetic oil used on our vehicle as lubricant to run the engine. These kind of lubricant essentially refined by crude oil. Recent development towards green technology had delivered responsive feedback from researches to invent new technology to reduce use of mineral oil. From figure 1.1, the high interest in research from year 2008 to 2013 of bio-lubricant is evidence of the increase gradually of publications to prove that palm-based oil which is one of the bio-lubricant is studied and investigated to manufacture a lubricant with similar performance of petroleum-based lubricant. The crude oil was consumed the equivalent of over 11 billion tonnes from fossil fuel every year. According to the reason of energy crisis, rapid increase in worldwide population, changing of human lifestyle and world pollution are highly valued. If crude oil which refine to be lubricant or engine oil is continuously overuse, oil resources could run out in our future time as well as contribute the pollution to the environment such as carbon emission and habitat destruction.

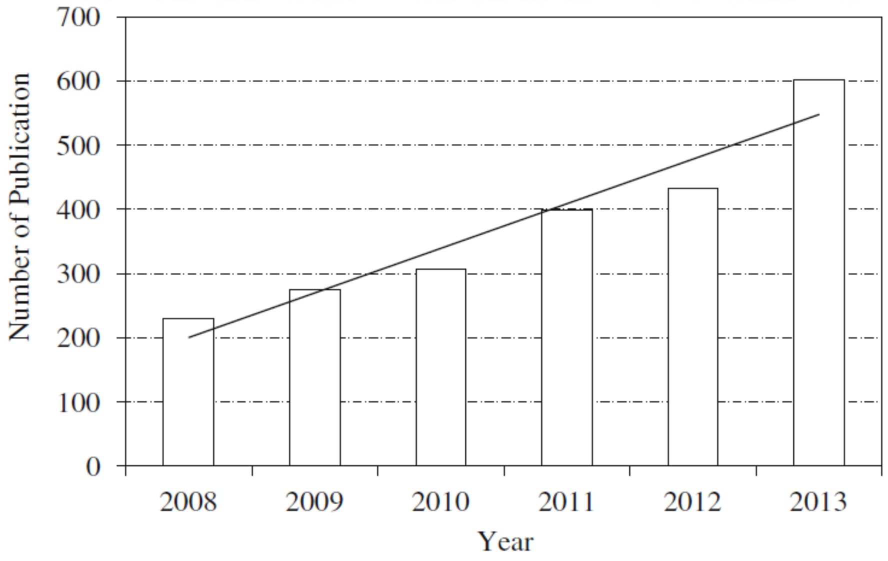

Figure 1.1: Number of researcher of bio-lubricant from 2008 to 2013 (Alotaibi and Yousif, 2016).

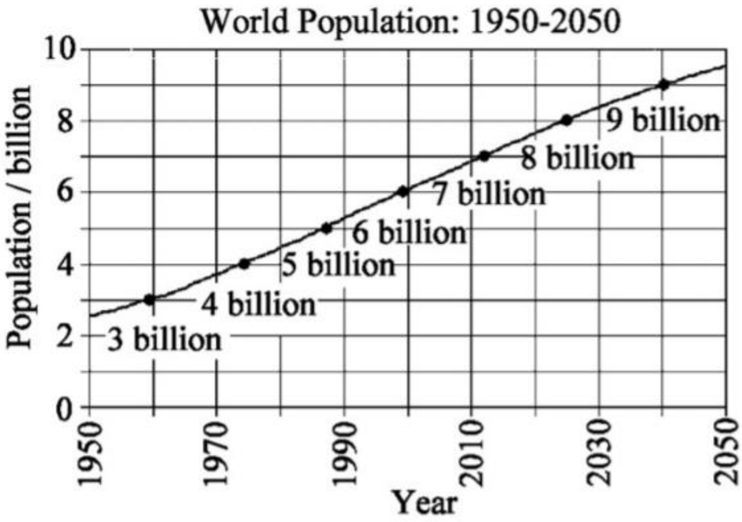

Figure 1.2: World population 1950-2050 (Korakianitis et al., 2011).

1.3 Objective

The objective of this project:

- Evaluate friction coefficient and wear scar diameter of ball bearing by conventional engine oil with different applied load and speed.
- To compare the friction coefficient and wear scar diameter of vegetable oils added with different nanoparticle additives.

1.4 Scope of project

The scope of this project:

- Parameter of speed and load used for the experiment are 1500,1750, 2000RPM and 20,30,40 kg respectively. The experiment is spiked as setting parameter against standard of four ball tester due to lubricant spilled out from cap holder.
- The conventional SAE 10W-40 engine oil and palm oil mix with hBN are main lubricant used. However, only the data of COF and wear scar diameter of engine oil obtained. The properties of lubricant may not in good condition always.

CHAPTER 2

LITERATURE REVIEW

2.1 Review on bio-lubricant

An essential review has been made on vegetable-based lubricant additives with some specific some properties, manufacturing process and benefits. Bio-lubricants have several valuable and useful physiochemical properties. They can be found technical advantages unlike those of typical petroleum-based lubricant. Bio-lubricants provide high lubricity (Quinchia et al, 2010; Suarez et al, 2009), high boiling point (Mobarak et al, 2014) and extreme low volatility and high elevation of viscosity indices represent minor changes with temperature and offer biodegradable properties (Quinchia et al, 2012; Reeves et al, 2017). The review below provides information of bio-lubricants detailing the category, discussing vulnerability and revealing enhancement techniques which higher lubricity conducting to:

- Lower friction losses and improved efficiency by more power output is produced and better fuel consumption.
- High dispersancy
- Higher shear stability
- Higher viscosity indices
- Higher detergency eliminating the need for detergent additives
- Lower volatility resulting in lessen release of exhaust
- Rapid biodegradation resulting in decreased environmental and toxicological hazards.

In another word, those properties from bio-lubricant are offered by engine oil that manufacture by petroleum-based oil. It can be a factor that bio-lubricants are able to replace the petroleum-based oil. Kania et al, (2015) found that there is a significant development of bio-lubricants derived from organic substance as additive to drilling fluids. Drilling fluids usually lubricate the surface of drilling and act as cooling agent to prevent overheat on the surface and drill. Lubricant is commonly used to reduce overheating and friction in a variety of engines, machinery, turbines and gears (Alotaibi and Yousif, 2016). With the statement above, these properties are much necessary when apply the bio-lubricant with additive to piston cylinder as it will get hotter after engine running for a several minutes. The bio-lubricant derived from vegetable oil has a better performance than mineral lubricants and hydrocarbon component are really presented. The triglycerides are the major content of vegetable oil in making bio-lubricant. Among its molecules, there have three long chain polar fatty acids attached at the hydroxyl groups via ester linkage (Kania et al, 2015). The triglyceride texture of vegetable oil provides lubricant film with strong interaction with metallic surfaces. There is a significant reduce in friction and wear when interaction is stronger (Kania et a., 2015). Palm oil is one of functional vegetable oil to act as new lubricant among other vegetable oils. Those acid such as palmitic, stearic, oleic, linoleic and linolenic represent its length chain of hydrocarbon which shown in Figure 2.1.

Vegetable oils	**Palmitic (16:0)**	**Stearic (18:0)**	**Oleic (18:1)**	**Linoleic (18:2)**	**Linolenic (18:3)**
Sunflower oil	6.1	5.3	21.4	66.4	-
High oleic sunflower oil	3.5	4.4	80.3	10.4	-
Safflower oil	6.4	2.5	17.9	73.2	-
High oleic safflower oil	4.6	2.2	77.5	13.2	-
High linoleic safflower oil	6.7	2.6	14.6	75.2	-
Soybean oil	6.0	5.2	20.2	63.7	5.0
High oleic soybean oil	6.2	3.0	83.6	3.7	1.7
Corn oil	10.6	2.0	26.7	59.8	0.9
Cottonseed oil	18.0	2.0	41.0	38.0	1.0
Rapeseed oil	3.5	0.9	19.4	22.3	8.2
Canola oil	2.5	1	64.4	22.2	8.2
Peanut oil	10	3	50	30	-
Linseed oil	5	3	22	17	52
Olive oil	14	2	64	16	2
Coconut oil	9	2	7	1	-
Palm oil	42	5	41	10	-

Figure 2.1: Fatty acid composition of vegetable oil (Annisa and Widayat, 2018).

Furthermore, bio-lubricant consider a green product because it does not contain harmful substance that will pollute and destroy our environment. Unlike petroleum-based lubricant, it will bring crisis to environment such as marine pollution or erosion of soil if the waste of such lubricant does not dispose properly. The environmental and toxicity problems of conventional lubricants, costly issue related to shortage and poor biodegradability led to invention of environmental friendly lubricant (Liew 2015). Environmental contamination and general awareness of the use of biodegradable lubricants have been triggered by the improper use of petroleum based oil. (Pop et al, 2008).

2.2 Conventional engine lubricant and related hazards

Majority of engine lubricants present in the current market are mixed with additives to improve the lubricating and cooling performance. The conventional engine oil composition composed of hydrocarbon base oil with 75wt% to 83wt%, viscosity modifier with 5 to 8wt% and additive package with 12 to 18wt% (Gulzar 2018). There are some other additives such as paraffins, isoparafines, naphthalenes and compound of sulphur and phosphorous which really bring harmful to our environment (Li et al, 2014). Moreover, these two hazardous chemical element is produced by zinc dialkyldithiophosphates (ZDDPs). ZDDPs have been widely used as lubricant additives which cause serious air pollution. Although vehicle has install car exhaust system to filter the hazardous gas with emission-control catalyst feature but it is not an efficient way to solve the pollution problem no matter directly or indirectly (Li et al, 2010). By using selective catalytic reduction (SCR), it is designed to allow nitrogen oxide (NO_x) reduction reaction to take place in an oxidizing atmosphere. Throughout real working experiment, SCR technology is believe that it can reduce emission of NO_x up to 90%. Figure 2.2 is the working principle of SCR.

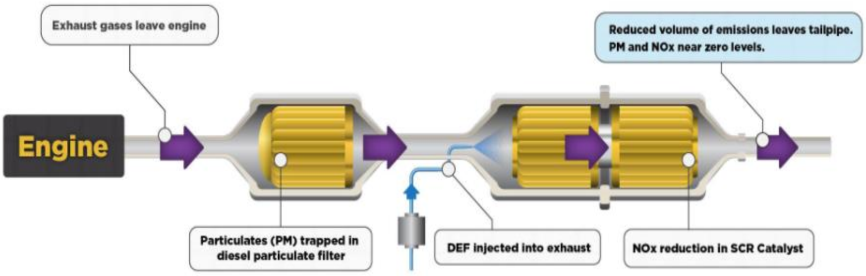

Figure 2.2: Block diagram of Selective Catalytic Reduction (SCR).

Lubricating oil released without proper process is posing a big trouble to the environment and bring health issue. The harvesting of wood in the world every year is recorded total amount of approximately 3713681 thousand m^3. Supposing there is a chainsaw uses 50mL of lubricating oil to gain $1m^3$ wood, eventually the total amount of oil used can be immense amount to huge area of harvesting wood. Table 2.1 shows the comparison of harvesting of wood and used oil divided into continents in 2017.

Table 2.1: Comparison of harvesting of wood and used oil in 2017 (Nowak et al, 2019).

Continental	Harvested Wood (Thousand m^3)	The amount of lubricating oil Used (Thousand L)
Asia	1117409	33522
Africa	737603	22128
Europe	725645	21769
Poland	42200	1266
Russia	205507	6165
North America	568915	17067
Central and South America	489982	14699
Oceania	74128	2224