TRIBOLOGICAL PERFORMANCE OF ADDITIVES IN COMMERCIAL LUBRICANTS

by

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DISSERTATION

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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(MECHANICAL ENGINEERING)

Approved by,

____
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TRONOH, PERAK
SEPTEMBER 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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MUHAMMED FARHAN BIN ABDUL SAMAD

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Special thanks to Universiti Teknologi PETRONAS and staffs for providing excellent facilities and assistance to complete my project conveniently, mitigating most of my difficulty along the way. Also, my appreciation goes to family and friends for their undying supports.

ABSTRACT

A detailed effect and relationship of tribological performance regarding friction and wear of two commercial additives (X and Y) in two types of commercial lubricants (A and B) has been investigated. Three samples were prepared for each commercial lubricants; with 10% additive X; 10% additive Y; and without additive. All six samples were tested using DUCOM Four Ball Tester and the data is collected with the aid of built-in software called WINDUCOM. The results showed significant differences in friction and wear when both commercial additives are blended in two different lubricants. Coefficient of friction increases with presence of additive X and decreases with presence of additive Y for both commercial lubricants. In contrast, higher wear damage is observed upon samples with additive Y compared to additive X. On the other hand, pure commercial lubricants without additional commercial additives showed stable performance in term of friction's coefficient and least wear damage comparing with other samples. These results have significant implications for commercial additives application in commercial lubricants. As the conclusion, commercial lubricants are superior without any additional commercial additives for automotive lubrication.

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1 CHAPTER 1: INTRODUCTION

1.1 BACKGROUND OF STUDY

"For centuries there was no word to describe the scientific concepts of friction, wear and lubrication." As a consequence, an organization was established in the early 1966 and introduced the word 'Tribology' based on greek word *tribos* which means rubbing [1]. Nowadays, tribology is defined as the engineering of interacting surfaces in relative motion including the study of friction, wear and lubrication. This study is classified as branch of mechanical engineering and broadly used in automotive sectors.

Base oil is lubrication grade oil which is produced either from refining crude oil or chemical synthesis. In another suggest, any oil with a boiling point range between 550°F to 1050°F and consists of hydrocarbon with 18 to 40 carbon atoms is considered as base oil. The idea to synthesis base oil chemically arises due to the limitation as less than 2% of crude oil in a barrel is suitable for refining into base oil [2]. Basically, major portion of commercial lubricants are made of base oil. Approximately 80% to 90% of the content of commercial lubricants are made of base oil. Due to technology advancement, there are more fully formulated lubricants are available in the market.

Oil additives are used in order to increase the performance of base oil as a lubricant. Normally, such additives made up 10% to 20% of a lubricant content. These additives are chemically manufactured and help to defend unwanted damage to engines especially as lubricants are widely used in industry of automotive. There are several types of additives existed in this industry and those additives are classified according to particular functions. Functions referred are anti-oxidant, anti-wear, friction modifier, dispersant, detergent, pour point depressant, viscosity index improver and anti-foaming [3]. Particular additive enable to perform two to three functions efficiently. Thus, more additives are needed in order to manufacture a lubricant which poses all functions. In short, the project entitled 'Tribological Performance of Additives in Commercial Lubricants' can be defined as the engineering study of either the friction, wear or lubrication performance of commercial lubricant with particular additives.

1.2 PROBLEM STATEMENT

In automotive industry, almost 15% of the total energy loss comes from the friction generated between sliding parts. In addition, engine failure might occur due to the permanent deformation of sliding parts called wear during internal combustion process in the engine. Thus, commercial lubricants with functional additives are used to reduce frictional losses and wear occurrence.

1.3 OBJECTIVE

The main objective of this project is to study the effect of additional additives on commercial lubricants in term of engineering means based on friction and wear performances. Another objective of this project is to analyze the relationship between friction and wear performances based on the experimental results in order to understand the lubrication function.

1.4 SCOPE OF STUDY

The focus of this project is to study, compare and analyze the relationship of both friction and wear performances of additives in commercial lubricants. This study is limited to two types of additives namely friction modifier and anti-wear together with two types of commercial lubricants that are available in market. A total of six samples are prepared with different composition of additives and commercial lubricants. Experiments are conducted to the samples in order to obtain friction and wear results in term of graphs using DUCOM Four Ball Tester.

1.5 RELEVANCY AND FEASIBILITY OF THE PROJECT

The importance of this project is to identify the validity of commercial additives available in the market. Proper and reliable machine is used to carry out experiments in order to study and relate both friction and wear performances. This project is highly feasible within the time frame as only commercial lubricants and additives are used. Besides that, the tester used is available in UTP.

2 CHAPTER 2: LITERATURE REVIEW

2.1 TRIBOLOGY

As mentioned in the background, Tribology can be defined as the science of interacting surfaces in relative motion. In a broader scope, tribologists define tribology differently according to the background of study namely physics, chemistry, mechanical engineering, and material science. As for the mechanical engineers, the concern is towards wear and friction in design of parts and machines [4]. Motion is described as the displacement measurement of a body to another relatively. Based on physic concept, rapid contact between two bodies may lead to other scientific occurrence such as wear and friction.

Loss of material of a body due to the motion with another body is understood as wear. Study of wear includes abrasion, corrosion, erosion, adhesion and cohesion. All types of wears undergo similar losing process and yet the differences are based on the type of body and losing method. Erosion is basically related to the natural phenomenon such as wind or water flow where the rock and soil are removed from the earth surface naturally. On the other hand, corrosion is a natural chemical process of the environment where normally the metal material is gradually destructed while abrasion is a mechanically forced act that can be controlled using abrasive.

Both wear and friction are interrelated. Adhesion and cohesion are actually friction which is one of the types of mechanical wear. Friction is a form of force that is created between two bodies that collide to each other. The friction force is directly proportional to the weight of bodies. Increase in weight of any bodies would increase the friction force formed. Both friction and body mass are related to the friction coefficients which are needed in most engineering calculations and models [4]. The relationship is as shown below.

$$\mu = \frac{F}{W}$$

Where μ = coefficient of friction

F = friction force

W = weight of body

Generally, there are few classifications of friction namely dry friction, fluid friction, lubricated friction, skin friction and internal friction. Based on this study, lubricated friction is the type of friction which is closely related. Lubricated friction can be easily understood via a case where a fluid separates two bodies or solid surfaces which are in contact. In both automotive as well as machining industry, friction and wear play an important role towards the overall performance [5].

A method by introducing lubricant between two surfaces with an objective to minimize possible wear occurrence is called lubrication. Commercial lubricants are widely used in several industrial sectors. Quality of a lubricant is measured based on the chemical properties such as boiling and freezing point, viscosity index and oxidation. Lubricants which possess high boiling point, low freezing point, thermal stability, high resistance to oxidation and high viscosity index are considered as good lubricants.

Viscosity is one of the main characteristic concerned in lubrication and is known as the thickness or internal friction of a fluid. By definition, viscosity is the fluid resistivity to flow related to the fluid state at particular temperature [6]. Viscosity is commonly measured in centiStrokes (cSt) [7]. The temperature effect of normal fluid as water is different from oil. As for water, increase in temperature would increase the energy of water molecules. This would cause the molecules to move apart and eventually change in state from liquid to gas when the temperature is above 100°C. In contrast, oil has much more higher boiling point. Increase in temperature would increase the molecular energy that lead to molecules move apart. Process of molecules moving apart is referred to as shear [7]. Instead of changing state, oil would have significant in viscosity. The viscosity decreases with increasing temperature. This would lead to the meaning of viscosity index (VI). In case of lubrication, the higher the VI the better. High VI means less viscosity loses as temperature increases and less viscosity gain as temperature decreases [6]. The desirability of choosing oil with higher VI is graphically illustrated in Figure 2.1 and Figure 2.2.

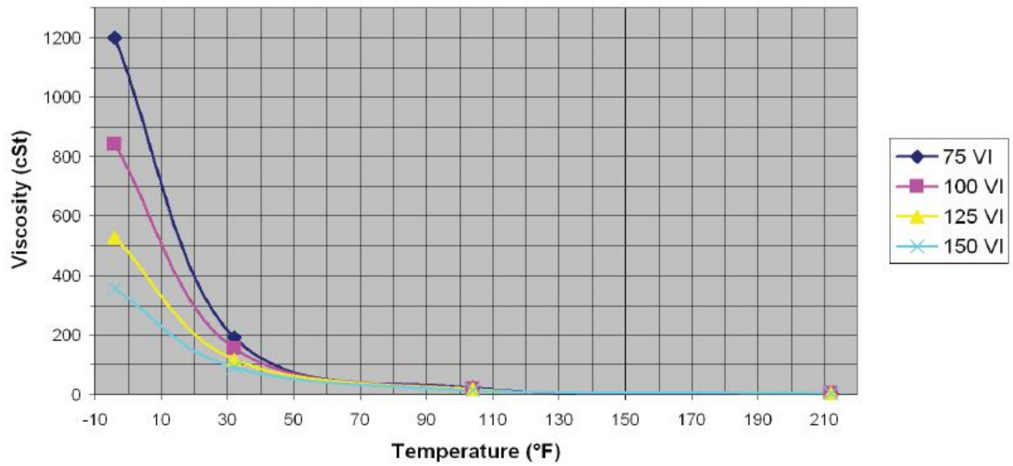

Figure 2.1: Weight Viscosity Index vs. Low-Temperature Viscosity Graph [6].

Figure 1 shows that oil with 75 VI is three times as viscous at -4°F compared to other oils which would lead to poor lubrication performance.

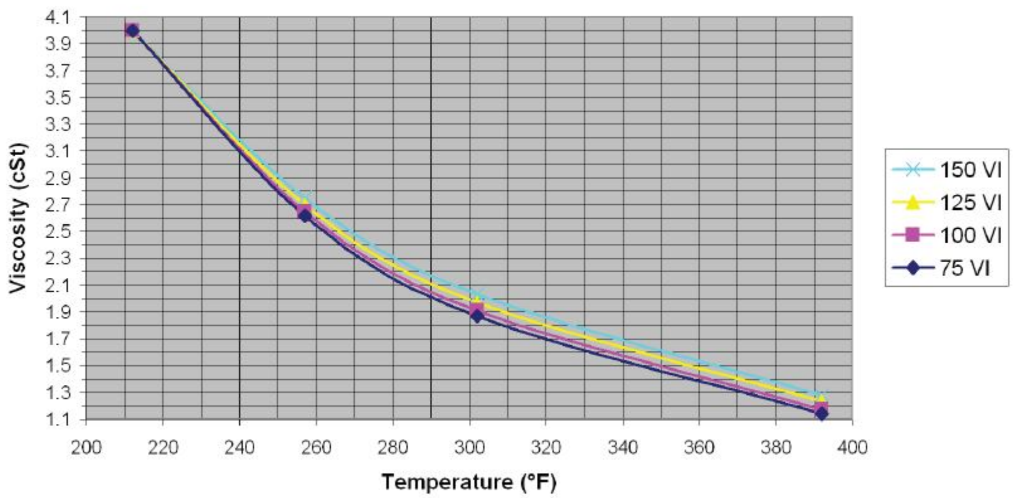

Figure 2.2: Weight Viscosity Index vs. High-Temperature Viscosity Graph [6].

While Figure 2 shows that oil with 150 VI is 20% more viscous at 392°F compared to other oils, showing the superior lubrication performance at high temperature.

2.2 BASE OIL

Base oil is categorized in different group's base on the initial chemical composition and VI of the base oil. According to American Petroleum Institute (API), the common groups are as illustrated in Table 2.1 with detail of chemical compositions such as sulphur, aromatics and saturate content together with respective VI for 4cSt at 100°C without additives.

Table 2.1: Summary of Base Oil Properties [7].

CATEGORY	SULPHUR (%)	AROMATICS (%)	SATURATES (%)	VISCOSITY INDEX (VI)
Group I	> 0.03 and/or	≥10	<90	80 ≤ VI ≤ 119
Group II	≤0.03 and	<10	≥90	80 ≤ VI ≤ 119
Group III	≤0.03 and	<10	≥90	≥120
Group IV	Polyalphaolefins (PAO)			
Group V	All others not included in Group I, II, III and IV			

Group I is actually fractionally distilled paraffinic base oil which is then refined by solvent extraction processes [7]. In addition, Group I base oils are composed of mixture of hydrocarbon chains with little or no uniformity as it is the least refined compared to other groups. The extraction processes contributed in removing wax to improve oxidation resistance and VI [7].

On the other hand, Group II base oils are composed of fractionally distilled paraffinic mineral oil that is refined through hydrocracking and has been solvent dewaxed [7]. Hydrocracking is a process to purify the hydrocarbon stream from sulphur and nitrogen atoms with the present of catalyst. This catalyst facilitated in breaking and rearranging hydrocarbon chains and adding hydrogen to aromatics. This is why the sulphur percentage in Group II is observed to be less compared to Group I in Table 2.1.

Group III base oils are product of further hydrocracking process of base oil Group II. This causes Group III base oils have higher VI compared to Group II. Another alternative in Group III production is by chemically modifying slack wax. Base oils Group III are also manufactured into very high viscosity index (VHVI) called Group III+ [7].

Group IV base oils are chemically manufactured synthetic base oil and one of the most common examples is PAO. Such base oils have highly uniform molecular chains and extremely stable chemical compositions. PAOs are created from the cracking of wax molecules products such as polymerizing olefin molecules [7]. These groups of synthetic and synthetic-blend product are commonly used for automotive and industrial applications.

Group V is base oil which is not included in Group I, II, III and IV. Group V base oils are used mainly in oil additives production which acts as additional beneficial properties to other base oil. Regular examples of Group V base oils are polyol ester, polyalkylene glycols (PAG) and perfluoropolyalkylethers (PFPAE) [7].

Another major factor in order to evaluate an oil performance is the distribution of molecular weights which is highly related to viscosity. Higher difference of molecular weights in a base oil lead to unwanted changes. This is because the viscosity would easily increase and changing other characteristics of oil as the lighter fractions evaporates due to present of heat. Figure 2.3 below shows the average molecular weight of each oil type as expressed by the relation between number of carbon atoms in each molecule and number of molecules.

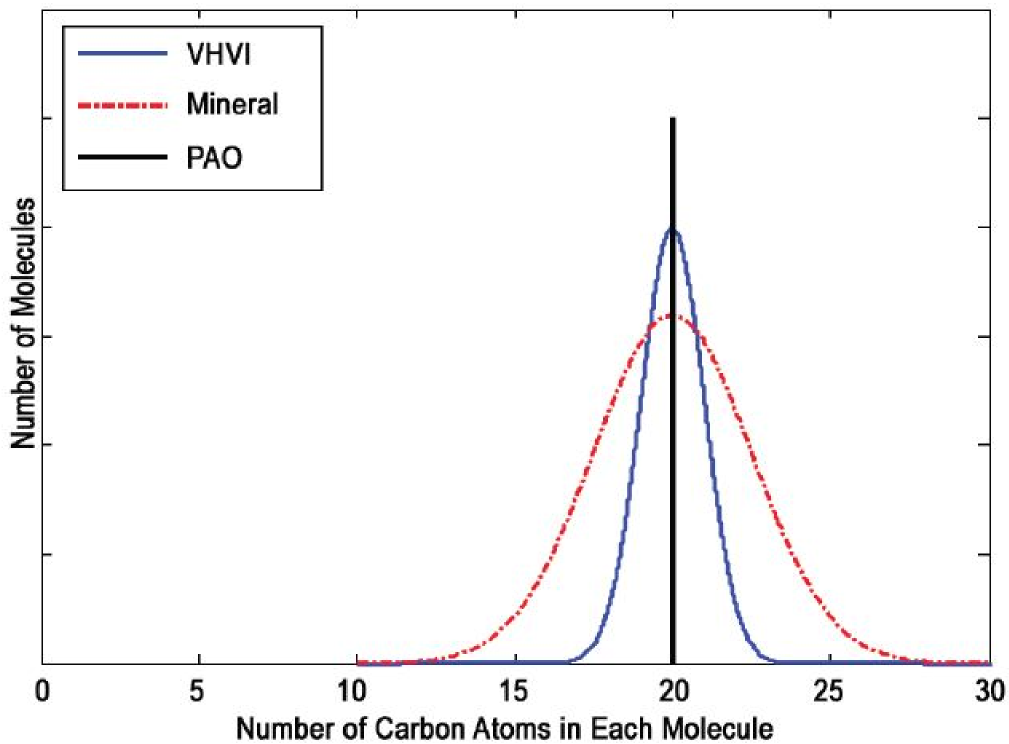

Figure 2.3: Distribution of Molecular Weights by Oil Type Graph [7].

Figure 2.3 above illustrated that PAO Group IV base oil consists of extremely narrow range of different molecular weights. In fact, VHVI Group III+ base oil has narrower range compared to the mineral which significantly identify both Group I and Group II base oils [7]. Based on the molecular weights concept, this figure proved that PAO has better effect on the lubrication performance compared to VHVI and mineral. In contrast, even PAO Group IV has superior characteristics, but they are not applicable to all applications compared to VHVI Group III+ [7].

In addition, polarity of base oil influences the lubrication performance as well. Polarity is defined as the measure of the electrostatic attraction of the base oil in relative. Polar oils have the tendency to naturally bond to metal or other polar molecules to avoid metal to metal contact. Otherwise, oils would easily displaced and unable to act as a lubricant [7]. Highly polar additives used in polar base oil would results the other way around. Those additives tend to bond with base oil and forming thicker reaction layer that influencing tribological performance [8]. Thus, polar additives blend with non-polar base oil perform better in lubrication act.

2.3 ADDITIVES

As per mentioned in the scope of study, additives that would be considered in this study are additives that perform particular functions such as VI improver, friction modifier (FM) and anti-wear (AW). In this section, possible types of additives for each function would be determined. Possible additives would be selected based on the availability in the market.

2.3.1 ANTI-WEAR

Anti-wear additives are used in lubricant in order to minimize metal to metal contact of two surfaces relatively. There are varieties of AW additives available in the market currently. Some of the concerns regarding the properties are such additives must be effectively soluble in lubricant and neither overly reduce the oxidation stability nor increase metal corrosivity. The most widely used AW additives in engine oils are zinc dialkyl dithio phosphates (ZDDP) [9].

ZDDP is invented by Casrol that featured chemical combinations between zinc and dithiophosphoric. ZDDP consists of long chain that can easily dissolve in both mineral and synthetic base oil. Such additive is available in Lubrizol, a well-known additives manufacturer. Figure 2.4 below illustrate the monomeric structure where R represents C_3-C_{10} (linear and/or branched) alkyl or C_{12} (branched) alkaryl.

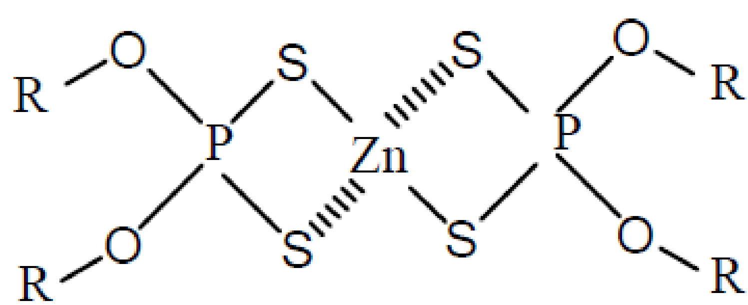

Figure 2.4: Structure of Monomeric ZDDP [10].

In fact, typically AW additives contain zinc and phosphorus compound. Some of the other AW additives are zinc dithio phosphate (ZDP) and tricresyl phosphate (TCP). Most AW additives function as extreme-pressure (EP) additives as well especially the sulphur compound. Generally, AW additives are designed to locate surface films under normal working conditions and thereby reduce the rate wear. In addition, AW additives function in several ways. Either deposits thick enough multilayer films or reloads monolayer films. On the other hand, EP additives function to form a metal compound such as iron sulfide by reacting with the metal surface [9]. One of the disadvantage based on the previous studies proved that ZDDP have undesirable effects on wear and causes increase in friction when operated in mixed and boundary lubrication regimes [8].

2.3.2 FRICTION MODIFIER

Friction modifier is additives added to the lubricants for the purpose of reducing friction generated in lubricated parts. Most common FM is organic FM. Organic FMs are basically made up of long, straight and slim hydrocarbon molecules consisting of at least ten carbon atoms. Besides that, one end of the chains consists of polar group which is significant as friction modifier. FM additives can be found in carboxylic acids, amides, phosphoric and organic polymer [9]. One of the eminent FM additives is glycerol mono-oleate (GMO). Figure 2.5 below shows the chemical structure of GMO.

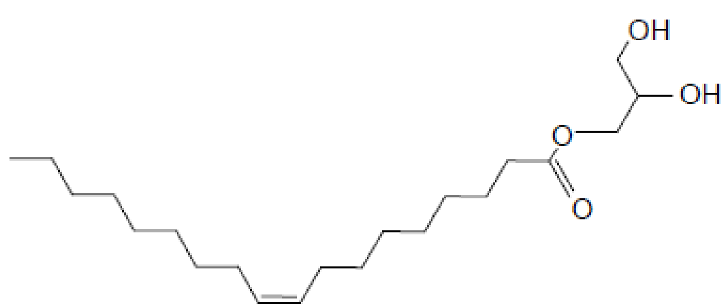

Figure 2.5: Chemical Structure of GMO [9].

The working principles of FM additives are considerably similar to AW additives where protective layers are formed through chemical reaction between the additives and metal surface. The active part of the additives is the polar head. The oil soluble tail dissolved in base oil and the polar head eventually attached to metal surface as the formation of absorbed layers as illustrated in Figure 2.6. Such process continues until all molecules are aligned perpendicular to metal surfaces and forming multilayer of FM molecules due to van der waals forces as shown in Figure 2.7 [9].

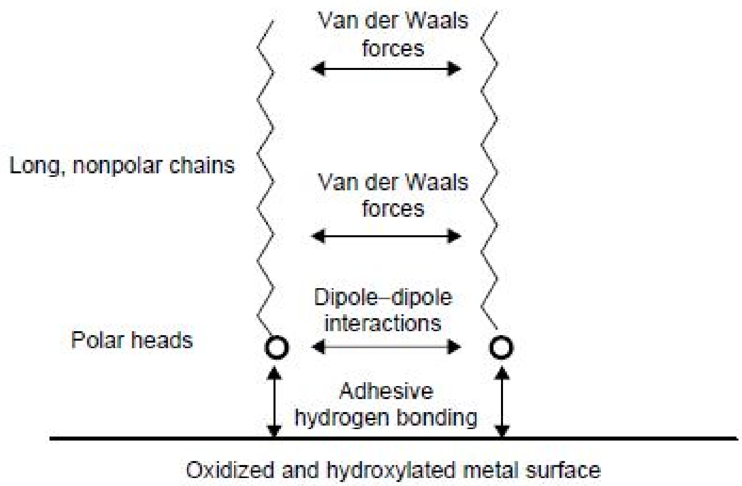

Figure 2.6: Formation of Absorbed Layers [9].

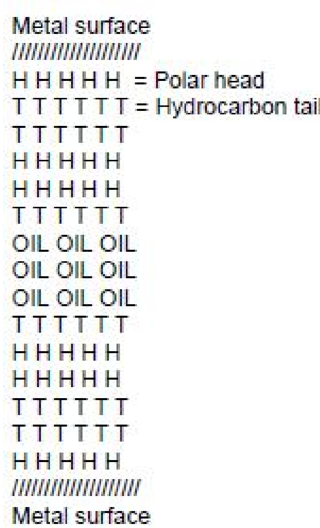

Figure 2.7: Multilayer Matrix of FM Molecules [9].

FM additives can be classified into two other types which are metallo-organic compounds and mechanical types. Under the mechanical types, some of the common FMs available are teflon (PTFE), polyamides and borates. Different classes of FM additives have dissimilar friction reducing mechanisms. In addition, main factors that influence friction reduction properties of FM additives are competing additives, contaminants, metallurgy and concentration. FM additives may have to compete with AW additives to attach to metal surface. Contaminants may lead to short-chain acid due to oxidative degradation of lubricants. Besides the type of steel alloy used, the concentration of FM additives also results in friction reduction performance at a particular point [9].

2.3.3 VISCOSITY INDEX IMPROVER

VI is explained earlier as the viscosity to temperature relationship. The less the change of viscosity value with changing temperature is preferable as the lubricant. VI improver additives ease in reducing temperature dependence of lubricants. VI improver additives are manufactured from appropriate monomers by polymerization. Most common examples of VI improvers are olefin copolymers (OCP), poly alkyl methacrylates (PAMA), styrene block polymers and ethelyne alpha olefin copolymers [11].

As the VI improvers dissolve in base oil, polymer coils are formed due to the present of long molecular chains. As the temperature rises, the polymer coil size increases to balance the decrease in base oil viscosity. In another mean, the polymer relaxes and fully extended as the temperature increases. As the result, the fluid flow resistance increases and relatively possesses stable viscosity balance under wide temperature range [11].

Figure 2.8 below illustrates the relationship of viscosity to temperature for three different samples. Based on the graph, Oil B + Viscosity Modifiers (VM) has most flat-test curve compared to other two samples. The flat-test curve proves that Oil B + VM have the least change in viscosity over temperature [11]. Effect of VI or VM additives is clearly illustrated as a contribution factor upon lubrication performance.

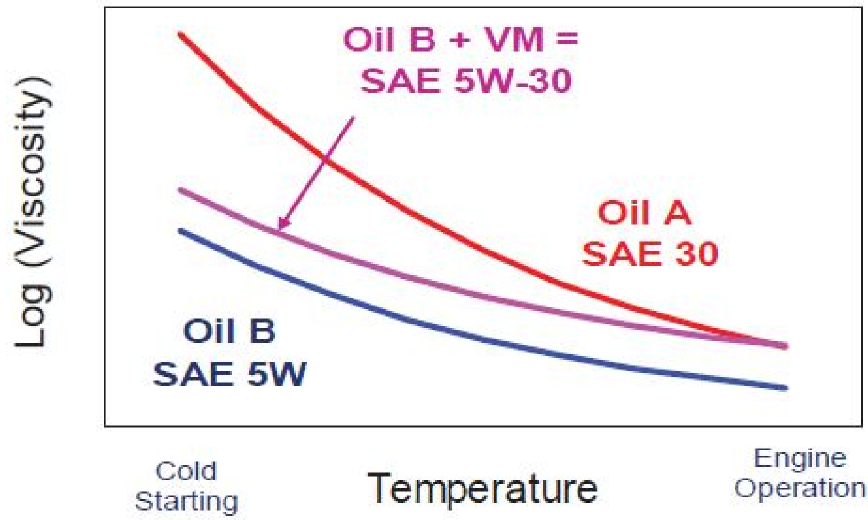

Figure 2.8: Reduce Temperature Dependence & Increase VI Using VI Improvers Graph [11].

Figure 2.9 illustrates the relationship between VI thickening and temperature. This graph shows that Base oil + VI Improver has less change in thickening state relative to temperature compared to Base Oil. Such graph proves that base oil with VI improver additives possesses high VI which would ease lubrication process.

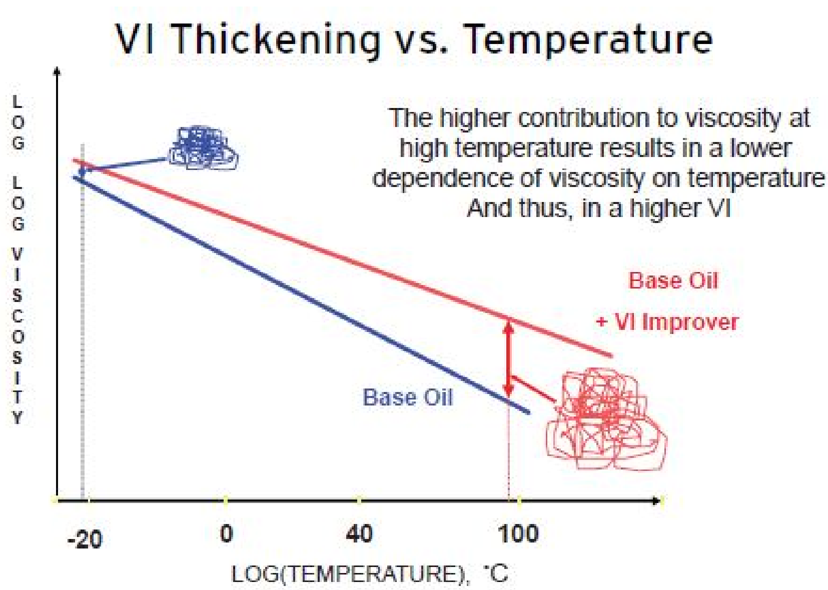

Figure 2.9: VI Thickening vs. Temperature Graph [11].

Table 2.2: Summary of Literature Review.

CONTENTS	REFERENCE
An organization was established in the early 1966 and introduced the word 'Tribology' based on greek word *tribos* which means rubbing.	[1]
Oil with a boiling point range between 550°F to 1050°F and consists of hydrocarbon with 18 to 40 carbon atoms is considered as base oil. Base oil is then chemically synthesis due to the limitation as less than 2% of crude oil in a barrel is suitable for refining into base oil.	[2]
Additives are classified according to particular functions such as anti-oxidant, anti-wear, friction modifier, dispersant, detergent, pour point depressant, viscosity index improver and anti-foaming.	[3]
Both friction and body mass are related to the friction coefficients which are needed in most engineering calculations and models.	[4]
Lubricated friction is a classification of friction where a fluid separates two solid surfaces which are in contact. Both friction and wear play significant role towards overall performance in automotive and machinery industries.	[5]
Viscosity is the fluid resistivity to flow related to the fluid state at particular temperature. In case of lubrication, the higher the VI the better. High VI means less viscosity loses as temperature increases and less viscosity gain as temperature decreases.	[6]
• Increase in temperature would increase the molecular energy that lead to molecules moving apart called as shear. • Summary of Base Oil Properties. • Polarity is defined as the measure of the electrostatic attraction of the base oil in relative. Polar oils have the tendency to naturally bond to metal or other polar molecules to avoid metal to metal contact.	[7]

• Highly polar additives tend to bond with polar base oil and forming thicker reaction layer that would interrupt lubrication performance. • ZDDP have undesirable effects on wear and causes increase in friction when operated in mixed and boundary lubrication regimes.	[8]
• The most widely used AW additives in engine oils is ZDDP. • Working principles of FM is similar to AW where the oil soluble tail dissolved in base oil and the polar head is attached to metal surface as the formation of protective layers.	[9]
Structure of Monomeric ZDDP	[10]
• VI improver additives ease in reducing temperature dependence of lubricants and common examples of VI improvers are OCP and PAMA. • Polymer coils are formed when VI improver dissolved in base oil. This polymer coil size increases to balance the decrease in base oil viscosity when temperature increases.	[11]
Expected coefficient of friction range for boundary lubrication is from 0.02 to 0.30.	[12]
An inverse relationship between the area of the wear scar and the coefficient of friction is indicated using Four Ball Tester.	[13]

3 CHAPTER 3: METHODOLOGY

3.1 RESEARCH METHODOLOGY

As mentioned, the objective of this project is to study the effect and analyze the relationship between friction and wear performances of additives in commercial lubricants. In order to achieve the aim, a list of procedure is constructed and implemented. The research method used in this project is the quantitative research methodology. The reason being is that only measurable data are used to study the effect and identify relationship between friction and wear. Friction is measured by coefficient of friction while wear is measured by micrometers. Those measurable data are obtained using DUCOM Four Ball Tester with the aid of built-in software called WINDUCOM 2006.

The main part of the research methodology is the experimental procedure. A total of six samples are prepared in order to study and compare tribological performances. Each commercial lubricant is used to prepare three samples; 100% pure commercial lubricant; commercial lubricant with 10% additive X; commercial lubricant with 10% additive Y. All samples are tested experimentally using DUCOM Four Ball Tester. At least two run are performed for each samples in order to gain proper results. The data obtained are illustrated in form of graphs for both friction and wear results. Experimental procedure of Four Ball Tester is as listed below.

<u>EXPERIMENTAL PROCEDURE</u>

1. Four 66 HRC steel ball with 12.7mm diameter are cleaned using ethanol to remove any stain.
2. One ball is fixed into the top ball pot while the other three balls are held firmly in the bottom ball pot with a sample inside the tester chamber.
3. In the WINDUCOM software interface, the normal load and rotational speed are set to be 392N and 600rpm.
4. The temperature is set at 75°C and left the sample to be heated.
5. The time is then set at 0.5hrs before the WINDUCOM software is started to acquire.
6. The machine is stopped after 0.5hrs and the data is collected.
7. Steps 1 to 6 are repeated with another sample until all six samples are tested.

3.2 PROJECT ACTIVITIES

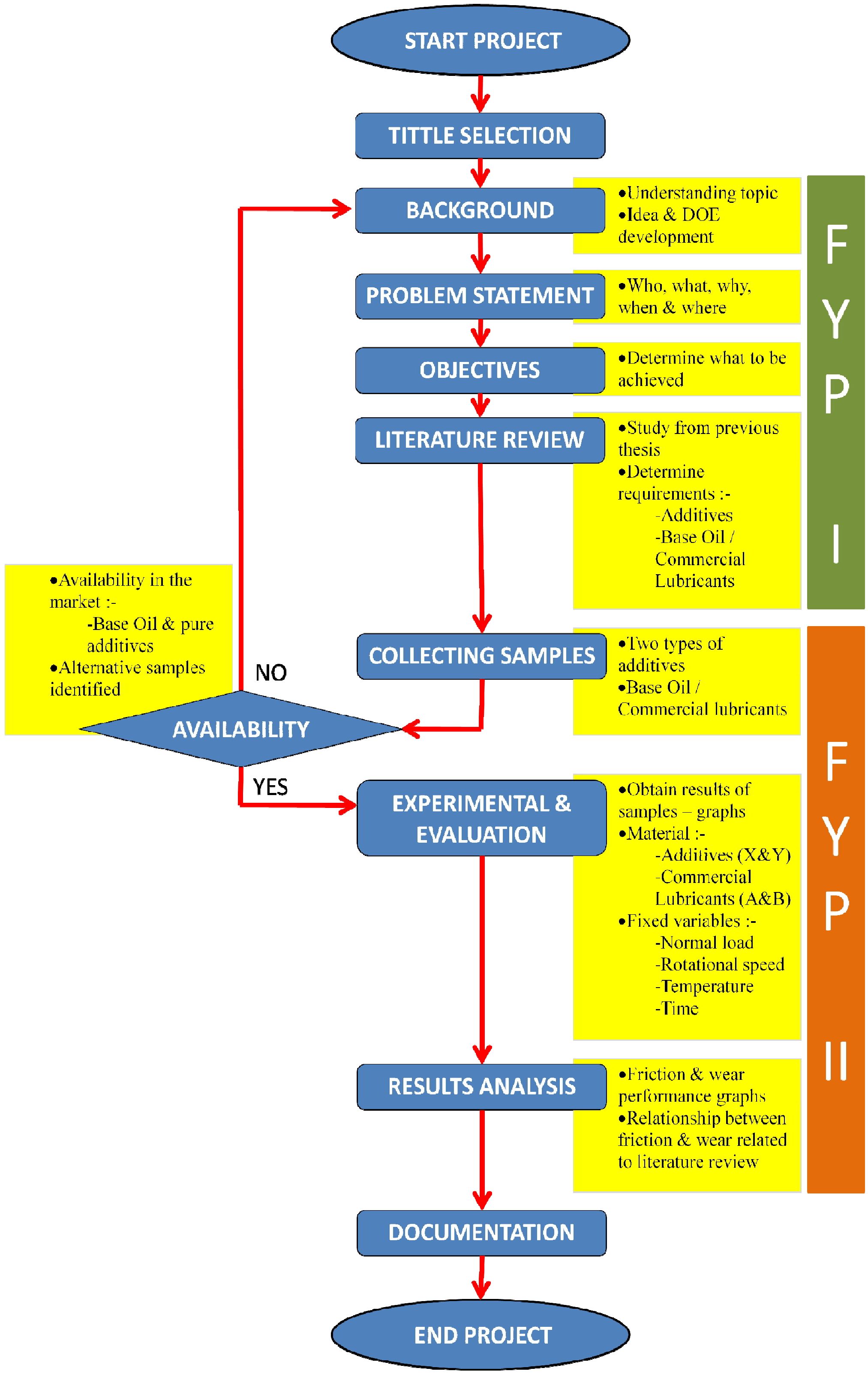

Figure 3.1: Project Methodology Flowchart.

3.3 GANTT CHART

Table 3.1: Final Year Project Gantt Chart.

ACTIVITIES	WEEK NUMBER																											
	SEMESTER I														SEMESTER II													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Tittle Selection																												
Introduction - Background of Study - Problem Statement - Objective - Scope of Study - Relevancy & Feasibility of The Project																												
Literature Review - Study of Thesis - Study of Additives & Base Oil																												
Extended Proposal Submission																												
Proposal Defence																												
Interim Report Submission																												
Collecting Samples - Additives & Lubricants																												
Experimental and Evaluation - Experimental Procedure																												
Results Analysis - Tribological Performances - Friction & Wear Relationship																												
Progress Report Submission & Pre-EDX																												
Oral Presentation																												
Technical Paper Submission																												
Documentation - Dissertation																												

3.4 EQUIPMENT

In order to achieve the objectives of this project, a proper machine called DUCOM TR 30 L is used to evaluate both friction and wear properties of a lubricant. This Four Ball Tester is widely accepted as the industry standard for conducting functional tests on lubricants. This test instrument has the unique capability of evaluating lubricants for all four different properties namely Wear Preventive (WP), Extreme Pressure (EP), Frictional and Fatigue Properties.

The instrument uses four balls, one on top and the other three at the bottom. Those bottom balls are held firmly in a ball pot containing sample under test and pressed against the rotating top ball. The sample under test is characterized for friction and wear performances by evaluating the wear scar formed on the balls after the test. In addition, this tester is compiled with the WINDUCOM software for data acquisition and display of results. Such built-in software allows the users to measure and set parameters for the test as normal load, rotating speed, temperature and time. Besides that, this software eases users to present collected data in various ways in order to view and compare the test results for further analysis. The Four Ball Tester specifications are illustrated in Table 3.2 below.

Table 3.2: DUCOM Four Ball Tester Specifications.

PARAMETERS	UNIT	MINIMUM	MAXIMUM
Speed	RPM	1000	3000
Maximum Axial Load	N	10 000	
Temperature	°C	Ambient	100
Test Ball Diameter	mm	12.7	

Both DUCOM Four Ball Tester and WINDUCOM data acquisition software interface are as shown in Figure 3.2 and Figure 3.3 for additional visual aid.

Figure 3.2: DUCOM Four Ball Tester.

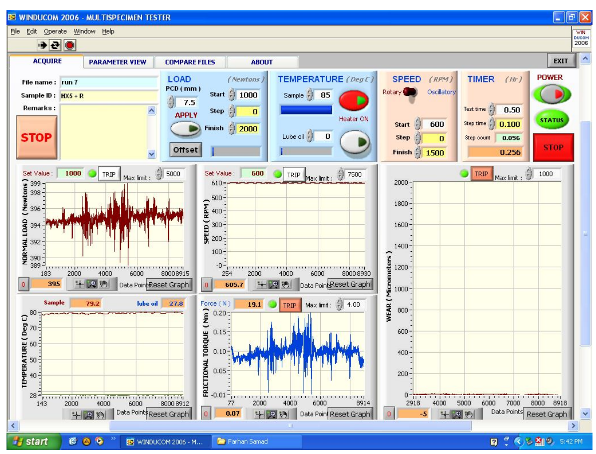

Figure 3.3: WINDUCOM Software Interface.

4 CHAPTER 4: RESULT AND DISCUSSION

4.1 DATA GATHERING

Based on the experiment conducted to all six samples using Four Ball Tester, the data obtained are in form of graphs. These graphs are generated by built-in software called WINDUCOM as a function of time. As for friction, this software illustrated the friction performance of respective samples in term of coefficient of friction for each seconds according to time requirement of the users. On the other hand, the tester illustrated wear performance of the samples in micrometers based on the scar formed on test balls during the experiment. Those findings are properly represented in graphs and explained in this section.

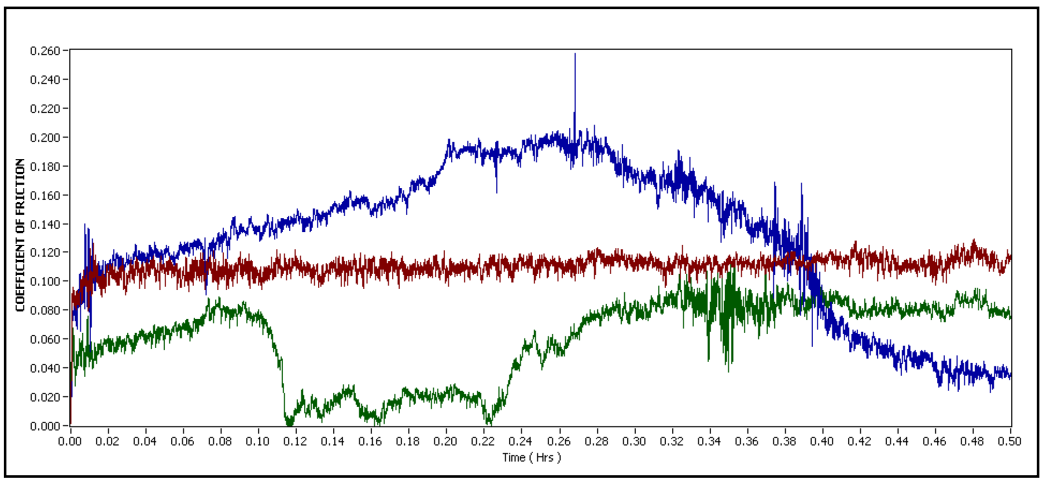

Figure 4.1: Coefficient of Friction vs. Time for Sample A Graph.

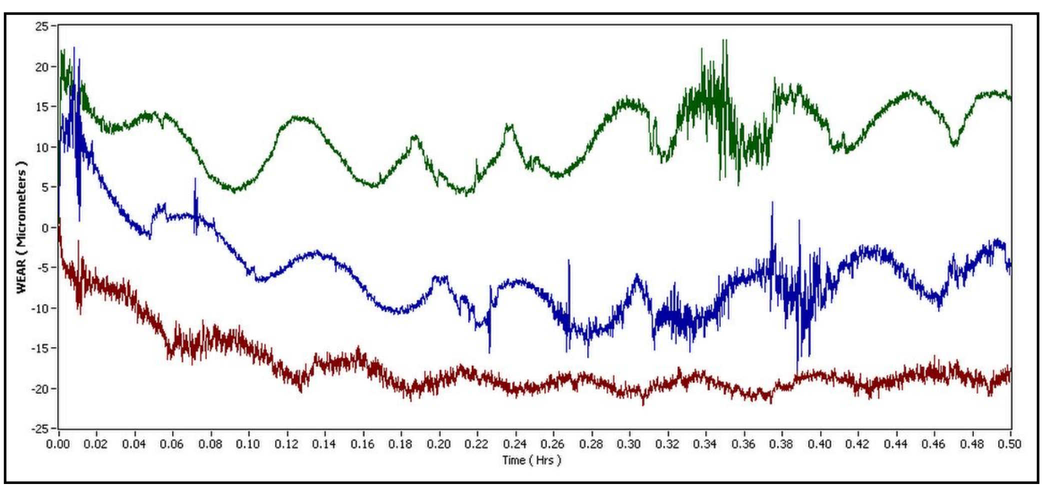

Figure 4.2: Wear vs. Time for Sample A Graph.

Table 4.1: Sample A Results.

SAMPLE	A	A + 10% X	A + 10% Y
COEFFICIENT OF FRICTION (MEAN)	0.110	0.130	0.059
WEAR AT 0.50 HRS (μm)	-20	-7	17

Based on the data gathering, Figure 4.1 represents the coefficient of friction value and Figure 4.2 shows the wear formed as a function of time for three commercial lubricants A samples, one without any additives and another two with presence of two types of additives. Those values are recorded for every second throughout the experiment period by WINDUCOM software. The software then generated a mean value for coefficient of friction and wear damage in term of micrometers as shown in Table 4.1 based on the collective value recorded.

According to the friction graph, sample A showed a stable condition of friction throughout experimental period which result in 0.110 as mean value for coefficient of friction. On the other hand, both samples A + 10% X and A + 10% Y illustrated unstable condition at every instant. As for sample A + 10% X, the value of friction coefficient increases from time 0hrs to 0.28hrs before started to decrease and eventually result in lower coefficient of friction comparing with other two samples after 0.40hrs. Such scenario might happen due to unstable chemical composition between lubricant and additive X at the early stage. The mean value of friction coefficient for sample A + 10% X recorded is 0.130. Coefficient of friction for sample A + 10% X is expected to be higher than sample A because additive X functions as anti-wear agent instead as friction modifier. Increment of 18% in coefficient of friction is observed for sample with presence of 10% additive X. While for sample A + 10% Y, coefficient values recorded are unstable but these values never exceeded sample A at any instant. According to the result obtained, the mean value of coefficient of friction for sample A + 10% Y is 0.059. At this instant, it is proven that the presence of friction modifier additive Y in commercial lubricants is significant as the value of friction coefficient is reduced up until 46%.

Based on the wear graph, all three samples shows fluctuate wear damage values in term of micrometers (µm) as a function of time. Throughout the experiment period of 0.50hrs, sample A + 10% Y showed highest wear damage value at every instant followed by A + 10% X. On the other hand, sample A alone demonstrated best wear damage condition comparing with other samples. Referring to point 0.50hrs, the wear damage for sample A + 10% Y, A + 10% X and A is 17µm, -7µm and -20µm respectively. Sample A + 10% Y is expected to has highest wear damage as presence of additive Y as a friction modifier agent might compete and deplete existing anti-wear agent in commercial lubricant A. This is proven as the wear damage for sample A with presence of 10% additive Y is almost double compare to original commercial lubricant A. While for sample A + 10% X, the wear damage recorded is surprisingly higher than sample A as it is expected to reduce wear damage with additional anti-wear agent in the sample. Such occurrence might be because of the composition of additive X as it is also compose of viscosity index improver. Based on the results obtained, it seemed that only minor composition of additive X is anti-wear agent. Thus, implication of additive X in commercial lubricant A in term of wear damage can not be identified clearly. Overall, original commercial lubricant which is sample A without presence of any additional additives showed superior property in term of wear damage.

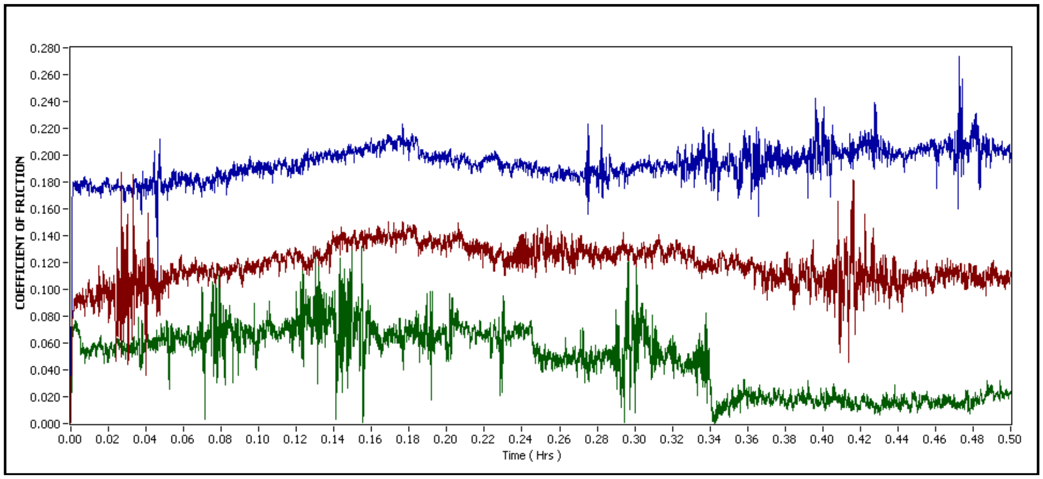

Figure 4.3: Coefficient of Friction vs. Time for Sample B Graph.

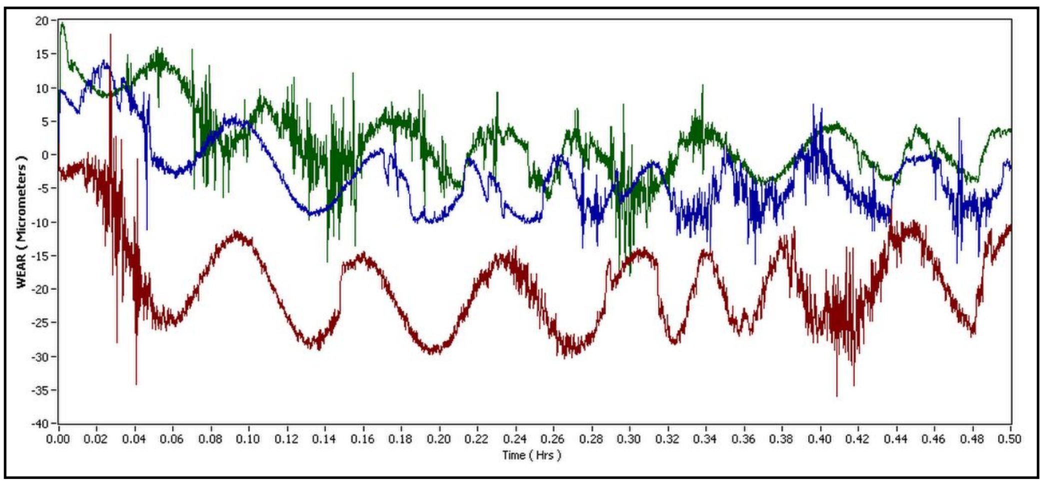

Figure 4.4: Wear vs. Time for Sample B Graph.

Table 4.2: Sample B Results.

SAMPLE	B	B + 10% X	B + 10% Y
COEFFICIENT OF FRICTION (MEAN)	0.119	0.194	0.048
WEAR AT 0.50 HRS (µm)	-12	-2	4

According to the results obtained, Figure 4.3 represents the coefficient of friction value over time for three commercial lubricants B samples while Figure 4.4 shows the wear formed as a function of time. Those three samples are one without any additives and another two with presence of two respective additives X and Y. Coefficient of friction and wear data are recorded for every second throughout the experiment period of 0.50hrs. The WINDUCOM software then generated a mean value for coefficient of friction and wear damage in micrometers as shown in Table 4.2 based on the collective value recorded.

Based on the friction graph for sample B, all samples show stable condition for coefficient of friction in contradict to sample A. This shows that additives X and Y are more compatible to commercial lubricant B compared to commercial lubricant A. Similarly to sample A, sample B + 10% X demonstrates the highest mean value of coefficient of friction which is 0.194 while sample B alone without any additional additives recorded mean value of 0.119. Presence of 10% additive X in lubricant B increases the coefficient of friction value approximately 63% and the result is as expected because additive X serves as anti-wear agent rather than friction modifier. On the other hand, sample B + 10% Y shows the most preferable value for coefficient of friction which is 0.048. A decrement of 60% in friction coefficient is observed with the presence of additive Y in commercial lubricant B.

Referring to the wear vs. time graph, all samples for lubricant B show values wear value throughout experiment period. There are not much different in term of wear damage value for sample B + 10% X and sample B + 10% Y as being referred to 0.50hrs. Both samples with presence of additives eventually increase the wear damage value of commercial lubricant B. Sample with additives Y shows significant increment in wear damage up to 133% while sample B + 10% X recorded increment of 117%. Addition of additive Y results in highest wear damage due to the competition between friction modifier agents inside the additive depleted anti-wear agent within commercial lubricant B. In contrast, additive X consists of minor portion of anti-wear agent that results in lesser wear damage comparing with sample B + 10% Y. Similarly to sample A, sample B alone without additional additives shows better wear performance.

4.2 DATA ANALYSIS

Based on the results obtained and analysis made, it is proven that additional additives in commercial lubricants affect the overall tribological performance in term of friction and wear. Presence of additive Y as a friction modifier agent in two commercial lubricants A and B is significant. Referring to coefficient of friction values recorded, reduction of 46% is observed for commercial lubricant A. In addition, decrement of 60% is observed for commercial lubricant B with the presence of 10% additive Y. Those figures showed that friction condition on an engine can be reduced by adding additional additive Y in commercial lubricants. This eventually might lead to less total power loss of a vehicle due to friction occurrence. In contrast, additional additive X in both commercial lubricants result in increasing of friction coefficient. In short, presence of additive Y in lubricants is preferable in order to improve the friction performance of automotive engine.

In terms of wear damage perspective, presence of additive X which consists small portion of anti-wear agent in both commercial lubricants A and B results in higher wear damage produced. Increment by 135% of wear damage is observed in lubricant A and 117% in lubricant B. The wear damage effect of additive X is unlikely determined due to minor composition of anti-wear agent inside it. Besides that, wear damage for both lubricants are at the highest point with presence of additive Y. It is observed that wear damage increases by 185% and 133% in commercial lubricants A and B respectively. Higher wear damage should be avoided to sustain the engine lifespan. In short, wear damage is at best without any additional additives in commercial lubricants.

According to the analysis, the relationship between friction and wear in lubrication is inversely proportional. Presence of additive X showed less wear damage but highest coefficient of friction. While presence of additive Y demonstrated minimum coefficient of friction and yet highest wear occurrence. This is because both types of additives have similar working principle and compete each other to perform specific function.

5 CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

As a conclusion, the effect of additional additive Y in commercial lubricants in term of friction is significant. 46% of friction coefficient reduction is observed with presence of additive Y in lubricant A while 60% decrement of friction coefficient reduction is observed in lubricant B. These proved that additive Y eases in friction reduction and eventually help in minimizing total power loss of an engine. However, presence of additive Y in both commercial lubricants leads to unacceptable wear damages. Highest wear damage is observed upon samples with 10% additive Y. Thus, additional additive Y might decreases total power loss of an engine but due to excessive wear damage, the engine lifespan might be shorten. For additive X, results showed negative feedback in both friction and wear performances. Samples with additive X increases 135% of wear damage in lubricant A and 117% of wear damage in lubricant B. Thus, additive X is unable to improve tribological performances. In addition, an inverse relationship is observed between friction and wear. Above all, pure commercial lubricants without additional commercial additives showed stable performance in term of friction coefficient and least wear damage comparing with other samples. In short, it is proven that commercial lubricants are superior without any additional commercial additives for automotive lubrication.

5.2 RECOMMENDATIONS

Based on the objectives, the effects of additives upon wear performance are unlikely determined. This is because additive X only consists minor portion of anti-wear agent. Significant of anti-wear agent in commercial lubricants is unclearly recorded. The wear damage for both lubricants with presence of additive X should be lesser than lubricant A and B. It is recommended that pure additives are used in order to study friction and wear performances in automotive lubrication. Besides that, chemically pure additives can be used to further the study by identifying proper portions of anti-wear agent and friction modifier agent inside commercial lubricants that would lead to better overall performances.

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