Faculty of Mechanical Engineering

THE EFFECTS OF ZINC DIALKYLDITHIOPHOSPHATES (ZINC DDP) AS AN ANTI WEAR NANOPARTICLES IN ENGINE OIL

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Bachelor Degree of Mechanical Engineering

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A report submitted

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DECLARATION

I Mu'Ammar Danii Bin Saifuddin declares that this project report entitled "The Effects Of Zinc Dialkyldithiophosphates (Zinc DDP) As An Anti-Wear Nanoparticles In Engine Oil", under the guidance of Dr. Mohd Rody Bin Mohamad Zin, and is my original work except references material.

Signature : ______________________________

Name : Mu'Ammar Danii Bin Saifuddin

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 Bachelor of Mechanical Engineering.

Signature : ______________________________

Supervisors Name : Dr. Mohd Rody Bin Mohamad Zin

Date : ______________________________

DEDICATION

I dedicated my study to my beloved mother and father who always give motivation and encouragement to finish my study until the ends. I also want to thanks to my brother and sister the person never left my side cheer and raise my spirit to work harder to complete the study. Not forgotten to my friends who always supported me throughout the process. Last but not least, I will always appreciated all they have done especially to Dr. Rody the person always guide me to finish the work, Ms. Ayuma who assisted me in the laboratory and sharing knowledge. I want to give special thanks again to all person who helps in this works and supported me to the ends.

ABSTRACT

This study aims to investigate the effect of Zinc Dithiophosphate (ZDDP) nanoparticles when used as an additive in lubricating oil. The lubricant + ZDDP oil was prepared by dispersing an optimal composition of 2 per cent of Zinc Dialkyldithiophosphate in Max Pro SAE 15W – 40 engine oil using an ultrasonic homogenizer. The tribological testing was performed using a pin on disk tester following the ASTM standard. Based on the experiment, it was found that the Nano – oil has a potential to decelerate the wear on the contact surfaces. More wear was observed on the worn surfaces of ball bearing lubricated with SAE 15W – 40 engine oil as compared with the Nano – oil lubrication.

ABSTRAK

Kajian ini bertujuan untuk mengkaji kesan nanopartikel zink dithiophosphate (ZDDP) apabila digunakan sebagai bahan tambahan dalam minyak pelincir. Minyak pelincir yang dicampurkan dengan ZDDP disediakan dengan mencampurkan komposisi optimum 2 peratus daripada Zinc Dialkyldithiophosphate dalam Max Pro SAE 15W - 40 menggunakan homogenizer ultrasonik. Ujian tribologi dilakukan menggunakan pin pada penguji cakera mengikut piawai ASTM. Berdasarkan kajian, didapati bahawa minyak nano mempunyai potensi untuk mengurangkan haus pada permukaan yang bergesel. Lebih banyak *wear* diperhatikan pada permukaan yang dipakai bola yang dilincirkan dengan minyak enjin SAE 15W - 40 berbanding dengan minyak pelincir nano.

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INTRODUCTION

1.1 BACKGROUND

The development of the new technologies solutions, such as introducing lightweight materials, less harmful fuels, controlled fuel combustion and more efficient gas after treatment are possible means to decrease environmental problems brought by vehicles and machines. Lubricant, fuel and engine materials are closely related to each other. The conventional mineral oil based lubricant is widely used in most of the engine system nowadays. However, the supply for this source is slowly decreasing as the source for this type of fuel comes from the based on fossil fuel (such as gasoline and diesel fuels). In order to recover the usage of the mineral oil, some additives are added to improve the quality of the mineral oil to maintain it sustainability. However, adding some additive will result in a good or a bad ways to the oil as it degrades lube oil quality and increases the wear rate of the engine components. There are various functions of lubricant oil which are to reduce wear and increase cooling that result from the contact surfaces in motion and reduce the coefficient of friction between two contacting surfaces. Other than that, the purposes of the lubricant is to prevent rust and reduce oxidation, to act as an insulator in transformer application and finally to act as a seal against dirt and dust and water. A lubricant is a liquid that can reduces friction and wear by providing a protective layer between two surfaces in contact. Good lubricants have a high viscosity index (VI), stable in thermal, very high boiling point, low freezing point, have an ability that can prevent corrosion and resist to oxidation.

1.2 PROBLEM STATEMENT

A huge amount of loss has become a whole wide problem that were caused by the friction and wear. Maximum efficiency and at the same time being environmental friendly can be obtain if the friction and wear in the automotive is reduced. By reducing waste consistently creates an increasing demand for research in Tribology, especially in lubrication. Accordingly, presenting more efficient lubrication or self – lubricating materials may be the solution in overcoming these problems.

Nowadays, studies on carbon reinforced with various types of matrix as reinforcement has become popular as an alternative to current lubricating materials has become an attraction in Tribology field. Studies on the use of natural products such as fiber into composites have already been done by a number of researchers such as Nirmal et. al (2015) and Bakry et. al (2013). However, there is a research gap on the use of waste as self – lubricating materials. The conventional mineral oil based lubricant was developed based on fossil fuel (such as gasoline and diesel fuels) which is not suitable for the biodiesel – fueled engine as it degrades lube oil quality and increases the wear rate of the engine components.

The supply mineral in this world is slowly decreasing and it is expected to go extinct in the few years to go. The addition of some anti – wear nanoparticles in into the mineral oil as the additive is like the solution for this problem as it will reduce the usage of the mineral oil. However, in order to get the optimum ratio of the anti – wear nanoparticles so that the additive will work perfectly in the mineral oil and not degrading the oil in a bad ways, a research have to be done.

1.3 OBJECTIVE

The study objectives were largely influenced by findings from other previous studies as well as anchored on the potential in reducing friction and wear. The scope and limitations of the study further limits the study to the following objectives:

1. To study the tribology of zinc dialkyldithiophosphate anti – wear nanoparticle lubricant under normal condition.
2. To study the effect of anti – wear nanoparticles lubricant on tribological properties of steel vs aluminum contact.
3. To compare the lubricant oil without zinc DDP as the anti – wear nanoparticles with the lubricant oil with zinc DDP additives.

1.4 SCOPE OF STUDY

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

1. Literature review

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

2. Experiment

The experiment of the Pin on Disk test will be made based on the data input

3. Analysis and proposed solution

Analysis will be presented on how the zinc dialkyldithiophosphate anti – wear nanoparticles can effects the lubricants efficiency. Solutions will be proposed based on the analysis.

4. Report writing

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

CHAPTER 2

LITERATURE REVIEW

2.1 Nano Technology

Today, almost all of the mobile parts need at least some amount of lubrication system to avoid wear during use. (Herdan, 2000). Commercial lubricants have been used mostly in a lot of vehicle such as cars, motorcycle and even in heavy vehicle like lorry and buses. However, the aim of the usage of the lubricants are always stay the same, which is to reduce wear to the lowest level as it can reach and to increase the coefficient of friction (COF) between two surfaces in contact (Obiols, 2014).

Nowadays, a lot of things has become a nano – invention as the world moves towards nano – technology. At this moment, lubricant technology has also moved to the nano – lubricants (Wu et al., 2007), giving an increase to the idea of discovering an optional nano – additive. (Zhou et al., 2001) explored that the purposes of LaF_3 – DDP nanoparticles as an oil additive can significantly increase the load – carrying capacity and anti – wear property of the base oil and has a good friction reducing properties.

2.2 Better Automotive Technology Demand

During 2014, Malaysian Government released a guideline statement following its new looks for the automotive industry. Under the National Automotive Policy, the Malaysian government informed that Malaysia will now undergoing and at the same time will also encouraging energy efficient vehicles or EEV mostly in the production of local car. Other than that, the Malaysian government also aim for the target of by the year 2020 for the EEV to at least reach the standard terms of carbon emission level and fuel consumption (Dasar Automotif Nasional, 2014).

Referring to the journal by Holmberg et. al (2012), at maximum, around 21.5% of the energy produced in the engine were fully used to move the car. He also stated that the energy loss were classified into loss to the exhaust, loss due to cooling process, and also mechanical power. The mechanical energy were then separated into friction loss and air drag resistance. 11.5% were loss at the engine, 5% were loss at the transmission, 11.55 were loss at the rolling resistance and the remaining of that are lost to the brakes which is 5%, all of that are come from the friction loss percentage. The friction at the rolling resistance, the brakes, and also the air drag were actually very impossible to be eliminated as it is important to move the car. In this case, there are a lot of energy loss in a single car at this moment. The division of the energy consumption were shown in Figure 2.1. Thus, it can be conclude that even if a minimum upgrade is made, the efficiency of the engine would be increased with respect to the increase of efficiency.

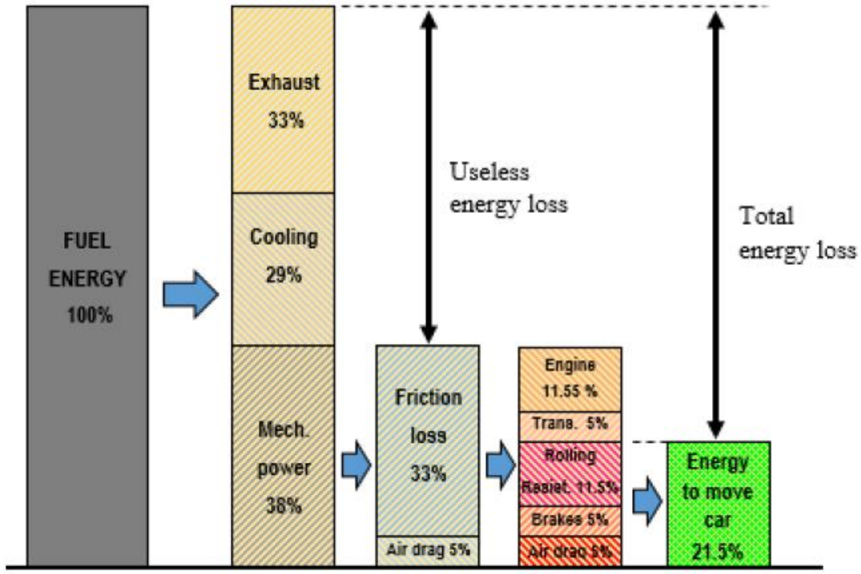


Figure 1: Breakdown of a passenger car energy consumption

[Source: Holmberg et. al (2012)]

From the figure above, Figure 2.1 it is obvious that the total energy loss were triple than the energy used to move the car. In order to increase the efficiency of the engine is by minimizing the energy dissipated to the surrounding due to mechanical interactions in the system. The mechanical contacts in the engine, which is the main objective of this study, are importantly the friction and wear between moving parts of the engine, including components such as bearings, clutches and pistons.

2.3 Lubrication Theory

The main reason to have a lubrication system in your vehicle is to reduce wear. Other than that, a lubrication is also widely used as a heat removal system between two contacting surfaces. The lubricants oil will acts as a layer that will avoid the two surfaces in contact from directly contacted. The separation lessens the impact of the friction and heat between the contacting surfaces will also be reduced as a result of the separation. As a result, the wear and tear of parts are reduced. Other than that, this will be a good alternative to avoid the damage in engine system become faster and will make the engine last longer. Lubrication is also used to reduce oxidation and prevent rust. According to Nosonovsky and Bushan (2012) sometimes, lubrication is used as insulation in components. Besides, the purposes of lubrication is also to clean the engine as it will help to remove the debris or particles and send them to an oil filter. The lubricants also help to produce a seal between two parts and thus avoid the compression gas escape into the crankcase area.

Lubrication can be divided into three groups, solid, liquid and gas type. Lubrication is introduced between two contacting surfaces to act as a boundary layer between those surfaces. This means that, the asperities between the surfaces are not touching each other technically. Figure 2.2 illustrates the presence of lubrication between two contacting surfaces.

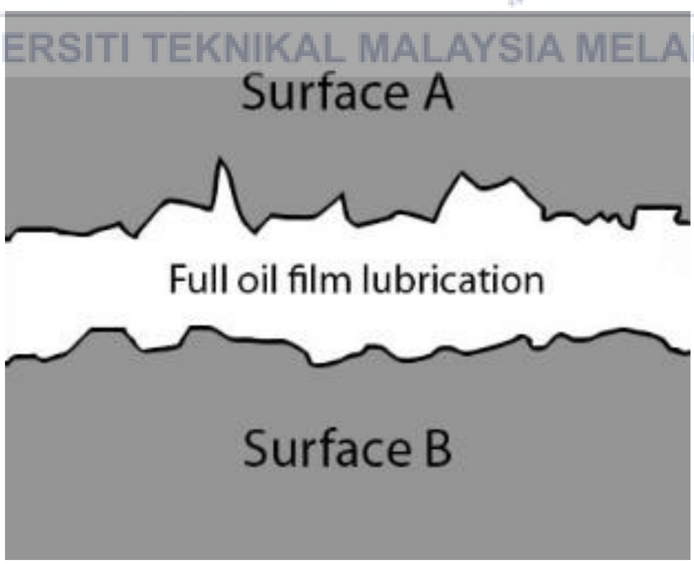


Figure 2: Lubrication between two contacting surfaces

2.4 Contaminants in Engine Oil

There are a lot of contaminants in the engine oil. The contaminants can be very harmful for the engine as it can make the combustion in the engine cannot happen effectively. Contaminants in engine oil can happen if the engine is not cleaned correctly and frequently. It also happen if some of the parts that are present in the engine are broken or loose.

One of the contaminants in engine oil is the road dust and dirt. The road dust and dirt can come from the external environment. It can be very harmful to the engine. It is the job of the oil system to remove these contaminants.

Other than that is the carbon and fuel soot. This happen because many particles of carbon and soot are not burned completely. Pressure produced by the combustion force some of this unburned fuel and carbon pat the rings into the crankcase area (blow – by).

The most common contaminants in engine oil the water contamination. It is due to the leaks in the cooling system or from water vapor from the combustion by – product. Blow – by process forces the water vapor into the crankcase area. As the water vapor enters the crankcase, it cools and condenses into a liquid. The water can produce problems with the sludge and acids. Sludge are produced when the oil becomes thickened with water or other contaminants.

Fuel contamination is also the most common contaminants that can obtained in the engine. It is due to the fuel dilution. The presence of fuel in excess of 5% gasoline or 7% diesel fuel may lead to rapid engine wear.

Oil oxidation. It is defined as the combining of hydrocarbons and other combustion products with oxygen. The oil oxidation can increases in oil temperature and in water in the crankcase enhance oil oxidation.

Other than that is the acids in engine. This contaminants can cause a lot of problems to the engine. One of the effects is it can cause the corrosion and failure to the engine.

2.5 Zinc Dialkyldithiophosphate

Mineral base engine oil has been used as lubricant in the engine for a long time. According to Gawrillaw (2003), base oil was used as lubricant to lubricate machineries since 1650BC. However, there is a limitation of using the mineral base oil as lubricant because the characteristics of base oil is low oxidation. This statement was supported by Cheenkachoma (2013), where he stated that an inherent property of base oils is low oxidative stability.

Therefore, adding the additive in the mineral base oil is one of the solutions. The additive that is suitable to overcome the oxidation is Zinc Dialkyldithiophosphate (ZDDP). A research by Johnson et al. 1986 found that the interactions between ZDDP and oxidations products were thought to have led to the observed decrease in activity. This statement also been supported by Barnes et al. 2001, it stated that ZDDP's were used mainly for their antioxidant properties and their ability to prevent wear.

CHAPTER 3

METHODOLOGY

3.1 Introduction of methodology

This chapter is describing all the methodology used in this project to obtain the best result of the tribological studies of zinc dialkyldithiophosphate (ZDDP) anti – wear nanoparticles lubricant under normal condition. This project starts by experimenting the most suitable way to obtain the best sample preparation. Thus, it will result in a good way to the experiment and the experiment will give a good result.

3.2 General Process

This project focused on finding the tribological effects of anti – wear nanoparticles lubricant under extreme temperature using the Pin on Disk Tester experiment. To achieve the discussed objectives that have been mentioned earlier in Chapter 1, the process was divided into six phases. The graphical diagram of the process is shown in Figure 3.1.

Phase 1 started with the Literature review. Basically, this involved with the research of the past journal that discussing the related topics. A few journals are taken as the reference for this experiment to ensure that the experiment is relevant and rational.

For Phase 2, started with the preparation of the materials. Particularly, this involved with the deciding the best percentage for zinc dialkyldithiophosphate (ZDDP) nanoparticles lubricant that will be used in this experiment. The percentages of the nanoparticles are decided based on the past journal.

For Phase 3, this involved with the preparation of the zinc dialkyldithiophosphate nanoparticles anti – wear. The nanoparticles anti – wear can be provided by the lab assistant or can be obtained from the supervisor. The process of mixing the nanoparticles anti – wear is also done in this phase.

Phase 4 is the pin on disk testing experiment. Once the nanoparticles and the oil are ready, the pin on disk test is done to the lubricant oil.

For Phase 5, it involves with the quantitative analysis calculation of COF, wear rate, and both wear and friction equation determination. All the reading from the experiment are recorded and a few calculations are made. The first analysis conducted was quantitative analysis through calculation of coefficient of friction and wear rate. Then, from the results, friction wear equation was proposed.

For Phase 6, it involves with the qualitative analysis and the worn surface analysis. Based on the calculation from the Phase 5, the analysis from the result are made to get the exact and useful information. The weight loss and the volume loss of the pin is measured by weighing the pin before and after the experiment. Discussion will be made and a conclusion can be done.

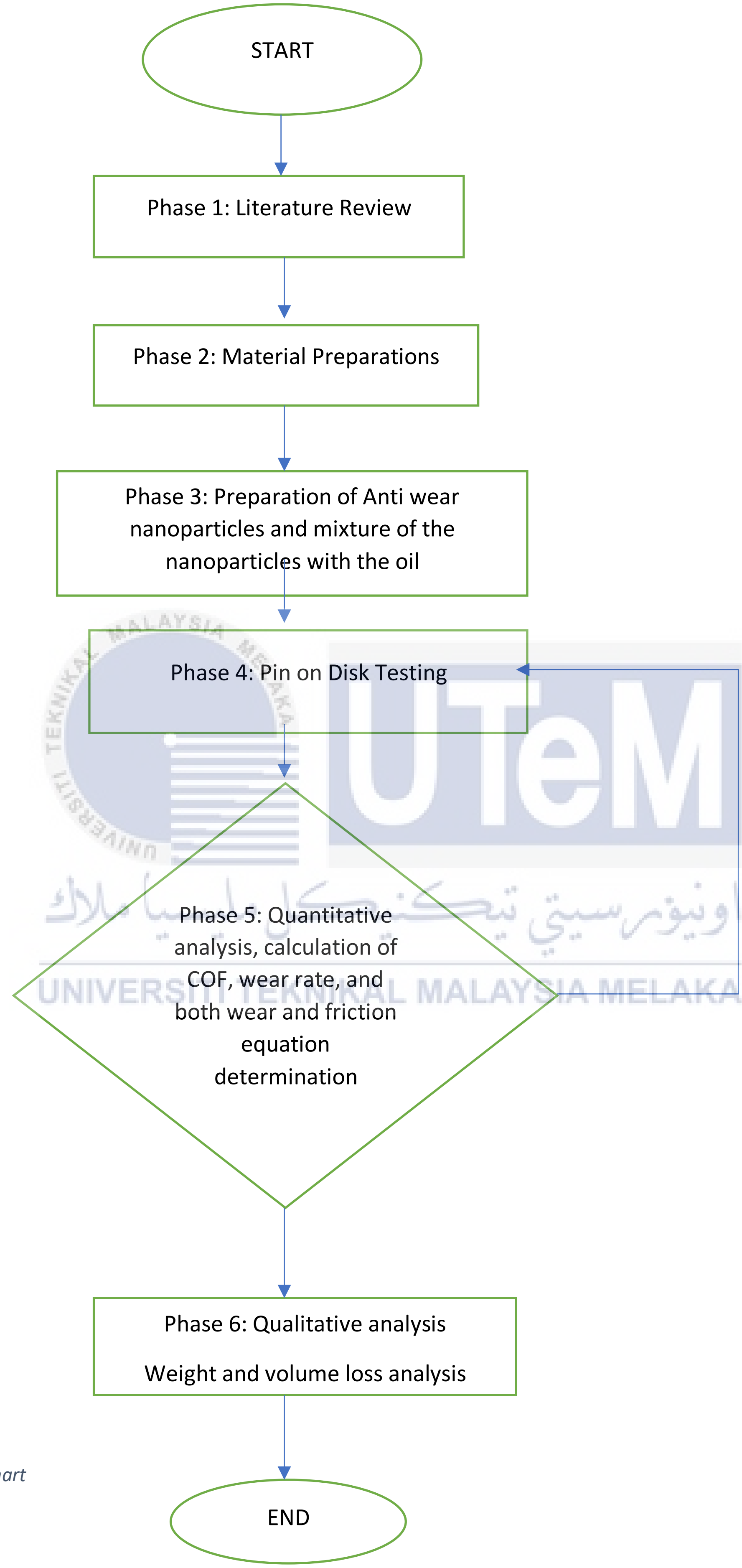


Figure 3: Flow Chart

Activity	Semester 1 Session 2017-2018														
	Week														
PSM 1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project planning															
Chapter 1: Introduction															
Chapter 2: Literature Review															
Chapter 3: Methodology															
Chapter 4: Preliminary results															
Progress report submission															
Report submission															

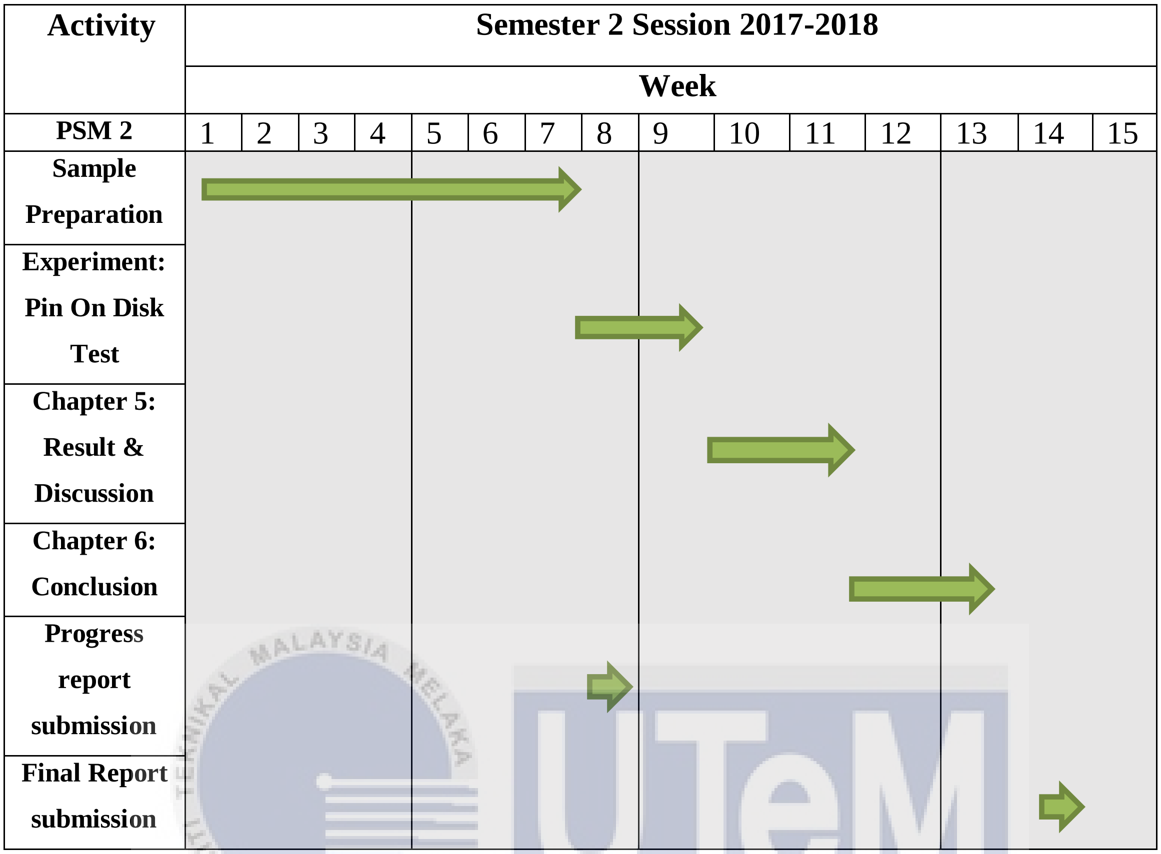


Figure 4: Gantt Chart

3.3 Pin on Disk Tester

The Pin on Disk test is used to determine the wear avoiding characteristics of a lubricants on two contact surfaces operating under a certain boundary lubrication conditions.

Standard of Procedure following the ASTM Standard:

1. The specimen is cleaned and dried prior to testing, and prior to measuring or weighing. The dirt and foreign matter is removed from the specimens. Non – chlorinated, non – film – forming cleaning agents and solvents is used. The materials is dried with open grains to remove all traces of the cleaning fluids that may be entrapped in the material. Steel (ferromagnetic) specimens having residual magnetism should be demagnetized. The ultrasonic bath is used with the help of acetone to clean the specimen.
2. The specimen is weighed using the electronic weighing scale to the nearest 0.0001 g.
3. The disk is inserted securely in the holding device so that the disk is fixed perpendicular ($\pm 1^\circ$) to the axis of the resolution.
4. The pin specimen is securely inserted in its holder and, if necessary, the specimen is adjusted so that it is perpendicular ($\pm 1^\circ$) to the disk surface when in contact, in order to maintain the necessary contact conditions.
5. The proper mass is added to the system lever or bale to develop the selected force pressing the pin against the disk.
6. The motor is started and the speed is adjusted to the desired value while holding the pin specimen out of contact with the disk. The motor is stopped once the desired speed is achieved.
7. The time taken for an experiment is set in the pin on disk test machine.
8. All the information such as speed, diameter of the rotation, time taken and applied load are recoded in the computer in the form of DUF and DWF file types.
9. The test is begin with the specimens in contact under load. The test is stopped when the desired time taken of revolutions is achieved. Test should not be interrupted or restarted.

10. The specimen is removed and is cleaned off with the ultrasonic bath to clean off any loose wear debris and oil. Note the existence of features on or near the wear scar such as; protrusions, displaced metal, discoloration, micro cracking or spotting.
11. Remeasure the mass of the specimen to the nearest 0.0001 g, as appropriate.
12. The test is repeated with additional specimens to obtain sufficient data for statistically significant results.

Figure 5: Pin On Disk Tester

Figure 6: Pin on disk machine controller

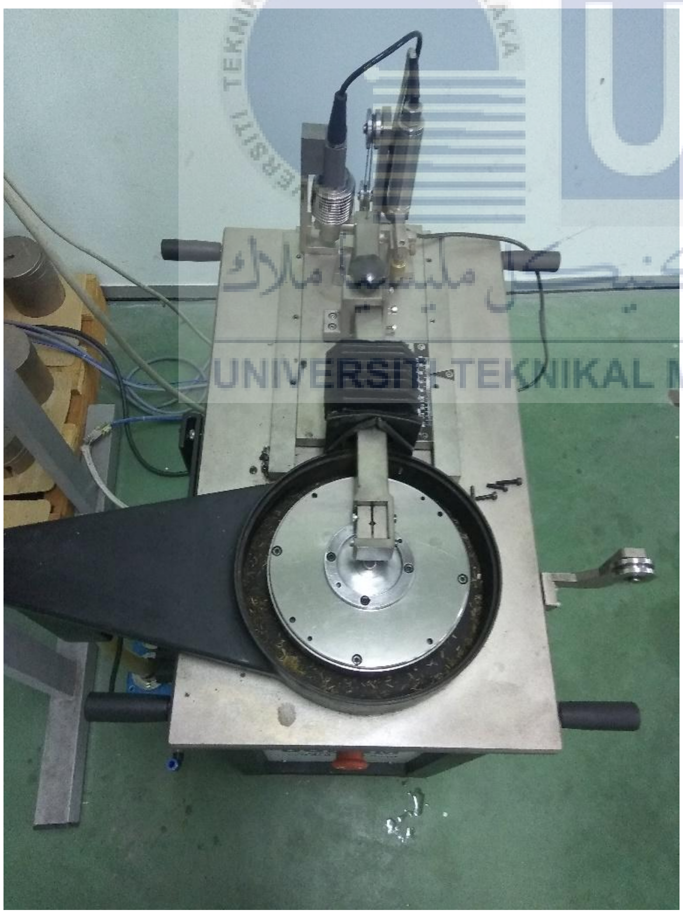


Figure 7: Pin on disk top view

3.4 Ultrasonic Bath

Ultrasonic bath is used to clean off the dirt and the microorganism that happen to be at the specimens. These unwanted microorganism will disturbed the weight of pin after tested and before tested. This is because, the weight that should be calculated is just the actual weight of the pin without anything attached to the pin. The used of acetone is vital in this cleaning process.

Safety issues:

1. Normal electrical precautions should be followed.
2. Gloves, eye and ear protection are required.
3. Avoid exposure to aerosols by using in a Biological Safety Cabinet.

Setting up:

1. The drain is make sure to be empty.
2. In a beaker, the sample is make sure to be submerged into acetone.
3. The beaker is placed in the ultrasonic bath.
4. The bath is filled with the tap water and is make sure to not fill pass the line.
5. The "Start" button is pressed to run the bath.
6. The bath is automatically stop after the desired amount of time set.
7. The bath is cleansed thoroughly after each use. The tap water is drained out after used and the beaker is cleaned properly.

Figure 8: Ultrasonic bath inside view

Figure 9: Ultrasonic bath

3.5 Ultrasonic Homogenizer

Ultrasonic homogenizer is used to mix the zinc dialkyldithiophosphate (ZDDP) with the oil. The process of mixing the zinc dialkyldithiophosphate cannot be done by stirring the substances manually as oil is very hard to mix with. Oil is very hard to mix even with water, therefore, the zinc dialkyldithiophosphate will also a few times harder to be mixed with. Thus, the ultrasonic homogenizer is used in this mixing process.

Safety issues:

1. Normal electrical precautions should be followed.
2. Gloves, eye and ear protection are required.
3. Avoid exposure to aerosols by using in a Biological Safety Cabinet.

Setting up:

1. The correct probe is choose according to the total volume of your liquid.
2. The probe is inserted by using a spanner.
3. The liquid container is put down on the base.
4. The base is lifted until the probe is half submerged into the liquid container.
5. The machine is switched on.
6. The machine is switched off after the mixing process is done.
7. The machine is cleaned thoroughly after used. The probe need to be clean by using acetone.

Guidelines to use:

1. Different volume of liquid requires different types of probe. Ensure the conditions for the sample are appropriate.
2. Consider closing the door to avoid noise from the machine.
3. Avoid leaving the machine while operating to make sure the condition of machine is under control.

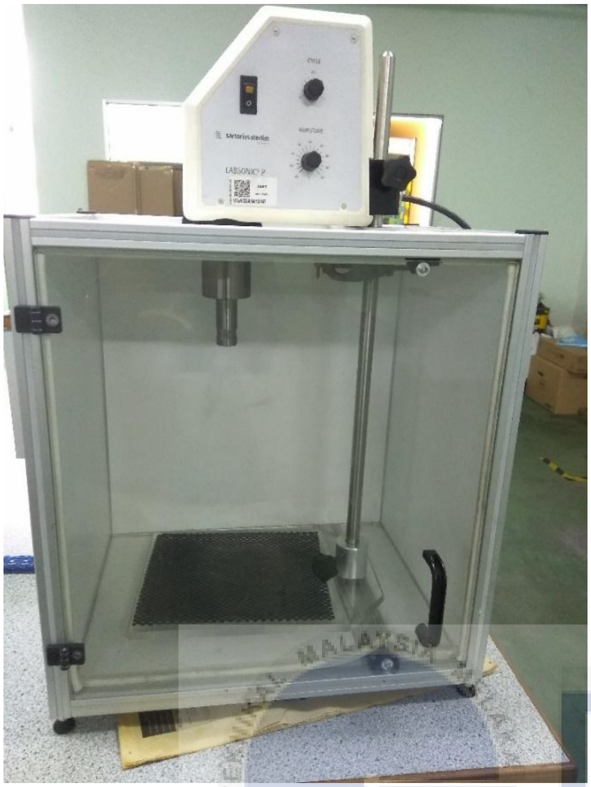


Figure 10: Ultrasonic homogenizer

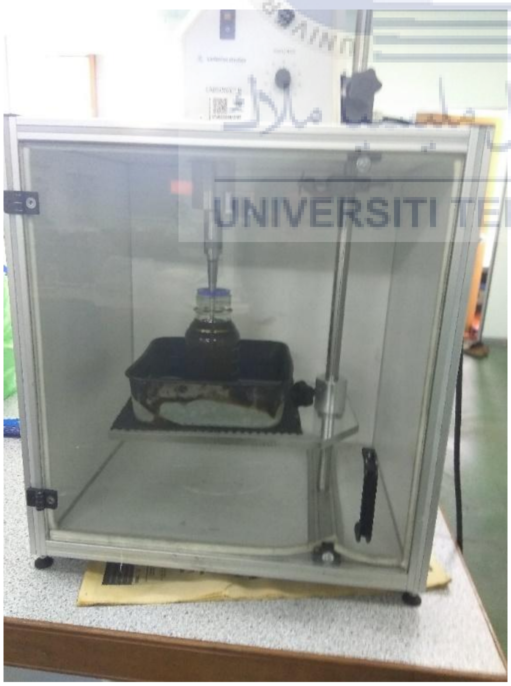


Figure 11: Ultrasonic homogenizer mixing process set up

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Sample Preparation

4.1.1 Determining the percentage ratio of Zinc DDP

Samples must be in a correct composition in order to be able to conduct the pin on disk test. However, some calculation is done in order to get the best ratio of the Zinc Dialkyldithiophosphates (zinc DDP) to be added into the lubricant oil. Zainal. 2015, investigated the physical property of canola oil when blended with zinc DDP as additive. From his experiment, he used 3 different concentration percentage of zinc DDP in the canola oil, which is 0% wt, 2% wt, and 5% wt. The result reported that the concentration which has the most anti wear affect is the 2% as it has the less coefficient of friction. In this experiment, the optimal ratio for the zinc DDP that is going to be added into the lubricant oil is 2% wt. Only 3ml of the lubricant oil is used for each set of the experiment. Since 1 ml is basically equal to 1 g in a direct conversion, thus, 2% of 3 ml is equal to 0.006 ml and it is almost impossible to measure it as the value is too small. A more accurate measuring instrument is required to get the exact measurement. Thus, I decided to enlarge the scale of the sample by preparing a sample of 100 ml of lubricant. Instead of preparing the sample once for each time of the experiment done, I decided to make a more sample so that I don't have to mix the sample too often and also it can save time.

$2\%\ of\ 3\ ml \rightarrow\ 0.006\ ml$ (Hard to measure)

$2\%\ of\ 100\ ml \rightarrow 2\ ml$ (Easier to measure, can be measure using syringe or measuring cylinder)

From the calculation,

$$\frac{2}{100} \times 100\ gm = 2\ gm$$

2% from 100 gm is equal to 2 gm.

Since,

1 gm = 1ml

2 gm = 2 ml

Thus, 2ml of zinc DDP is used in this experiment. This value is possible to be measured using the measuring cylinder or using the syringe to get a more accurate value.

	Lubricant Oil (Max Pro SAE 15-W 40)	Zinc DDP	Total
Weight (%)	98%	2%	100%
Weight (g)	98 g	2 g	100 g
Volume (ml)	98 ml	2 ml	100 ml

Figure 12: Weight percentage of the Lubricant oil and the zinc DDP

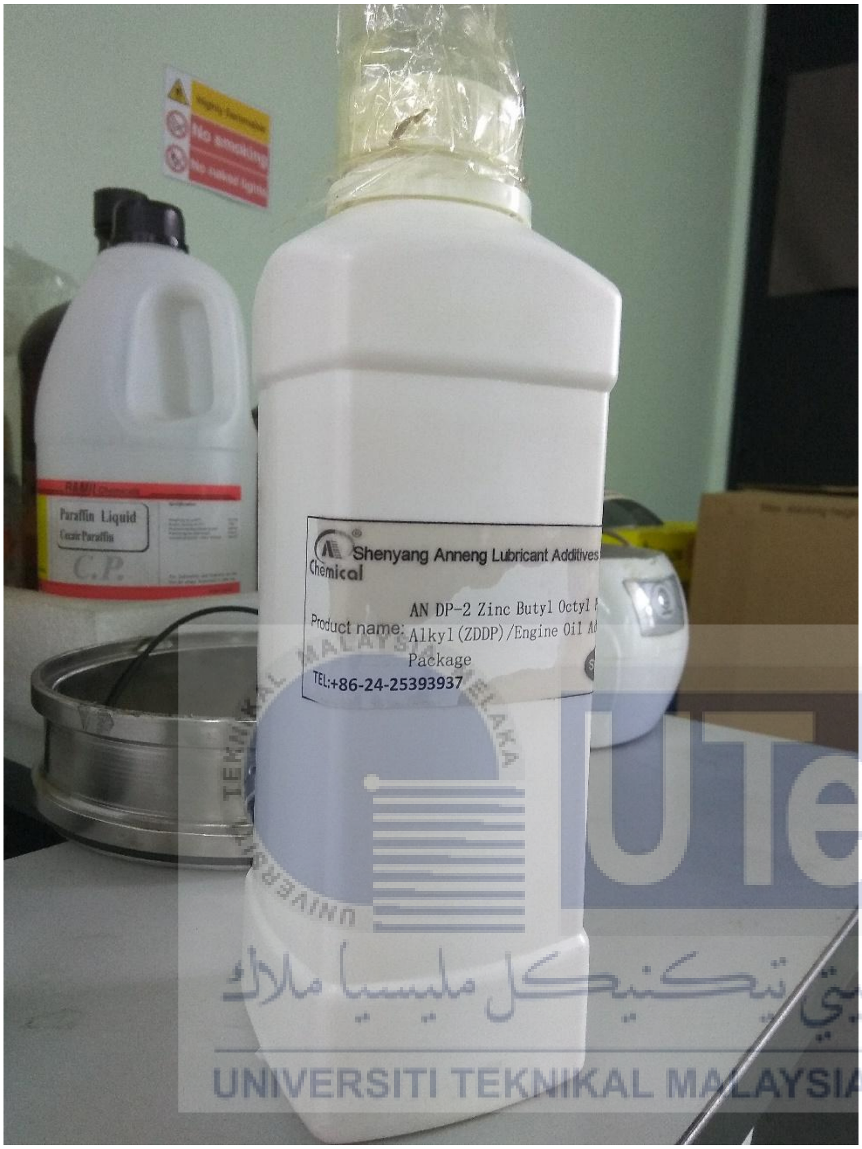


Figure 13: Zinc dialkyldithiophosphates (Zinc DDP)

4.1.2 Weighing process of the Zinc DDP

An empty beaker is weighted using the electronic weighing balance. Then, the zinc DDP is poured into the empty beaker until the weight of the beaker increased by 2 g. Another empty beaker is weighted also using the electronic weighing balance. Then, the lubricant oil (Max Pro SAE 15W-40) is poured into the beaker until the weight of the beaker and the lubricant oil increased by 98 g. The zinc DDP is then mixed into the oil in a glass container size of a bottle. The glass container is first to be cleaned using the tools solvent such as acetone and cleanser alcohol. This is to make sure that there is no chemical substances inside the glass container as it will disturb the composition of the mixture and will cause the zinc DDP to be ineffective.

Item	Weight (g)
Empty beaker	60.02
Zinc DDP	2.00
Beaker + Zinc DDP	62.02

Figure 14: Data for the weighing process of the Zinc DDP

Figure 15: Electronic weighing balance

4.1.3 The mixture process of Zinc DDP and lubricant oil

The zinc DDP and the lubricant oil are mixed using the ultrasonic homogenizer. The setting for the instrument is kept under the normal condition which is at 0.5 for the cycle and 50 for the amplitude. The mixture is mixed for 30 minutes to make sure that the mixture mixed well and there is no longer separation between the oil and the zinc DDP, as oil is very hard to be mixed with. 30 minutes is enough to mix the zinc DDP and the oil as the zinc DDP is in the state of liquid. A longer time must be required if the zinc DDP is in the state of solid as solid has a stronger molecular bond than in the liquid state.

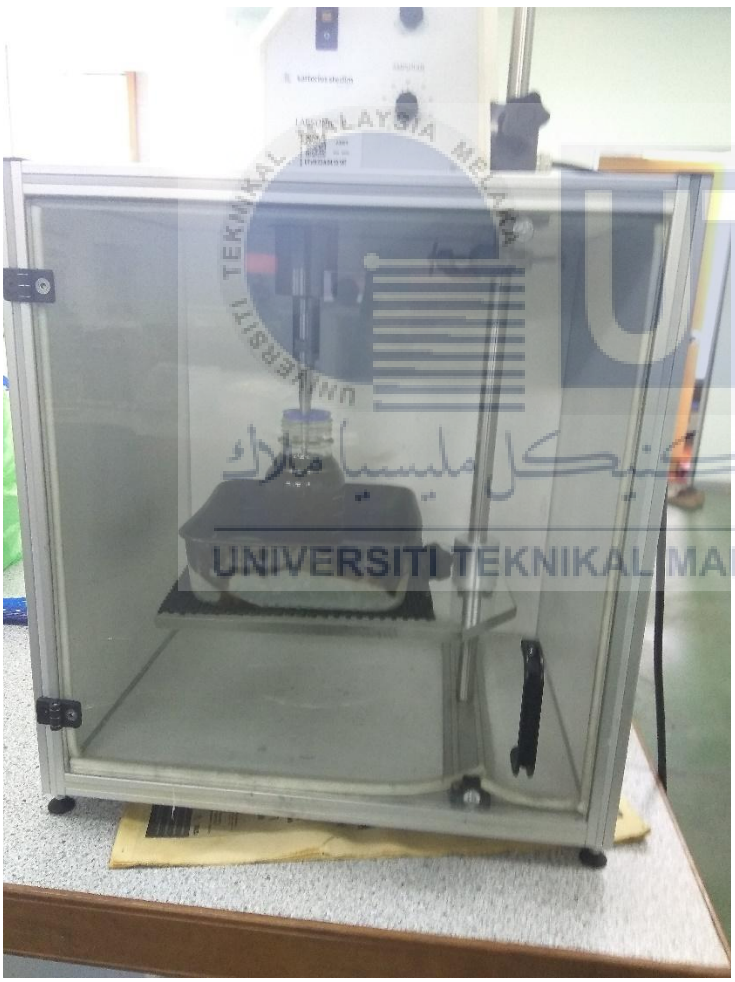


Figure 16: Mixture process of Zinc DDP and lubricant oil (Max Pro SAE 15W-40) using ultrasonic homogenizer)

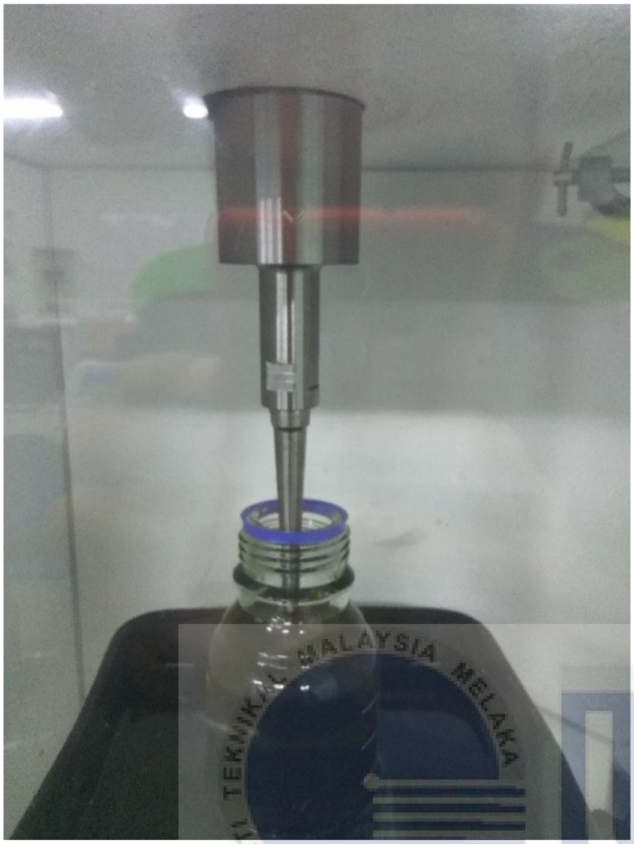


Figure 17: Ultrasonic homogenizer mixing process set up

Figure 18: The condition setting for the mixture process (amplitude and the cycle)

4.2 Experiment Process

4.2.1 Determining the parameter of the experiment

There are a few parameters that are need to be determine before carrying the experiment. The parameters are the speed of the pin on disk, the diameter of the rotation of pin on the disk, the sliding distance, the total time for an experiment, the material of the pin and disk, and the load applied to the pin on disk.

These parameters need to be decided carefully as it will decide the outcome of the experiment whether it will go bad or go well. There are also some characteristics that needed to be taken care of to ensure that the result of the experiment is logical and acceptable. However, determining the parameters of the experiment must also following the standard.

a) Speed of the pin on disk

The speed of the pin on disk depends on the condition and type of the experiment to be carry. For example, if the condition of the experiment to be done is the extreme condition, thus, the larger speed will be used, such 400 rpm and above. If the condition is a normal condition, thus, the speed which is less than 200 rpm can also be used.

As for this experiment, the condition is the normal condition, thus a slower speed will be used in this experiment. A speed of 200 rpm will be good for this experiment, however, the used of oil in this experiment will be the limiting factor. This is because the oil will be splattered all over the places if the speed is too fast. Pin on disk actually is not the most ideal instrument to use to test an oil, the most ideal one is the four ball tester as the oil placement is fully covered and no oil will be splattered. The pin on disk uses the disk as the oil placement. Most of the disk does not have a full cover on the top. This will cause the oil to be splattered as the machine start to spin fast.

Thus, using a slower speed can be a good way to avoid the oil from splattered. A range of speed lower than 100 rpm can be good enough for this experiment. However, I decided to use 80 rpm for this experiment as the lower speed can reduce the noise. The faster the speed, the more noise that will happen in the experiment. Noise happen due to a lot of factor. One of the factor is the condition of the testing instrument. If the instrument is still in a good condition, thus, a higher speed can used as the possibilities to get a high noise value is low. The condition of the pin on disk in the lab is quiet old and it will cause a lot of noise if the parameters is not taken care of.

b) The diameter of the rotation of pin on the disk

The diameter of the rotation of pin will effects the time taken for an experiment. The longer the diameter, the shorter the time for an experiment. The diameter also plays an important role on reducing the noise during the experiment. This is because, if the diameter is too big, the rotation of the pin will be bigger, the circular shape of the scar that will be produced on the disk will be bigger. In this experiment, 3 diameter of the rotation of pin on the disk that will be used which is 30mm, 40mm, 50mm.

Diameter (mm)	Time Taken
30	Longest
40	Short
50	Shortest

Figure 19: The time taken to complete the sliding process.

c) The sliding distance

The sliding distance must be fixed for each experiment to ensure that a fair comparison can be done. In this experiment is fixed to 100 m for each experiment. This is enough for this experiment as the material of the pin used in this experiment is far softer than the material of the disk used in this experiment. If the material of the pin used in this experiment is as the same strength as the disk used in this experiment, thus a longer sliding distance will be needed to make sure that the weight loss during the sliding process is significant. This is because the weight of the pin will be measured before and after the experiment is done to determine the weight loss of the pin.

d) Total time for an experiment

The total time for the experiment depends on the speed of the pin on disk and the radius of the rotation of pin on the disk and it can be calculated using a formula of:

$$l = 2\pi r N t$$

$$t = \frac{l}{2\pi r N}$$

Where

l = sliding distance;

r = radius of the rotation of the pin on the disk

N = speed of the pin on disk

t = time taken for an experiment.

e) The material of the pin and the disk

The material of the pin and the disk play a crucial part in getting a good result in this experiment. Choosing a softer material for the pin and the harder material for the disk is a must as the weight loss of the pin will be measured. If the material for the pin and the disk is of the same strength, thus, a longer sliding distance will be needed to see the weight and volume loss of the pin and sometimes it is almost impossible to see the changes in the weight and volume of the pin. In this experiment, an aluminium pin is used and a steel is used for the disk.

Characteristics / Material	Steel	Aluminium
Density (g/cm^3)	7.85	2.7
Yield strength (MPa)	250	7 - 11

Figure 20: The density and the yield strength of the pin and the disk

f) Load Applied

The load applied is depends on the condition of the experiment, if the experiment is the normal condition, thus, a lower load will be applied. A load ranging less than 3kg will be good for the normal condition. Meanwhile if the experiment is the extreme condition experiment, thus, a higher load must be applied. A load ranging higher than 5kg will be good enough for the extreme condition. In this experiment, a 1kg, 2kg and 3kg load will be used. 3 different load will be used to get a variety results and to get a more significant value of the weight loss of the pin.

Load Applied	Weight loss
1 kg	Lowest
2 kg	Low
3 kg	Highest

Figure 21: The load applied

4.3 Carrying out the Experiment

4.3.1 The Engine Oil Max Pro SAE 15W – 40 Experiment

The experiment is carried out following the ASTM standard as stated in the methodology chapter. The parameters used in the first set of the experiment is as followed:

Load applied (N)	9.81 (1 KG)	19.62 (2 KG)	29.43 (3 KG)
Diameter of rotation on pin-on-disk (mm)	30	40	50
Time to complete rotation which is equal to 100m (min:sec)	13:26	9:57	7:57
Speed (rpm)	80	80	80
Sliding distance (m)	100	100	100

Figure 22: The experiment parameters for the Max Pro SAE 15W – 40

4.3.2 The Engine Oil Max Pro SAE 15W – 40 + Zinc Dialkyldithiophosphate (ZDDP) Experiment

The experiment for the Max Pro engine oil plus Zinc DDP is carried out using the following parameters:

Load applied (N)	9.81 (1 KG)	19.62 (2 KG)	29.43 (3 KG)
Diameter of rotation on pin-on-disk (mm)	40	40	40
Time to complete rotation which is equal to 100m (min:sec)	9:57	9:57	9:57
Speed (rpm)	80	80	80
Sliding distance (m)	100	100	100

Figure 23: The experiment parameters for the Max Pro SAE 15W – 40 + Zinc DDP

The experiment is carried out using the diameter of 40 mm for all set of experiment. This is to reduce the time to complete the sliding distance which is fixed to 100m. If the smaller diameter is used for this experiment, thus, it will increase the time to complete the sliding process. Whereas, if the bigger diameter is used, it will increase the possibilities of getting a lot of noise.

4.4 THE DATA AND ANALYSIS OF ENGINE OIL MAX PRO SAE 15-W 40

4.4.1 Experiment Data

Initial aluminium pin weight, (g)	0.6114	0.6011	0.6095
Load applied (N)	9.81 (1 KG)	19.62 (2 KG)	29.43 (3 KG)
Diameter of rotation on pin-on-disk (mm)	30	40	50
Final aluminium pin weight, (g)	0.6110	0.6007	0.6090
Time to complete rotation which is equal to 100m (min:sec)	13:26	9:57	7:57

Figure 24: Experiment results and data

4.4.2 Calculation and Analysis

Speed on Pin-on-disk = 80 rpm (fix to all load applied)

Fix length of distance for this experiment = 100 m

Time to complete rotating is calculated by using the derivation of

$$l = 2\pi rNt$$

where $l = length\ (m)$

$r = radius\ pin\ on\ disk\ (m)$

$N = speed\ on\ pin\ on\ disk\ (rpm)$

i) For

Load = 9.81 N

Diameter = 30 mm

Length = 100 m

Time = ?

$l = 2\pi rNt$

$100\ m = 2\pi(0.015m)(80\ rpm)t$

$t = \dfrac{100\ m}{2\pi(0.015m)(80\ rpm)}$

$t = 13\ min\ 26\ s$

ii) For

Load = 19.62 N

Diameter = 40 mm

Length = 100 m

Time =?

$$l = 2\pi rNt$$

$$100\ m = 2\pi(0.020m)(80\ rpm)t$$

$$t = \frac{100\ m}{2\pi(0.020m)(80\ rpm)}$$

$$t = 9\ min\ 57\ s$$

iii) For

Load = 29.43 N

Diameter = 50 mm

Length = 100 m

Time =?

$$l = 2\pi rNt$$

$$100\ m = 2\pi(0.025m)(80\ rpm)t$$

$$t = \frac{100\ m}{2\pi(0.025m)(80\ rpm)}$$

$$t = 7\ min\ 57\ s$$

4.4.3 Graphical Analysis

For

Load = 9.81 N

Diameter = 30 mm

Length = 100 m

Time = 13 minutes 26 seconds

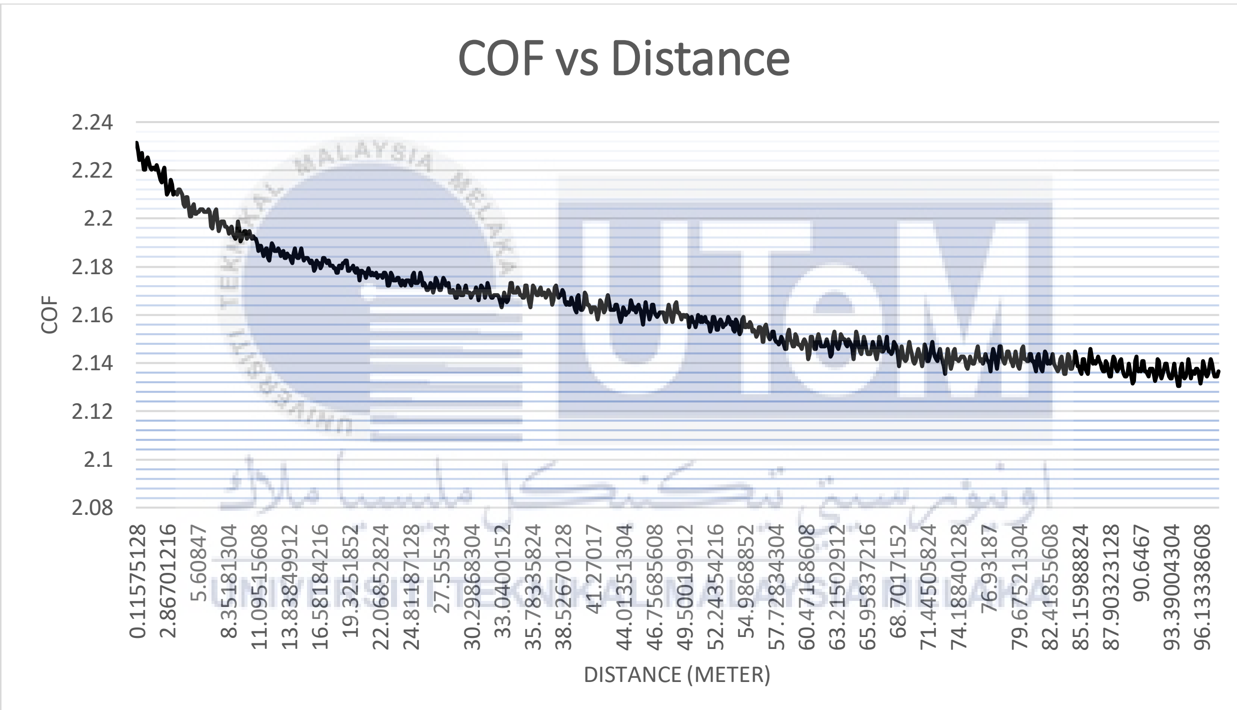


Figure 25: The graph of COF vs Distance for load 1 kg of Max Pro SAE 15W – 40

Average Coefficient Of Friction = 2.136

For

Load = 19.62 N

Diameter = 40 mm

Length = 100 m

Time = 9 minutes 57 seconds

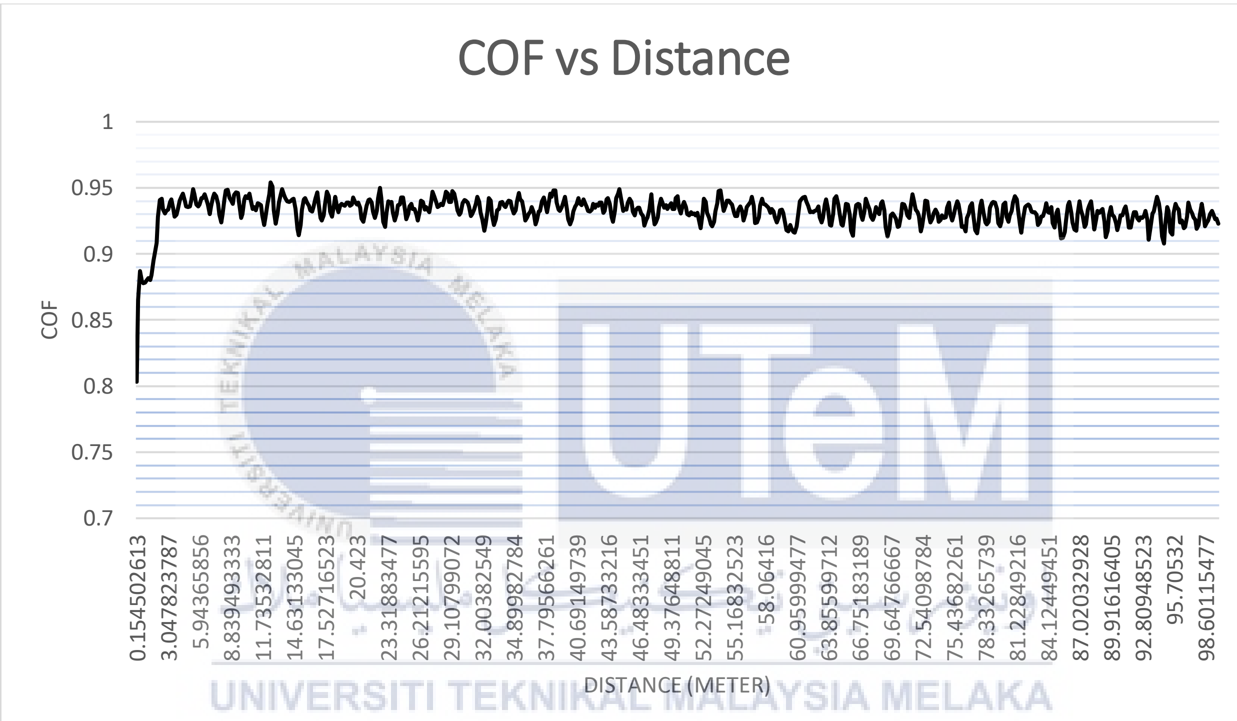


Figure 26: The graph of COF vs Distance for load 2 kg of Max Pro SAE 15W – 40

Average Coefficient Of Friction = 0.9292

The fluctuation that exist in the graph is due to the noise that happen during the experiment. this noise can be reduced by applying some of the precaution before starting the experiment such as tightening every single screw of the pin on disk machine. Other than that, noise can be reduced by using a lower load, and slower speed to make sure that the machine does not overwork.

For

Load = 29.43 N

Diameter = 50 mm

Length = 100 m

Time = 7 minutes 57 seconds

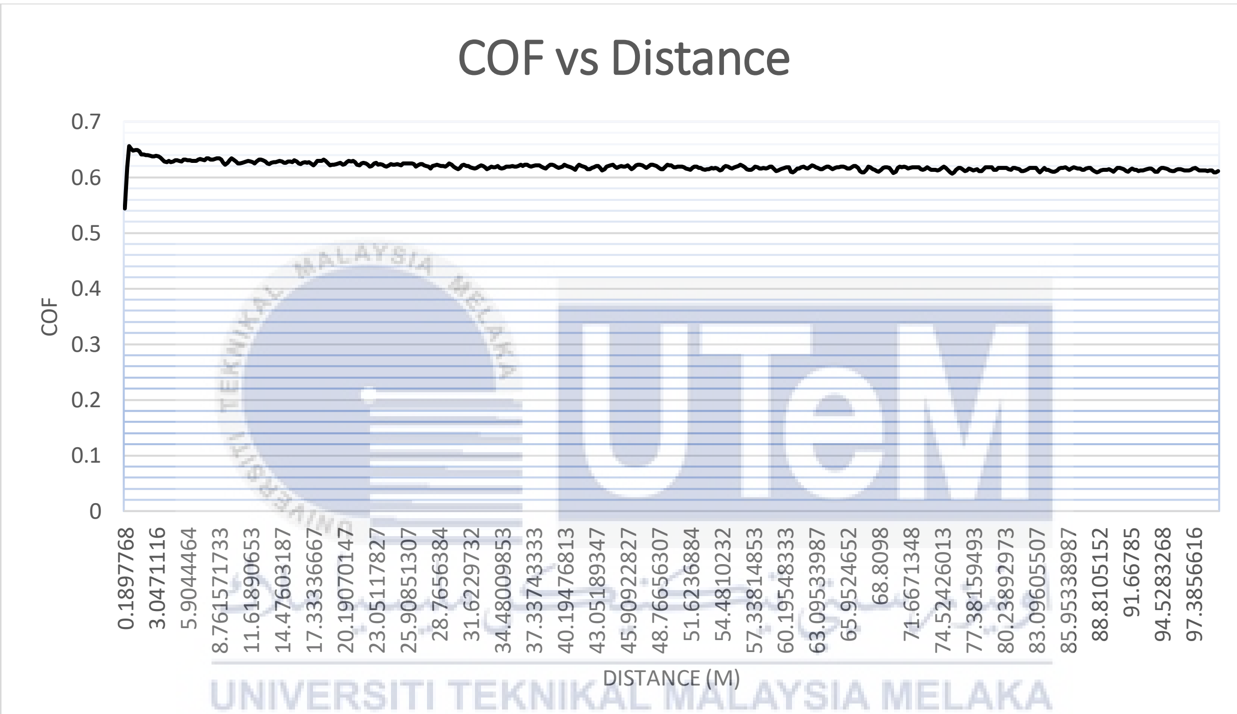


Figure 27: The graph of COF vs Distance of load 3 kg for Max Pro SAE 15W – 40

Average COF = 0.6184

The average coefficient of friction is calculated once the value of the coefficient start to stable. For example in the above graph, the value is taken from the distance of 5.9044 m. The first value of COF until before 5.9044 m value is ignored because it is when the pin on disk start to spin. Thus, the force and the friction is very high because the acceleration is high which is from zero to 80 rpm, and that is why the value of COF is the highest during that time.

Graph of Load Applied against the coefficient of friction for Max Pro Engine Oil SAE 15-W 40

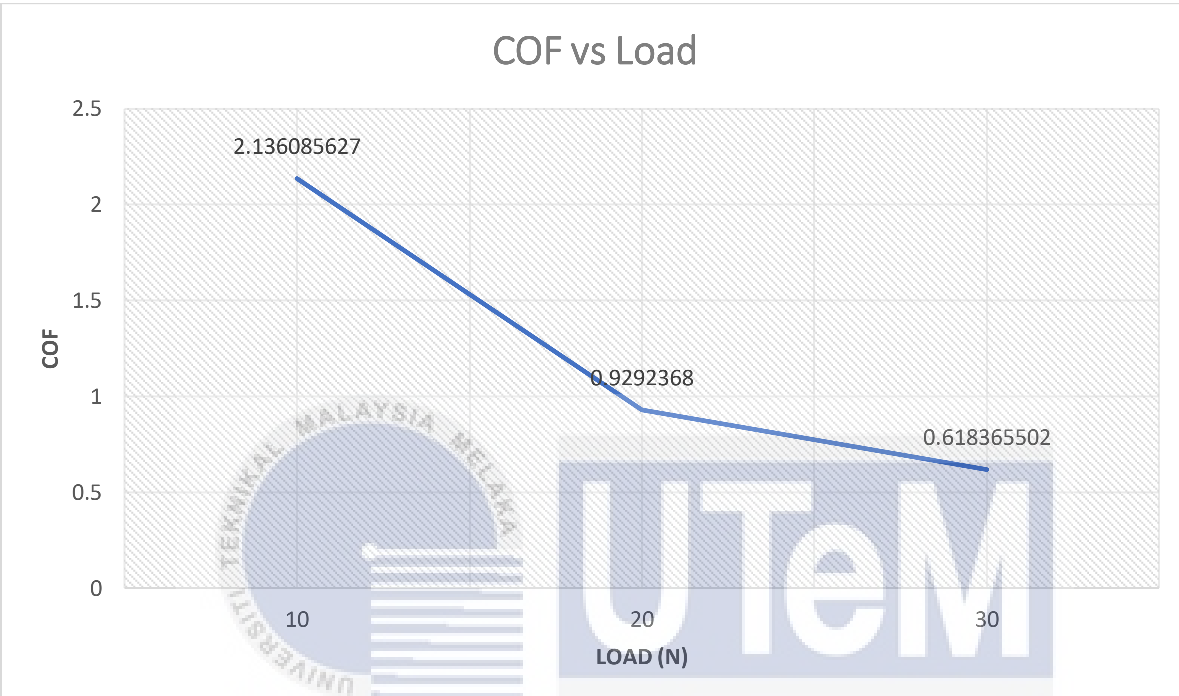


Figure 28: The graph of COF vs Load for 1 kg, 2kg, and 3 kg.

Average coefficient of friction for Max Pro lubricant oil

Load	Average Coefficient of Friction
9.81 N (1 KG)	2.136
19.62 N (2 KG)	0.9292
29.43 N (3 KG)	0.6184

Figure 29: The table for the load and the average coefficient of friction

Referring to the graph, the value for the coefficient of friction decrease as the load increase. This can be explained through the formula to calculate the coefficient of friction.

$$F = \mu N$$

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

Where

F is the force

N is the applied load

μ Is the coefficient of friction

The force, F can be obtained through the data of the experiment which is recorded by the computer and the pin on disk machine. The data is recorded into a Microsoft Excel file. The file also contain the time taken which is then converted to distance by manual calculation using formula of:

$$Sliding\ distance, l = 2\pi rNt$$

Where

N is the rotational speed of the pin on disk

T is the time in minutes

Thus, increasing the load applied will decrease the coefficient of friction as the value to be divided by the forces increase.

Weight Difference for Max Pro lubricant oil

Load	Weight Difference (Initial weight – Final Weight) in grams
9.81 N (1 KG)	0.0004
19.62 N (2 KG)	0.0004
29.43 N (3 KG)	0.0005

Figure 30: The weight difference of load 1 kg, 2 kg, and 3 kg for Max Pro SAE 15W – 40

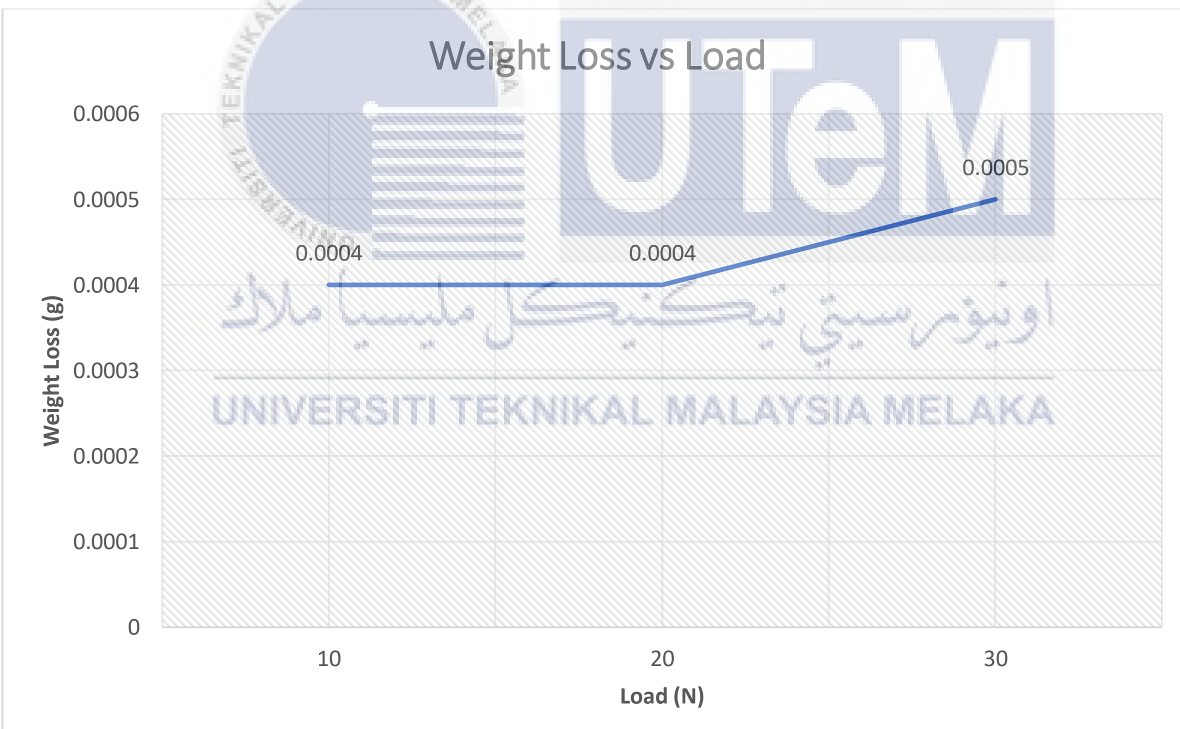


Figure 31: The weight loss vs Load graph for Max Pro SAE 15W – 40

Referring to the graph above, the value for the weight loss decreased as the load increase. This can be explained as the load increase, the more force is applied to the pin, thus, creating more friction to the pin and disk contacting surface.

$$F = ma$$

Where

F is the force

M is the mass

a is the gravitational acceleration

Therefore, if the mass in increased, thus the force applied to the pin will also be increased. The load is in the form of load of weight 1 kg, 2 kg, and 3 kg. The gravitational acceleration is 9.81 N.

The increasing of force will make the pin become more and more corroded thus, the weight reduction will be higher with respect to the load applied.

Calculating the wear volume, k of the pin.

The wear volume can be calculated using a few parameters that are recorded during the experiment. The parameters are, volume loss, mm^3, load applied, N and sliding distance.

The volume loss can be calculated using the density formula:

$$Volume\ loss, mm^3 = \frac{mass\ loss, g}{density, g/cm^3}$$

$$Wear\ volume, k = \frac{Volume\ loss, mm^3}{WL}$$

Where

W is load applied in newton, N

L is sliding distance in millimeters (mm).

For 1 kg load (10N)

$$Volume\ loss, mm3 = \frac{0.0004\ g}{2.7\ \frac{g}{cm^3}} \times 1000$$

$$= 0.148148mm^3$$

$$Wear\ volume, k, \frac{mm^3}{Nm} = \frac{0.148148\ mm^3}{9.81\ N\ \times 100\ m}$$

$$= 1.51\ \times 10^{-4}\ \frac{mm^3}{Nm}$$

For 2 kg load (19.62 N)

$$Volume\ loss, mm3 = \frac{0.0004\ g}{2.7\ \frac{g}{cm^3}} \times 1000$$

$$= 0.148148 mm^3$$

$$Wear\ volume, k, \frac{mm^3}{Nm} = \frac{0.148148\ mm^3}{2 \times 9.81\ N\ \times 100\ m}$$

$$= 7.55\ \times 10^{-5} \frac{mm^3}{Nm}$$

For 3 kg load (29.43 N)

$$Volume\ loss, mm3 = \frac{0.0005\ g}{2.7\ \frac{g}{cm^3}} \times 1000$$

$$= 0.185185 mm^3$$

$$Wear\ volume, k, \frac{mm^3}{Nm} = \frac{0.185185\ mm^3}{3 \times 9.81\ N\ \times 100\ m}$$

$$= 6.2923\ \times 10^{-5}\ \frac{mm^3}{Nm}$$

Plotting the graph of Wear Volume, k versus Load, N.

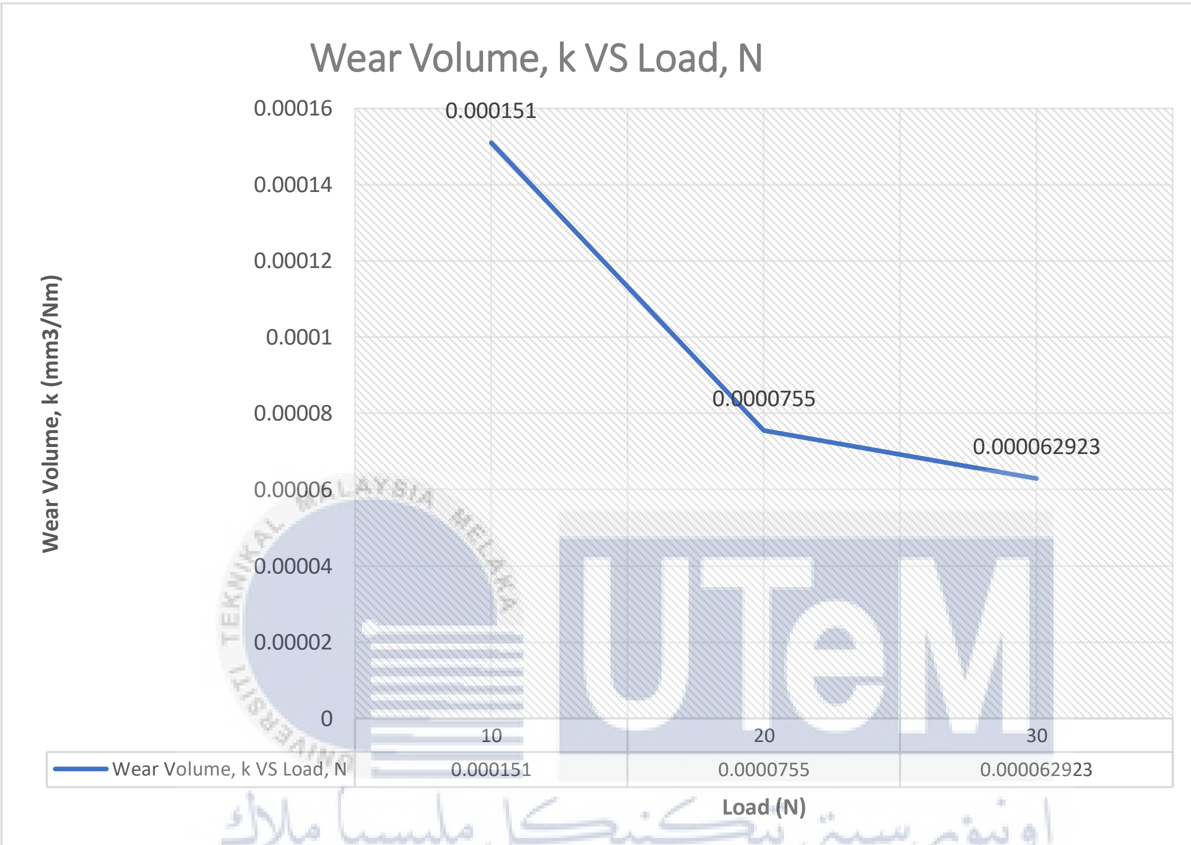


Figure 32: The graph of Wear volume, k vs Load

Referring to the graph, the value of the wear volume, k decreased as the load is increased. This can be explained through the formula to calculate the wear volume which is:

$$Wear\ volume, k = \frac{Volume\ loss, mm^3}{WL}$$

As the load applied, W is increased thus, the volume loss will be divided with a greater number. Therefore, the k value will be decreased. The sliding distance, L is fixed to 100 m for all the set of experiment, thus, it will not affect the calculation of the wear volume, k. The only number that can affect the wear volume is the applied load. Therefore, the higher the load applied, the lower the wear volume.

4.5 THE DATA AND ANALYSIS OF ENGINE OIL MAX PRO SAE 15-W 40 WITH ZINC DIALKYLDITHOPHOSPHATE (ZDDP)

4.5.1 Experiment Data

Initial aluminium pin weight, (g)	0.6087	0.6006	0.6112
Load applied (N)	9.81 (1 KG)	19.62 (2 KG)	29.43 (3 KG)
Diameter of rotation on pin-on-disk (mm)	40	40	40
Final aluminium pin weight, (g)	0.6085	0.6004	0.6109
Time to complete rotation which is equal to 100m (min:sec)	9:57	9:57	9:57

Figure 33: The table for experiment data and results for the Max Pro SAE 15W – 40 + Zinc Dialklydithiophosphate

4.5.2 Calculation of time

Speed on Pin-on-disk = <u>80 rpm</u> (fix to all load applied)

Fix length of distance for this experiment = <u>100 m</u>

Time to complete rotating is calculated by using the derivation of $l = 2\pi rNt$

where $l = length\ (m)$

$r = radius\ pin\ on\ disk\ (m)$

$N = speed\ on\ pin\ on\ disk\ (rpm)$

i) For

Load = 9.81 N (1 kg)

Diameter = 40 mm

Length = 100 m

Time = ?

$$l = 2\pi rNt$$

$$100\ m = 2\pi(0.02m)(80\ rpm)t$$

$$t = \frac{100\ m}{2\pi(0.015m)(80\ rpm)}$$

$$t = 9\ min\ 57\ s$$

ii) For

Load = 19.62 N (2 kg)

Diameter = 40 mm

Length = 100 m

Time =?

$$l = 2\pi rNt$$

$$100\ m = 2\pi(0.020m)(80\ rpm)t$$

$$t = \frac{100\ m}{2\pi(0.020m)(80\ rpm)}$$

$$t = 9\ min\ 57\ s$$

iii) For

Load = 29.43 N (3 kg)

Diameter = 40 mm

Length = 100 m

Time =?

$$l = 2\pi rNt$$

$$100\ m = 2\pi(0.02m)(80\ rpm)t$$

$$t = \frac{100\ m}{2\pi(0.025m)(80\ rpm)}$$

$$t = 9\ min\ 57\ s$$

4.5.3 Graphical Analysis

For

Load = 9.81 N (1KG)

Diameter = 40 mm

Length = 100 m

Time = 9 minutes 57 seconds

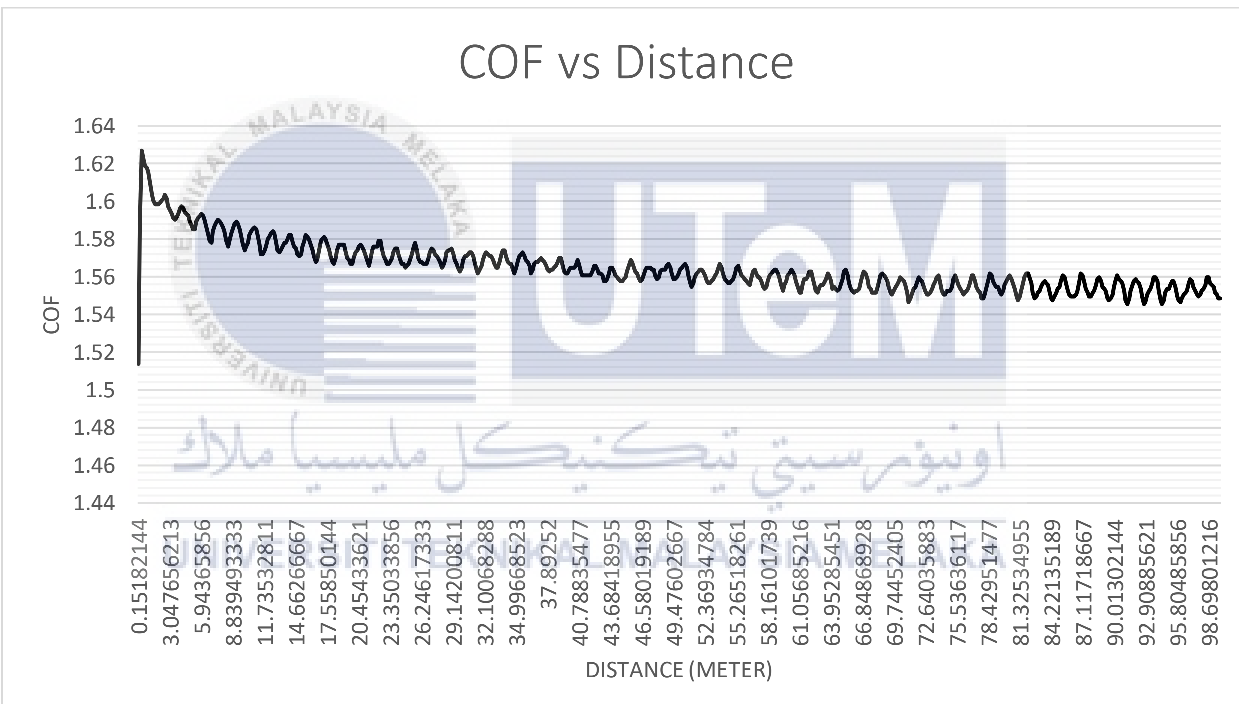


Figure 34: The graph of COF vs Distance for Max Pro SAE 15W – 40 + Zinc DDP load 1 kg.

Average coefficient of friction (COF) = 1.556

For

Load = 19.62 N (2 KG)

Diameter = 40 mm

Length = 100 m

Time = 9 minutes 57 seconds

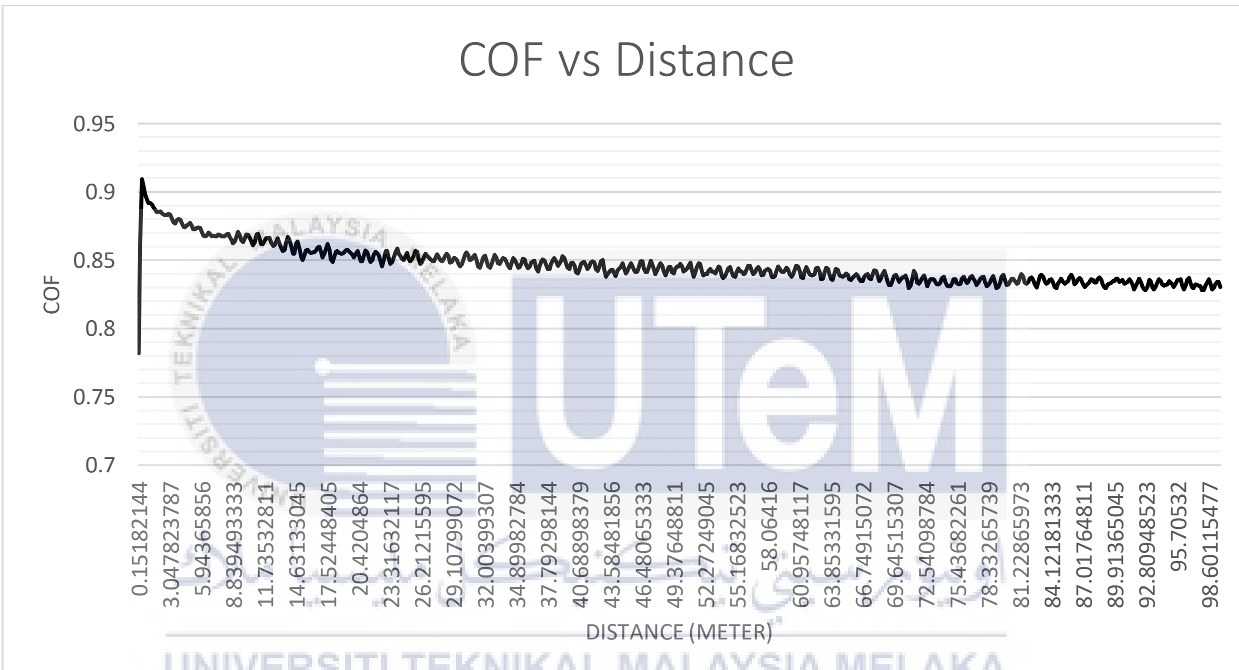


Figure 35: The graph of COF vs Distance for Max Pro SAE 15W – 40 + Zinc DDP for load 2 kg.

Average coefficient of friction (COF) = 0.8375

For

Load = 29.43 N (3 KG)

Diameter = 40 mm

Length = 100 m

Time = 9 minutes 57 seconds

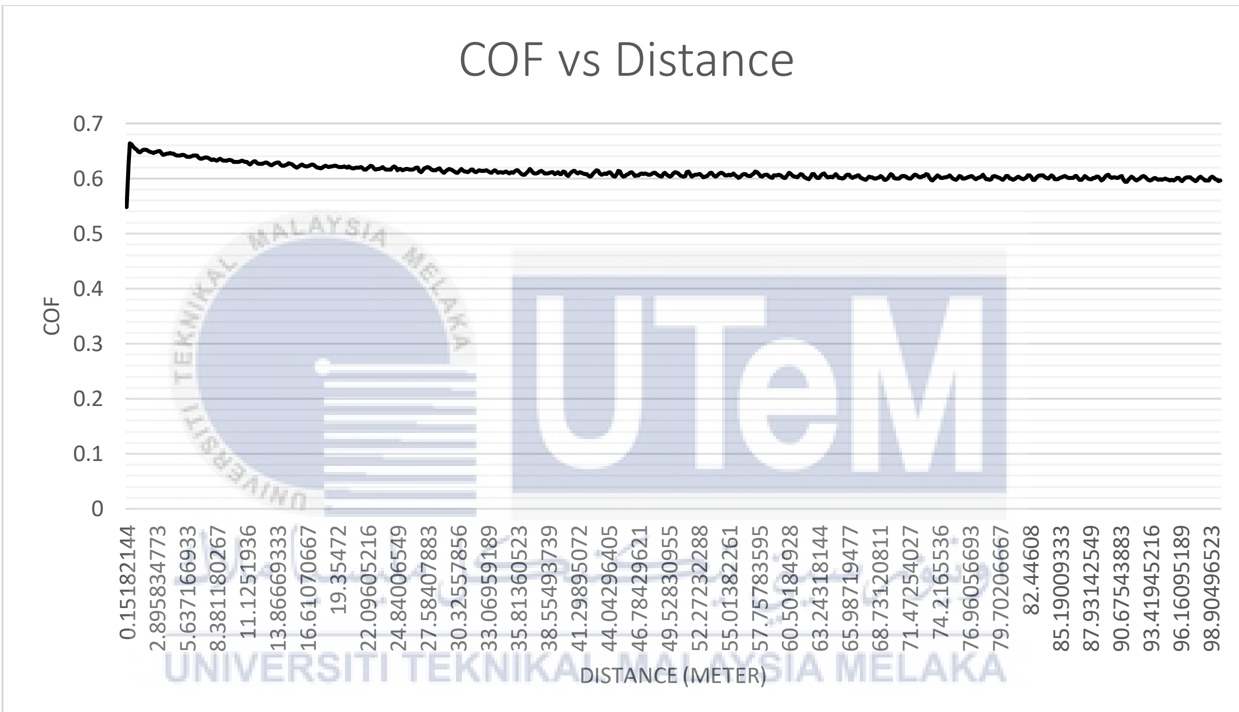


Figure 36: The graph of COF vs Load for SAE 15W – 40+ Zinc DDP for load 3 kg.

Average coefficient of friction (COF) = 0.603749

Graph of Load Applied against the coefficient of friction for Max Pro Lubricant Oil SAE 15-W 40 with Zinc Dialkyldithophosphate (zddp)

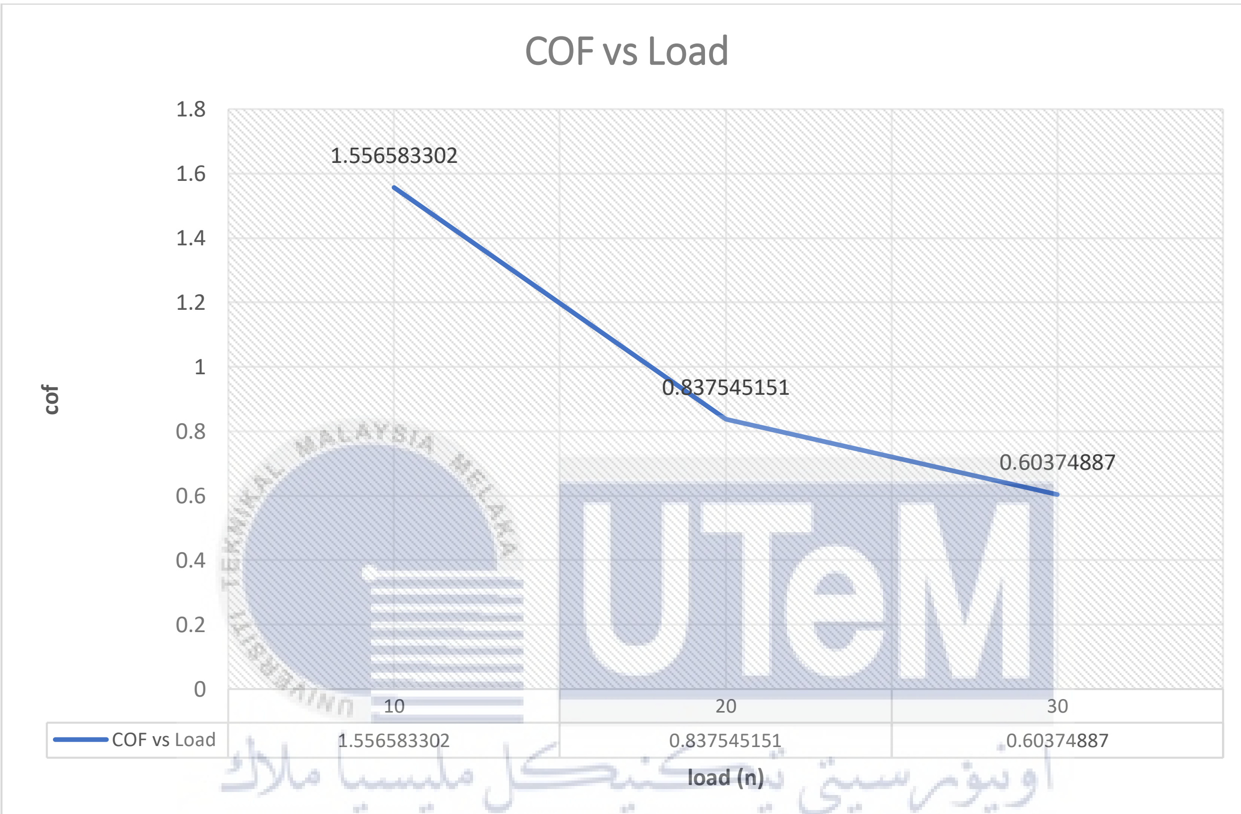


Figure 37: The graph of COF vs Load for SAE 15W – 40 + Zinc DDP

Average coefficient of friction for Max Pro lubricant oil with ZDDP

Load	Average Coefficient of Friction
9.81 N (1 KG)	1.556
19.62 N (2 KG)	0.8374
29.43 N (3 KG)	0.6037

Figure 38: The load and average coefficient of friction for Max Pro SAE 15W – 40 + Zinc DDP

Weight Difference for Max Pro lubricant oil with ZDDP

Load	Weight Difference (Initial weight – Final Weight) in grams
9.81 N (1 KG)	0.0002
19.62 N (2 KG)	0.0002
29.43 N (3 KG)	0.0003

Figure 39: Load and weight difference for Max Pro SAE 15W – 40 + Zinc DDP

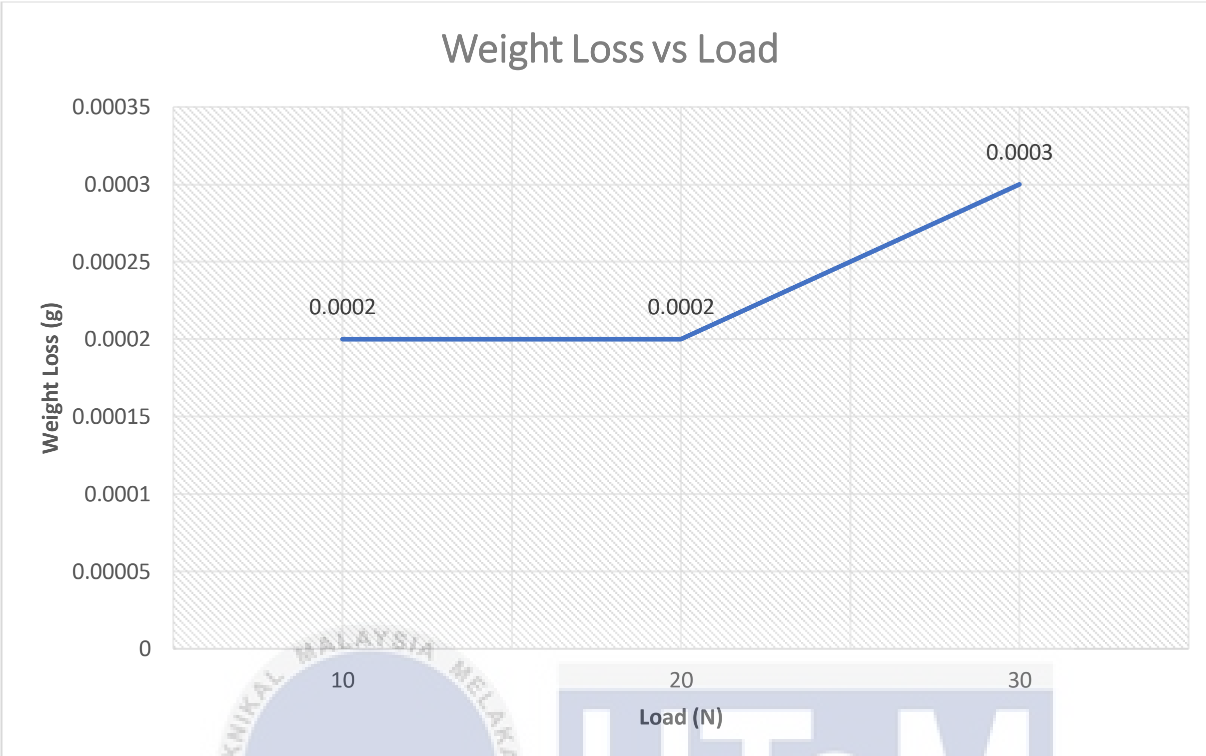


Figure 40: The graph of Weight loss vs Load for SAE 15W – 40 + Zinc DDP

Calculation of wear volume for Max Pro engine oil + Zinc DDP

For 1 kg load (9.81N)

$$Volume\ loss, mm3 = \frac{0.0002\ g}{2.7\ \frac{g}{cm^3}} \times 1000$$

$$= 0.074mm^3$$

$$Wear\ volume, k, \frac{mm^3}{Nm} = \frac{0.074\ mm^3}{9.81\ N\ \times 100\ m}$$

$$= 7.543\ \times 10^{-5} \frac{mm^3}{Nm}$$

For 2 kg load (19.62 N)

$$Volume\ loss, mm3 = \frac{0.0002\ g}{2.7\,\frac{g}{cm^3}} \times 1000$$

$$= 0.074mm^3$$

$$Wear\ volume, k, \frac{mm^3}{Nm} = \frac{0.074\ mm^3}{2 \times 9.81\ N\ \times 100\ m}$$

$$= 3.77\ \times 10^{-5}\,\frac{mm^3}{Nm}$$

For 3 kg load (29.43 N)

$$Volume\ loss, mm3 = \frac{0.0003\ g}{2.7\ \frac{g}{cm^3}} \times 1000$$

$$= 0.1111\ mm^3$$

$$Wear\ volume, k, \frac{mm^3}{Nm} = \frac{0.1111\ mm^3}{3 \times 9.81\ N\ \times 100\ m}$$

$$= 3.775 \times 10^{-5}\ \frac{mm^3}{Nm}$$

Plotting Graph of Wear Volume, k versus Load, N

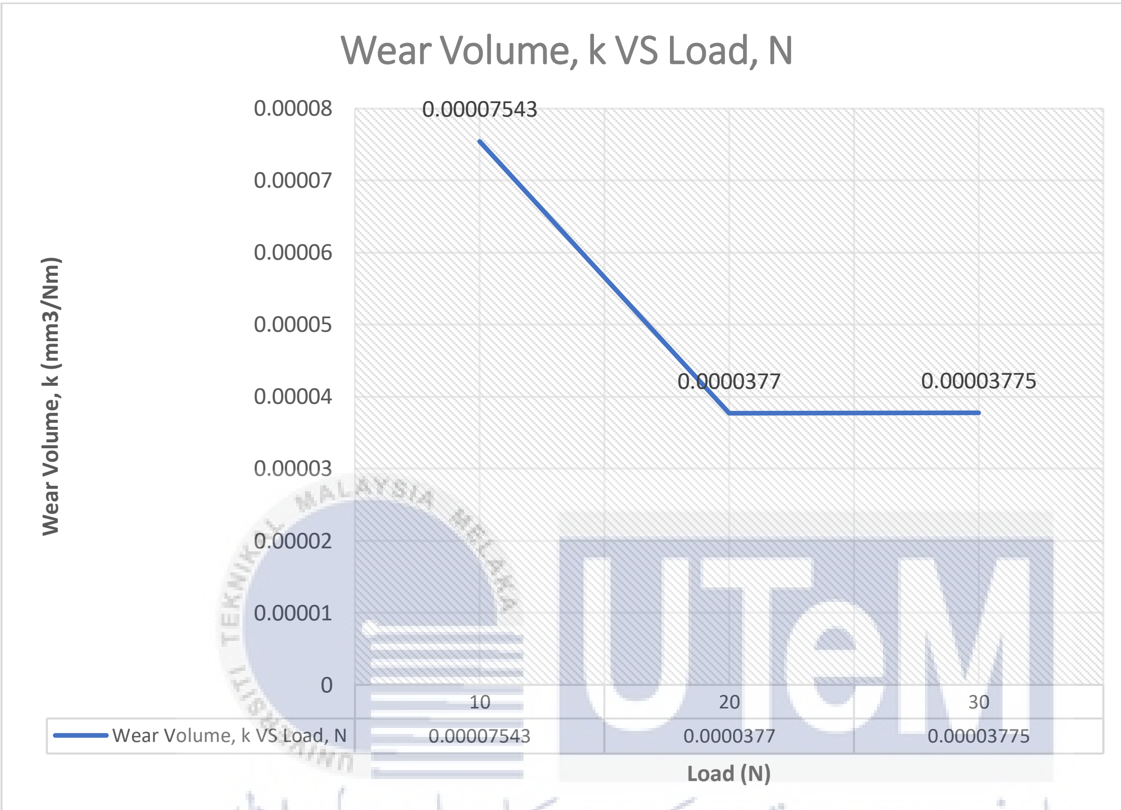


Figure 41: Graph of Wear volume, k vs Load for Max Pro SAE 15W – 40 + Zinc DDP

4.6 Comparison of data analysis between Max Pro oil and Max Pro with ZDDP oil

4.6.1 Comparison of coefficient of friction with load (N)

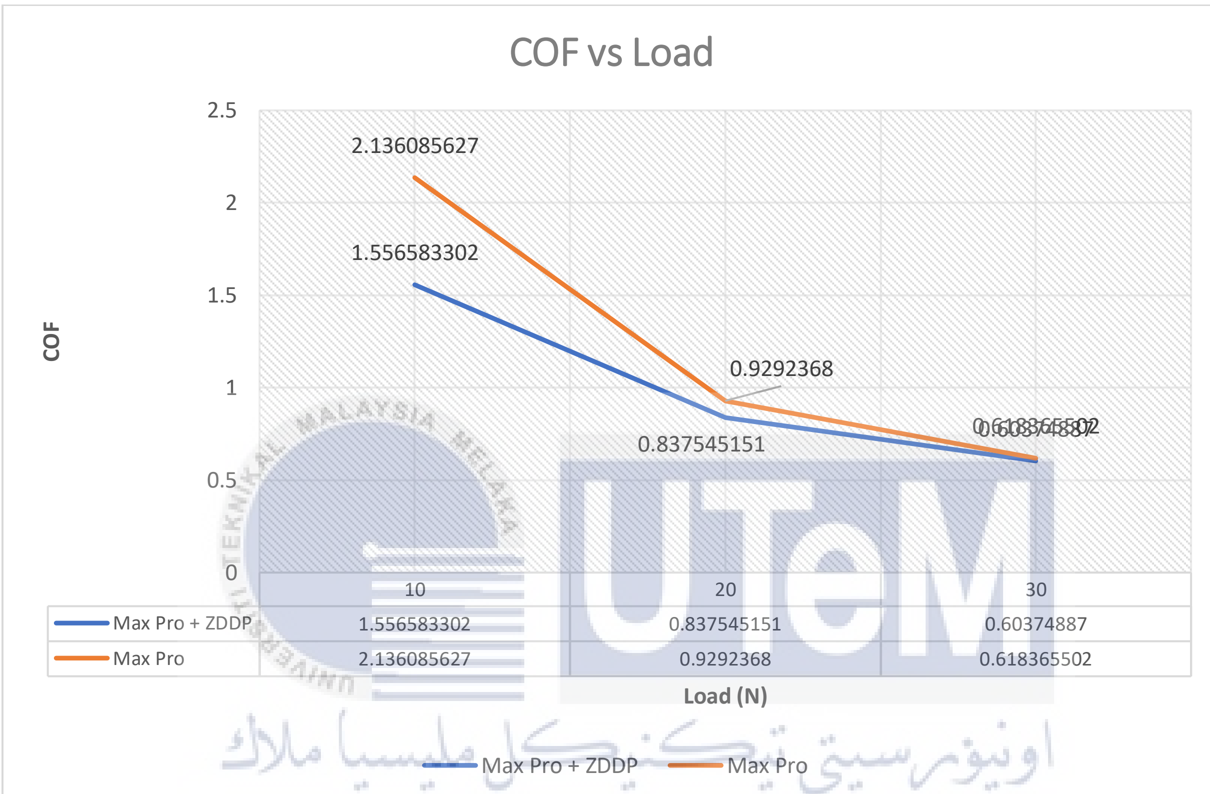


Figure 42: Graph of COF vs Load for Max Pro and Max Pro + ZDDP

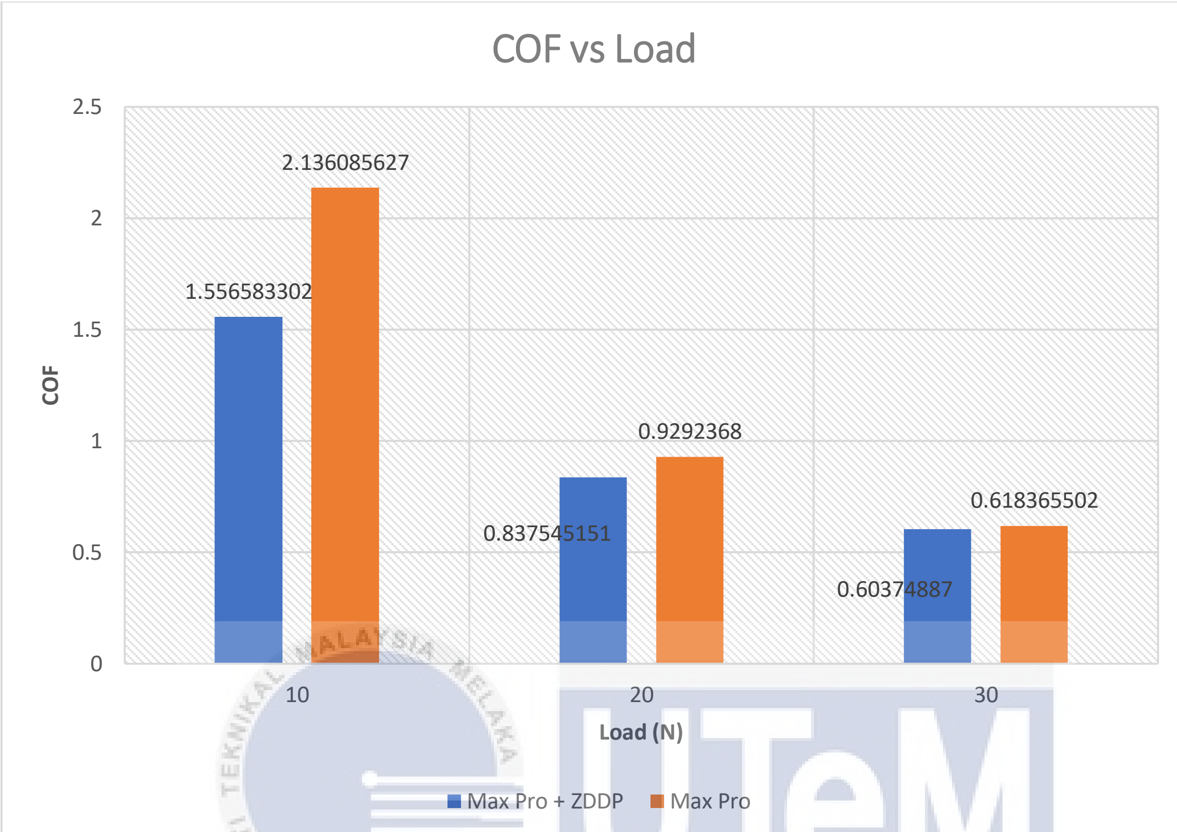


Figure 43: Graph of COF vs Load for Max Pro and Max Pro + ZDDP

Referring to the graph, the value of the coefficient of friction for the Max Pro + Zinc DDP is lower than the value for the Max Pro only. This is because the effect of the zinc DDP as the anti-wear nanoparticles decrease the friction force that is applied to the pin and the disk.

4.6.2 Comparison of weight loss (g) and load (N)

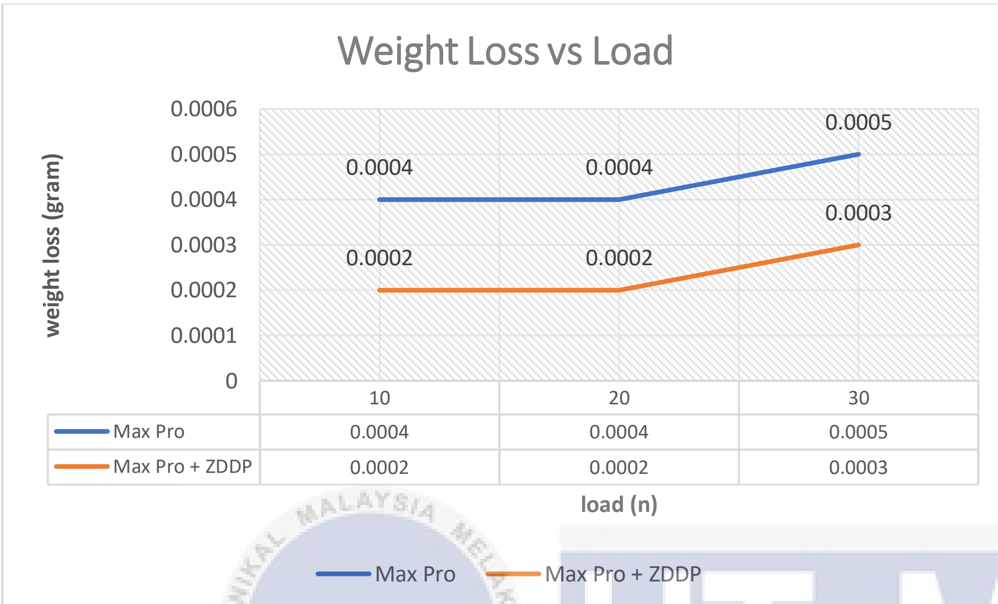


Figure 44: Graph of Weight loss vs Load for Max Pro and Max Pro + ZDDP

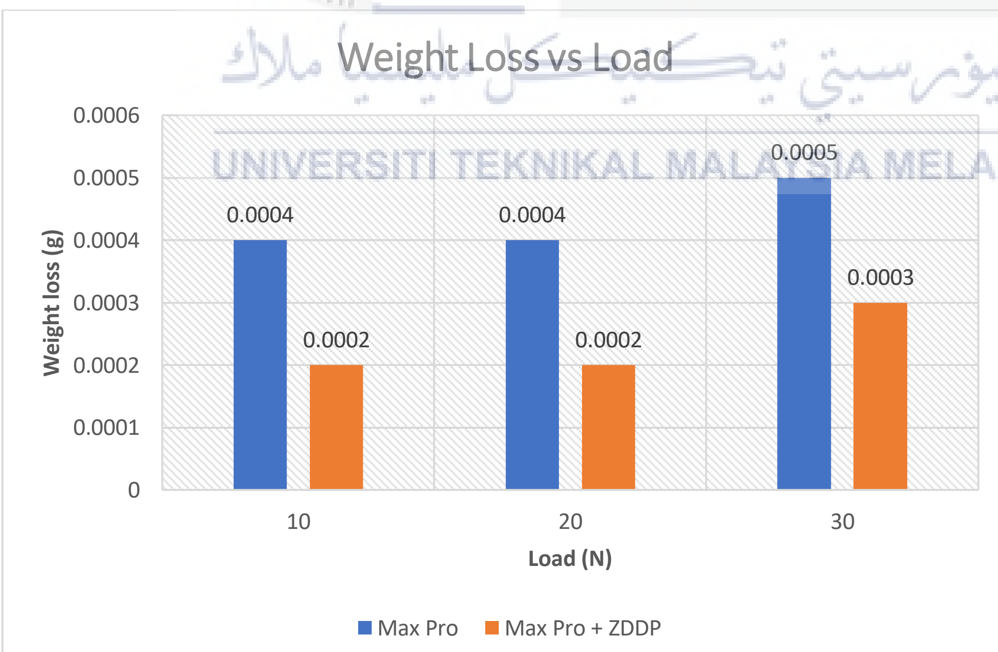
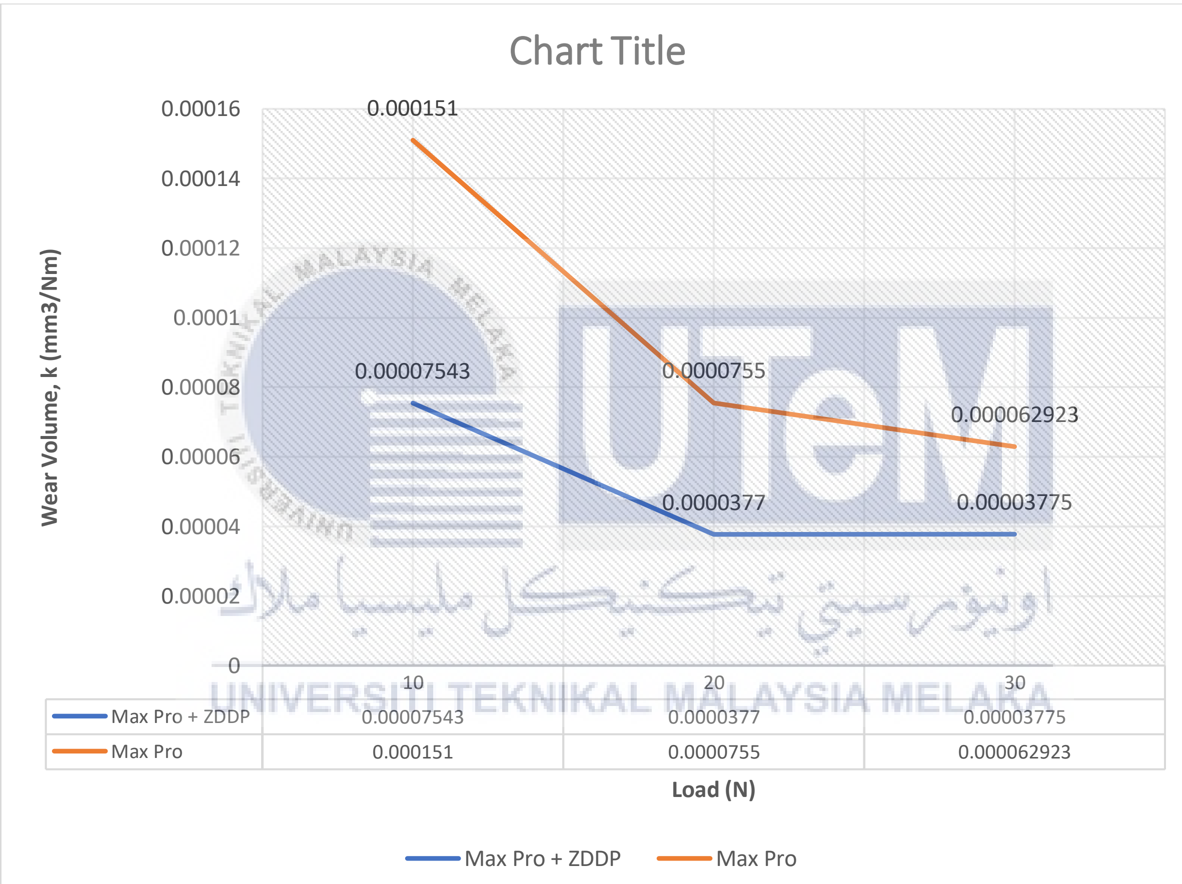


Figure 45: Graph of Weight loss vs Load for Max Pro and Max Pro + ZDDP

The weight loss for Max Pro + Zinc DDP is lower than the Max Pro only. The presence of the zinc DDP in the oil act as the anti – wear additives that reduces the wear of the pin and reduces the friction between the surfaces of the pin and the disk.

4.6.3 Comparison of Wear Volume, k (mm3/Nm) and Load (N)



	10	20	30
Max Pro + ZDDP	0.00007543	0.0000377	0.00003775
Max Pro	0.000151	0.0000755	0.000062923

Figure 46: The graph of wear volume, k vs Load for Max Pro and Max Pro + ZDDP

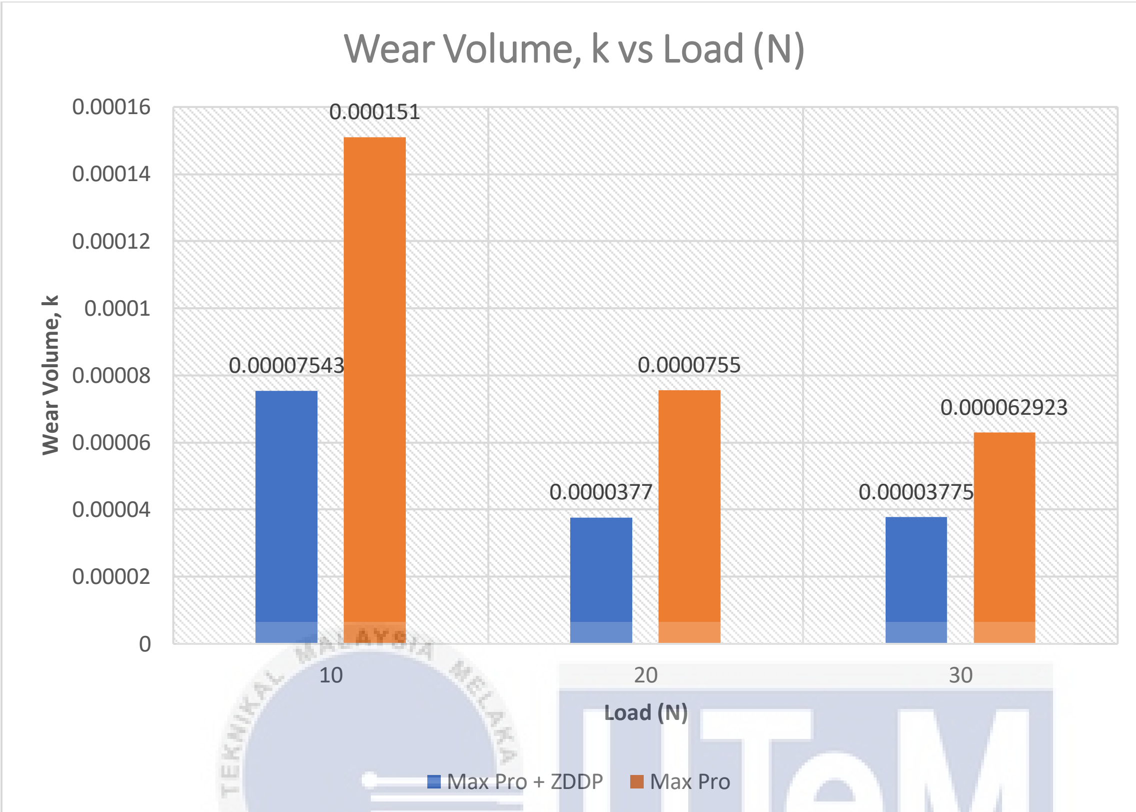
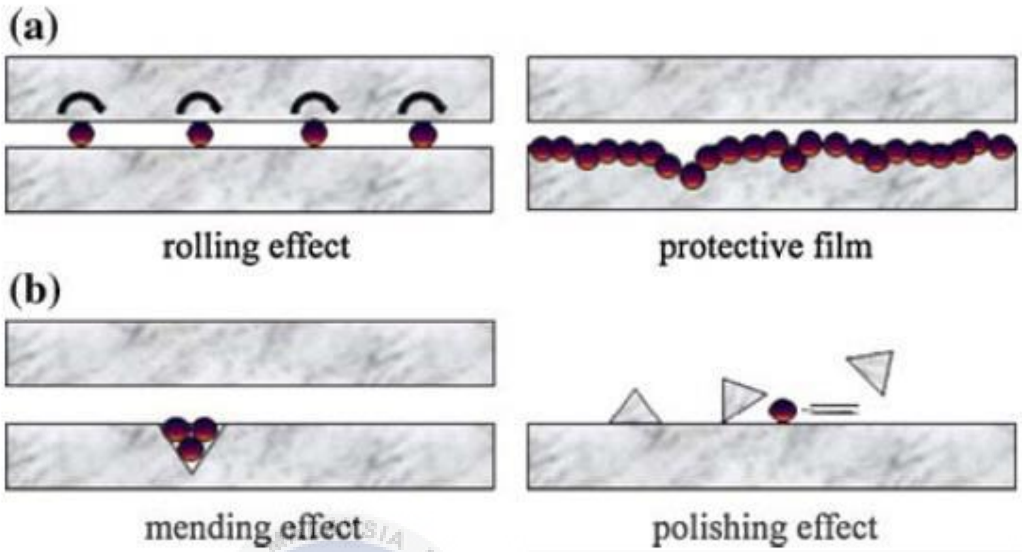


Figure 47: The graph of wear volume, k vs Load for Max Pro and Max Pro + ZDDP

4.7 Zinc Dialkyldithiophosphate (Zinc DDP)



a) The nanoparticles suspended in lubricating oil play the role of ball bearings and reduce contact between frictional surfaces.
b) The nanoparticles also make a protective film to some extent by coating the rough friction surfaces.
c) The nanoparticles deposit on the friction surface and compensate for the loss of mass, which is known as mending effect.
d) The roughness of the lubricating surface is reduced by nanoparticle – assistes abrasion, which is known as a polishing effect.

The basic mechanism of Zinc dialkyldithiophosphate as anti – wear is the reaction of Zinc DDP with the metal surface to form a solid protective film and the reaction layer. When metal is in contact or treated with the Zinc DDP solution in a lubricant or other non – polar solvent, a protective film is rapidly formed at the metal surface. The protective film and the reaction layer formation by Zinc DDP have four – step processes as shown below;

- Break in
- Physical or chemical adsorption
- Additive – surface reaction
- Reaction layer growth

Chapter 5

Summary

5.1 Conclusion

As the conclusion, the addition of zinc dialkyldithiophosphate (ZDDP) as an additive in lubricant oil or engine oil will give a better performance and it can act as an improver of physical properties in engine oil compared to the engine oils without Zinc DDP. Based on the result that been discussed above, the coefficient of friction, wear volume and weight loss of the engine oil with Zinc DDP is lower than the engine oil without the zinc DDP. Thus, the above statement is proven to be true.

5.2 Recommendation

As for the recommendation, I recommended that this experiment can be improved by using the base mineral oil without any additive. This is to ensure that the weight loss reduction, wear volume reduction, and coefficient of friction reduction is totally caused by the additional of zinc DDP into the engine oil. Thus, the exact effects of the zinc DDP can be determined through the experiment. This is because the engine oil used in this experiment which is Max Pro SAE 15W – 40 contain some additives. Thus, the comparison in the wear volume, weight loss, volume loss and the coefficient of friction is maybe actually caused by the zinc DDP and the other additives added.

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