INVESTIGATIONS ON HEAVY-DUTY GEARBOXES TEMPERATURE AND THE VISCOSITY OF THE LUBRICANT THROUGH SIMULATION AND EXPERIMENT METHOD

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ORIGINAL LITERARY WORK DECLARATION

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Name of Degree: Master of Mechanical Engineering

Title of Project Paper/Research Report/Dissertation/Thesis ("This Work"):

Investigation on heavy-duty gearboxes temperature and the viscosity of the lubricant through simulation and experimental methods

Field of Study: Energy

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INVESTIGATIONS ON HEAVY-DUTY GEARBOXES TEMPERATURE AND THE VISCOSITY OF THE LUBRICANT THROUGH SIMULATIONS AND EXPERIMENTAL METHODS

ABSTRACT

The development of gear transmissions nowadays is focusing on four main reasons which are noise, vibration, and harshness to reduce the surrounding sound pollution, load capacity, wear and tear which will lessen friction and productivity. Gearboxes are as often as possible outlined conservatively with a supply of oil to ensure operational unwavering quality. The present study will focus on the viscosity of plastic extruder line gearbox oil and how the oil temperature is maintained. In this study, two types of lubricants will be used to demonstrate which lubricant performs well. use a calculation method to prove the efficiency of the heat exchanger before and after the gear oil temperature. An earlier investigation focused more on oil temperature and did not show what would happen due to high oil temperature and didn't demonstrate simulation results with gear oils of actual viscosity. This study aims to collect actual data and prove it by simulation and experimental methods. This research is more effective for high voltage cable industry production because normally the extrusion line will be run for two or three weeks non-stop to reach the target of the order. The data also show an exponential trend between the average wear rates and the surface fatigue lives. Lubricants with similar viscosities but differing additives and compositions had somewhat differing gear surface fatigue lives and wear rates. It determined the way to reduce gearbox portion temperature and maintain the lubricant additive and also the viscosity index number. The method to eliminate water and acid contained in the plastic extruder gearbox during the machine operating at high temperature.

Keyword: Viscosity index number, gearbox temperature, water content, total acid number, heat exchanger

PENYIASATAN KE ATAS SUHU KOTAK GEAR TUGAS BERAT DAN KELIKATAN PELINCIR MELALUI SIMULASI DAN KAEDAH EKSPERIMEN

ABSTRAK

Pembangunan transmisi gear pada masa kini memberi tumpuan kepada empat sebab utama iaitu hingar, getaran, kekasaran untuk mengurangkan pencemaran bunyi di sekeliling, kapasiti, pembawa beban, haus dan lusuh yang akan mengurangkan geseran dan produktiviti. Kotak gear sekerap mungkin digariskan secara konservatif dengan bekalan minyak untuk memastikan kualiti operasi yang tidak berbelah bahagi. Kajian ini akan memberi tumpuan kepada kelikatan minyak kotak gear talian penyemperit plastik dan bagaimana suhu minyak dikekalkan. Dalam kajian ini, dua jenis pelincir akan digunakan untuk menunjukkan pelincir yang berprestasi baik. Kaedah pengiraan akan digunakan untuk membuktikan kecekapan penukar haba sebelum dan selepas suhu minyak gear. Siasatan awal lebih menumpukan pada suhu minyak dan tidak menunjukkan perkara yang akan berlaku akibat suhu minyak yang tinggi dan tidak menunjukkan hasil simulasi dengan minyak gear dengan kelikatan sebenar. Kajian ini bertujuan untuk mengumpul data sebenar dan membuktikannya dengan kaedah simulasi dan eksperimen. Penyelidikan ini lebih berkesan untuk pengeluaran industri kabel voltan tinggi kerana kebiasaannya talian penyemperitan akan dijalankan selama dua atau tiga minggu tanpa henti untuk mencapai sasaran tempahan. Data juga menunjukkan aliran eksponen antara kadar haus purata dan hayat keletihan permukaan. Pelincir dengan kelikatan yang sama tetapi bahan tambahan dan komposisi yang berbeza mempunyai hayat keletihan permukaan gear dan kadar haus yang agak berbeza. Ia menentukan cara untuk mengurangkan suhu bahagian kotak gear dan mengekalkan bahan tambahan pelincir dan juga nombor indeks kelikatan. Kaedah untuk menghapuskan air dan asid yang terkandung dalam kotak gear extruder plastik semasa mesin beroperasi pada suhu tinggi. Kata kunci: Nombor indeks kelikatan, suhu kotak gear, kandungan air, jumlah nombor asid, penukar haba

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Table Of Contents

List Of Figures

List Of Tables

List of Appendices

CHAPTER 1: INTRODUCTION

1.1 Background

Lubrication is more important for the gearbox and also for the bearings system to decrease friction and wear. In addition, it will be providing an oil film to protect the internal rolling system's contact surface. Because of the constant contact between solid-to-solid surfaces, whenever the gear drive teeth meshed with the driven gear teeth, friction occurs. During operation, heat will be generated due to friction, as rolling system lubrication is the solution to keep the metal surface against expansion due to overheating, whenever the gear teeth expand due to overheating, the gear teeth will start to plastic deformation and the end gear teeth will start to break. Scuffing is another issue that will occur if the lubrication film is not maintained. This failure occurs due to the increase in temperature causing the surface to be damaged. Lubricating oils have several functions, including providing surface wear prevention, avoiding metal surface corrosion, and cooling the gearbox's interior components. The previous study investigated the flow of oil distribution inside the gearbox when in operation with low or high speed. This study uses computational fluid dynamics (CFD) to predict lubricant flow and transmission power loss during the gears meshed process (Mastrone, Hartono, Chernoray, & Concli, 2020). Previous research looked into the impact of modifying the oil viscosity in a gearbox drive system on variable speed drive power characteristics (VSD). An experimental investigation based on a 10-kW gear train with four different oils was carried out after studying the effect on the gear transmission. Current and voltage measurements are used to build diagnostic capabilities for both static and dynamic features, which are subsequently tested under various operating situations. (Abusaad et al., 2015).

1.2 Problem Statement

Plastic extruder machines are commonly used in the wire and cable sector to manufacture different sizes of wire with outer insulation. The extruder gearbox is an important part of this plastic extruder line. Due to this extruder machine is running mass production continue 2 weeks for produce spec of wire 11kv, the temperature of the outer screw coupling portion is always reached up to 98°C. Because of this high-temperature lifespan of lubricant become shorter. During continuous running mass, the production maintenance department is unable to change lubricant because of the tight schedule of the final process line. When the gearbox lubricant reach 98-100°C the oil seal rubber became oxidized and expanded the shape of the oil seal after 6 months of operation. Due to the expansion of the oil seal, the oil in the gearbox started to leak and the oil level does not maintain the maximum level. However, if the transmission oil is insufficient, there are some possibilities for bearing systems to fail. In addition, in the process of mass production of the machine, the inside of the gear system will rotate with high force, and at the same time, there will be friction between the drive gear and driven gear, due to occurring friction on the surface of gear tooth will begin to wear and damage.

1.3 Research Objective

The purpose of the project is to investigate two different types of lubricants for high-temperature plastic extruder gearboxes.

1. To investigate the temperature of the extruder gearbox at different gearbox portions.
2. To determine gearbox lubricant properties before and after 3 months of operation.
3. To simulate lubricant heat transfer inside extruder gearbox by the use of a heat exchanger.

1.4 Scope Of Project

1. The property of the lubricant that will be determined are total acid number, water content, and viscosity index number

2. This study will introduce heat exchanger for plastic extruder gearbox and use a simulation method to determine the temperature of gearbox lubricant before and after the heat exchanger.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

The Surface contact occurs between moving parts or rolling parts due to surface roughness. Area roughness creates friction, deformation, poling, adhesion, abrasion, delamination in it. All these happen in lube oil due to the long use of oil. The thermal breakdown has also occurred in lube oil. The lubricating oil forms a liquid film between the contacting surfaces and reduces direct material contact and also maintains an adequate distance between the surfaces. Lubricants are used to the reduction of friction and wear on mating surfaces, remove heat and pollution, and the improvement of the performance and life of all rolling parts. The lubricant additive has anti-wear, severe pressure, rust and corrosion preventing qualities, and heat stability. To upgrade gearbox performance, several additives are added to the base oil.

2.2 Lubricating Oil Flow and Gear Power Loss

According to the previous investigation has been done with computational fluid dynamics (CFD)-the investigation aims to predict lubricating oil flow and gear power loss during the running mood. the researcher has done the experimental with used numerical approaches. The mathematical method is validated with Torque(Nm) measurement and rate of oil flow data from Particle Image Velocity (PIV). The loss of torque from the bearing and other rolling components has been removed from the torque measurement. To reduce the total weight of the test stand, the driving gears have been replaced by a belt-driven transmission. The previous investigation candidate has used a KISTLER Torque sensor for measured maximum operating torques in this study, in which the torque sensor is mounted on a gear shaft, thus the method is used to measure gear torque. The test case and gears are made of clear PMMA to maximize optical accessibility for PIV measurements, and the test oil was Nytex 810 by Nynas, chosen for its clean look. Several speed stages (250/2000 RPM) were used to calculate average torque loss. The bearing and other rolling parts' lost torque has been removed from the measured torque. Without the gear set in the configuration, bearing and other auxiliary losses are measured in the same way (Mastrone, Hartono, Chernoray, & Concli, 2020).

Table 2.1: **Geometrical Characteristic Of Gearbox**

	Unit	Gear	Pinion
Number of teeth	–	24	16
Module	Mm	4.5	
Centre distance	Mm	91.5	
Face width	Mm	14.0	
Tip diameter	Mm	118.4	82.5
Pitch diameter	Mm	109.8	73.2

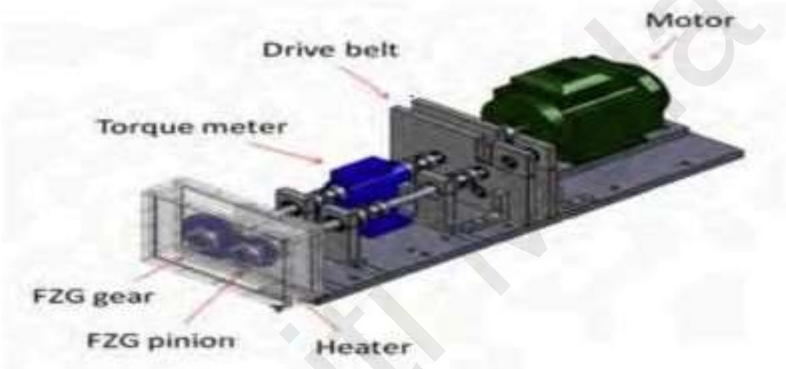


Figure 2.1 View Of The Entire Test Rig

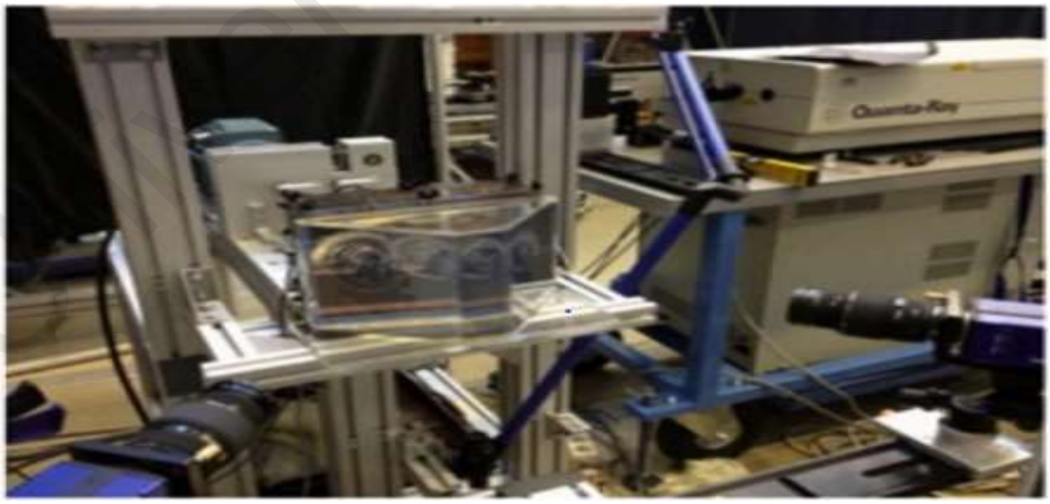


Figure 2.2 Experiment Setup

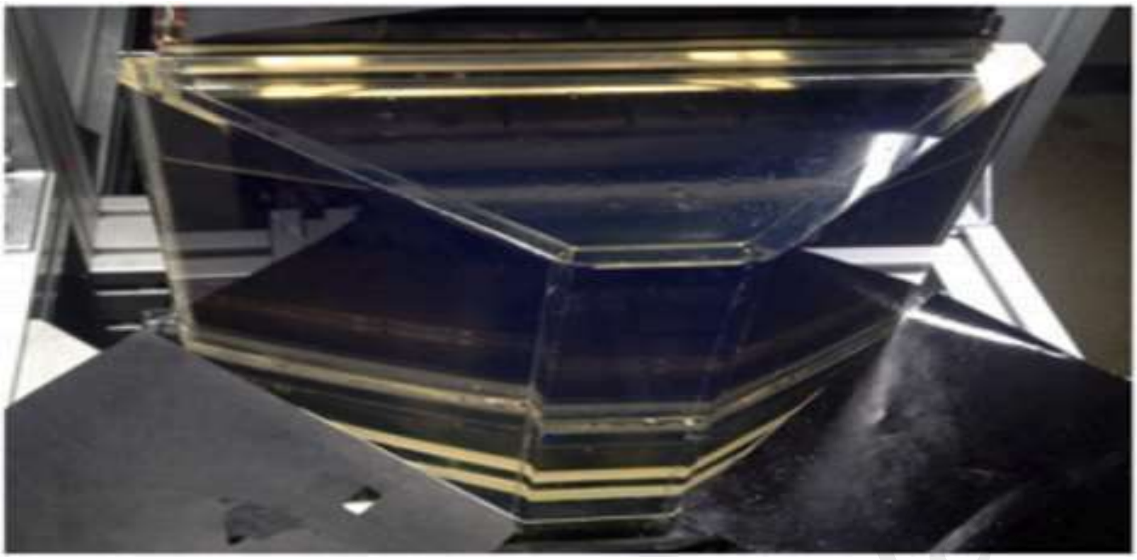


Figure 2.3 Fill-Up With Prism Liquid (Mastrone, Hartono, Chernoray, & Concli, 2020)

The resulting PIV is a phased average of 100 images. The last 3 transfers were performed with a window size of 32 x 32 pixels2, 50% overlap, and a rounded Gaussian weighting factor of 1:1. The results of previous studies were obtained under various operating conditions related to gear speed. The PIV was performed in the slow range because the formation of bubbles in the oil sump blocked optical access at high speeds. In contrast to PIV, torque measurements were performed in the faster range. This is because the torque value is small at low speeds, which causes great uncertainty in the results (Mastrone, Hartono, Chernoray, & Concli, 2020)

Table2.2: The Velocities of The Wheels In The Various Case Studies

Simulation	Gear rotation velocity [rad/s]	Pinion rotation velocity [rad/s]	Oil level	Corresponding experiments
1	10.00	15.00	centerline	PIV
2	20.00	30.00	centerline	
3	30.00	45.00	centerline	
4	26.20	39.30	centerline	Torque
5	52.40	78.60	centerline	
6	78.50	117.75	centerline	
7	105.00	157.50	centerline	
8	130.90	196.35	centerline	
9	157.5	236.25	centerline	
10	210.00	315.00	centerline	

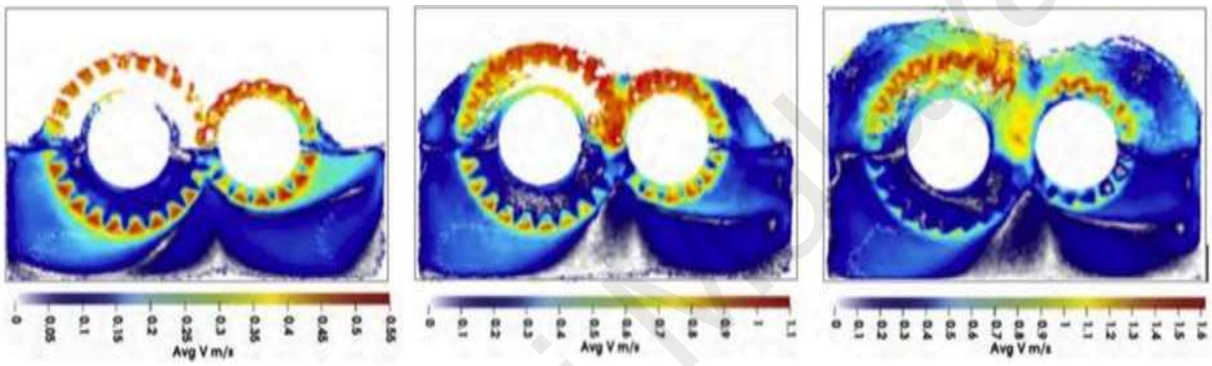


Figure 2.5 Showing Result of PIV (Chernoray, & Concli, 2020)

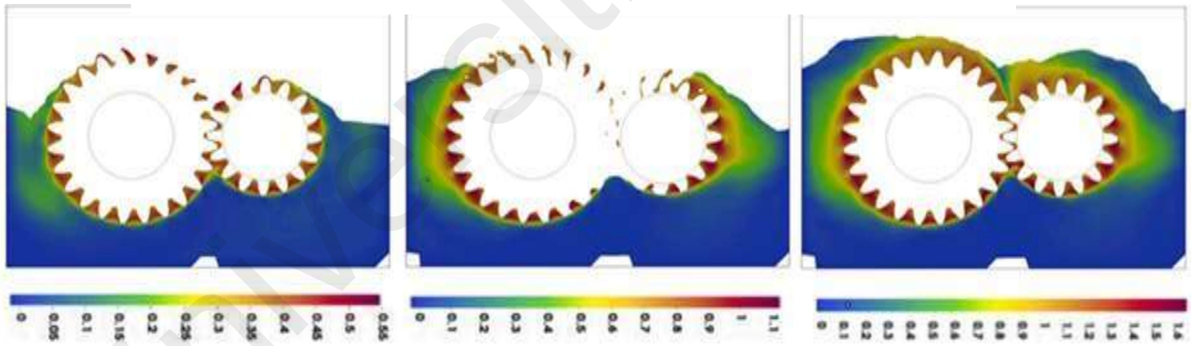


Figure 2.4 Showing Result of CFD (Chernoray, & Concli, 2020)

Figure 2.4 PIV results and 2.5 CFD results show the gear system operating with three different angular and tangential gear speeds. From left to right 10rad/s (0.55 m/s tangential speed), 20rad/s (1.1 m/s tangential speed) and 30rad/s (1.6 m/s tangential speed)

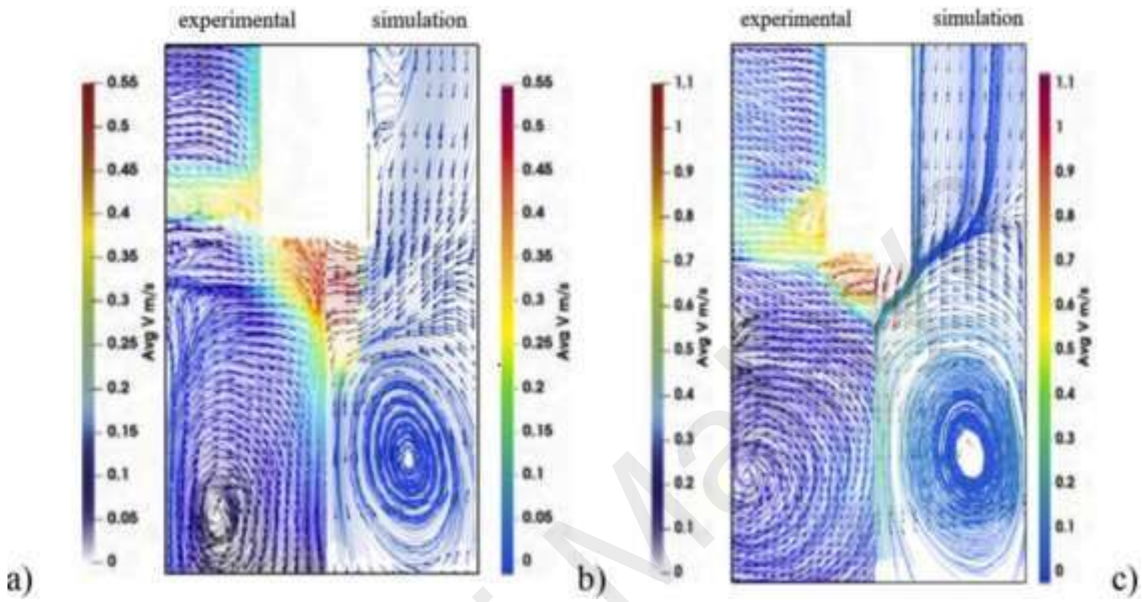


Figure 2.6 Stereo-PIV Sagittal Measurement Plane(Chernoray, & Concli, 2020)

Experimental and numerical flow comparison on a cross-flow plane with a gear speed of less than 10rad/s (Tangential speed 0.55m/s and C a rotational speed of less than 20 rad / s. (Tangential velocity 1.1m/s). The experiment result is displayed Numerical data on the left and right sides side of the velocity field. Important because the correct prediction of secondary movement is important Accumulation of rate of heat transfer. The thickness of the boundary layer under the gear was very well captured. The power loss has proven the model's ability to accurately predict the loss with less than 10% variation from the experimental data. The model can be utilized for gearbox studies because it has been validated for both lubricant flow and power loss, offering clear benefits to transmission design considerations. (Mastrone, Hartono, Chernoray, & Concli, 2020)

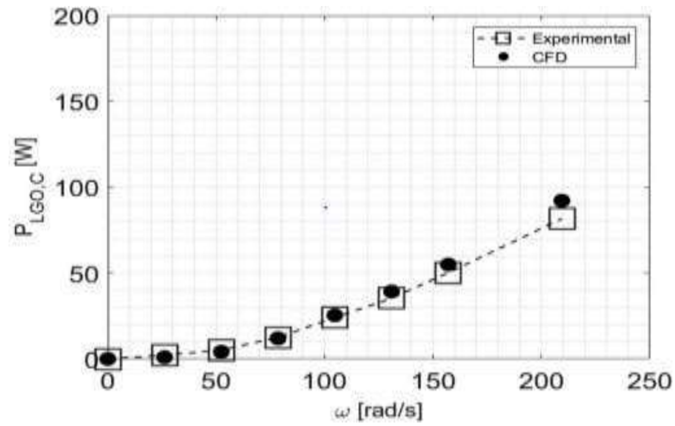


Figure 2.7 Comparison Result Of Experiment And CFD

2.3 Oil Degradation Is Being Investigated

Another researcher investigated to identify oil degradation using transmission power supply system metrics. Experimental studies based on 10 kW industrial gearboxes powered by the sensor (VSD) show that measurable differences in static power and dynamic behavior occur with the lubricating oil tested. The static power function can therefore be used to indicate the change in viscosity at low and medium operating running speeds. The dynamics function can separate the changes in viscosity for all the different cases tested. As an outcome, this study investigates the influence of altering the viscosity of the oil in a gearbox drive system on variable speed drive power characteristics (VSD). Another candidate developed the experiment with upgrading electrical motor power from 10kw to 15kw. Both mechanical systems and electrical systems were used to experiment. A 15 kW AC motor is used to connect the gearbox input shaft by a coupling. the whole system is connected to the PLC program and different speed loads are generated and also used AC VSD, 550c park drive, to offer the control load to the ac motor and the system is also controlled by the operator, they will adjust the loads and torsion they need. Dynamic data was used to evaluate the efficiency of conventional analytical methods for identifying and analyzing various oil viscosities, as well as comparing samples obtained from static data. Also collected gearbox oil temperature to identify lubricant viscosity conditions (Abusaad et al., 2015)

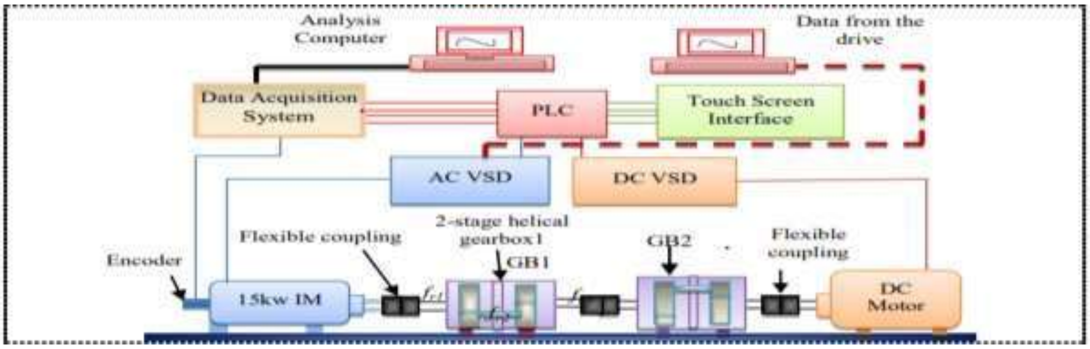


Figure 2.8 Schematic Of The Test System**(Abusaad et al., 2015)**

The above testing was carried out with a standard industrial gearbox system, with a gear ratio of 3.6 and a motor power of 10kW at 1460rpm. Four different types of oil were in use, each with a different viscosity range. In the table below, the oil specifications are already specified **(Abusaad et al., 2015)**

Table 2.3: The Quality Of The Oil Used In The Experiment

	Specific Gravity (at 15°C)	Kinematic Viscosity (at 100°C, c.St)	Kinematic Viscosity (at 40°C, c.St)	Viscosity Index	Pour Point (°C)	Flash Point (°C)
EP 100	0.885	10.95	100	93	-9	200
EP 320	0.901	23.5	320	92	-9	200
EP 1000	0.927	71.0	1000	140	-6	200

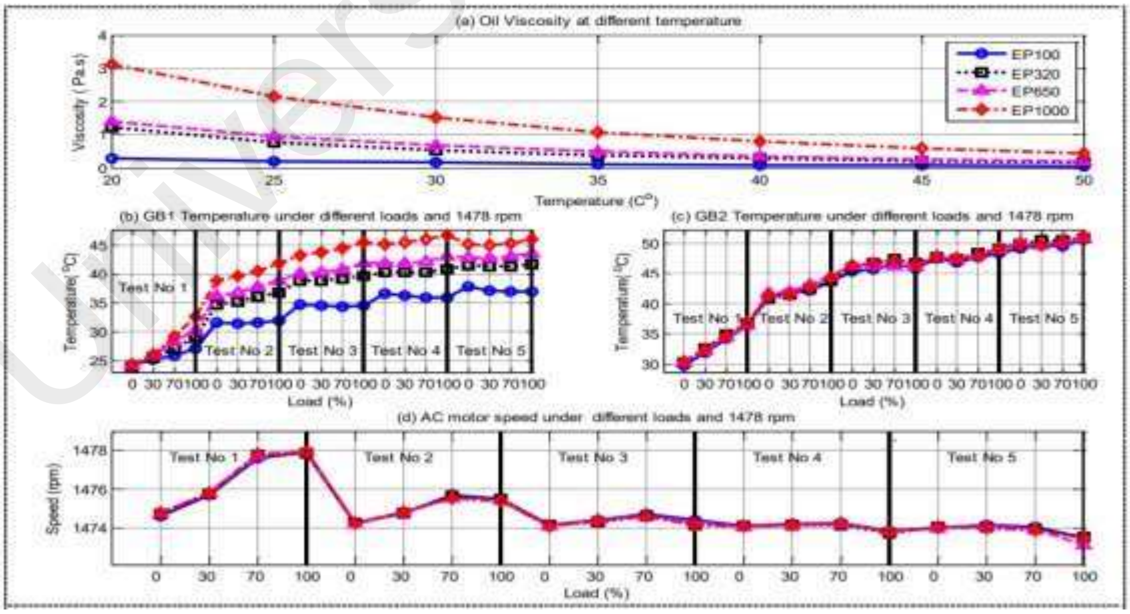


Figure 2.9 System Behaviours Under Different Operating Conditions(Abusaad et al., 2015)

The transmission motor for each cycle rate, attempting to test sensor performance under three and four different speed and load operations 50 percentage,75 percentage, and 100 percent of maximum motor speed are common scenarios in real-world applications. To ensure the quality of the data for a reliable comparison, each speed/load cycle was performed five times consecutively for each oil. As a result, there are noticeable differences in viscosity values of tested, which get smaller as temperature rises. The result (d) is that the VSD performs poorly in maintaining the system's speed at the set-point during the low-temperature operation for the first test run, leading to increased speed under high load. The VSD, on the other hand, can manage the speed with more accuracy under diverse load settings once the system has reached its stable conditions, as evidenced by the speed results for testing runs 3 to 5. Based on these findings, measurements from the third and fourth test runs show fewer uses performance and are more stable for studying the influence of lubricant viscosity. (Abusaad et al., 2015)

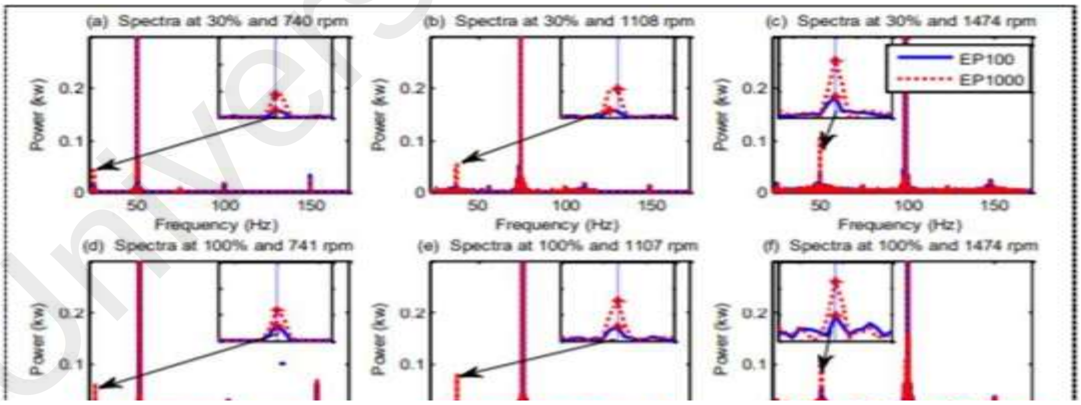


Figure 2.10 Power Spectra For Various Operational Circumstances (Abusaad et al., 2015)

The result is described if turn up the speed in high means the figure 4c is showed low-efficiency performance in making the difference between oil grade 650 and oil grade 1000. If there are more interruptions from oil churning and splashing, the poor result is explained in further detail. To ensure system reliability, the drive changes the electrical supply settings, resulting in greater noise and the inability to separate data at full speed. (Abusaad et al., 2015)

An increase in oil viscosity leads to a measurable increase in power consumption due to the effect of viscous friction and churning. Based on these two changes a static power feature and a dynamic power feature can be developed to make differences between different oils under different operating conditions (Abusaad et al., 2015)

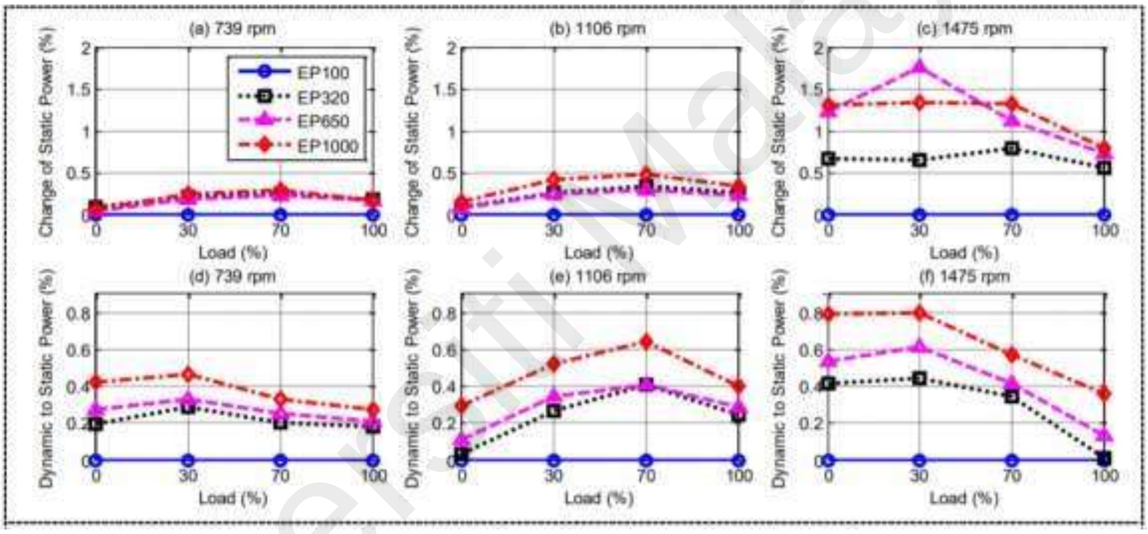


Figure 2.11 Power signal changes under various operational circumstances

2.4 Temperature In A Spur Gear Type Gearbox

The previous studies show that less viscosity oil temperature is higher than the high viscosity oil. The high-temperature oil reduced the lifespan of the gearbox and also drop the efficiency of the gearbox. The experimental result was carried out by the previous researcher used seventeen various mineral and synthetic oils were tested. Oils with viscosities greater than ISO VG 320 were not examined since their high viscosity puts them outside of the acceptable range for usage in car gearboxes. For both kinematic viscosity and pressure viscosity coefficient, data from AGMA 925-A03 datasheets are provided at 40 and 100 degrees centigrade. Therefore, used ASTM D341 was to collect the data with interpolated between this temperature logarithmic method (Douglas & Thite, 2015)

Table 2.4: Lubricant Grade List

Oil Test Number	Lubricant type	ISO Viscosity grade
1	Mineral oil	320
2	PAO	320
3	PAG	320
4	Mineral oil	220
5	PAO	220
6	PAG	220
7	Mineral oil	150
8	PAO	150
9	PAG	150
10	Mineral oil	100
11	PAG	100
12	Mineral oil	68
13	Mineral oil	46
14	Mineral oil	32
15	Mil-L-23699E	23
16	MIL-L-7808K G4	17
17	MIL-L-7808K G3	12

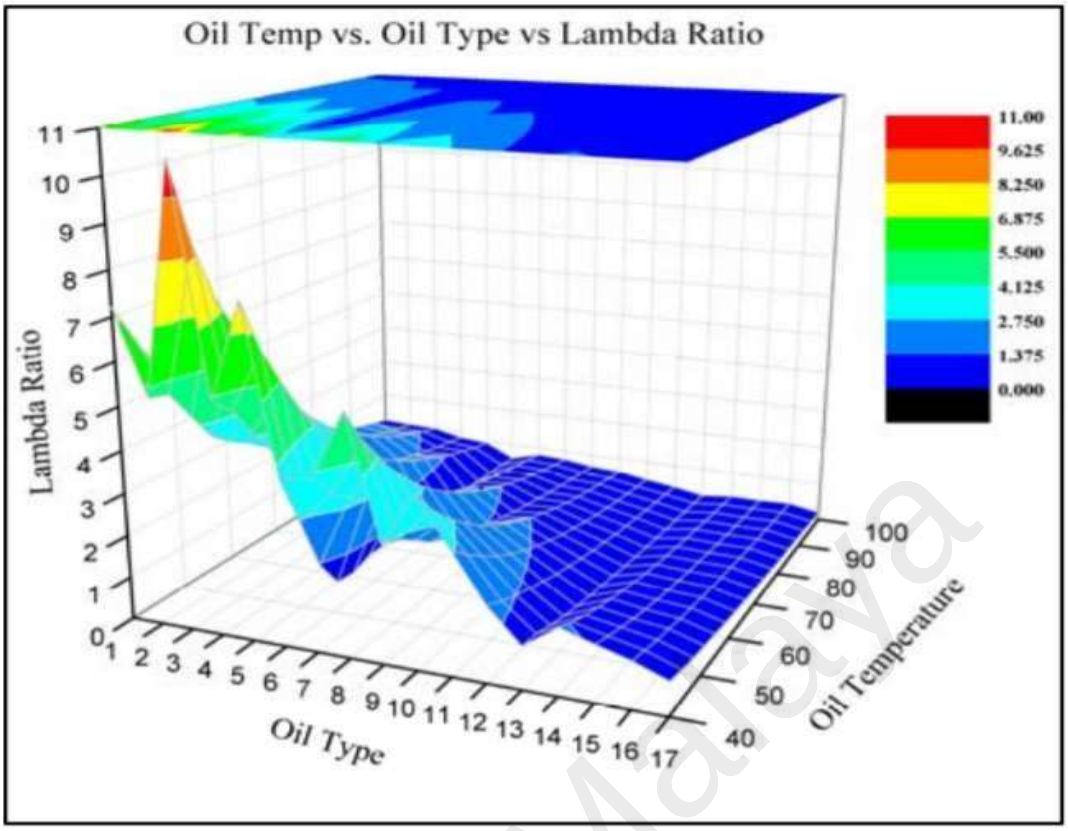


Figure 2.12 Temperature range in different oil viscosity (Douglas & Thite, 2015)

The graph shows that a thinner oil coating raises the temperature of the oil during operation.

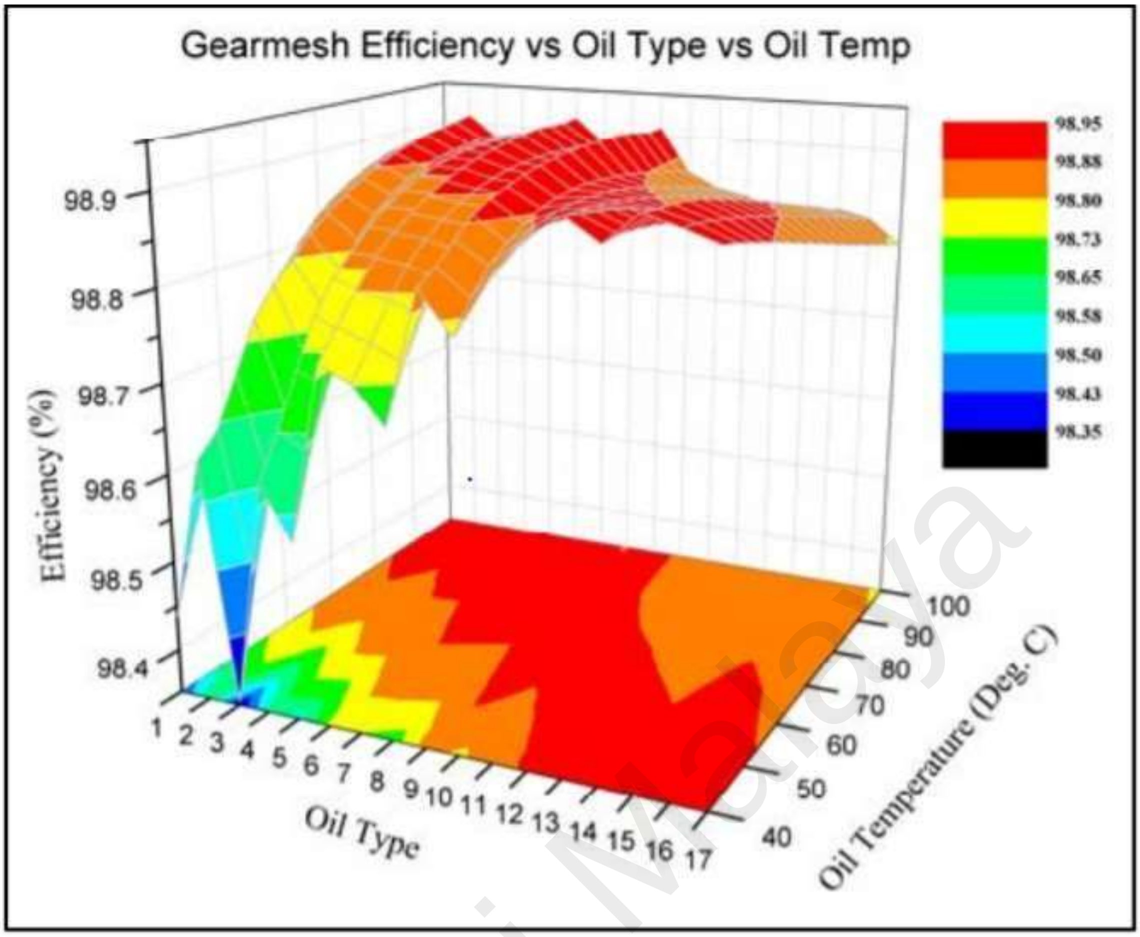


Figure 2.13 Efficiency Of The Gearbox Against Vs Type Of Oil And Gearbox RPM (Douglas & Thite, 2015)

The oil with high viscosity is more effective for giving better efficiency also the temperature of the oil will be maintained. power loss is not too much different if compared to low viscosity oil. the internal rolling part lifespan increased and is also good for gearbox performance. Figure 2.13 showed whenever oil temperature is reached 100Deg the capacity of lower film thickness efficiency will start to drop the performance of the gearbox and rolling parts friction will occur and the lifespan of the machine gearbox is reduced. It is obvious that for the oil to operate well in terms of both oil film thickness and efficiency, the oil's working temperature must be maintained. oil temperature should be maintained warm to extend the machine’s gearbox capability. The effect of oil temperature on its lifespan is significant; for every 10 °C drop in oil temperature, lubricant life is doubled. (Douglas & Thite, 2015)

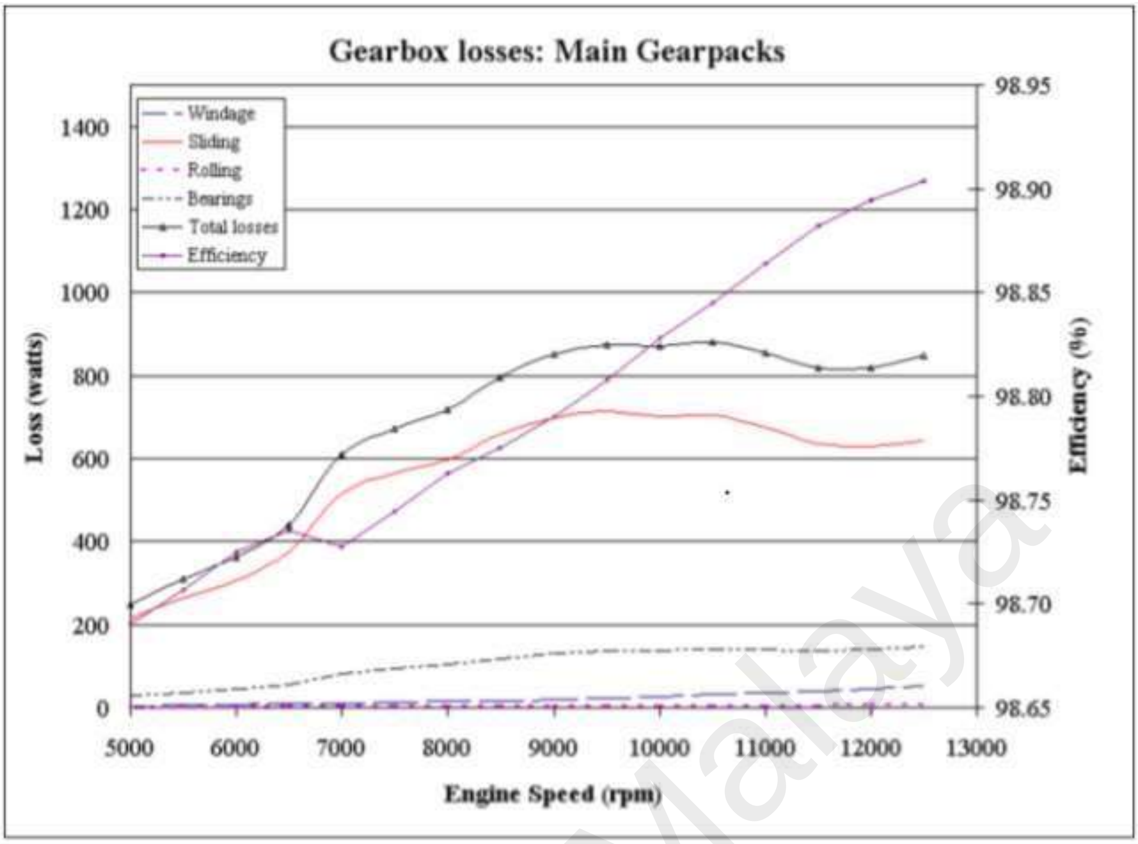


Figure 2.14: Gearbox Failures Are Divided Into Categories (Douglas & Thite, 2015)

The researcher proves it clearly to greater the performance of gearbox oil. the temperature of gearbox oil needs to maintain at a minimum level temperature to increase the lifespan of oil. (Douglas & Thite, 2015)

2.5. Oil Temperature's Influence on Gear Failure

According to (Höhn & Michaelis, 2004) Oil temperature in the lubrication system causes gear surface damage such as wear, scuffing gear teeth, micro pitting, and pitting, thus Increases in temperature have been linked to metallurgical changes and a reduction in material endurance limitations. Temperature and time have a significant impact on the reactivity of gear oil additives that produce tribological layers. Because of all these occasional consequences, the temperature has an impact on gear breakdowns. Wear is a continual failure in thin dividing film circumstances, often at slow pitch line velocities with asperity contact. Scuffing is a type of instant failure that occurs whenever the edges of gears are welded together in temperature and pressure, usually without a protective layer between both solid surfaces. Micro-pitting is a surface fatigue failure that occurs primarily in the negative sliding zones below the pitch circle, while micro-cracks cause material breakage. Pitting is caused by surface cracks propagating through the material and developing further under high levels of implicit shear stress. As previously stated, increasing the temperature always results in a thinner film, but it can also result in increased chemical activity and, as a result, protection of the contact surface by wear layers

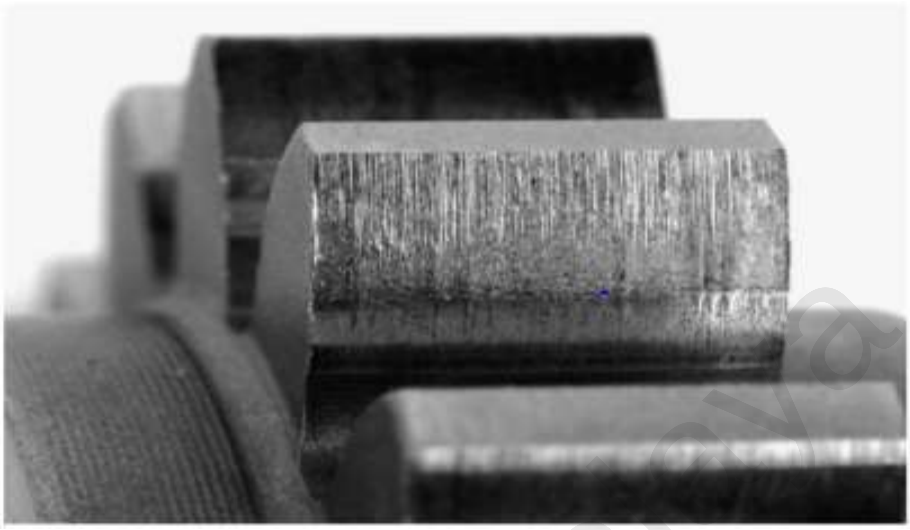


Figure 2.15 Wear (Höhn & Michaelis, 2004)

Figure 2.16 Scuffing(Höhn & Michaelis, 2004)

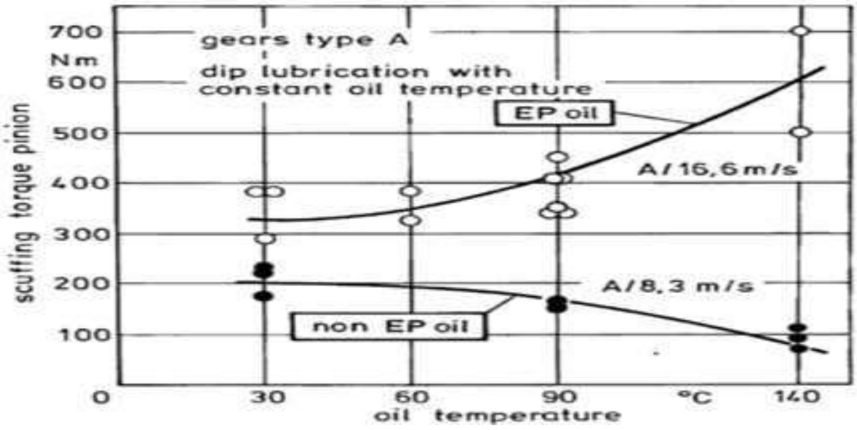


Figure 2.17 Influence Of Temperature On Scuffing(Höhn & Michaelis, 2004)

As the temperature of the gearbox oil rises, the viscosity quality of the oil decreases, while the chemical reaction in the oil increases.

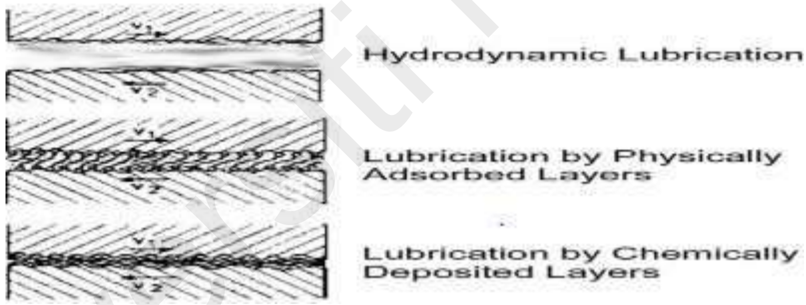


Figure 2.18 Mechanisms Of Surface Protection (Höhn & Michaelis, 2004)

• Temperatures increasing in the gearbox, leads to lower viscosity

•Adhesion force reduces as temperature rises.

•The chemical activity is raised, and the reaction kinetics are changed.

2.6 Consequence Of Oil Testing

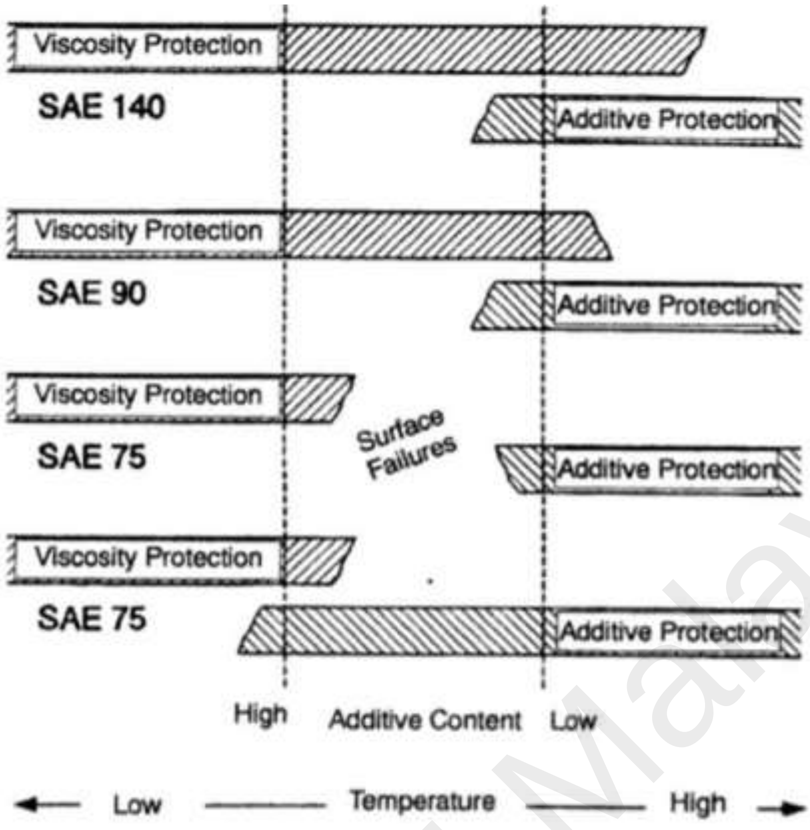


Figure 2.19 Temperature Difference In Viscosity And Additive Protection (Höhn & Michaelis, 2004)

According to the data collected by the previous researcher highlighted, the oil temperature is usually increased to reduce the oil film thickness and thus worsen the lubrication conditions. As has been shown, due to the temperature of the lubricant being increased the film thickness will be thin. The figures show the gap of oil film if oil viscosity provided for oil the surface protection, unable to protect from scuffing.

2.7 Effect Of Lubricant Temperature On Angular Contact Dynamic Behavior Bearing

Another researcher has been done investigating the effect of temperature and different types of lubricant reactions on sliding the combination of behavior and frictional forces. Change of temperature of the rolling element system lubricant affects the impact load between both the balls and the raceways, therefore affecting the slip and impact load (Liu et al., 2020)

As figure 2-20 the high axial load induces a lower coefficient of traction and a higher tensile load between the balls and the raceway. Whenever axial load became more than 500 N, then the tensile load will reach its optimum range. Particularly if the axial load is maintained in low, the temperature of the lubricant has a major impact on tensile behavior

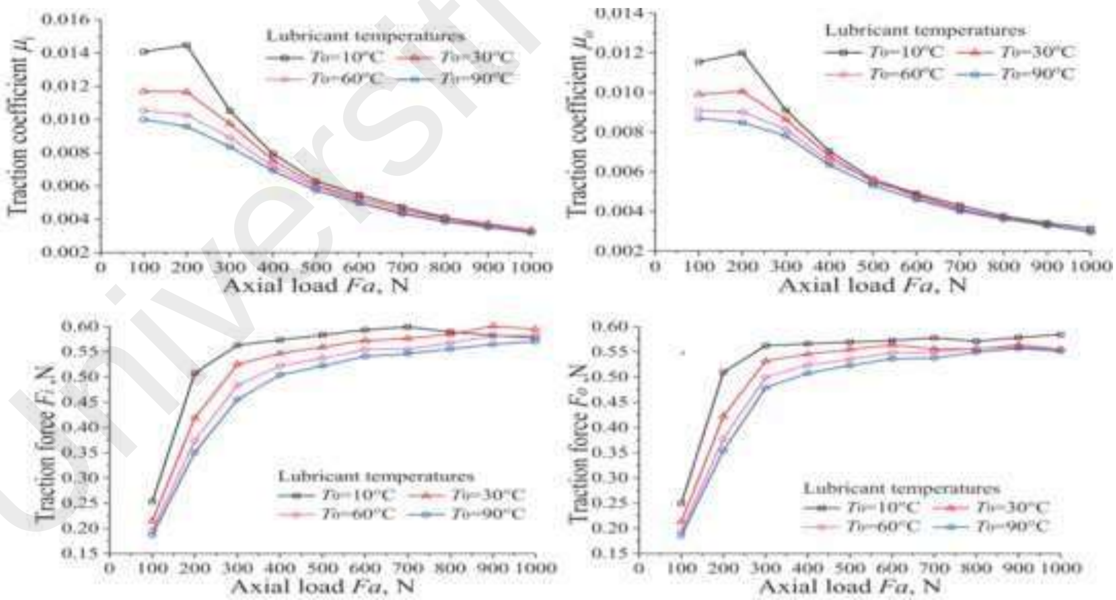


Figure 2.20 The Effect Of Lubricant Temperature On The Ball's Skidding Behaviour (Liu et al., 2020)

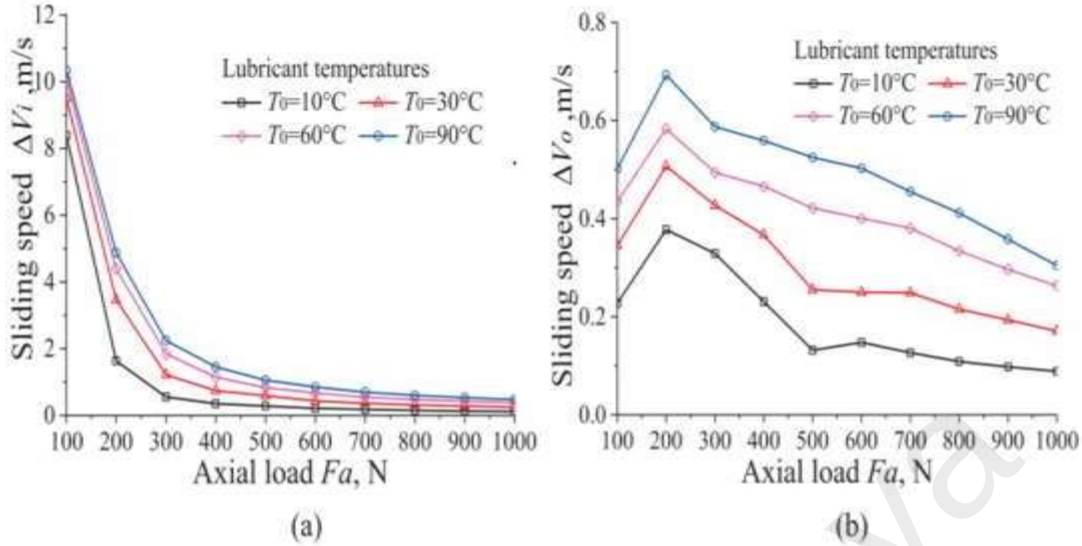


Figure 2.21 The Effect Of Lubricant Temperature On The Ball's Skidding Behavior (Liu et al., 2020)

According to the previous experiment, if the bearing is operated at a higher lubricant temperature, the axial load may be the occurrence of sliding behavior between the balls and the raceways. Axial and radial loads together. The effect of oil temperature on the bearing's dynamic characteristic under combination axial and radial loads is then examined. The load between the ball and the cage lowers as the oil’s temperature rises (Liu et al., 2020)

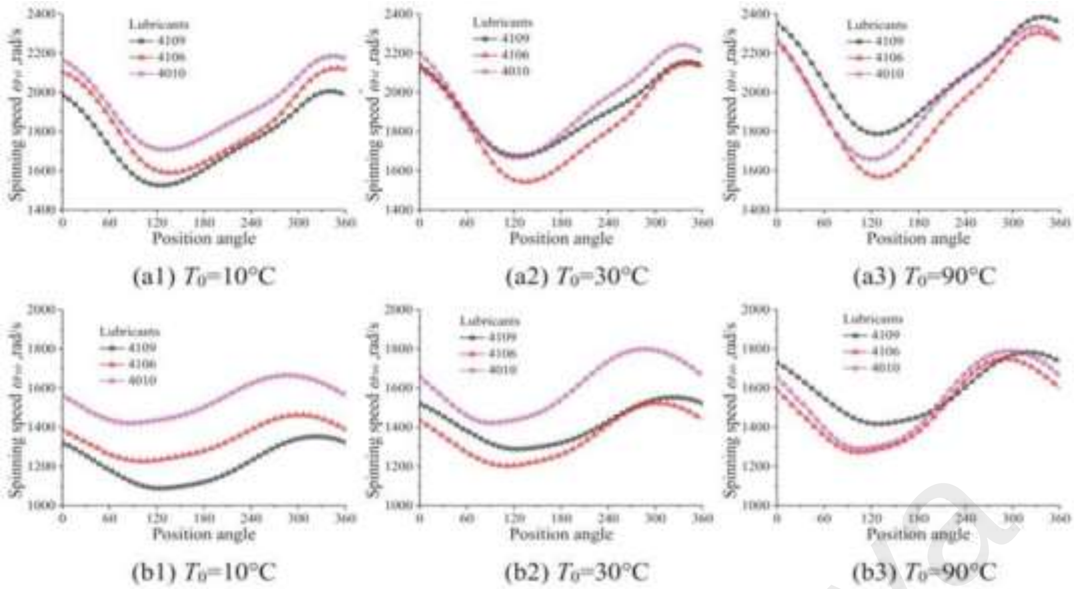


Figure 2.22 The Effect Of Lubricants On Ball Spinning Speed At Different Lubricant Temperatures (Liu et al., 2020)

The speed of ball bearing after lubricating with different types of lubricant, the outcome result shows a different graph with keep increasing temperature of the lubricant. Considering with other two lubricants, the rotational speed shows much less variation (Liu et al., 2020).

2.8 Summary

In this chapter, learned about the efficiency and performance of lubricants in each rolling system. Several types of lubricant studies have been performed by several researchers based on lubricant temperature, loss, including performing different speeds with different lubricant viscosities for analysis of lubricant film thickness. In the chapter, observed that some research was not conducted properly on lubricant properties, and some information was not clear. By the way, appreciate the previous investigator for analyzing some key parts of lubricant research.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter describes the methodology process for accomplishing the objective of this project. The lubricant oil activities are discussed thoroughly and planned to enable the final year project to be completed on time to obtain accurate results. The process involved is temperature determination on the gearbox portion, ASTM test, and analysis by using Ansys Fluent software. The activities that involve are literature review, lab test, modeling of the system, analysis of the system compared with other systems, data analysis on the components, and report preparation. The used oil sample send to lab test to find out kinematic viscosity and total acid number also water content, Lotus laboratory service sdn. bhd conducted three lubricant properties tests.

3.2 Determination of temperature

Figure 3.1: Infrared Temperature Reader

After the machine runs the mass production, an infrared temperature reader was used to measure the actual temperature of the plastic extruder gearbox.

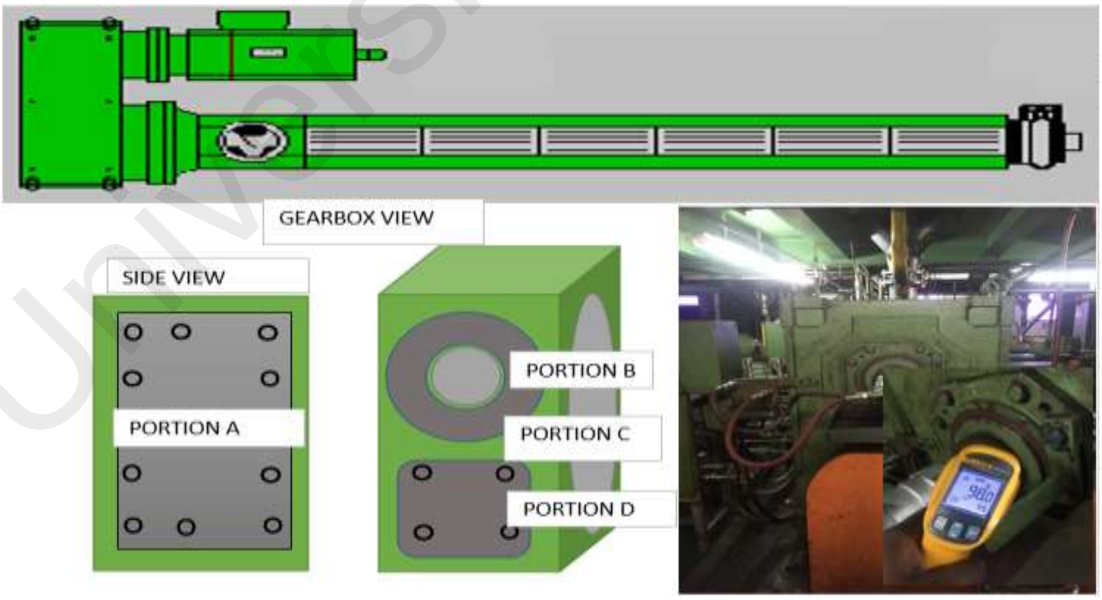


Figure 3.2: Gearboxes Temperature Taken View

Portion A

Portion D

Figure3.3: Gearbox side view

Portion B

Portion C

Figure 3.4: Gearbox front view

3.3 The method is used to determine lubricant properties

3.3.1 kinematic viscosity @40-100 degree C ASTM D445

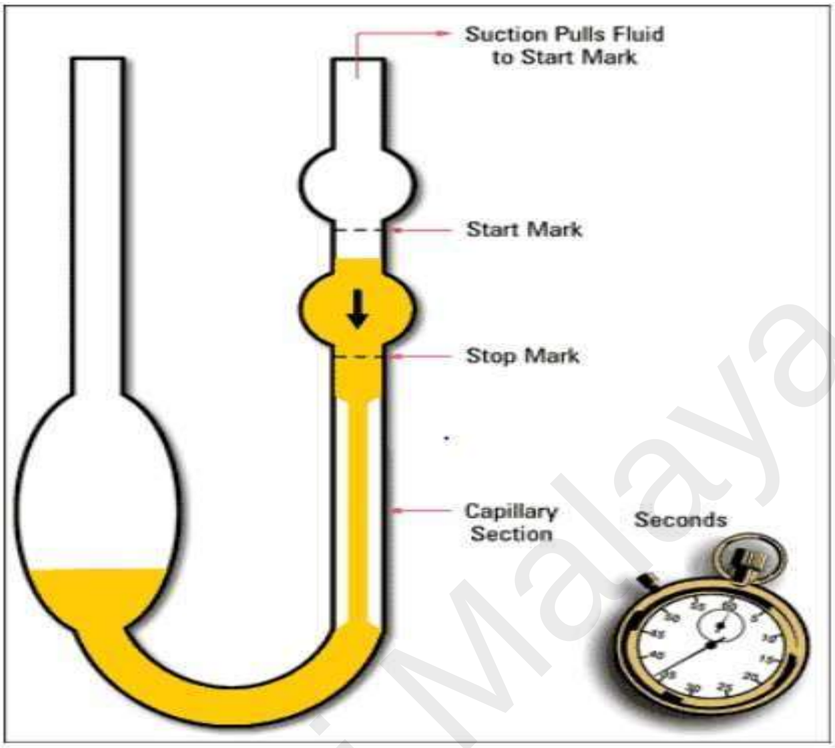


Figure 3.5: Capillary U-Tube Viscometer

The ASTM D445 Kinematic viscosity experiments have been executed at different temperatures to determine the current lubricant efficiency and to compare before and after kinematic viscosity characteristics. This kinematic viscosity ASTM D445 test was conducted by using a capillary U-Tube Viscometer and also a stopwatch. Therefore, the time it takes for the oil to pass through the hole of the capillary under gravity is used to calculate kinematic viscosity. The hole in the kinematic tube of the viscometer creates a constant resistance to the flow. The test was conducted at Lotus laboratory service sdn. Bhd.

3.4 Total Acid Number ASTM D664

The ASTM D664 test has been conducted to identify the overall acid quantity in used oil, the purpose of this test is to compare with fresh and used oil acid numbers. Acidic constituents may be present as additives or as degradation products generated during service, such as oxidation products, in new and used petroleum products. The acid quantity is often used as a guide in lubricating oil formulation quality control. This test is more useful to identify the quality of lubricant properties. The test cannot be used to estimate the corrosiveness of an oil under service conditions because a variety of oxidation products contribute to the acid number, and organic acids have a wide range of corrosion properties. Lotus laboratory service sdn. bhd. has conducted the test

Figure 3.6: ASTM D664 Equipment

3.5 Water Content ASTM D6304

The determination of water quantity in lubricant is more important for lubricant oil and additives. The water content of a new oil indicates its value and predictability of lubricant properties, whereas the water content of a service oil maintains its useful life in service. Water can accelerate the decomposition, oxidation, and sludge formation of petroleum and fail to protect internal rolling elements. This method is useful for measuring low levels of water in petroleum products, hydrocarbon solvents, and automatic transmission fluids. The reaction between the electrochemically produced Karl Fischer reagent (including iodine) in the titrator and the water in the sample is monitored by the coulometric. The water content of a sample is expressed in mg (ppm) of water per kg of sample. The test was conducted by Lotus laboratory service sdn. bhd.

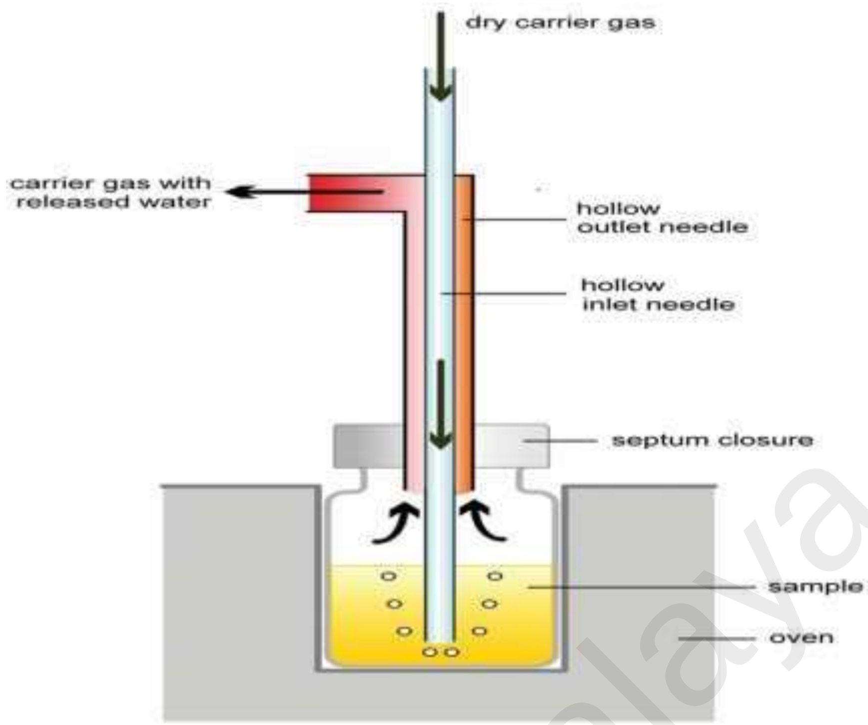


Figure 3.7: ASTM D6304 test Equipment and Method

3.6 Viscosity Cup

The viscous cup test had been conducted to find out the viscosity of lubricant oil, this test is used to measure mineral and synthetic oil viscosity. The cup is dipped and filled with the substance. After a few seconds of lifting the cup out of the substance, the measurement of viscosity for this test used stopwatch for measure time, until the liquid streaming out of it breaks up, this test is corresponding “efflux time” which is measured in centistoke.

Figure 3.8: Equipment for viscosity cup test

3.6.1 Procedure

The test was conducted at the working place.

1. Pour the original fresh gearbox oil into a medium container
2. Insert the viscosity cup into the container until a bubble found or oil has fulfilled the cup
3. Take out the viscosity cup and start the stopwatch

. 4. Stop the stopwatch immediately when the oil stopped flowing or dripping

5. Repeated steps 1 to 13 to mineral oil

3.7 Numerical Of Viscosity Index

3.7.1 Viscosity Index Number ASTM D2270

A viscosity index is a number assigned to hydraulic oil or gearbox lubricant based on its Variability of viscosity as a function of the temperature. The higher the viscosity index. When the temperature is high, the value of viscosity in gases will be increased, but when the temperature is high in fluid, the viscosity of the fluid will decrease. Because it is a lower operating temperature, the viscosity index number for gearbox lubricant should be as high as possible. As a result, this study's viscosity index results were derived using the formula The kinematic viscosity of mineral and synthetic oils is measured at 40°C and 100°C, respectively. After six months of mass production, the parameter value was used to refer to the ASTM D2270 table, which calculated the viscosity index number of lubricants.

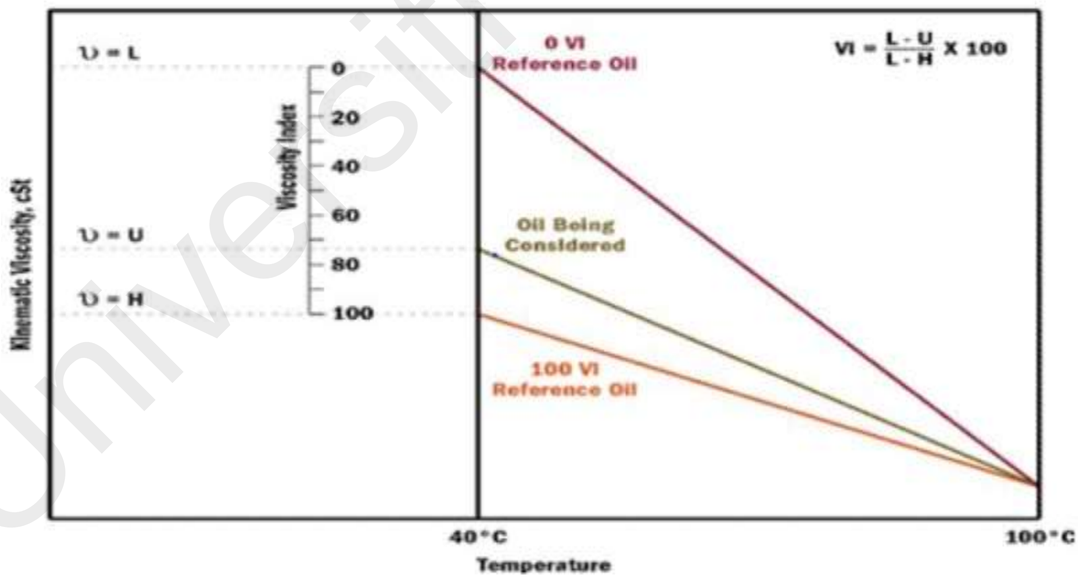
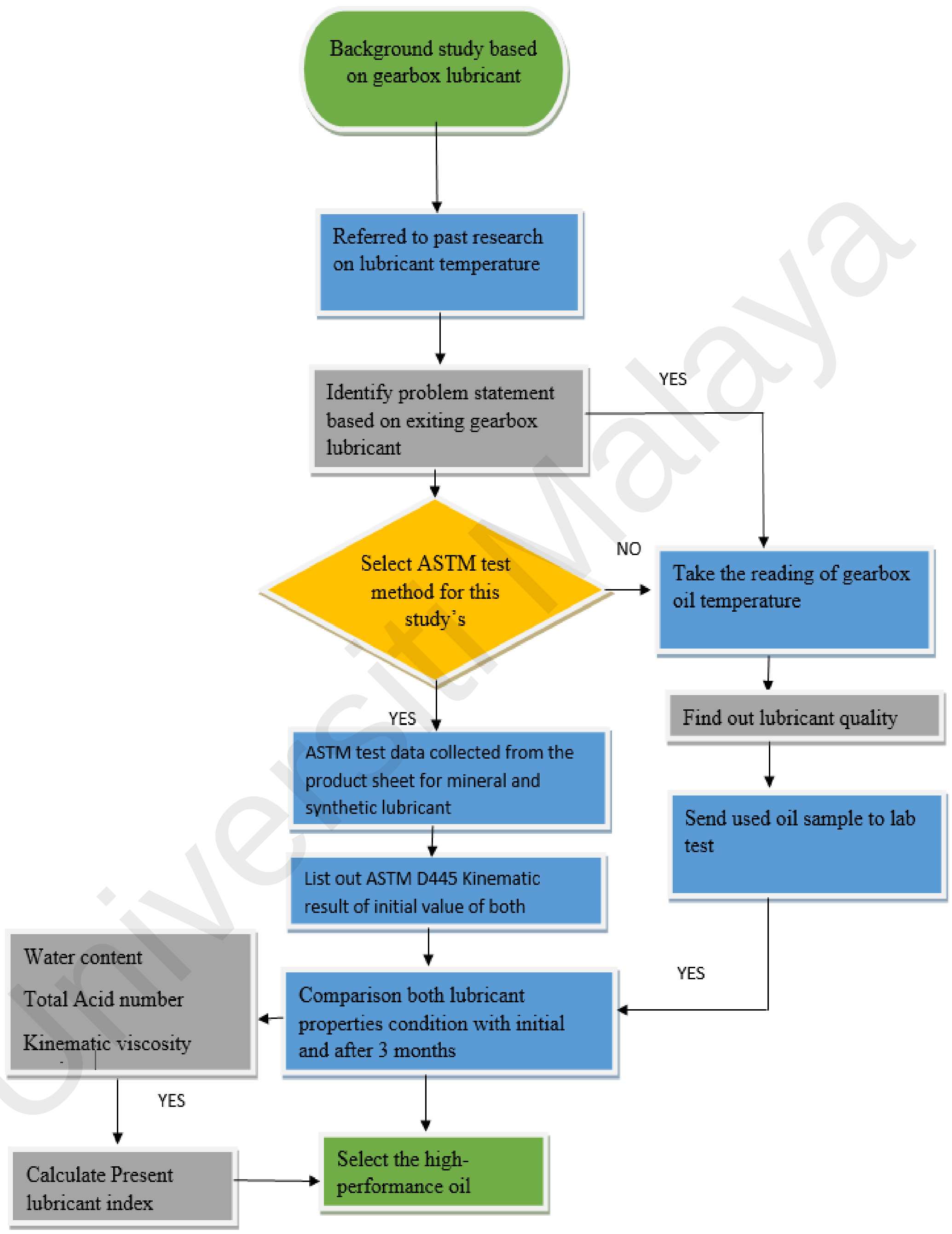


Figure 3.9 Viscosity index number Graph

3.8 ANSYS Fluent Software

The ANSYS Fluent software is used to determine the amount of heat transfer from existing oil temperature. This software is used to predict the performance of shell and tube heat exchangers. The simulation system was used the lubricant properties and for inlet hot temperature T1 is input with existing gearbox lubricant temperature. Also, as a water inlet temperature was used T1 cold water was 22°C. The rate of heat transfer and fluid flow velocity performance is all shown in a graph clearly.

3.8 Flow Chart



3.9 Ansys software

The diagram of the shell and tube in the gearbox has been drawn in Ansys software. The 3D geometry design in ANSYS software as per details to find the result of the inflow. The figure below shows the 3D geometry.

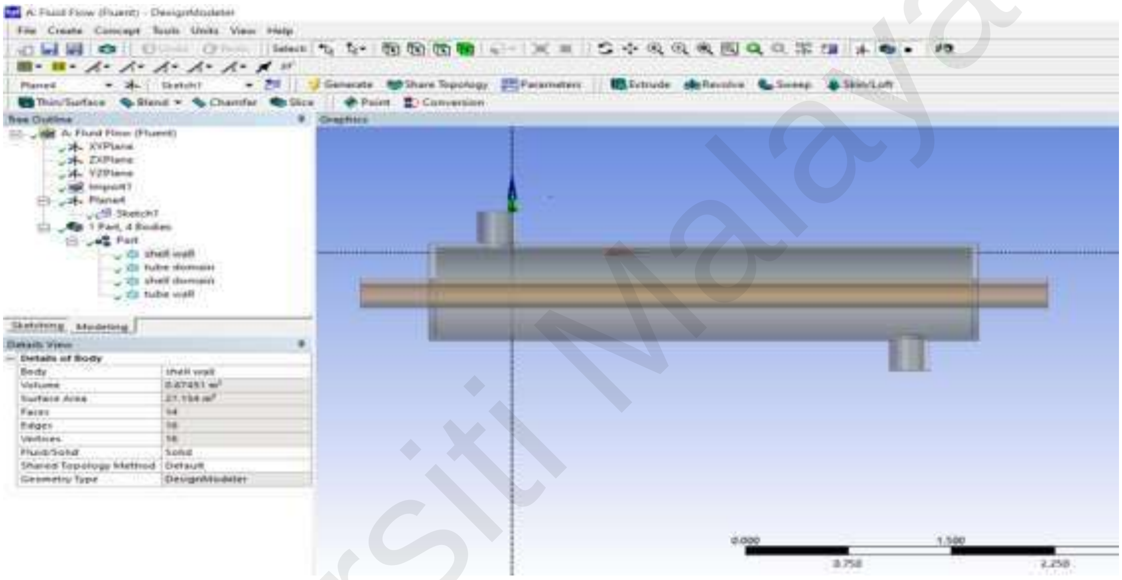


Figure 3.10: 3D Domain

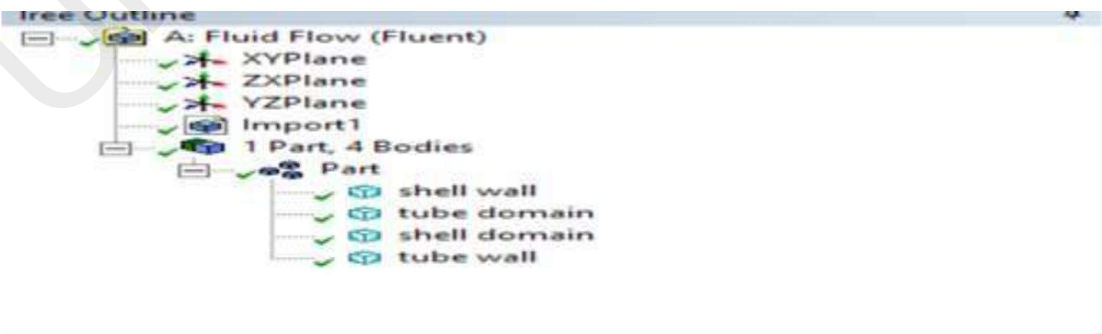


Figure 3.11:Selected Name For Boundary Condition

Table 3.1: Mesh Setup

Details of "Mesh"	
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Element Order	Linear
Element Size	0.3 m
Export Format	Standard
Export Preview Surface Mesh	No
Sizing	
Use Adaptive Sizing	No
Growth Rate	Default (1.2)
Max Size	Default (0.6 m)
Mesh Defeaturing	Yes
Defeature Size	Default (1.5e-003 m)
Capture Curvature	Yes
Curvature Min Size	Default (3.e-003 m)
Curvature Normal Angle	Default (18.0°)
Capture Proximity	No
Bounding Box Diagonal	5.3442 m
Average Surface Area	1.8756 m^2
Minimum Edge Length	0.62832 m
Advanced	
Number of CPUs for Parallel...	Program Controlled
Straight Sided Elements	
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Default (2.7e-003 m)
Generate Pinch on Refresh	No
Statistics	
Nodes	41832
Elements	103065

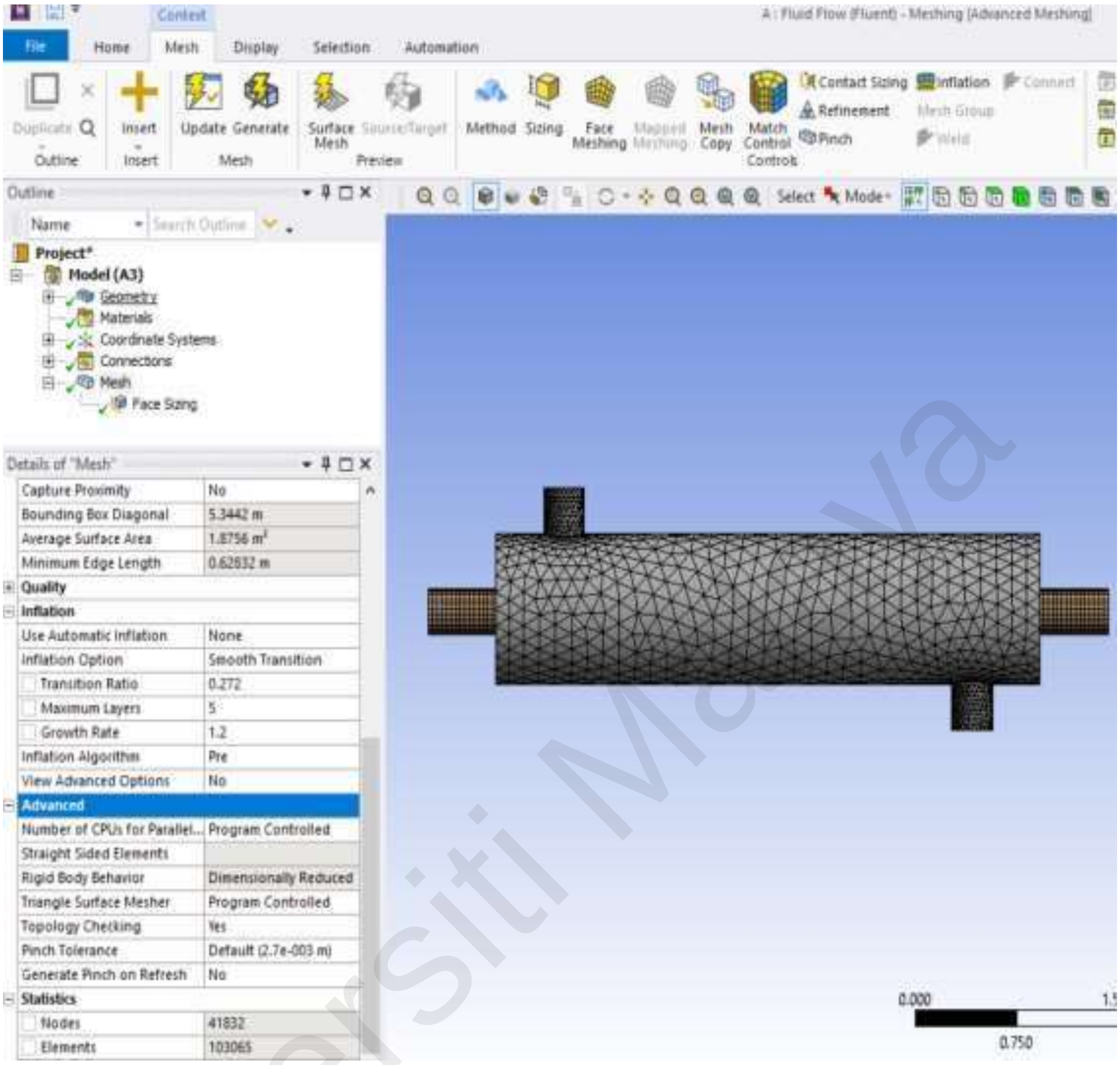


Figure 3.12: Meshing condition

The figure above shows the mesh for the shell and tube. Meshsing part has few sizes that have been modified to obtain the simulation result such as Max size 1.5e.-003m and min curvature size 3.e-003m others left as default. the setting is made to obtain good simulation results and to achieve success in the project.

3.9.1 VALUE SET IN ANSYS

The value is set in ANSYS software, the system can generate the coordination for the flow set. Whereby the value is set according to the date was get. before set value, set the boundary name for the camber and set the direction of the flow .as per the diagram below

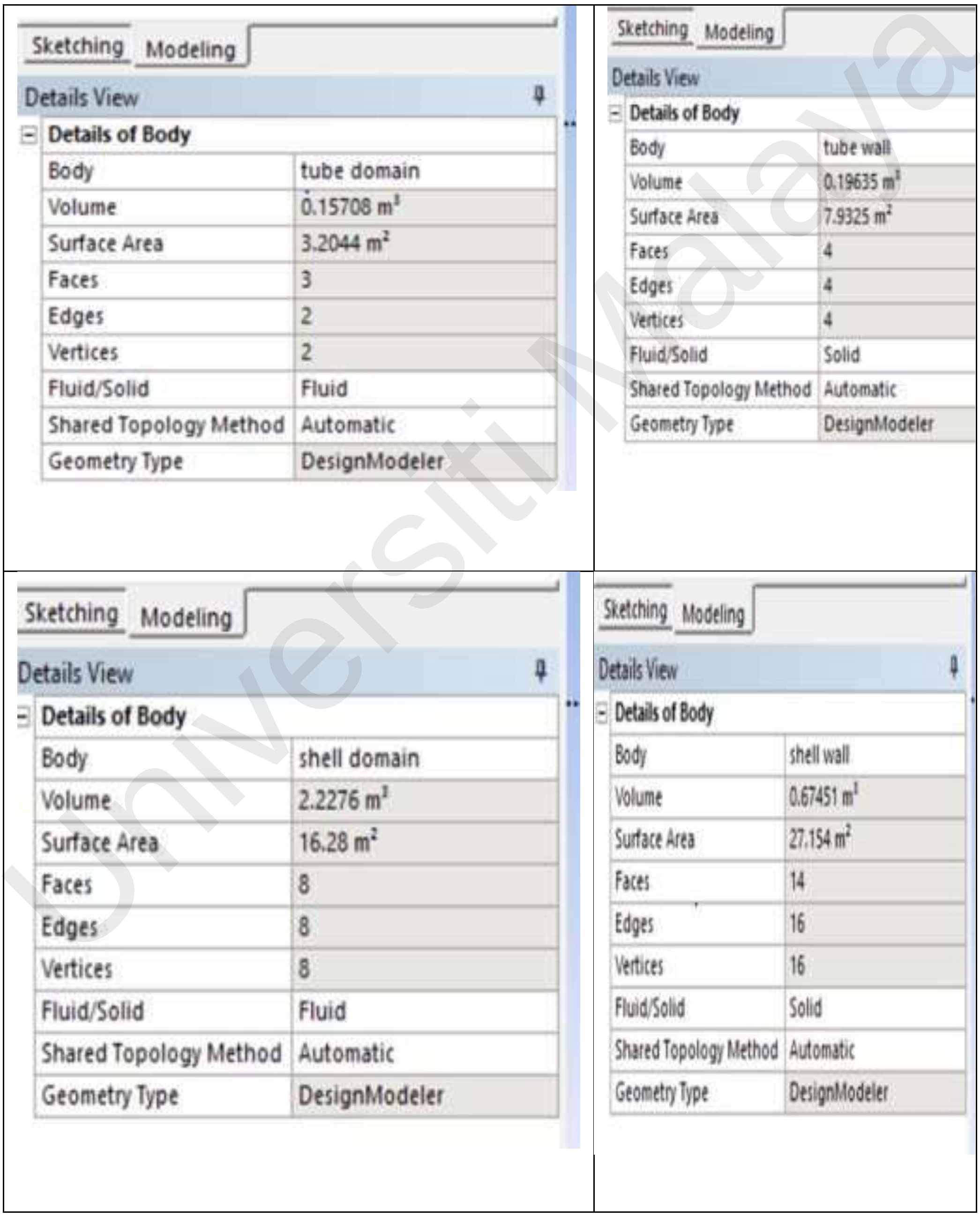


Figure 3.13 Boundary Condition

Figure 3.14: Setup Page

Select in benchmark table set up after dimension must be in 3D and options list activate double-precision, display mesh after reading

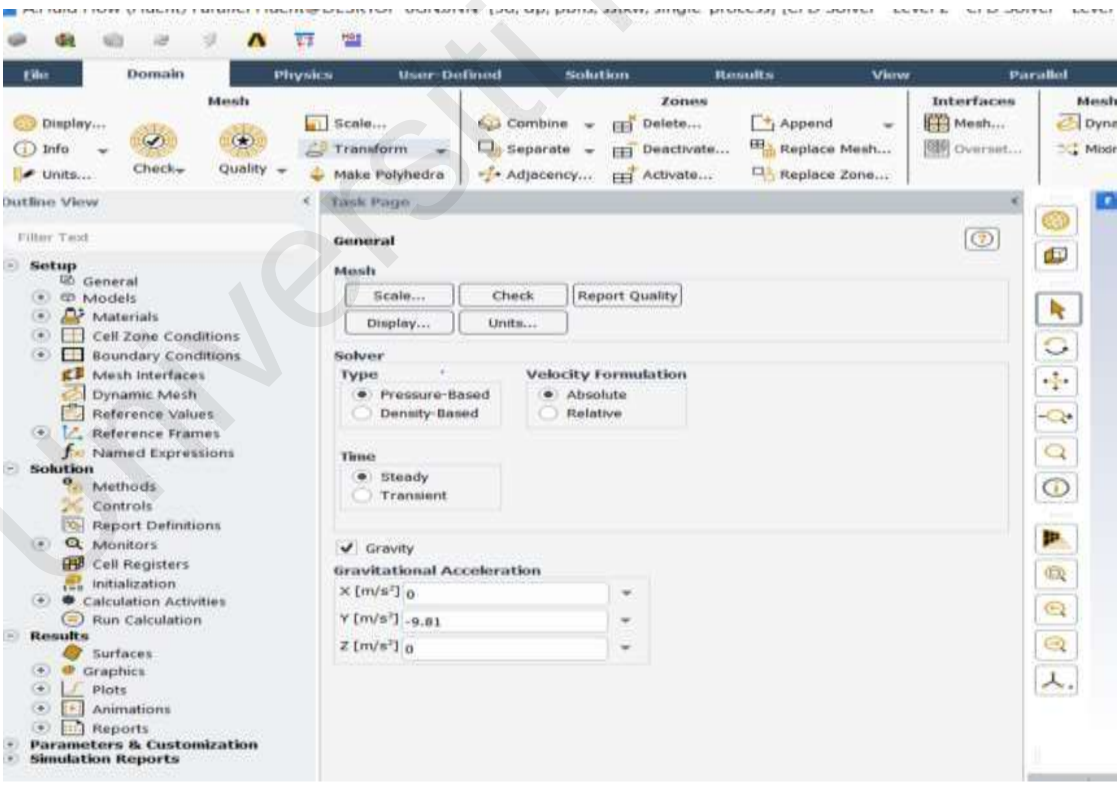


Figure3.15: Setup In General

activate the gravity and input value is -9.81 after setting the page go to models and turn on energy for heat transfer simulation

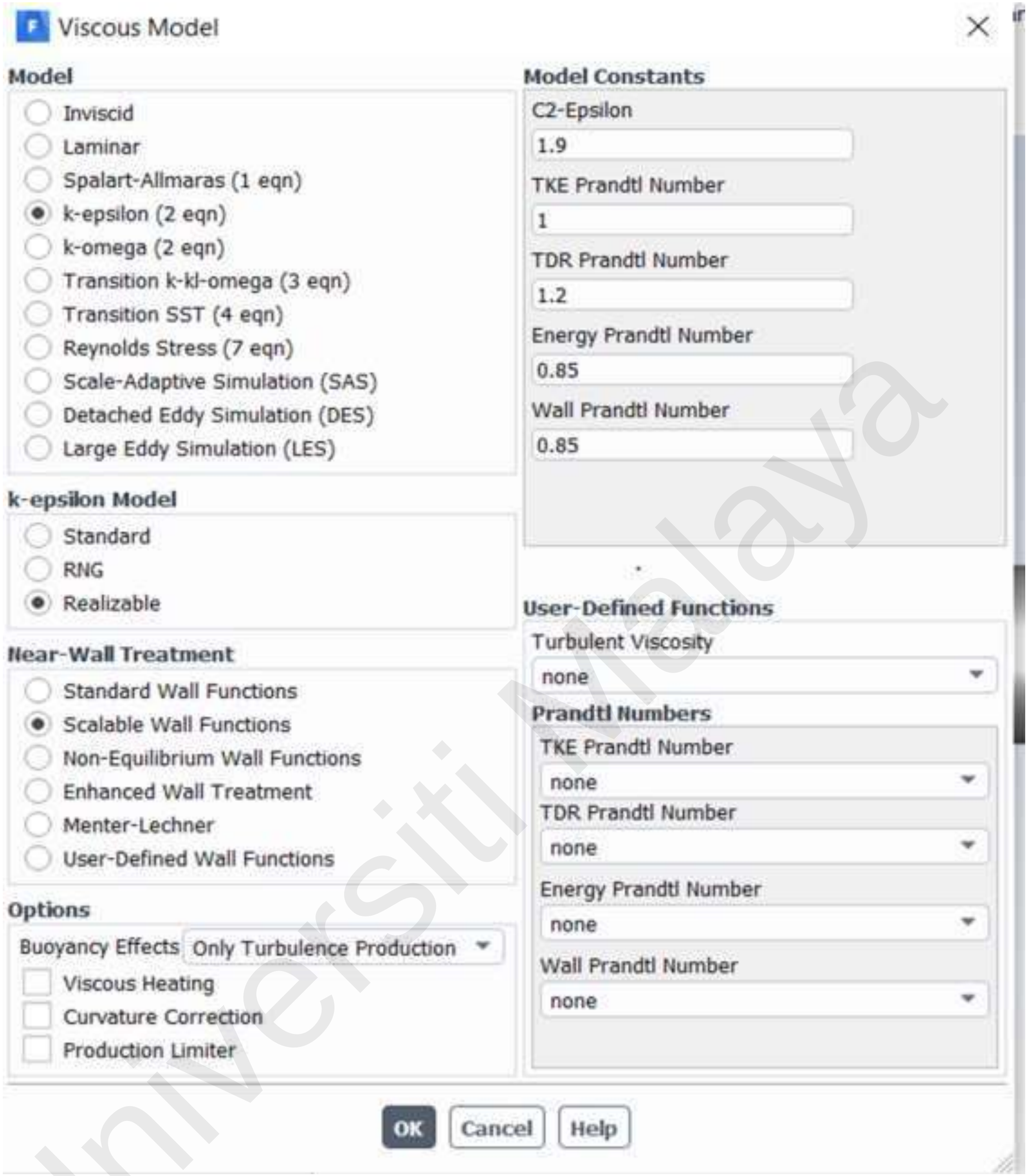


Figure 3.16: Viscous mod

Table 3.2: Input Parameter For Simulation

Parameter Lubricant	Data	Parameter Water	Data
Specific heat capacity (kj/kg°C)	1.67	Specific heat capacity (kj/kg°C)	4.18
Mass flow (kg/s)	2	Mass flow (kg/s	1
Temperature inlet (hot) °C	A:82 B:102 C:98 D:82	Temperature inlet (cold) °C	22
Density(kg/m³)	886.3	Density(kg/m³)	1000

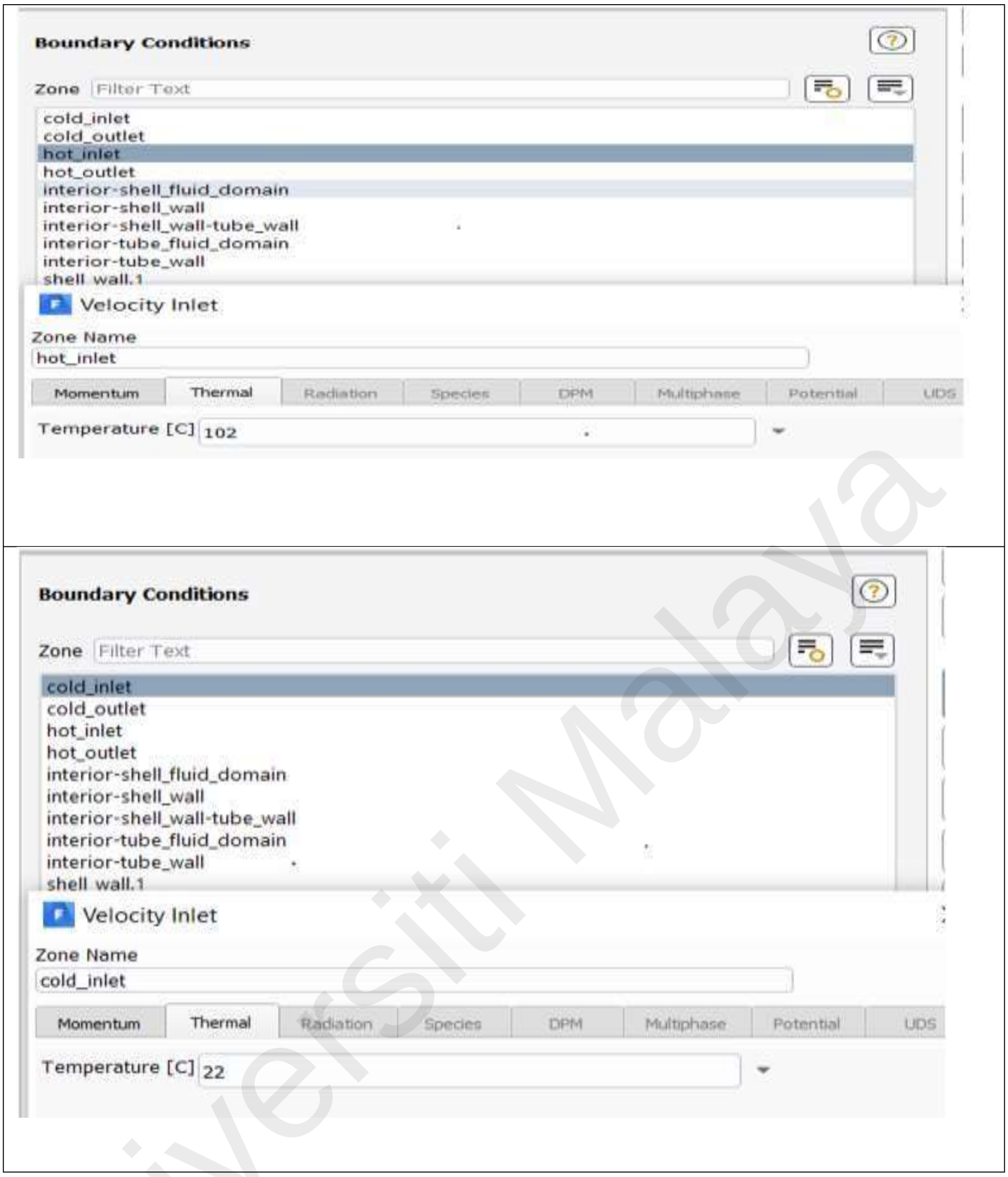


Figure 3.18: Temperature setup

CHAPTER 4:RESULT AND DISCUSSION

4.1 Introduction

This experiment was carried out to investigate the properties of mineral and synthetic oil after running mass production for 3 months with operation temperature 98-100 degrees Celsius. All the data was collected to analyze to ensure the performance of lubricants. The ASTM test data is used to calculate the viscosity index number, that data is used to compare the initial value of both lubricants. ANSYS fluent simulation was used to ensure the rate of heat transfer, by end of this research, data will be useful to implement the shell and tube heat exchangers for the plastic extruder gearbox. The lubricant oil sample was collected from both oil and viscous cup tests has been conducted to compare the results of the kinematic viscosity test.

4.2 Results

4.2.1 Extruder Melting Point Temperatures Setting

Table 4.1:Value Set In HMI Machine Extruder

INSULATION XLP EXTRUDER PLASTIC 175											
TITLE	SCREW	HOPPER	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	CLAMP 1	CLAMP 2	HEAD	TEMP
PRODUCTION	105	50	120	120	120	120	120	120	120	120	C
SERVICE	90	50	80	80	80	95	105	105	90	90	C
TOLERANCE +	5	5	5	5	5	5	5	5	5	5	C
TOLERANCE +	5	5	5	5	5	5	5	5	5	5	C
ACTUAL VALUE	104	50	121	119	120	120	121	120	120	120	C

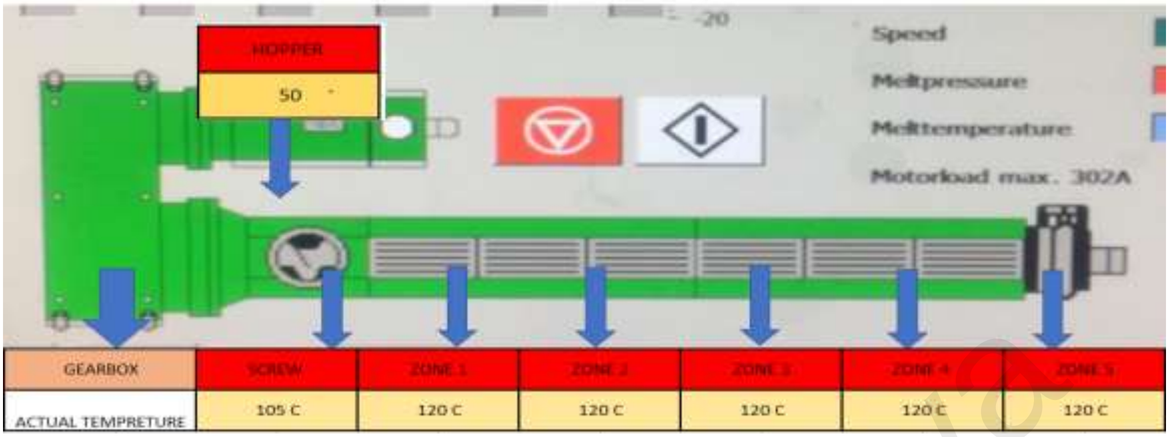


Figure 4.1: Extruder Barrel Heat Up Section

The table above is one of the most important parts of this plastic extruder line because temperature parameters are all input into the production column. The production machine technician is set all values. Once the temperature for actual is reached with the setting value that means production is ready to run mass production. This machine is normally running mass production for wire specification 11kv is takes a long time to finish the target length. The machine will be running for 2 or 3 weeks nonstop with 11kv. This machine temperature system is running with a tempering unit. The extruder barrel section has connected with the hot water supply and return pipe, this circulation system will be activated until the end. Therefore, water will circulate at the barrel section for melting the plastic compounds. Due to used steam water at section barrel and screw connecter section. The temperature of the barrel and screw is transferred heat to the gearbox rolling system. Because the gearbox is a major part of this plastic extruder, the screw will spin according to the motor speed. Due to heat transfer occurring during mass production between barrel to gearbox rolling system, the oil temperature is begun to hot.

4.3 Temperature Of Gearbox Portion

Table 4.2 Determination of temperature data

Gearbox temperature data collected at every end of mass production after 14 days						
Job Order	After 2 Weeks	Portion A	Portion B	Portion C	Portion D	Duration
1St job order	End of production after 2 week	85.8°C	100.5°C	95.3°C	81.4°C	14days
2nd job order	End of production after 2 week	82.4°C	102.5°C	98.2°C	81.9°C	14days
3rd job order	End of production after 2 week	81.1°C	102.0°C	100.6°C	84.1°C	14days
4th job order	End of production after 2 week	78.7°C	103.5°C	97.9°C	80.6°C	14days
Average Temperature		82°C	102°C	98°C	82°C	

The operational temperature reading is taken after the machine runs mass production after 2 weeks every job order. The temperatures of the existing gearbox were taken by using an infrared temperature reader for recorded the operation temperature. This plastic extruder line is not similar to an ordinary extruder line. Because this extruder line only produces high voltage and medium voltage cables. This extruder line before running mass production needs to wait for all screw barrel zone heat up and the actual temperature value must reach the setting value. The whole heating system there were used steam-water circulation. every heat-up zone section has a boiler system and a water pump that is used to transfer hot water into the system. After reaching all section zone temperatures of 120°C, the mass production will run until the job is completed in order. This research data was collected based on 11kv wire specification order. The operational temperature was taken before stopping mass production which means the end of production.

4.4 Determination properties of Mineral And Synthetic Oil Sample Before And After Use.

Mineral oil

Synthetic oil

Figure 4.2 Sample Oil Taken From Workplace

The figure 4.2 oil sample was taken from the existing machine gearbox to conduct this experiment. The sample oil for both lubricants is already used in the machine for 3 months. This oil is collected to investigate oil present condition through the ASTM test. In this case study, fresh oil properties are taken from the product data sheet, because already gives initial kinematic viscosity in temperature 40°C and 100°C.

4.5 Index Number Comparison of Both Lubricants

Kinematic viscosity for fresh oil is already given in the properties table of mineral oil and synthetic oil. In this experiment focused on lubricants grade ISO 220, both lubricants are a similar type of grade. The ASTM D445 test method is used to determine kinematic viscosity values of sample used oil at 40°C and 100°C.

L - kinematic viscosity at 40 °C of a viscosity index 0 oil with the same kinematic viscosity at 100 °C as the viscosity index to be calculated, mm2 /s

Y- kinematic viscosity of the oil to be calculated viscosity index at 100°C, mm2 /s

H - kinematic viscosity at 40 °C of a viscosity index 100 oil with the same kinematic viscosity at 100 °C as the oil whose viscosity index is to be calculated, mm2 /s

Table 4.4: Product Data Sheet For Mineral Oil

Product Data Sheet

Typical data

	Sinopec L-CKD Heavy Duty Industrial Gear Oil							
ISO viscosity grade	68	100	150	220	320	460	680	1000
Kinematic viscosity, ASTM D 445								
cSt @ 40 ℃	68.24	99.16	149.9	217.0	313.0	432.0	688.7	1002.0
cSt @ 100 ℃	8.80	11.08	14.5	18.3	23.1	29.6	42.0	57.0
Viscosity index, ASTM D 2270	101	96	95	93	92	97	102	110
FZG scuffing test, fail load stage, A/8.3/90, DIN 51354	12+	12+	12+	12+	12+	12+	12+	12+
Timken OK load, lb, ASTM D 2782	60	60	60	60	60	60	60	60
Four ball EP, ASTM D 2783								
weld load, kg	250	250	250	315	315	315	315	315
load wear index	465	465	465	549	565	588	587	605
Rust prevention, synthetic sea water, ASTM D 665B	pass	pass	pass	pass	pass	pass	pass	pass
Copper corrosion, 3 hours @ 100 ℃, ASTM D 130	1b	1b	1b	1b	1b	1b	1b	1b
Foaming characteristics, ASTM D 892								
sequence I	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
sequence II	10/0	10/0	10/0	10/0	10/0	10/0	20/0	20/0
sequence III	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Demulsibility @ 82 ℃, ASTM D 2711								
water in oil, %	1.0	1.0	0.8	0.5	0.5	0.9	0.8	1.0
emulsion, mL	0.5	0.5	0.3	0.2	0.5	0.2	0.60	0.8
separated water, mL	84.0	84.0	83.0	86.3	84.6	83.2	81.9	81.5
Pour point, ℃, ASTM D 97	-17	-17	-14	-12	-9	-9	-9	-9
Flash point (COC), ℃, ASTM D 92	234	246	249	242	250	238	270	246
Density @ 20 ℃, kg/cm^3, ASTM D 4052	876.6	878.8	888.7	886.3	896.6	898.7	899.5	898.5

These data are given as an indication of typical values, not as exact specifications.

4.6 Kinematic viscosity, ASTM D445 data collected from mineral oil grade 220

MINERAL OIL (ORIGINAL)		
PARAMETER	TEST METHOD	RESULTS
kinematic viscosity@40°C,cSt	ASTM D445	217
kinematic viscosity@100°C,cSt	ASTM D445	18.3

Used numerical index number equation for determining viscosity index number for fresh oil. The data was taken from the ASTM D2207 (2020) table.

VI =L-U/L-H X 100%

Data: VI: 93 substituted collected data into the equation to find out VI.

L:420.7 VI =L-U/L-H X 100%

H:201.0 =420.7-217.0/420.7-201.0 X 100%

U:217.0 =93

The fresh mineral oil index number is tally with the datasheet when calculated with the used equation

4.6.1 Kinematic viscosity, ASTM D445 data collected from mineral oil grade 220

MINERAL OIL (SAMPLE AFTER 3 MONTHS)		
PARAMETER	TEST METHOD	RESULTS
kinematic viscosity@40°C,cSt	ASTM D445	141
kinematic viscosity@100°C,cSt	ASTM D445	13.1

Numerical index number equation used for determining viscosity index number for used oil. The data was taken from the ASTM D2207(2020) table.

VI =L-U/L-H X 100%

Data: VI: 83 — substituted collected data into the equation to find out VI.

L:235.0 — VI =L-U/L-H X 100%

H:122.9 — =235.0-141/235.0-122.9 X 100%

U:141 — =83

The viscosity index number is not equal to the initial index value. Due to the operating temperature of gearbox, lubricant being maintained with high temperature it affected lubricant index number.

4.7 Mineral Oil ASTM D445 Kinematic Viscosity @40°C, cSt Test Result Between Fresh Oil And Used Oil In The Graph

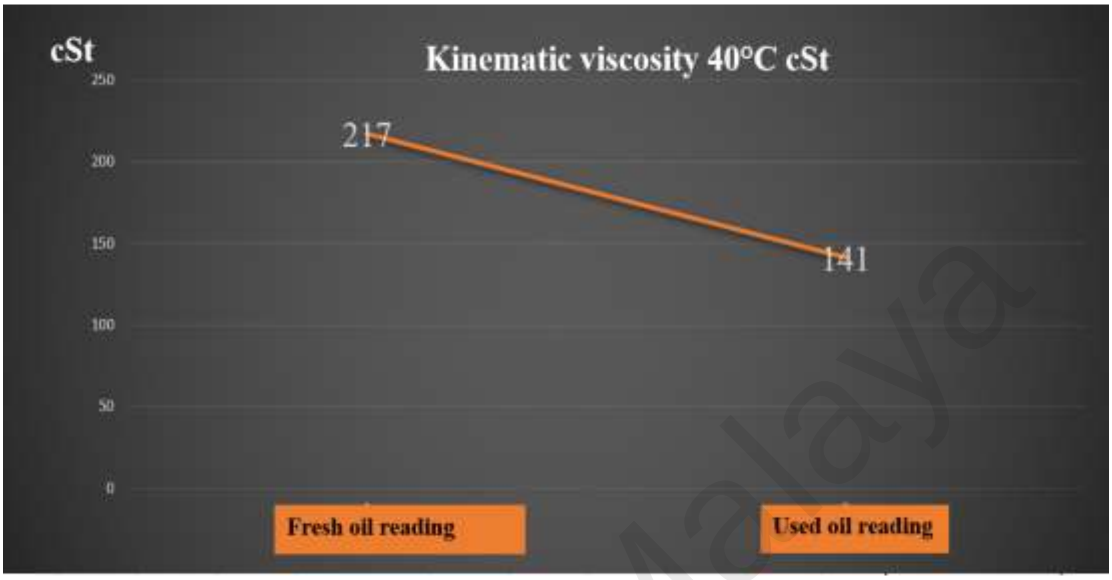


Figure 4.3: ASTM D445 40°C Result Between Fresh Vs Used Oil

4.7.1 Mineral Oil ASTM D445 Kinematic Viscosity @100°C, cSt Test Result Between Fresh Oil And Used Oil Showing In The Graph

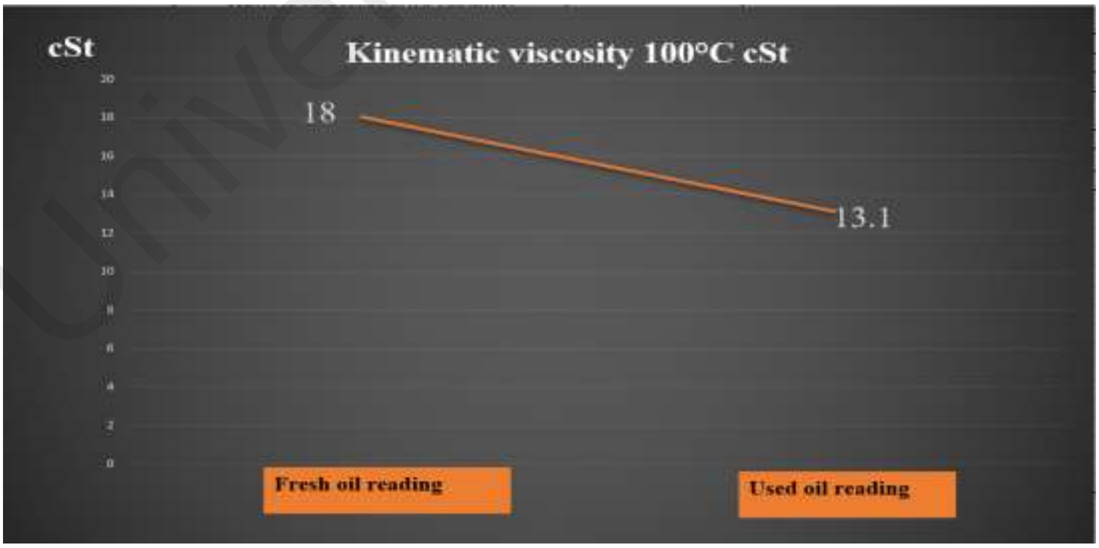


Figure 4.4: ASTM D445 100°C Test Result

4.7.2 Mineral Oil Viscosity Index Number Comparison Between Fresh Oil Value Vs Used Oil

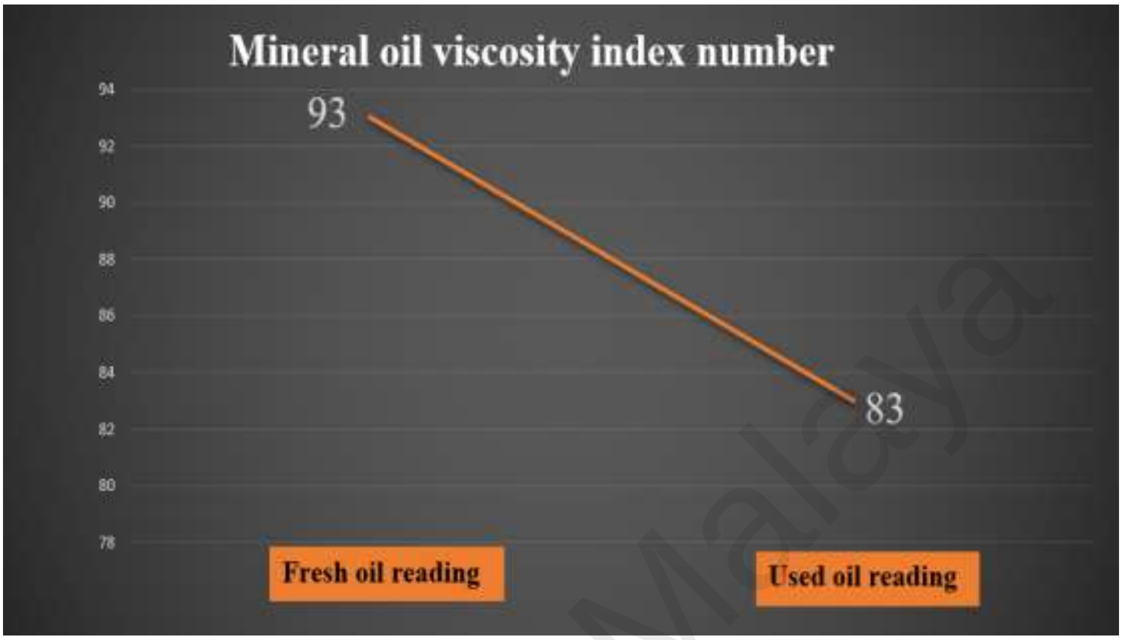


Figure 4.5 Mineral Oil Viscosity Index Number Comparison Between Fresh Vs Used Oil

The result of mineral oil viscosity index number drops by 10 points different from 93 to 83. due to the operating temperature being high; the lubricant viscosity index number is affected.

Table 4.5: Product Data Sheet For Synthetic Oil

Test	ASTM Method	Typical Results		
ISO Grade		**220**	**320**	**460**
S.A.E. Grade, wt.		90	-	140
Viscosity				
cSt @ 40°C	D-445	220	320	460
cSt @ 100°C	D-445	24.9	33.7	45.1
Viscosity Index	D-2270	143	148	153
Flash Point, °F	D-92	540	550	558
Pour Point, °F	D-97	-44	-37	-25
4-Ball Wear Scar, mm (40Kg,75°C, 1hr @ 1200rpm)	D-4172	0.34	0.33	0.33
Conradson Carbon, wt. %	D-189	<0.5	<0.5	<0.5
Oxidation Test, Minimum Hours	D-943	20,000	20,000	20,000
FZG Gear Test, Stage Pass	DIN 51354	12	12	12
Service Temperature Range, °F		-44 to 540	-37 to 550	-25 to 558

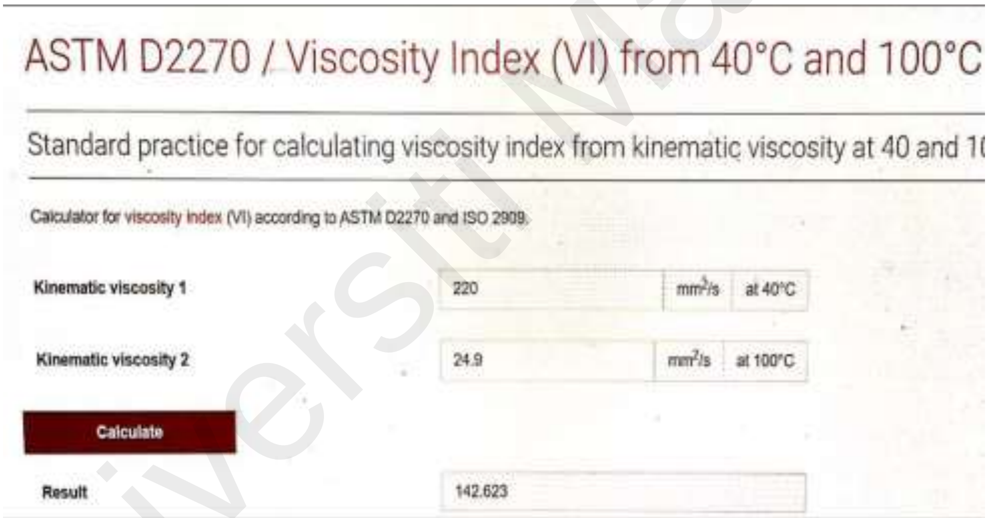
Test	ASTM Method	Typical Results
ISO Grade		**680**
S.A.E. Grade, wt.		-
Viscosity		
cSt @ 40°C	D-445	680
cSt @ 100°C	D-445	-
Viscosity Index	D-2270	153
Flash Point, °F	D-92	560
Pour Point, °F	D-97	-16.5
4-Ball Wear Scar, mm (40Kg,75°C, 1hr @ 1200rpm)	D-4172	0.33
Conradson Carbon, wt. %	D-189	<0.5
Oxidation Test, Minimum Hours	D-943	20,000
FZG Gear Test, Stage Pass	DIN 51354	12
Service Temperature Range, °F		-16.5 to 560

4.8 Kinematic viscosity, ASTM D445 data collected from synthetic oil grade 220

SYNTHETIC OIL(ORIGINAL)		
PARAMETER	TEST METHOD	RESULTS
kinematic viscosity@40°C ,cSt	ASTM D445	220
kinematic viscosity@100°C ,cSt	ASTM D445	24.9

ASTM D2270 viscosity auto counts viscosity index number for synthetic oil. The data was taken from the properties table to input into the system.

The fresh synthetic oil viscosity index number is tally with the datasheet when calculated with the user system.



The viscosity index number for fresh oil is 143.

Figure 4.6: Synthetic Fresh Oil Viscosity Index Number Result

4.8.1 Kinematic viscosity, ASTM D445 data collected from synthetic oil grade 220

SYNTHETIC OIL(SAMPLE AFTER 3 MONTHS)		
PARAMETER	TEST METHOD	RESULTS
kinematic viscosity@40°C,cSt	ASTM D445	202
kinematic viscosity@100°C,cSt	ASTM D445	22.5

used ASTM D2270 viscosity auto count the viscosity index number for synthetic oil. The data was taken from the properties table to input into the system.

Figure 4.7: Synthetic Used Oil Viscosity Index Number Result

The viscosity index number for sample oil is 135.

The viscosity index number is not equal to the initial index value. Due to operating temperature of gearbox, lubricant being maintained with high temperature, it affected lubricant viscosity index number

4.8.2 Synthetic Oil ASTM D445 Kinematic Viscosity @40°C, cSt Test Result Between Fresh Oil And Used Oil In The Graph

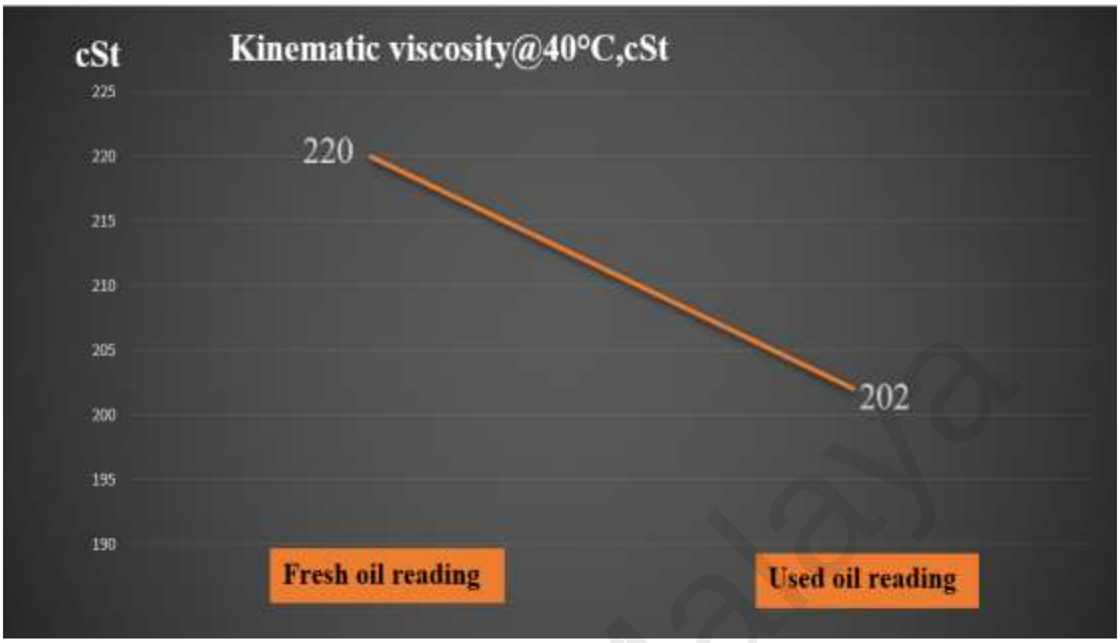


Figure 4.8: ASTM D445 Kinematic Viscosity @40°C cSt Test Result

4.8.3 Synthetic Oil ASTM D445 Kinematic Viscosity @100°C,cSt Test Result Between Fresh Oil And Used Oil Showing In The Graph

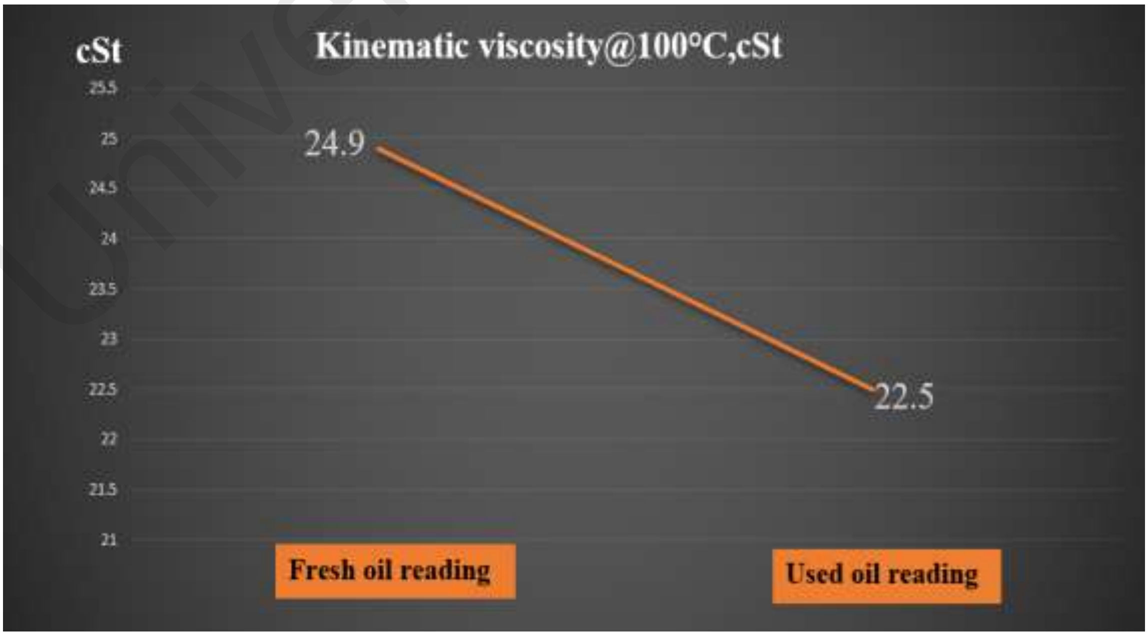


Figure 4.9: ASTM D445 Kinematic Viscosity @100°C,cSt Test Result

4.8.4 Synthetic Oil Viscosity Index Number Comparison Between Fresh Oil Value Vs Used Oil

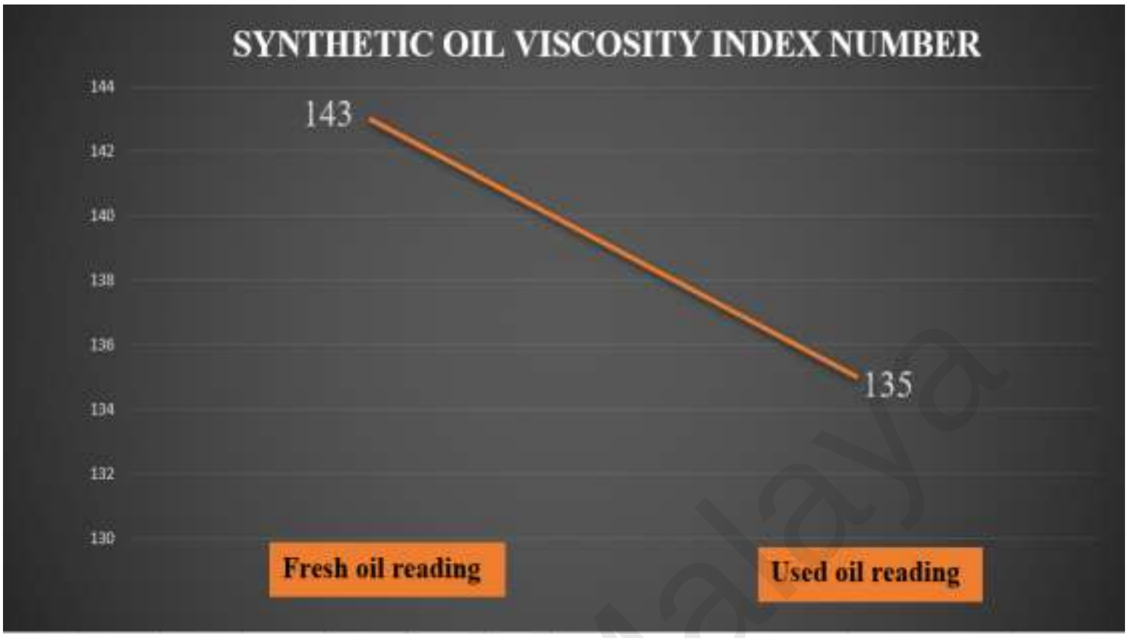


Figure 4.10: Synthetic Oil Viscosity Index Number Comparison Result Between Fresh Vs Used Oil

The result of the synthetic oil viscosity index number is not maintained with the initial value. Due to operating temperature is high. The index number is affected. Within three months the initial value drops 8 points from 143 to 135.

4.9 Viscosity Cup Result

These results were obtained from the viscosity cup test method. from these tests measuring oil kinematic viscosity for comparison between laboratory test results.

<u>Method to convert Zahn Seconds to Centistokes to calculate the viscosity of the lubricant</u>

V= C (T- K)   V=Kinematic viscosity   k = constant   T=time

V=3.5(t – 14)

Table 4.10.1 Kinematic viscosity measurement results for new and old oil

Table 4.6:Viscosity Cup Time Taken(S) for mineral oil

MINERAL OIL 220				
Time Taken	1st instance	2nd instance	3rd instance	average
New oil	75.3	76.1	76	75.8
Old oil	55	55.3	54.29	54.86

New oil

V=3.5(t – 14)

= 3.5(75.8-14)

= 216.3cSt

old oil

V=3.5(t – 14)

= 3.5(54.86-14)

= 143.01cSt

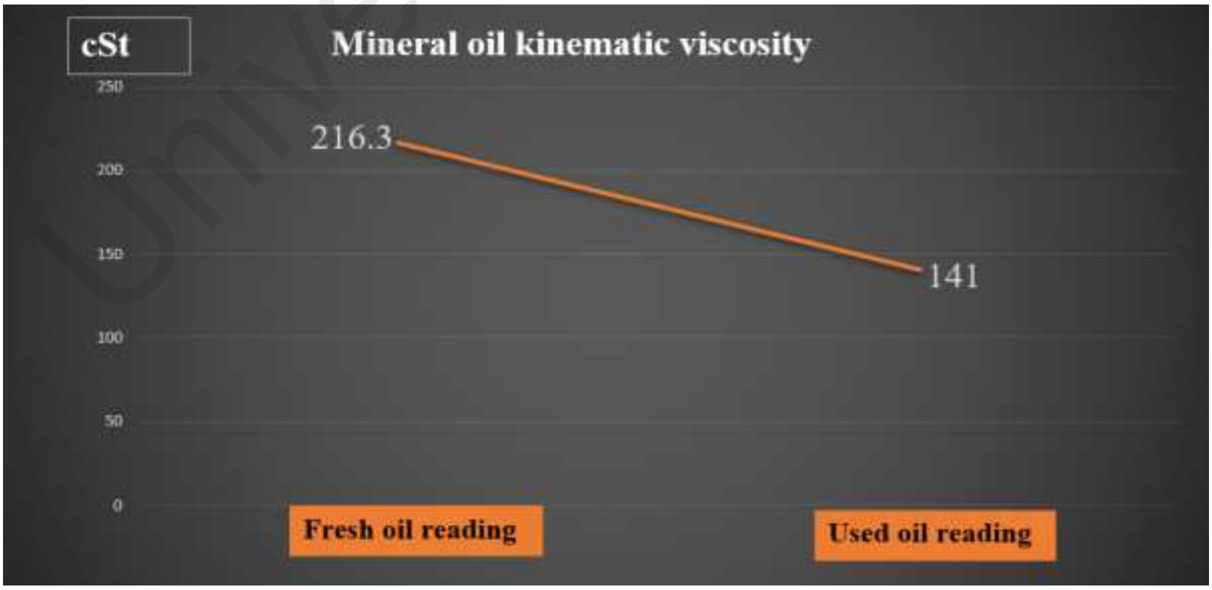


Figure 4.11: Viscosity Cup Result For Mineral Oil

Table 4.7: Viscosity Cup Time Taken(S) For Synthetic Oil

SYNTHETIC OIL 220				
Time Taken	1st instance	2nd instance	3rd instance	average
New oil	76.85	76.5	76.8	76.75
Old oil	71	70.1	71.3	70.8

New oil

$V = 3.5(t - 14)$

$= 3.5(76.75-14)$

$= 219.63$cSt

old oil

$V = 3.5(t - 14)$

$= 3.5(70.8-14)$

$= 198.8$cSt

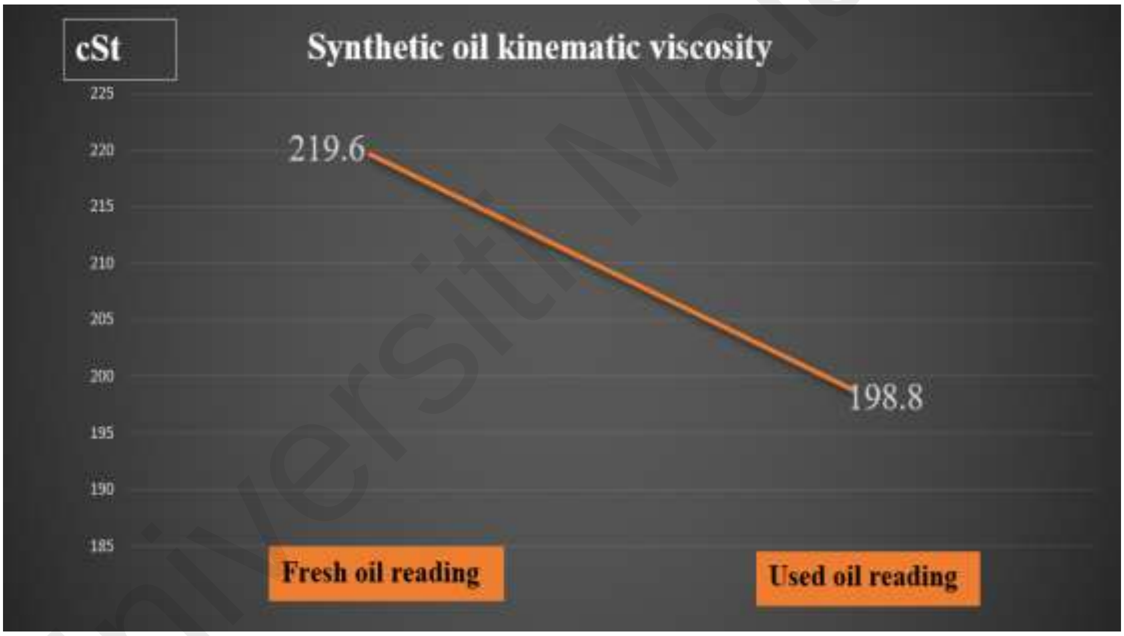


Figure 4.12: Viscosity Cup Result For Synthetic Oil

The result obtained from the viscosity cup is not too much different when compared with the laboratory ASTM D445 test result. thus, mineral and synthetic oil sample viscosity slightly drop the initial value. That means the lubricant film is not in good condition. Due to high viscosity drops, there have more chances to occur friction and wear.

4.10 Total Acid Number

The total acid number test ASTM D664 has been conducted by lotus laboratory services. According to the result obtained from this test. The total acid number for industrial gearbox oil is has fixed the limit with 0.5 mgKOH/g to 1 mgKOH/, when the oil is already used 8000 hours until 9000hours. Lubricant properties already calculated the oil can be used how many running hours, for example, synthetic oil can be used until 9000 hours, if the oil kinematic viscosity is still in acceptable stage means, the EndUser can extend the schedule for change gearbox oil. Before a decision for extending the schedule for change gear oil must be done with ASTM D664 and ASTM D445 test.

Table 4.8: Result For Total Acid Number In Mineral And Synthetic Used Oil

TOTAL ACID NUMBER FOR MINERAL OIL	
TEST METHOD	RESULT
ASTM D664	0.7

TOTAL ACID NUMBER FOR SYNTHETIC OIL	
TEST METHOD	RESULT
ASTM D664	0.2

The result obtained from this sample oil for synthetic and mineral. The result is showing mineral oil is already near to 1mgKHO/g. Therefore, the oil lifespan will be shorter, and also oil seal will be damaged very fast.

4.11 Water Content ASTM D6304

Table 4.9: ASTM D6304 Result Obtained From Lab Test For Mineral And Synthetic Used Oil

WATER CONTENT IN MINERAL OIL	
TEST METHOD	RESULT
ASTM D6304	0.02

WATER CONTENT IN SYNTHETIC OIL	
TEST METHOD	RESULT
ASTM D6304	0.001

The result is was obtained from the ASTM D6304 test. This test had been done with mineral and synthetic used oil samples for verified oil conditions after 3 months of mass production. The oil has a limited water content level. The statement was given by the oil supplier, oil-water content must be below 0.03% if the water content is more than 0.03% means the appearance of oil is changed. the result of sample oil is showing the water content is already near to limited range. The below graph is showing oil appearance if the water content goes up.

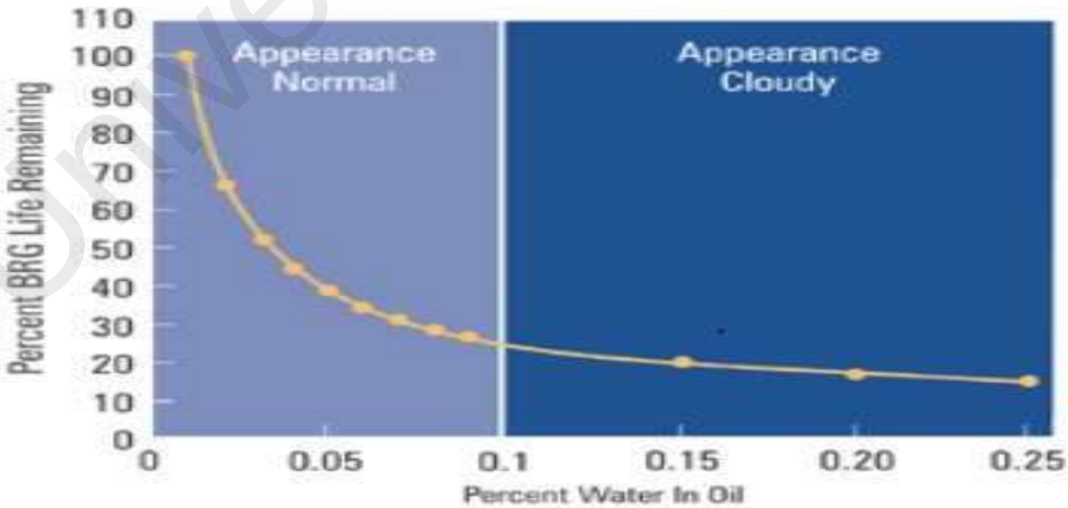


Figure 4.13: Oil Appearance

4.12 Heat Exchanger Geometry

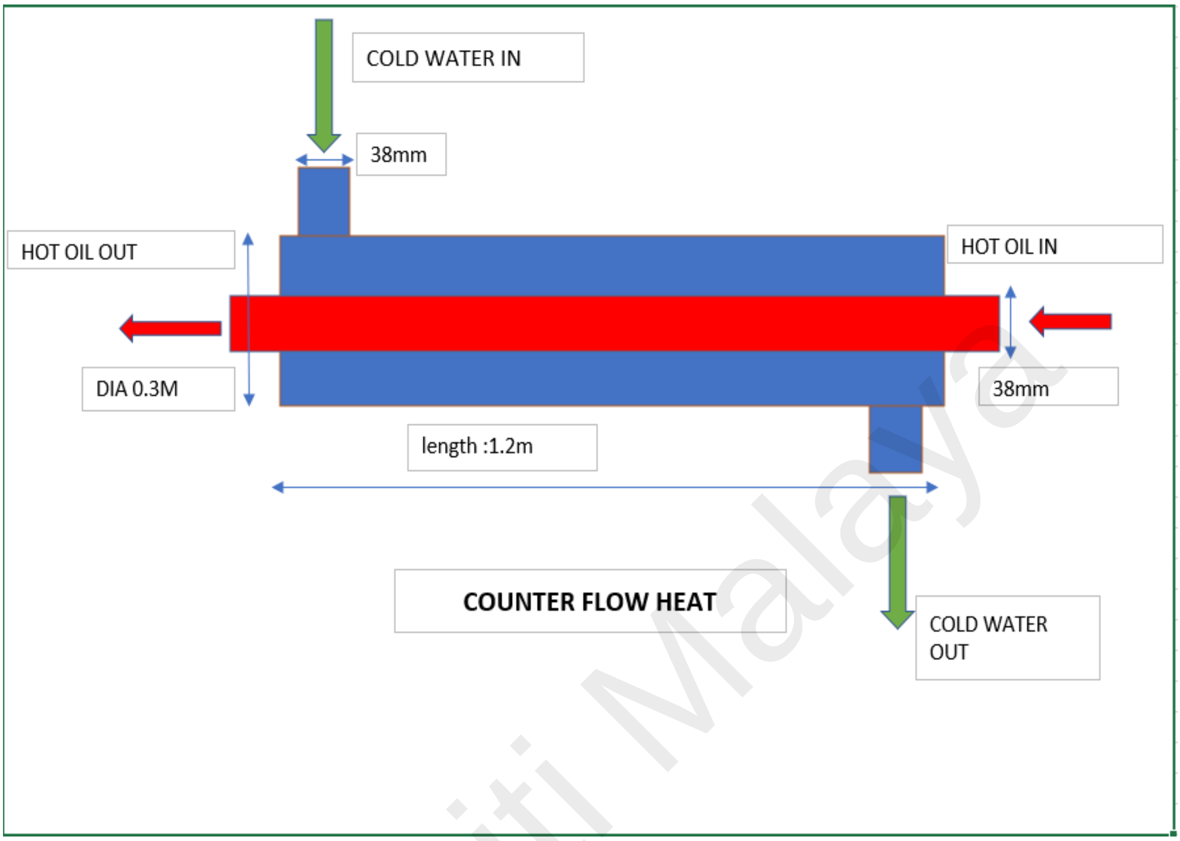


Figure 4.14 Heat exchanger general flow

The general diagram of heat counter flow in the chamber shows the direction of hot oil and cold water passes through the chamber and the heat transfer takes place in it. When the cold water passes through the surface of the tube and the molecule of heat transfer to the cold water. Therefore, the oil and water will flow in opposite direction. The counter flow heat exchanger is more efficient than the parallel-flow heat exchanger. This study currently focuses on how to maintain the temperature of oil during machines in mass production. This heat transfer system can reduce lubricant temperature. As a result, the section is already proven through the calculation method. By calculation method already reconfirmed T2 hot oil, exit from heat exchanger temperature is lower than T1 hot oil. Therefore, this cooling system is more useful for maintaining lubricant temperature and also can extend the lifespan of the lubricant

4.13 Heat Exchanger Simulation Result

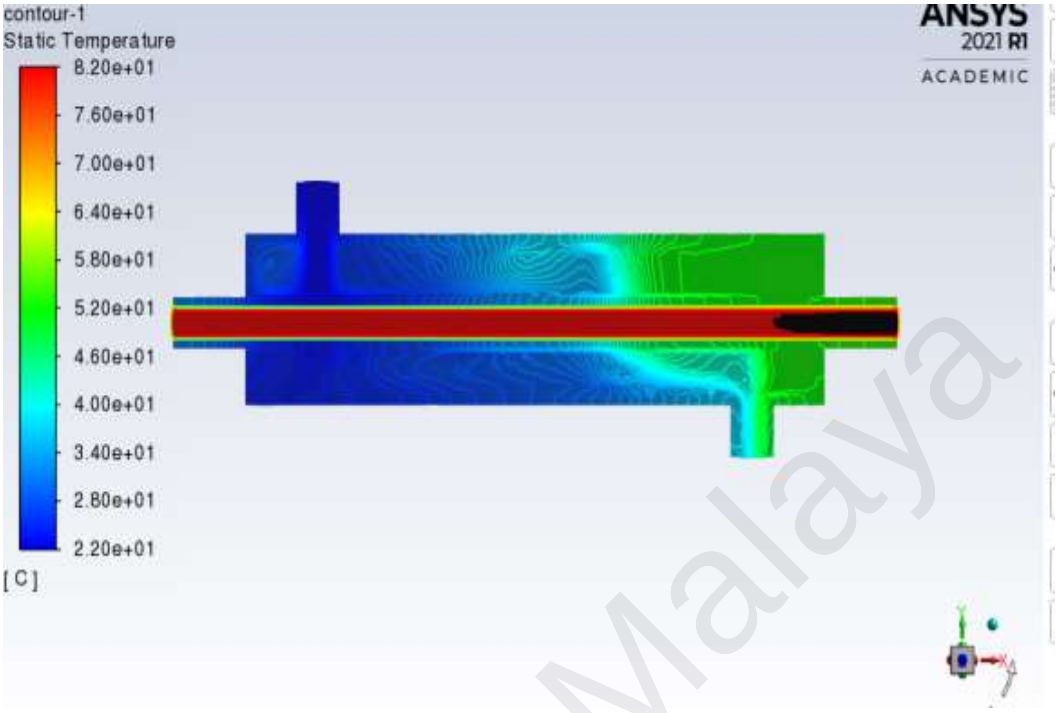


Figure 4.13.1: Result of Hot Oil Temperature Transfer Portion A

In this simulation was used T1 for hot oil inlet 82°C and as a cold-water inlet used T1 22°C. After the run-in ANSYS fluent system. The result for oil temperature T2 can reduce from 64°C to 22°C. The requirement of the machine maker is already highlighted in the machine manual book that the gearbox oil temperature should not exceed more than 80°C. From this result, to increase the lifespan of the oil the reading of temperature should be maintained below 80°C as proved.

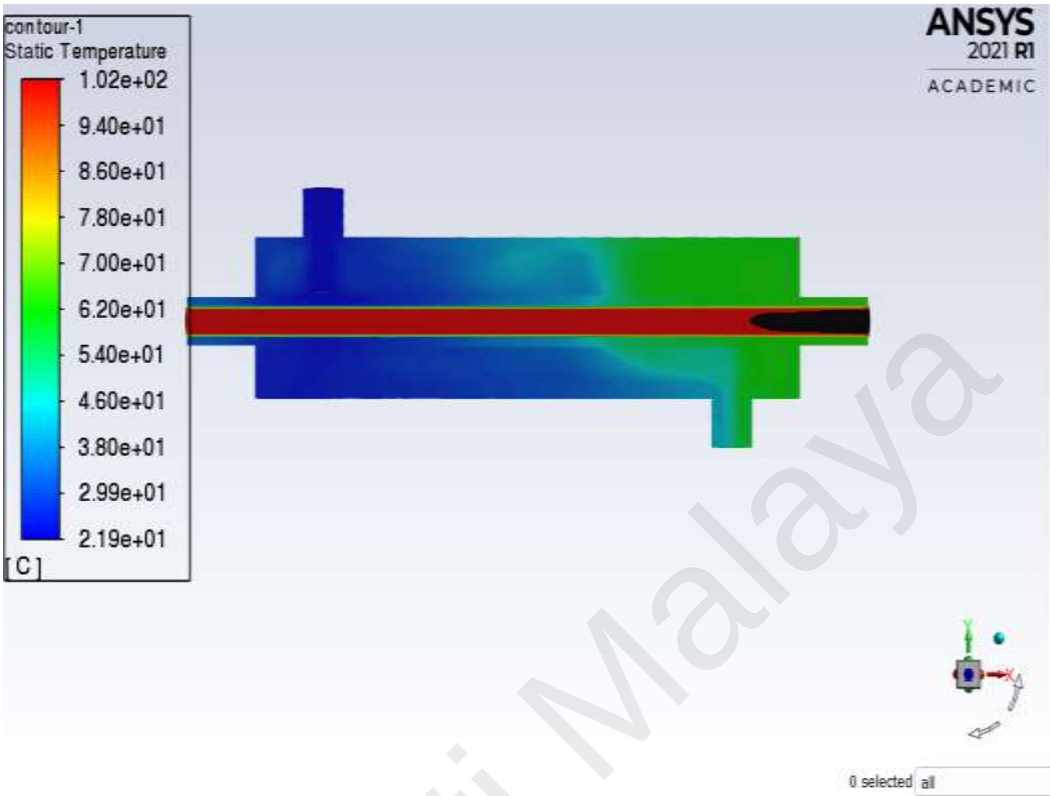


Figure 4.13.2: Result of Hot Oil Temperature Transfer Portion B

In this simulation was used T1 for hot oil inlet 102°C and as a cold-water inlet used T1 22°C. after the run in ANSYS fluent system. The result for oil temperature T2 can reduce from 86°C to 22°C.

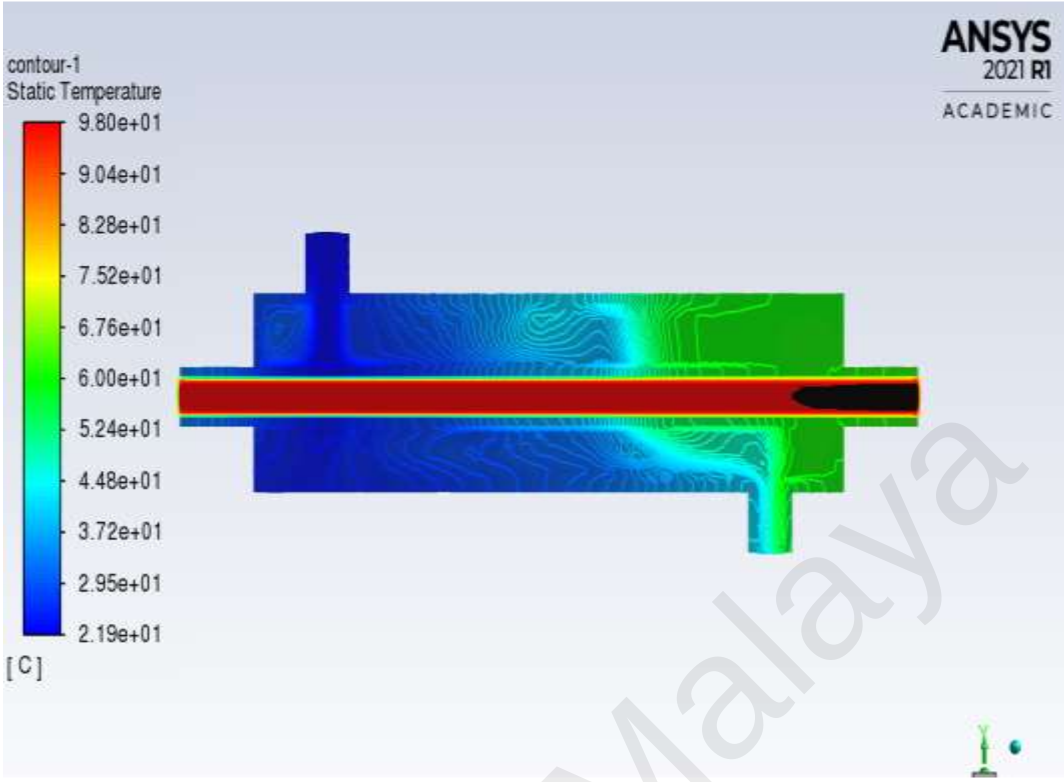


Figure 4.13.3 Result of Hot Oil Temperature Transfer Portion C

In this simulation was used T1 for hot oil inlet 98°C and as a cold-water inlet used T1 22°C. after the run in ANSYS fluent system. The result for oil temperature T2 can reduce from 82°C to 22°C.

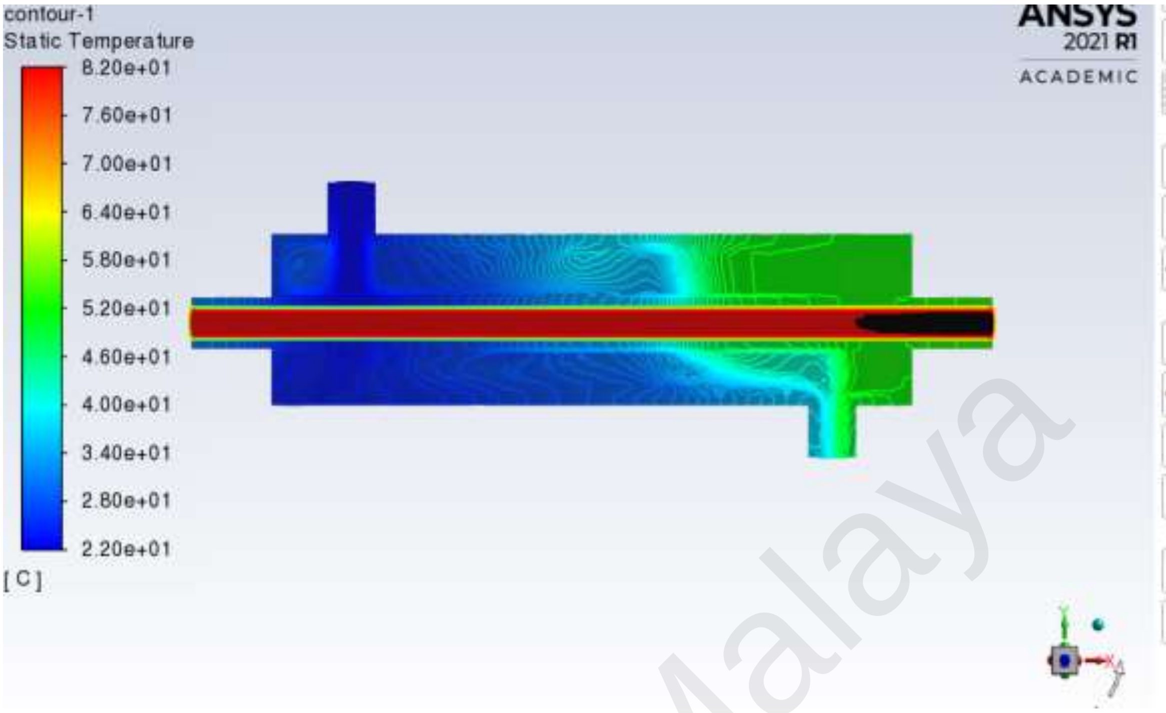


Figure 4.13.4: Result of Hot Oil Temperature Transfer Portion D

In this simulation was used T1 for hot oil inlet 82 C and as a cold-water inlet used T1 22°C. after running in ANSYS fluent system. The result for oil temperature T2 is can reduce from 64°C to 22°C.

4.14 Discussion

Each oil has its capacity for the lifetime of its use. The use of the oil is to reduce the friction between the gear, but the speed of the gearbox function is also another factor that decreases the index number of the oil. As the temperature increases the quantity of the oil will decrease. Another factor is burn smell its occurs when the hydrocarbon constituents of oil combine chemically with oxygen. The change of the color of the lubricant is because of the oxidation that occurs in the oil.

The simulation result showed that the existing gearbox lubricant temperature can be reduced through the heat exchanger. If the temperature is well maintained, the viscosity of the index number will not be affected. The viscosity index number can be used to predict the changes to the lubricant qualities when operating at high temperatures. It is also already known how to prevent lubricant viscosity index numbers as shown in the result of this experiment. If the temperature of the oil is maintained between 60°C and 70°C the lifespan of the oil will be extended, and the viscosity of the oil will not diminish.

Friction heat is generated at the tooth contacts, which raises the temperature of the gear assembly and gearbox. This increase in oil temperature accelerates oil deterioration, changes in viscosity, oxidation, and reduces the overall oil film thickness between gear surfaces. The viscosity of the oil depends on the operating temperature and operating time of the machine. By concluding that both oils have their capacity but the factor that affects them is the running time, place, and state of use. Finally, in the project, we can conclude that syntactic oil is best used in our production activity.

5.0 CONCLUSION

As per the above investigation, the objective of the project is achieved, thus by completing the test will be able to learn more about oil that is used in industry. By comparing mineral and synthetic oil, it comes across that syntactic oil is more efficient compared to mineral oil. Syntactic oil has high quality compared to minerals because syntactic oil has a high boiling point compared to mineral oil. Moreover, syntactic oil also has good viscosity compared with mineral oil, syntactic oil has 135 viscosity index numbers which are proven by calculation in the discussion part. Other than that, water contained in mineral oil is more compared to synthetic oil. As per the consent synthetic oil is good compared to mineral oil in this project. The finding has been proven by the American Society for Testing and Material (ASTM) test report.

i. From this investigation, it determined the way to reduce gearbox portion temperature and maintain the lubricant additive and also the viscosity index number.
ii. Based on this investigation, able to find out the method to eliminate water and acid contained in the plastic extruder gearbox during the machine operating at high temperature. This is one such method of maintaining the ecological balance and reducing harmful gas emissions such as co2.
iii. Heat exchanger will be more efficient to maintain the gearbox oil temperature. It has been proved by the simulation that has been conducted from this project.

5.1 RECOMMENDATION

For future use of bio lubricant to reduce depending on petroleum oil. Hence, in the new era of technology, everyone would be more focused on bio lubricant if petroleum is no longer existing in this world. Bio lubricant viscosity index can be modified to the maximum level needs of the machine gearbox and also it helps to save more cost and less emission.

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