MEASUREMENT AND EVALUATION OF THE PERFORMANCE PROPERTIES OF SELECTED LOCALLY PRODUCED LUBRICANTS (ENGINE OIL)

BY

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MSC/ENG/00642/08-09

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AHMADU BELLO UNIVERSITY,

ZARIA

DECEMBER, 2014

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A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER'S DEGREE IN MECHANICAL ENGINEERING.

DEPARTMENT OF MECHANICAL ENGINEERING, FACULTY OF ENGINEERING,

AHMADU BELLO UNIVERSITY, ZARIA

DECEMBER 2014.

DECLARATION

I declare that the work in this Thesis entitled Measurement and Evaluation of the Performance Properties of Selected Locally Produced Lubricants (Engine Oil) has been carried out by me in the Department of Mechanical Engineering. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this Thesis was previously presented for another degree or diploma at this or any other institution.

ROBSON HASSAN ATABO		21/01/15
Name	Signature	Date

CERTIFICATION

This thesis entitled MEASUREMENT AND EVALUATION OF THE PERFORMANCE PROPERTIES OF SELECTED LOCALLY PRODUCED LUBRICANTS (ENGINE OIL) by ROBSON HASSAN ATABO meets the regulations governing the award of the degree of Master of Science of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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Member, Supervisory Committee	Signature	Date
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Prof. A. Z Hassan	_____	_____
Dean, School of Post Graduate Studies	Signature	Date

DEDICATION

This thesis is dedicated to the almighty God and my daughters Victorious Ikebe Atabo and Evidence Om'ojo Atabo.

ACKNOWLEDGEMENT

My appreciation goes to my supervisors Prof A. I. Obi and Dr. M. Dauda, who created this great opportunity for me and whose guidance and encouragement made this work a success.

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I want to specially appreciate my wife Akaji Rhoda Atabo and my children Victorious and Evidence Atabo for their patience and understanding as the time need of this thesis really interrupted their deserved attention.

Finally, I am most grateful to God Almighty for the inspiration and provision for both the health and financial needs of this thesis.

ABSTRACT

The performance of the oils selected in this work was tested for considering Viscosity, Viscosity Index, Density, Flash Point, Pour Point, and Carbon Residue. The most important of all the properties which makes the oil protect against wear is viscosity that helps to reduce friction between moving parts in the engine. The Viscosities of the oils; Oando SAE 20W50, Total SAE 20W50, Mobil 1 SAE 0W40, Total SAE 40, and AZ SAE 20W50 at 24.8°C (room temperature) and 100°C (maximum test temperature) are 290 cSt and 18 cSt, 290.5 cSt and 20 cSt, 286.4 cSt and 21.20 cSt, 295.2 cSt and 15.60 cSt, 296.8 cSt and 19.60 cSt respectively. This implies that the Mobil 1 is most preferred as it has the least change in viscosity with respect to change in temperature and Total SAE40, a monograde oil as the least preferred as it has highest change in viscosity with respect to change in temperature when high temperature is expected in the service environment. The pour points of the oils are -24^0C, -22^0C, -28^0C, -15^0C, and -22^0C respectively. Based on this, all the oils are suitable for use in internal combustion engine in Nigeria and Africa. However, in an environment where very low temperature is expected during winter, the Mobil 1 (synthetic Oil) is most preferred and the monograde Oil is not suitable as the flowability may not be good enough at engine start up. The flash point of the Oils is 175 ^{0}C, 160 ^{0}C, 160 ^{0}C, 102 ^{0}C, and 170 ^{0}C respectively. These Oils are suitable for use in internal combustion engine as all the flash points are above the expected temperatures (^{0}C) during a normal working condition. The carbon residue found in the Oils was 0.95 %, 0.90 %, 0.60 %, 1.00 %, and 0.95 % respectively. The Synthetic Oil has the lowest carbon residue and the monagrade Oil has the highest carbon residue, and so the synthetic Oil is most preferred based on carbon residue result since high amount of carbon residue is a disadvantage. In all the results of laboratory test, all the Oils were seen to be suitable in internal combustion engine with the most preferred Oil as the synthetic followed by the multigrade and the least performing oil is the monograde. To carry out Pressure Mapping Experiment in this work, a pressure mapping equipment was developed. An Internal Combustion Engine, Thermocouple, Tachometer and Pressure Tube were obtained from the market and integrate together to function as desired based on the theoretical background of pressure mapping. The pressure mapping experiment is a fast method of measuring the performance of the lubricating Oil by mapping the pressure of the Oils in an internal combustion engine. This Oil pressure mapping is recommended for the evaluation of the performance properties of the Oils in our local market.

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SYMBOLS AND ABBREVIATIONS

SYMBOLS

ρ - Density (kg/m^3)

V - Volume (m^3)

μ - Dynamic viscosity (cSt)

T - Temperature (°C)

M - Mass

ABBREVIATIONS

AMU - Atomic Mass Unit

API - American Petroleum Institute

SAE - Society of Automotive Engineers

PAO - Polyalphaolefin

SHCs - Synthesized Hydrocarbons

PAG - Polyalkylene glycols

ASTM - American Society For Testing And Materials

PIO - Polyinternal Olefins

TBN - Total Base Number

TAN - Total Acid Number

ILSAC - International Lubricant Standardization and Approval Committee

JASO - Japanese Automotive Standard Organization

OEM - Original Equipment Manufacturers.

HTHS - High Temperature High Shear

CHAPTER ONE

1.0 INTRODUCTION

1.1 Preamble

From time immemorial, liquids, including water, have been used as lubricants to reduce friction and wear and remove heat between two surfaces in contact. At present, lubricating oil also called lube oil is the most commonly used lubricant because it has found a wide range of application in the field of engineering.

A lubricant, sometimes called lube, is a substance (often a liquid) which is introduced between two surfaces in contact moving relative to each order to keep them separate under all loads, temperatures and speed thus minimizing friction and wear. The substance may act as cooling fluid removing heat from the system and also protect surfaces from the attack of aggressive products formed during the operation. Lubricants may also perform the function of dissolving and transporting foreign particles (http://www.Weareoil .com/technical_properties_of_lubricant.htm)

Majorly, there are solid and liquid lubricants. Air and other gas based lubricants are there, but for the purpose of this research work, consideration is limited to liquid lubricants. Examples of liquid lubricants are: mineral oils, vegetable oils and synthetic oils.

The most common liquid lubricants are the mineral oils. This is because of the supply of crude oil. The term mineral oil is used here to mean lubricating base oil derived from crude oil that is refined from naturally occurring petroleum. Since they are commonly used, important information about their properties is now available. As products derived from crude oil, they can be produced in a wide range of viscosities for the various applications. There are low-viscosity oil (for easy starting at low temperatures) having hydrogen-carbon chain of about 200 atomic mass unit (amu) and there are also high viscosity oils (for better engine protection at the normal

running temperatures) with high molecular weight of about 1000 amu. All other mineral based oils have viscosities that fall within this range (API 1509 2002).

The American petroleum institute (API) has a designation for several types of lubricant base oils as follows:

Group I-saturates < 90%. This is known to have the Society of Automotive Engineers (SAE) viscosity index (VI) of 80 to 120

Group II- Saturates over 90% and SAE VI of 80 to 120

Group III- Saturates > 90% and SAE VI over 120

Group IV-Polyalphaolefin

Group V All others not included above.

Groups III, IV and V are synthetic oil with group III usually described as synthesized hydrocarbons, SHCs. The lubricant used in the internal combustion engine could solely consist one of the groups mentioned above, yet additives are added to improve the performance properties of the oil.

Vegetable oils are triglyceride esters gotten from both plants and animals. The common ones are:

- Palm oil
- Rapeseed oil
- Sun flower seed oil
- Castor oil, etc.

Vegetable oils are mostly hydrolyzed to give the acids which. when selectively combined, form synthetic esters.

Synthetic Oils include the following:

- Polyalphaolofin (PAO)
- Synthetic esters

- Ionic fluids
- Silicate esters
- Phosphate esters
- Alkylated naphthalene
- Polyalkylene glycols (PAG)

1.2 Statement of the Problem

Over time, it has been noticed that there is an increasing demand for engine oil as it remains the most effective lubricant in automobiles. As a result of this, existing lubricant producing companies now increase their volume of production to meet with the increasing demand and make more profit.

The US lubricant market now exceeds 2.5 billion gallons per year. For the 1970 to 1980 period it was estimated that the petroleum lubricant market would grow 25% from the 2.1 billion gallons per year to 2.6 billion gallons per year. Synthetic lubricants were projected to grow about 40% over the decades to a volume of some 60 million gallons per year by 1980. The overall growth rate for all lubricants has been averaging less than 2% per year, the ever increasing demands being placed on lubricants for improved performance in automotive engines, transmissions, hydraulic fluids, e.t.c. have resulted in very significant growth for the oil additive segment of the market (Henry, 1975).

This is not different from the present situation in Nigeria. There is expansion in the automobile market as cars and other vehicles are continuously been imported into the country.

The consequence of the increased demand for engine oil which may have resulted from the use of more cars and power generating sets (diesel/petrol) in our society is the tendency to find substandard engine oils in our local markets. Therefore, there is the need for the measurement and evaluation of the general properties and performance of selected locally

produced engine oil for the purpose of monitoring them. This project will provide the main methods for evaluating and monitoring some selected locally produced engine oil.

1.3 AIM AND OBJECTIVES OF THE RESEARCH

The aim of this work is to measure and evaluate the performance properties, provide a fast and efficient method of evaluating the performance properties and to provide Engineers and the user society with useful and essential information about the lubricants in our local market.

The specific objectives are:

i. To investigate the performance properties of the lubricants in our local market through laboratory tests considering Viscosity, Viscosity Index, Flash Point, Pour Point and Carbon Residue.

ii. To compare the results obtained from the laboratory experiments and recommend the preferred oils based on the service condition.

iii. To develop a Pressure Mapping Equipment and use it to determine the protecting ability of the oils under consideration in an internal combustion engine by Oil Pressure Mapping Experiment.

iv. To compare the outcome of the Pressure Mapping Experiment with the Laboratory Experiment and recommend a better method for evaluation of lubricants' properties.

v. To provide useful and essential information to Engineers, Technicians and the user society by discussing the results obtained from both the Laboratory Experiment and the Pressure Mapping Experiment.

vi. To suggest, amongst the oils under consideration, which is most preferred and for which application, putting into consideration the cost implication.

1.4 SCOPE OF THE RESEARCH

This research covered an engine test procedure for evaluating automotive engines oil for some high-temperature performance characteristics such as oil thickening, varnish deposition, oil consumption, viscosity index and engine wear. Only the oils used in spark-ignition engines and diesel engines were considered. The experiments and laboratory tests carried out were those obtainable in A.B.U. and National Research Institute of Chemical Technology (NARICT).

1.5 JUSTIFICATION

To say that the use or demand for lubricants (Engine Oil) in Nigeria is on the increase cannot be over emphasized. This is true as vehicles and equipment that use internal combustion engine which require engine oil for lubrication are continuously been imported into the country.

This in turn will lead to the expansion of the lubricant market in Nigeria as there will be a continuous increase in the demand for lubricant.

The expansion of lubricant market in Nigeria means that the existing manufacturers may increase their volume of production, other entrepreneurs may venture into the business and importers may import more to meet demand and achieve their aim.

To ensure quality products in our market, it is important to continuously monitor the products through quality assurance tests, measuring and evaluating the performance properties of lubricants (Engine Oil) in our market.

For this reason, Measurement and Evaluation of the Performance Properties of Selected Locally Produced Lubricants (Engine Oil) is inevitable.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Review of Past Work

Engine oils being the most effective lubricant in automobiles have attracted researcher's interest. Extensive research has been carried out on lubricants and their performance properties by international research institutes and students in the field of engineering

In August 2012, Shi Yanping and Zang Yong in the Department of Mechanical Engineering, Huaihai Institute of Technology, Lianyungang, Jiangsu 222005 China, published an article titled “A Novel Lubrication Oil Pressure Measuring Method Based on Magneto-elastic Effect for Auto Engines”. A measuring method that uses Fe-based amorphous alloy was studied to achieve accurate measurement of the lubrication oil pressure of auto engines.

In November 2008, Gray Belvins and Dan Burger published an article titled “Mapping Oil Pressure to Measure Bearing Wear”. One of the buzzwords used in regard to condition monitoring is “Oil Pressure Mapping”. This article explains oil pressure mapping, why this diagnostic technique was developed and how it is used to measure engine bearing wear.

Dauda and Obi (2000) determined some properties of engine oils. It was recommended that other methods should be used to determine the performance properties of lubricating oils.

Obi (2010) presented an article titled “Conformity to standards of Engine oils manufactured in Nigeria” at the Nigeria Institute of Mechanical Engineers Conference organized by Port Harcourt.

Shafiqur (1997) investigated the hydrodynamic lubricating properties of some common oils. This investigation was necessary as oils can best be selected for a given application when its properties are known to be suitable for that application.

Nunaya (2009) did measurements of physical and chemical properties of some selected Nigerian lubricants and Mathias (2009) determined the service specifications of Nigeria produced engine oils using their hydrodynamic, thermal and chemical properties. It was then recommended that there is need for regular investigation of these properties for the purpose of monitoring the oils in our local markets.

Osebi (2002) investigated the hydrodynamic lubricating properties of some Nigerian made oils. He then concluded that multi-grade oils performed better and recommended that similar work be carried out to verify the chemical properties of these oils.

Aremu (2000) did the Evaluation of some Nigerian Engine Lubricating Oils, he concluded that the result he obtained could help users to make good choices and that the inability to challenge the oils in a way similar to the normal working condition of lubricants is a major limitation.

Otu (2000) did the Evaluation and Performance Characteristics of some Nigerian made Engine Oil. He then recommended that similar work be done in our local market.

2.2 Functions/Applications of lubricants

One of the largest applications of lubricants is protecting the internal combustion engine in motor vehicles and powered equipment. To do this lubricants perform the following key functions.

2.2.1 Lubricants keep moving parts apart.

The major function of lubricants is to separate two surfaces moving relative to each other in a system thereby reducing friction, surface fatigue, heat generation, noise of operation and vibrations. This function is made possible by the formation of physical barrier i.e a thin layer of lubricant in between the two surfaces. This phenomenon is known as hydrodynamic lubrication. In a situation where the pressure and temperature on the surfaces are high, the oil layer gets

thinner and part of the forces are transmitted between the surfaces through the thin films of lubricant. This is referred to as elasto-hydrodynamic lubrication (Bowden, and Tabor, 1953).

2.2.2. Lubricants reduce friction.

Ordinarily, a system without lubrication posses much higher friction as compared to one with lubrication. Thus the fact that the use of lubricant in a system reduces the overall friction of the system should be agreed with. The reduced friction is to an advantage as the heat generated between the surfaces is reduced as well as wear particles and as such there is an improvement in the efficiency of the entire system. Friction modifiers which may be contained in lubricants as additives, chemically bind to metal surfaces reducing the frictions on the surface even when the lubricant present in the system is not enough for hydrodynamic lubrication, for example, in protecting a car engine at start up.

2.2.3. Lubricants carry away contaminants and debris.

In internal combustion engines, there are usually filters fixed along the circulation path of the lubricants. The internally generated debris and external contaminants that may enter the system are carried in the oil where they are removed by filtration. Additives such as detergents and dispersants are always added to motor oil for use in internal combustion engine. These additives help for transporting debris and contaminants that may have entered the system, the filter gets clogged up and would require to be replaced. At this time it may be recommended to change the filter and the oil in the system. In gear bones however, the system is closed. Instead of filter, magnet may be used to attract microscopic metal chips that may be in the system as a result of wear.

2.2.4. Lubricants transfer heat.

Liquid lubricants for their high specific heat capacity are very effective in the transfer of heat in internal combustion engines. Generally lubricants in a system could be used to cool or

warm the system when its required to regulate temperature. The rate of flow of lubricant in the system determines the amount of heat that is transferred or carried away at any given time. High flow rate would carry away larger amount of heat per unit time and an additional benefit is the reduction of thermal stress that is built up within the lubricant in the system. The disadvantage of the high flow rate is that it requires a large sump and big cooling unit which eventually will amount to additional cost of operation and maintenance. Also a high flow that depends on flow rate to protect the lubricant from thermal stresses can be faced with catastrophic failure during sudden system shut down. A good example of this is an automotive oil cooled turbochargers. Turbochargers get red hot during operation and the cooling oil only survives as the total time in the turbocharging system is very short. If the system is suddenly shut down, the oil in the turbocharger gets oxidized blocking oil ways with deposits of the products of oxidation. This blockage reduces cooling and eventually the turbocharger totally fails.

2.2.5. Lubricants protect against wear and corrosion.

A good quality lubricant is formulated with additive that can chemically bind to metal surfaces to prevent corrosion. Lubricants also contain anti wear or high pressure additives for better performance against wear and fatigue (Bowden, and Tabor, 1953).

2.3 Quality of lubricants

Lubricant marketers may claim superior quality of their lubricants but sometimes with no factual evidence. The quality of a lubricant is proven by reference to famous brands, sporting figures or some professional endorsement. All motor oil labels have mark of outstanding quality or quality additives. In most applications, lubricants are required to be non-resinous pale-coloured, odorless, and oxidation resistant. Several tests to reveal the typical technical properties of the lubricants are used to grade and classify lubricating oils. According to the American society for testing and materials ASTM, the typical technical properties of lubricants are measured by the followings tests.

2.3.1 Kinematic viscosity

Test Number & Name: ASTM D-445 Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids.

Significance & Use**:** The proper operation of equipment depends on the proper kinematic viscosity at operating temperature of the oil used for its lubrication.

This means that kinematic viscosity is a measure of a liquid's flow under the influence of gravity. It's handy to think of lubricant's kinematic viscosity as its "ID. Card" synthetic lubricants' kinematic viscosities are midrange, close to neither the high nor low limits. That helps components work their best and helps the lubricants stay in grade.

2.3.2 Viscosity Index

Test Number & Name**:** ASTM 0-2270 Standard Practice for Calculating Viscosity Index from Kinematic Viscosity at 40°C and 100°C.

Significance & Use: Viscosity index indicates how much a lubricant's viscosity will change according to changes in temperature between 40°C (104°F) and 100°C (212°F), which roughly define the normal temperature range of most operations.

This means that the smaller a lubricant's viscosity change as a result of temperature change, the higher that lubricant's viscosity index. High viscosity index lubricants protect better in operations with temperature variations.

The viscosity of oil generally decrease with increase in temperature but the rate or extent of decrease in viscosity varies among the oils.

Some oil's viscosity change rapidly with change in temperature and are said to have low viscosity index. Oils with high viscosity index have minimum change in viscosity with change in temperature.

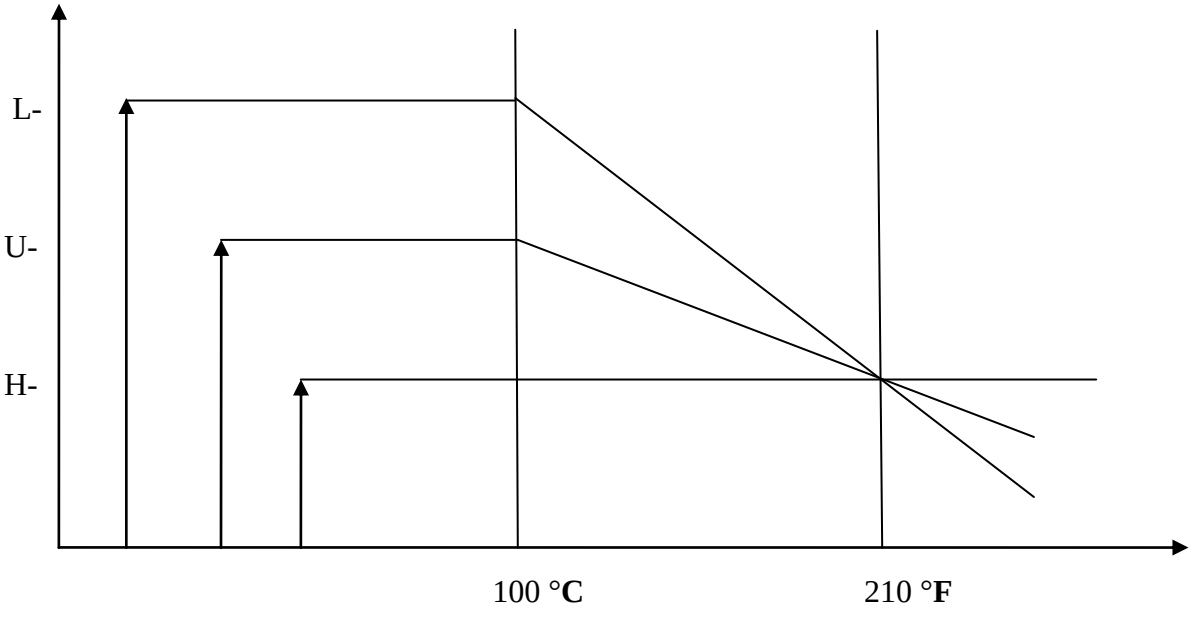


Fig 2.1 Graphical representation of Viscosity Index Interpolation.

In 1932,Davis, G. M. Lapeyrouse and Dean devised a means by which the Viscosity Index of an oil can be found by interpolation.

The fig 2.1 above shows the graphical representation of this interpolation method.

L – Low viscosity index

U – Unknown viscosity index

H – High viscosity index all in Saybolt Universal Second

VI = $100\ X\ \frac{L-U}{L-H}$

The values of L and H can be obtained from ASTM document D 2270-04; Basic Values for L and H for kinematic viscosity in 40 and 100 °C System.

2.3.3 Cold Crank Simulator Apparent Viscosity

Test Number & Name**:** ASTM D-2602 Standard Test Method for Apparent Viscosity of Engine Oils at Low Temperature Using the Cold-Cranking Simulator.

Significance & Use**:** Apparent viscosity has been established as a valid predictor of engine-cranking viscosities at specified low temperatures. Apparent viscosity depends on temperature and shear rate.

This means that cold cranking viscosity affects the start-ability of engines and other equipment in cold temperatures. Low cold cranking viscosities make for easier cold cranking and more dependable cold temperature starting.

2.3.4 Borderline Pumping Temperature

Test Number & Name**:** ASTM 0-3829 Standard Test Method for Predicting the Borderline Pumping Temperature of Engine Oil.

Significance & Use**:** Borderline pumping temperature is a measure of the lowest temperature at which engine oil can be continuously and adequately supplied to the components of an automotive engine.

This means that the lower the borderline pumping temperature, the lower the temperature in which the engine is protected by circulating oil. Synthetic motor oil's extremely low borderline pumping temperatures assure excellent low temperature protection (www.**astm**.org/Standards/D3829.htm).

2.3.5 Pour Point

Test Number & Name**:** ASTM D-97 Standard Test Method for Pour Point of Petroleum Oils.

Significance & Use**:** The test determines the lowest temperature at which an oil flows as the jar is tilted for a prescribed period. The pour point of oil indicates the lowest temperature at which an oil may be used in some applications.

This means that the lower the pour point, the more useful the lubricant is in cold temperatures.

2.3.6 Flash and Fire points

Test Number & Name**:** ASTM D-92 Standard Test Method for Flash and Fire Points by Cleveland Open Cup.

Significance & Use**:** Flash point is the lowest temperature at which application of a flame causes specimen vapors to ignite. Flash point is used to assess the overall hazard of a material and is used in shipping and safety regulations to define "flammable" and "combustible" materials.

Fire point is the lowest temperature at which a specimen sustains burning for five seconds.

This means that lubricants with high flash and fire points, such as synthetic lubricants, are safer to use and transport than lubricants with lower ones and have a greater high temperature operating ranges.

2.3.7 Noack Volatility

Test Number & Name: ASTM D-5800 determining the Evaporation Loss of Lubricating Oils (Noack's Method).

Significance & Use**:** Test determines the evaporation loss of lubricating oils at high temperature. Evaporation loss is particularly important to motor and cylinder lubrication, due to the high temperature of these operations and the tendency of evaporative loss to increase in high temperatures. Significant evaporative loss of oil leads to excessive oil consumption and destructive changes in oil properties.

This means that lubricants with low Noack scores, lose less to volatility than lubricants with high scores. Low-loss oils keep their original protective and performance qualities longer than high-loss oils do, which keeps oil consumption low and fuel economy and equipment protection high

2.3.8 High Temperature/High Shear Viscosity

Test Number & Name**:** ASTM D-4683 Standard Test Method for Measuring Viscosity at High Temperature and High Shear Rate by Tapered Bearing Simulator.

Significance & Use: Viscosity at the shear rate and temperature of this test is considered representative of the condition encountered in the bearings of automotive engines in severe service. Lubricant viscosity in the bearings of automotive engines in severe service is a critical factor in bearing wear.

This means that lubricants with high scores, maintain their viscosity in high temperatures after exposure to high shear. That means they continue to protect engine bearing even after exposure to severe service conditions.

2.3.9 Four Ball Wear Test

Test Number and Name**:** ASTM D-4172B Standard Test Method for Wear Preventive Characteristics of Lubricating Fluid (Four-Ball Method).

Significance & Use**:** Test method determines the relative wear preventive properties of lubricants in sliding contact under the test conditions. Lubricant comparisons are made by comparing the average wear scars on three fixed balls made by one ball in rotating contact with them in baths of the test lubricants.

This means that the smaller the average wear scar, the better the protection.

This research work is aimed at ascertaining the quality of the locally produced oils and providing methods for evaluating and monitoring them.

Viscosity, the oils resistance to flow at specific temperatures and pressures seem to be the most important of all the properties. The most important factor in determining the correct viscosity of the oil has been the application and operating temperature for instance, too viscous oil offers very high resistance to the metals moving against each other and much low viscous oil could be squeezed out from between the surfaces under heavy load thereby offering insufficient

lubrication. The saybolt standard universal viscometer is the instrument for measuring the viscosity of petroleum based lubricants between 70 and 210 ^{0}F (21 and 99^{0}C). The unit of viscosity is the Saybolts Universal Second which is the time taken for 50 mils of the oil to flow out of a saybolt viscometer cup through calibrated tube orifice at a specific temperature.

The specific gravity of an oil is dependent on the method by which the crude was refined and the type and amount i.e percentage of additives present in it. Additives such as lead compounds, molybdenum compounds, Zinc compounds and other metal containing additives e.g gold dihydrocarbylphosphorodithioate salts, dithiocarbonates and dithiophosphates etc. when present in an oil influence the specific gravity of the oil and give the oil the ability to resist extreme mating surface pressures and cold temperatures (Arnell, et al. 1991)

The flash and fire points differ from brand to brand of oils depending on the crude oil's origin. The specifications established by the Society of Automotive Engineers SAE are the ones used to classify common oils by viscosity and performance

2.4 Sources of Lubricating Oil

Lube oils are one of many fractions, or components that can be obtained from crude oil or raw petroleum which is actually an oily well of yellow-to-black, flammable liquid mixture of several hydrocarbons i.e. organic compounds containing carbon and hydrogen atoms only. Petroleum deposit is formed by the decomposition of organic matter (Plants and animals) that lived several years ago. As a result of difference in climatic and geographical changes occurring in the earth's crust, the decomposition rate of the organic matter differ from region to region. Consequently, the nature and percentage of the hydrocarbons formed differ from region to regions; the physical and chemical properties of the crude oil obtained from different sites also differ widely. For instance, the California crude oil has specific gravity of 0.92 gram/milliliters; the pennsylvania crude has 0.81 gram/milliliters. Specific gravity is an important property speaking, the specific gravity of crude oils range from 0.8 to 0.97 gram/milliliter.

Other oils like the vegetable oils which are triglyceride esters are obtained or extracted from plants and animals and are capable of lubrication. Lubricating oils such as polyalphaolefin (PAO), polyalkylene-glycol (PAG), Alkylated Naphthalene etc are synthetic oils synthesized through laboratory reactions (Arnell, et al 1991).

2.5 The Motor Oil

The motor oil is oil used in the lubrication of internal combustion engines. It functions mainly in the lubrication of moving parts; it can also clean, prevent corrosion, and cool the engine by carrying heat between the moving parts. Motor oil also improves sealing.

Motor oils are derived from petroleum based chemical compound i.e. mineral base oil and from non-petroleum-synthesized chemical compound i.e. synthetic oil. The minerals, polyalphaolefins (PAO), polyinternalolefins (PIO) are motor oil base oils derived from hydrocarbons, thus they are organic compounds which consist of carbon and hydrogen only.

2.5.1 Uses of Motor Oils (engine oils)

This is a lubricant used in internal combustion engines. The internal combustion engine include motor or road vehicles such as cars and motorcycles, there are also heavier vehicles such as buses, lorries trucks and other commercial vehicles, non-road vehicles such as boats, large agricultural equipment locomotives and static engines such as electrical generators. In engines, the parts which move against each other cause friction which waste energy that would have being useful in the system by converting it to heat energy. When the moving parts make contact, wear occurs and this in turn reduces the efficiency of the engine. This could lead to increase in fuel consumption and a decrease in power output of the engine and could even lead to engine failure if not checked (Bowden, and Tabor, 1953).

The lubricating oil forms a separating film between surfaces moving relative to each other to minimize or avoid direct contact between them thus reducing wear and decreasing heat produced by friction thereby protecting the engine.

When the motor oil is in use in the engine, by means of air flow ever the surface of the oil pan, an oil cooler and through the buildup of oil gases evacuated by the positive crankcase ventilation system, heat is transferred through convection.

In spark ignition engines, towards the top of the cylinder, the top piston ring can expose the oil to a temperature of about 320^0F (160^0C) while in compression ignition engines i.e diesel engines oils can be exposed to a temperature of 600^0F (315^0C). The oil with higher viscosity index thins less at these elevated temperatures and provides or maintains better lubrication properties. When metal parts are coated with oil, the parts are said to be isolated from the environment. Thus they are no longer exposed to oxygen and so oxidation is inhibited at elevated operating temperatures preventing rust or corrosion. Additives for corrosion inhibition can sometimes be added to enhance the property of the oil as desired. In other to keep the engine clean and minimize oil sludge build-up, dispersants and detergents are added to some oils. (Barbour, et al. 2000)

When the metallic parts of an engine rub against each other, microscopic metallic particles are produced from the wearing of the surfaces. The particles so produced could circulate as carried in the oil and grind against moving parts thereby causing wear. In the internal combustion engine, there is an oil filter in the oil lubricating system which removes or filters off harmful particles from the oil as it circulates the system. Oil pumps are used to pump the oil from the oil pan usually at the base of the engine throughout the engine and the oil filter.

Motor oil lubricates rotating and sliding parts between the crankshaft journal bearing and connecting rods connecting the piston to the crank shaft within the crankcase of a vehicle engine. In horse power rated small engines like lawn mowers, dippers are found at the bottom of the connecting rods which dip into the bottom plate and splash the oil in it around the crankcase to lubricate the internal parts as desired. In car engines, the oil pump pumps oil from the oil pan/bottom plate through the filter to the oil galleries. The oil from here lubricates the main

bearings which hold the crankshaft in place at the journals and the bearings of the camshaft which operates the valves. In modern vehicle engines, the oil from the oil galleries which move under the influence of the pumping pressures to the main bearings enters holes in the main journals of the crankshaft from where it moves through passage ways inside the crankshaft to the holes in the rod journals to lubricate the rod bearings and connecting rods. Simpler designs depend on the rapidly moving parts to splash and lubricate the surfaces between the piston rings and the interior surfaces of the cylinders. Modern design is such that there are passage ways through the rod to carry oil from the rod bearings to the rod piston connections to lubricate the contacting surfaces between the piston rings and interior surfaces of the cylinders. The oil film here seals up the gap between the piston rings and cylinder walls separating the combustion chamber on the cylinder head from the crankcase.

2.5.2 Properties of Motor Oil

Most of the engine oils are made from petroleum hydrocarbon base stock obtained from crude oil containing additives to improve performance properties. Any engine oil consists of hydrocarbon with 18 to 34 carbon atoms per molecule. For an oil to maintain lubricity between moving parts one of the most important properties is its viscosity. The viscosity of an oil or a fluid is that property of the fluid that makes it to resist flow; it can be thought of as a measure of the thickness of the fluid. The viscosity of lubricating oil must be high enough to maintain a lubricating film and also low enough such that the oil can always flow around the internal parts of the engine even at low temperatures (start up). Viscosity index is a measure of the extent to which the viscosity of oil changes with change in temperature. Oil is said to have a high viscosity index if its viscosity changes less with temperature. Generally the smaller a lubricant's viscosity changes as a result of change in temperature, the higher that lubricant's viscosity index. High viscosity index lubricants protect better in operations with temperature variation (Gouw, et al. 1966)

Oil must be able to flow adequately at the lowest possible temperature in its service environment in order to maintain lubricity between moving parts at start up of the engine. This property of the motor oil is described by its pour point. The Pour Point of oils is the indication of the lowest temperature at which the oil may be used in an application, that is to say "an index of the lowest temperature of its utility" for a given application (ASTM D97).

Flash point is another very important property of engine oil. The flash point is the minimum temperature at which vapors from a lubricant mixed up with air ignites on the application of flame. As is it dangerous for oil in an engine to ignite and burn, a high flash point is desirable.

Total Base Number (TBN) is another important property of engine oils. This is a measure of the reserve of alkalinity in the oil i.e the oil's ability to neutralize acids.

Total acid number (TAN) is analogous to TBN. It is the measures of the acidity of the oil.

The properties mentioned here are those of the physical and chemical properties of oil which are usually reported after analysis in oil test labs. However some other important properties known to be imparted to the oil by additives but which are not routinely reported can be revealed by "performance" test. These "performance" tests are not carried out during routine oil samples analysis because they are expensive, involve prolonged test periods and may require large sample volumes. However it is important that those in charge of machine reliability and the user community get to know what they get from the oil they buy and use in their equipments.

2.5.3 Motor Oil Performance Tests

The performance tests that are used to portray the quality and the performance capability of any oil are unlike the ordinary used oil analysis that reveals the physical and chemical properties of the oil mentioned above. The performance tests really challenge the lubricants in some ways similar to the real working environment where that oil is expected to

serve. The result of such tests gives the extent to which the oil will respond in service. The following are typical examples of performance tests (http://www.Machinerylubrication.Com/Read/1763/lube-oilproperties).

2.5.3.1 Film Strength

This is the ability of lubricant to reduce friction and control wear under wide-ranging rolling and sliding conditions. The ASTM has several methods that attempt to measure this property of engine oil. Adhesive wear, contact fatigue and two-body abrasion are examples of wears that can be affected by a lubricant's film strength. For this purpose, anti-wear and extreme pressure additives are added to the lubricants. With time and as the lubricant ages and gets contaminated these additives are subject to depletion and impaired performance.

The common oil analysis tests do not measure film strength.

2.5.3.2 Air-handling Ability

This is the ability of a lubricant to release entrapped air rapidly and to suppress the formation of foam. Use of certain additives and the quality of a lubricant's base stock can define the air-handling ability of the lubricant.

2.5.3.3 Water-Handling Ability

This is the ability of the oil to efficiently shed water during static condition. Loss of water handling ability reveals risks from oil-water emulsions and poor performance of other properties. The common used oil analysis may not reveal the water-handling ability of a lubricant.

2.5.3.4 Corrosion Control

A fundamental objective of the formulation of any lubricant is corrosion control. The ability of a lubricant to neutralize acidic or corrosive agents or form a protective covering on surfaces of machine parts reveals the extent to which the lubricant controls corrosions. Many additives known as sacrificial additives are used for this purpose. These additives can loss their

effectiveness with time. The total base number (TBN) test is capable of reporting the effectiveness of the corrosion protecting quality of oil in use.

2.5.3.5 Oxidation Stability

Most lubricants are formulated with oxidation inhibitors to reduce the rate of oxidation. Almost all lubricants in our market today emphasize on this important property of lubricants. It is therefore evident that oils with low oxidation stability are not desirable especially in high temperature service environment like in internal combustion engines.

2.5.4 Grades of Motor Oil

Motor oils are graded according to their viscosity characteristics. The society of automotive engineers (SAE) has a numerical code system under which motor oils are graded. The SAE viscosity grading include:

0, 5, 10, 15, 20, 25, 30, 40, 50 or 60. The numbers 0, 5, 10, 15 and 25 are suffixed with the letter W, the W here means winter or cold start viscosity i.e at low temperatures the number 20 sometimes comes with W in which case it is used to denote cold viscosity grade and some time without W in which case it denotes hot viscosity grade.

The grading of kinematic viscosity is done by measuring the time it takes for a calculated amount of standard oil to pass/flow through a standard orifice at standard temperature and pressure. The more time it takes for a given oil to flow through the orifice, the higher the viscosity of that oil and as such higher SAE number.

However, it should be noted that gear, axle and manual transmission oils have a separate SAE grading system which should not be confused with engine oil viscosity (SAE J 306). For

instance 75W-140 is a gear oil with high number. The higher numbers than that of engine oil does not mean that it has higher viscosity than engine oil.

The motor oil can be divided into single grades motor oil and multigrade motor oil.

2.5.4.1 Single Grade Motor Oil.

The oils which contain no viscosity modifier additives, whose viscosities are appreciably affected by changes in temperature, are the monograde oils. Viscosities generally reduce with increase in temperature but the extent to which viscosity changes with respect to temperature can be reduced or controlled with the presence of polymeric viscosity index improvers. Since the single grade motor oil does not contain this, it is not suitable in applications involving a wide range of temperature. There are eleven (11) viscosity grades available for the monograde oils; they are 0w, 5w, 10w, 15W 20W, 25W, 20, 30, 40, 50 and 60. Six out of the eleven are known to be winter grades and so have the W designations (SAE J 300) the viscosities are measured at different cold temperatures in MPa or centipoises (cP) using the Cold Cranking Simulator (ASTM D5293) and the mini-rotary viscometer (ASTM D4684). Based on the coldest possible temperature at which the oils flow, they are graded as SAE viscosity grade OW,5W,10W,15W,20W or 25W. the lower the viscosity grade of the oil, the lower the pour point of the oil i.e the lowest temperature at which the oil can flow or below which the oil solidifies. For instance if an oil passes at 5W and 10W specifications but failed to pass at OW specification, it cannot be labeled OW because it is not suitable for applications that require that specifications as it does not flow at that very low temperature. It cannot as well be labeled 10W as it could be suitable for applications below temperature specifications of 10W.

The viscosities of the single non-winter grades are measured at 100^0C (212^0F) in mm^2/S or centistokes (cSt) depending on the viscosity range an oil fall at the measuring temperature, the monograde non-winter oils are graded as SAE 20,30,40,50 or 60

(www.astm.org/Standards/D5293.htm).

The higher the viscosity of oil measured at this temperature, the higher the SAE viscosity grade.

In applications where the temperature range in use is not too wide like in classic cars, lawn mowers etc the single grade motor oil is recommendable.

2.5.4.2 Multi-grade Motor Oil

In most applications the motor oil is exposed to a wide range of temperature from low start up temperatures in winter to high operating temperatures in summer. Some will have high viscosities when cold and low viscosities at high operating temperatures of the engine in which they serve. For the single-grade oils discussed above and as mentioned earlier, the difference in viscosities between to low temperature and the high temperature is too large.

In the multi-grade oils, the polymer additives called viscosity index improvers are added to bring the difference in viscosities closer so that the oil can serve in applications where there is a wide range of temperatures. The additives make a monograde oil a multigrade one because of the properties they will impart to it. However a multi-grade oil can be made without additive, the idea is to make an oil have a viscosity of the base grade when cold and the viscosity of the second grade when hot so as to be suitable for a wide range of temperatures i.e an oil can be used in winter when cold and also in summer when it's hot. The viscosity of multigrade oil also varies with temperature but to a very much less extent as compared to that of mono-grade oil. The variation of viscosity with temperatures depends on the amount and kind of additives added to the base oil.

The multi-grade oil has SAE designation of two viscosity grades, for example, 20W-40 is one of the common multi-grade oil. The two numbers have their individual definition in mono-grade oils and as such an oil labeled as 20W-40 must have the SAE viscosity requirements of both 20W and 40 and their limitations i.e. an oil labeled 20W-40 will and must not have the viscosity requirement for 10W. If an oil has no additives but has the viscosity requirement of a multi-grade oil can be labeled either multi-grade or mono-grade. For example

20W-20 is simple multi-grade oil that can be made from the base stock without additives. This oil can be labeled 20W-20, 20W, or 20. If however viscosity index improvers are used, the oil cannot be labeled mono-grade.

2.5.5.0 Engine oil Performance Standards

The performance standard of any oil is dependent on the properties of the oil. These properties could be both physical and chemical properties.

The minimum acceptable performance levels are often denoted by specifications. Superior performances are always announced by the marketers of lubricants supported by adverts and sponsorship of sporting events. This is however not all the time true as consumers now have performance claims but is very difficult or even impossible to identify. The marketers are therefore expected to show data that could support their claims giving the consumers, confidence in the oil they buy.

Several national bodies have set minimum for the performance standards of lubricants, they are as below.

2.5.5.1 The American Petroleum Institute (API) has a minimum performance standard of lubricants. Lubricants particularly engine/motor oils are used for lubrication, cooling and cleaning of internal combustion engine. For the oil to perform these functions, certain physical and chemical properties of the oil must be in place. An oil could be composed of a lubricant base stock only in which case the oil is non detergent, or a lubricant base stock containing additives to improve the detergency, extreme pressure performance and corrosion inhibition ability. As stated above in the introduction, lubricant base stocks are categorized into five groups by the API, groups I to V (www.scribd.com/.../API-1509-2002)

The service classes of the API has two general classifications; S meaning “service” and which originates from spark ignition (passengers cars and other vehicles using gasoline engine) and C for “commercial” which originates from compression ignition (diesel engines). When any engine oil is seen to meet the API performance standard after testing may display the API service symbol (Donut) with the service designation on containers.

SM is the latest API service standard designation for gasoline automobiles and high-trunk engines. This standard i.e SM actually refers to a group of laboratory and engine test which include the latest series for the control of deposit at elevated temperatures. The most current API service categories are the SM, SL and SJ for gasoline engines. The previous service designations like SA, SB, SC, SD etc are now obsolete except that SF/SG standards are still used for motorcycle oils. The current categories have limitation on the phosphorus content for some SAE viscosity grades. This is because phosphorus has a chemical poisoning on catalytic converters. Phosphorus is a major antiwear component in motor oil and so to completely eliminate it is technically not advisable. As such recent API categories place lower phosphorus and zinc limits for certain SAE viscosity grades. This has actually brought a controversial issue as low level of phosphorus in engine oils means there will not be oil needed for the older engines. The older engines with sliding tappets are sensitive to the presence of phosphorus and zinc in oils. One of the engine tests required for API SM designation is a sliding tappet to test specifically for cam wear protection. There are also special cases as in performance engines or fully race built engine, which the requirements for engines protection are much higher than the APT requirements. This is why there are oils in the market today with high levels of phosphorus and zinc than are recommended by the current API categories. For instance, the API SG rating contained 1200-1300ppm level of zinc and phosphorus but the current SM category contains this major anti-wear components below 600ppm. It has been discovered that this drastic reduction in

anti-wear chemicals in oils would lead to pre-mature failures in camshafts and high pressure bearing in internal combustion engines.

1. **2.5.5.2 The International Lubricant Standardization and Approval Committee (ILSAC)** is one of the known bodies that has a standard for engine oil performance. The newest standard being the Gf-4 which was approved in 2004 and is applicable to SAE OW-20, 5W-20 OW-30, and 10W-30 viscosity grade oils (www.oilspecifications.org/ilsac.php)

Generally ILSAC and API work together to create new specification for oils but ILSAC is known for adding extra requirement of fuel economy testing. For instance the Gf-4, a sequence VIB, fuel economy Test is required but it is not required in the API SM service category.

A new ILSAC test for GF-4 which is also applicable to the API SM category is the sequence IIIG. This test involves running a 3.8L equivalent to $232in^3$, GM 3.8L V-6 at 125hp, 3,600 rpm, and 150^0C (300^0F) oil temperature for 100 hours [8]. Oils which pass this test serve better in cars that push their oil temperature above 100^0C (212^0F), mostly turbocharged engines and engine of small capacity and high power output. The IIIG test is about 50% more difficult than the earlier IIIF test which was used in GF-3 and API SL oils. The engine oils bearing the API starburst symbol is compliant with the ILASC GF-4.

Consumers recognize oils that meet the ILSAC requirement by the API “starburst” certification mark.

Others are the Association Des Construction European d’ Automobiles (ACEA), the Japanese Automotive standard organization (JASO) and OEM, the original equipment manufacturers.

In the 90s, the OEM car manufacturers thought that API oil standard was not meeting up with the oil requirements to be used in their cars. Consequently an OEM oil standard was developed by the European car manufacturers. VW50.*O* and MB22*** are examples of the

standards developed. The VW50*O* was from Volkswagen group and the MB22*** from Mercedes Benz. Others are the W55 standards, BMW special oil and BMW long life standards etc.

Now very highly specialized extended drain, long life oil has being developed so that a petrol engine with reference to Volkswagen group of vehicles, can go up to 2 years or 50,000km, approximately 31,000mi before a change of oil is required.

Most OEM standards would require long drain of about 340,000km and above. This is achieved by the use of HTHS (High Temperature High Shear) viscosity, many around 3.5cp (3.5Mpa.s). [9]

2.6 Manufacturing Process of a Lube Oil.

Lubricating oil is obtained from the crude oil. The crude oil is made to undergo some purification processes during which it is purified before it is pumped into a fractionating column where the several hydrocarbons are separated by fractional distillation. A high efficiency fractionating tower/column could be up to 10 meters in diameter and 122 meters tall. The towers in order to resist corrosion that would be induced by the components of the crude oil are made of high grade steel. The inside of the fractionating column is fitted with ascending series of condensate collecting trays to collect condensate at different levels depending on the boiling point of individual hydrocarbon (www.Machinerylubrication.Com/Read/1763/).

As the vapor rises up the tower, the fractions cool and condense to liquid. The rate at which any fraction of the hydrocarbon condenses is governed by the boiling point of that hydrocarbon. (The lower the number of carbon atoms in the molecule of hydrocarbon the lower its boiling point and the lower it rises before condensing). The components condense in the order; natural gas-gasoline-kerosene-fuel oil-lubricants-tars.

The processes involved in the manufacturing of lube oil are summarized below:

2.6.1 Sedimentation

During this process the crude oil is transported from the oil well into the refinery where it is allowed to settle. Water being lighter than the oil settles on top and solid contaminants like sand and rock settle at the bottom. The crude oil is at this stage made free of these impurities.

2.6.2 Fractionating:

In this stage, the crude oil from process 1 above is pumped into a fractionating tower after it is heated up to a temperature of about 700^0F (371^0C). At this temperature, the crude oil breaks down into a mixture of hot vapor and liquid. Now the hot vapor flow up the tower and cool. As they cool, they condense and are collected in the trays at different levels. Normal atmospheric pressure is maintained here and about 80% of the crude vaporizes at this stage.

The remaining 20% of the crude is heated again and pumped into a second tower. In this tower, the residual oil boiling point is lowered by vacuum pressure so that the oil can now vaporize at low temperatures. The oil can now vaporize leaving the heavier compounds with high boiling points, such as tar and inorganic compounds for further processing.

2.6.3 Filtering and Solvent Extraction

During this process the oil collected in the two towers above is passed to ultrafine filters to remove impurities that may still remain in the oil. Now aromatic hydrocarbons which can affect the viscosity of the oil still remain and need be removed. By solvent extraction process, the oil is treated with solvent and the aromatic hydrocarbon which is more soluble dissolves in the solvent and is removed from the oil.

2.6.4 Addition of Additives

Finally additives are added to the oil to give it desired properties and test carried out on the oil to ascertain whether the oil meets with standard or not. The oil is then packaged and labeled according to the viscosity and standard tests carried out on it.

2.7 Oil Additives

As the demand for lubricants for use in internal combustion engines and other applications increases by the day, research efforts have being devoted to developing improved lubricants.

Additives are chemical compounds added to base oils to improve their lubricating and aging properties. Depending on the desired properties and service environment, oils today contain additives to make them do their best in service. The additives are grouped according to functions they perform in the oil (Henry, 1975).

2.7.1 Oxidation Inhibitors: These additives slow down the rate of oxidation in the internal combustion engine. As the lubricants are exposed to high temperature during operation, the tendency for the oil to get oxidized is high but at this stage, the chemical compound containing nitrogen, phosphorus and alkyl-phenol now react with the hydrogen peroxide formed initially by the oxidation of the lubricant. This single action now stops the chain reaction which could have led to the formation of sludge and vanish in the engine.

The prevention of the formation of these aggressive compounds minimizes the corrosion of zinc and copper bearing alloys. Zinc, barium and calcium thiophosphates are used in internal combustion engines.

2.7.2 Anti Wear Additives: These additives prevent the wearing away of surfaces by minimizing friction. The friction is minimized when the anti-wear agent produces protective film/coating on the surface by chemical or physical absorption mechanism under the conditions of boundary lubrications. Anti wear agents are compounds of oxygen, sulfur, chlorinated wax,

phosphorus and organic lead. In hydraulic pumps, gear and the likes, zinc dialkyldithiophosphates are widely used.

In extreme pressure applications where asperities may penetrate oil film and make contact with asperities of mating surfaces i.e. severe metal-to-metal contact, active sulfur, chlorine and lead compounds have to be used. These additives undergo chemical reaction forming sulfides and chlorides in form of a film on the surface. This low shear strength film allows for relative movement of the surfaces and avoids direct contact of asperities thereby enhancing the lubricating property of the lubricant

2.7.3 Viscosity Index Improvers: These additives function to improve the viscosity index of engine oils. In internet composition engine, the operating temperature is usually high and so an oil with low viscosity index will not find use. With these additives the change in viscosity with respect to change in temperature is kept within a small range so that the oil becomes useful in applications where temperature variation is high as in internal combustion engine. It is also needed that these additives have an advantageous effect on the pour point of the oil in which it is in use. The common types of viscosity improvers are the polymethacrylates, polyisobutylsuccinic acid. The primary function of the viscosity improver is to thicken light oil to a higher viscosity while maintaining the original viscosity temperature coefficient.

2.7.4 Detergents;

Detergents as additives help to clean the internal part of the engine by preventing and/or removing deposits of oil sludge, varnish and lead. Barium and calcium sultanates and phenates are used in automotive and diesel engines. Ash less detergents have now been developed to minimize low temperature sludge formation.

Detergents are multifunctional as they can in addition to detergent properties prevent rusting and improve the viscosity index and pour point of the oil.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The samples of lubricants considered in this research work are those on the table 1 below.

The various experiments undergone here were carried out on all the samples to the same extent.

The materials, equipment and the experimental procedure are stated in each experiment in this chapter.

Table 3.1 Samples Examined In All The Experiments:

Samples	Manufacturers	SAE N0s	Grades	Cost (=N=)
Mobil 1 SAE 0W40	Mobil oil	0w40	Synthetic oil	8,900
Oando SAE 20W50	Oando oil	20w50	Multigrade oil	2,800
Total SAE 20W50	Total oil	20w50	Multigrade oil	2,900
AZ SAE 20W50	AZ Petroleum	20w50	Multigrade oil	2,850
Total SAE 40	Total oil	40	Monograde oil	2,300



Plate 3.1 Samples in the laboratory during the laboratory experiments.

Several methods are in place for testing for the protecting ability of engine oil in an internal combustion engine. A few of these methods as stated below were considered in the course of this research work.

3.1 Viscosity Determination

Viscosity is a measure of the oil's resistance to flow or the resistance of each successful layer to sliding over the adjacent one.

This is a very important property to be considered in the evaluation of the performance properties of lubricating oil.

3.1.1 Equipment / Materials

1. Brookfield Viscometer
2. Thermometer
3. Magnetic stirrer hot plate
4. Mechanical stirrer
5. 800 ml Beaker



Plate 3.2 The Brookfield Viscometer

(www.brookfieldengineering.com/products/viscometers/laboratory-dial-reading.asp)

3.1.2 Procedure

600 ml of the sample was gently poured into the 800 ml beaker and two thermometers immersed. The average of the temperature read on the two thermometers was taken to be the sample's room temperature T_0

The beaker was now positioned appropriately on the viscometer and the spindle lowered until the oil level was just at mark on the spindle.

The viscometer was now set to a speed of 60 rpm and switched on. The viscometer was left at this speed to run until it oscillated. It was then stopped and the reading on the dial gauge taken. The product of the dial reading and the factor (40 in this experiment) gave the corresponding value of the viscosity at that temperature T_0.

The sample was now placed on the magnetic hot plate with the stirrer immersed. As the sample was been heated and stirred continuously, the temperature read on the thermometers was still averaged and recorded at 40 °C and the sample here quickly and carefully placed under the viscometer for the viscosity to be measured as above at this temperature.

This was repeated at 10 °C interval from 40 °C to 100 °C.

This procedure was undertaken for the entire five samples and the results recorded.

3.2 Density Determination

3.2.1 Equipment/ Materials

1. Digital balance
2. Magnetic stirring electric heater
3. Mechanical stirrer
4. Thermometer

5. 800ml beaker
6. 0.7 liter of each oil sample
7. 50ml density bottle

3.2.2 Procedure

The mass of the density bottle was measured and recorded as m_b. 500ml of the oil sample whose density was to be measured was poured into an 800ml beaker. Two thermometers were immersed into the oil sample and their temperatures read and the average taken as the room temperature to. The sample was poured into the 50ml density bottle and placed on the digital balance. The mass of both sample and bottle was then measured and recorded as M.

The 800ml beaker containing the sample was now placed on the electric heater and heated continuously and stirred at regular intervals.

The temperature of the sample was read by taking the average of the readings on the two thermometers immersed in the oil sample as the heating continued.

At any desired temperature the sample was quickly poured into the 500ml density bottle and the mass measured as usual. This was repeated at 10 degrees intervals from 40 °c to 100°c for all the samples.

Now the mass of the sample = M - M_b

Volume of the sample = volume of density bottle V_b

Sample's density $\rho = \frac{M - M_b}{V_b}\ g/cm^3$

3.3 Pour Point Determination

3.3.1 Equipment/ Materials

1. Test tube
2. Bath Thermometer
3. Oil Thermometer
4. A jacket of crushed ice
5. Samples to be tested

3.3.2 Procedure

The sample was gently poured into the test tube. The test tube containing the sample was placed inside the crushed ice in the jacket. The sample was allowed to freeze here until it ceases to pour.

The temperature at which the sample ceased to pour was noted and 5 °F added to it to be the pour point of the sample.

The procedure was repeated on the entire sample and the pour points recorded.

3.4 Flash Point Determination

Flash point is the temperature at which sufficient inflammable vapor is given off by any fuel to cause a flash when a flame is brought near its surface.

The higher the flash point of oil the better that oil will serve in a high temperature environment. This is a very important factor in the selection of lubricating oil. If a low flash point oil is used in an environment where high temperature is expected as a result of the heat generated in the system, the oil could lose the lubricating properties and which will in turn lead to catastrophic failure in the system. Also the risk of fire incidence is imminent.

3.4.1 Equipment/Material

Several apparatuses are used for the determination of flash point of petroleum products but in this work the Cleveland Open Cup Apparatus was used.



Plate 3.3a The Cleveland Open Cup Apparatus
(www.humboldtmfg.com/flash_point_testers.html)

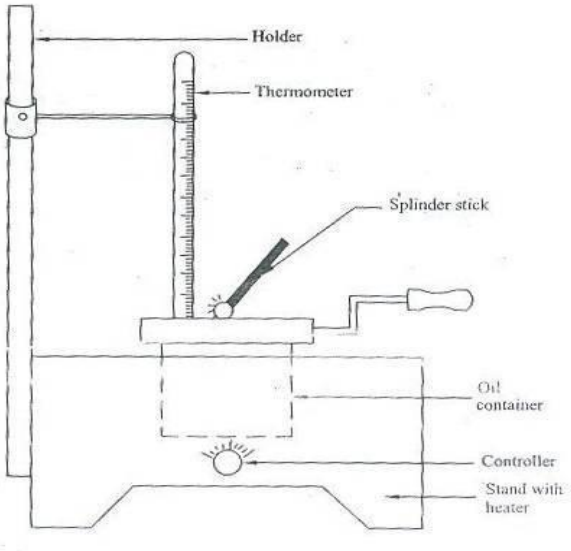


Plate 3.3b The schematic diagram of the Cleveland Open Cup Apparatus.

3.4.2 Procedure

The oil sample was poured into the open cup in such quantity as to just touch the prescribed mark on the inside of the cup and heating of the sample commenced using a Bunsen burner. While the heating continued, a thermometer suspended on a retort stand and immersed into the oil was used as the stirrer. The vapors emitted were tested with a pilot flame from a gas burner every 30 sec until flash occurred.

The temperature at which flash occurred was noted as the flash point of the sample under test.

3.5 Carbon Residue Experiment

3.5.1 Equipment/Materials

1. Porcelain crucible.
2. Skidmore crucible.
3. Chimney wire support.
4. Sand bath.
5. Burner.
6. Oil samples.

3.5.2 Procedure

Approximately 2g of the oil sample was weighed in the crucible and this was placed in the center of the skid more crucible.

The sand was leveled in the sand bath and the skid more crucibles were set in the triangle in the center of the sand bath.

The crucible was covered appropriately with the arrangement for free exit of vapors formed.

Heating was done with strong flame from a gas burner for about 10 minutes when ignition occurred with blue flame.

Slow heating was now continued for about 5 minutes and followed by strong heating for about 15 minutes when vapor ceased to appear.

The apparatus was allowed to cool and the weight of the residue determined.

This was expressed as a percentage of the original sample of the oil

3.6 Oil Pressure Mapping Experiment

One of the most recent methods in evaluating the performance properties of internal combustion engines' lubricating oil is the Oil Pressure Mapping Experiment.

Mapping oil pressure is dependent on the fact that an oil pump like most pumps produces a rapid increase in output as speed increases until at some critical point where the output drops off again.

To prevent erosion damage to the bearing from the excessively high oil pressures possible with the high-capacity oil pumps fitted to modern diesel engines, a pressure-relief valve is fitted to the engine oil pump. This vents excess oil back to the sump when the maximum allowable pressure is reached.

Oil pressure mapping is used to verify that the oil pressure follows this curve. When there is a change in the shape of the curve, means a fault of the pump or an increase in bearing clearance as a result of wear leading to oil leakage from the system.

3.6.1 Equipment/ Materials

1. An Internal Combustion Engine
2. Tachometer

3. Oil Pressure Gauge
4. Pressure Tubing
5. The Oil Samples

3.6.2 Materials Selection

The selection of the materials and the equipment here was based on the requirement from theoretical background.

For pressure mapping to measure the ability of any lubricating oil to protect an internal combustion engine, the oil's properties must be tested for while in use. This means testing the oil properties in its working environment. This will give a very good information about the oils protecting ability. Equipments for pressure mapping are not readily available around but the bottom line is testing the properties of oils in an internal combustion engine. This equipment or set up was improvised.

Improvising this equipment, the following were sourced from our local market:

3.6.2.1 Honda Civic 1986 Engine;

Engine model. = 1.5L 1493 CC 14 GASSOHC.

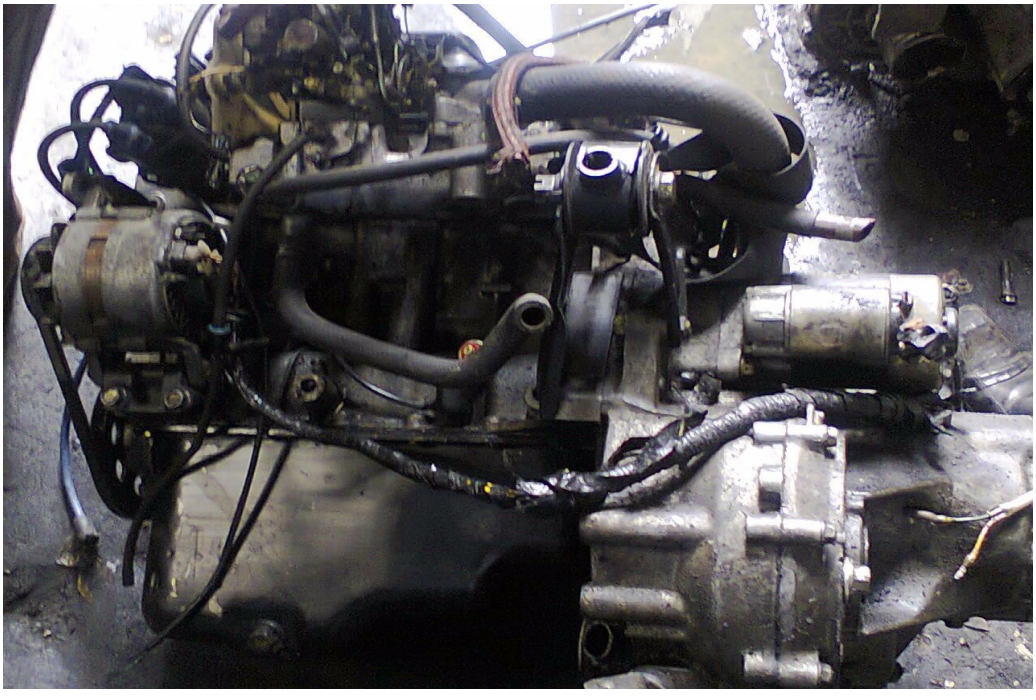


Plate 3.4 Honda Civic Engine (1986 model)

Justification for this selection:

a) The required is an internal combustion engine

b) Required oil pressure range 0-10bar is normal for an internal combustion engine

c) It has the oil pressure switch that can easily be adapted to an oil pressure gauge using tubing network for oil pressure reading during the experiment

d) It is more economical to get this engine from auto engine market in Nigeria as compared to others.

3.6.2.2 Thermometer /Thermocouple:

The instrument for temperature measurement selected was the normal car engine temperature gauge. It was obtained from the market and connected appropriately.

This instrument is capable of measuring up to 100 °c but maximum expected temperature on the engine is 72 °c. 72 °c is actually a high engine temperature whit the cooling system working properly and the lubricant circulating normally.

3.6.2.3 Tachometer

The tachometer employed here was the normal tachometer for car engine speed measurement. It was obtained from the market and connected appropriately to measure the speed of the engine in RPM during the experiment.

This can measure up to 7000 RPM but the maximum engine speed in this experiment was 4000 RPM, meaning this was a suitable instrument for this engines speed measurement.

3.6.2.4 Oil Pressure Gauge

The oil pressure gauge selected here was that of the range of 0-10 bar which is the recommended pressure gauge range for internal combustion engine; see recommended pressure gauge range for general equipment on Table 3.2 below.

Table 3.2 Recommended pressure gauge ranges for general equipment

	SI Metric	Alternate Metric	Japanese	Imperial
Engines	0 - 1 000 kPa	O - 10 Bar	0 - 10 kg/cm²	0 - 160 psi
Transmissions	0 - 6 000 kPa	0 - 60 Bar	0 - 60 kg/cm²	0 - 1 000 psi
Hydraulics	0 - 2 500 kPa	0 - 25 Bar	0 - 25 kg/cm²	0 - 400 psi
	0 - 60 Mpa	0 - 600 Bar	0 - 600 kg/cm²	0 - 10 000 psi



Plate 3.5 Thermocouple, Tachometer and Oil Pressure Gauge displayed on the panel.

3.6.2.5 Pressure Pipe.

Considering the maximum service temperature & pressure and the required flexibility of the pipe to fit in for the job, aluminum pipe of 0.08” internal diameter was selected.

All these were coupled together appropriately to give the pressure mapping equipment.



Plate 3.6a The Pressure Mapping Equipment Improvised

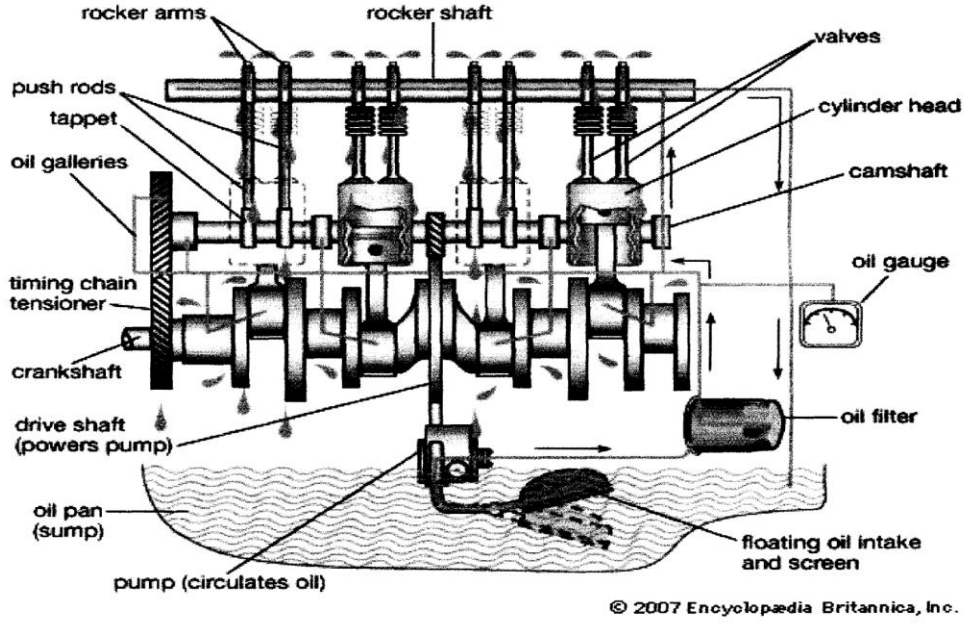


Plate 3.6b The Schematic Diagram of The Lubricating System of an Internal Combustion Engine.

3.6.3 Experimental Procedure

Samples of the lubricants on table1 above were randomly selected in our local markets from lubricant marketers within Kaduna State.

The samples were tested separately by pouring each sample into the sump of the equipment, starting it and allowing it to run at the idle speed for a long enough time for the temperature to stabilize.

The engine speed was then gently increased; using the improvised accelerator positioned beside the carburetor, to the maximum and allowed to return to the idle speed.

The maximum and idle speeds were noted with their corresponding temperatures and pressures.

The engine was then run at the idle speed until it attained the full operating temperature after which it was run at randomly selected engine speeds for a period of 3 hours.

The oil pressure and temperature was then measured at a 10 speed intervals equally spaced between the idle and maximum speed.

On the graph of Oil Pressure against Engine Speed, a straight line was drawn from the first reading taken at idle speed to the reading taken at maximum speed. All the other points between the two extreme points lie above this line as shown below in figs 4.10, 4.11, 4.12, 4.13 and 4.14.

The tables 4.10, 4.11, 4.12, 4.13 and 4.14 below were generated for each of the samples as readings were taken during the experiment, from the gauges on the panel of the Pressure Mapping Equipment set up.

3.7 Spent Oil Analysis

After espousing the oils to the same conditions for the same period of time in the internal combustion engine, laboratory tests were carried out again on the spent oil to confirm how easily an oil can get depleted by considering the dynamic viscosity and carbon residue of the spent oil.

The same procedure for viscosity and carbon residue determination was undergone and the results obtained from the laboratory test on the spent oil were tabulated and compared as shown below on tables 4.16 and 4.17.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

Table 4.1 Viscosity Determination Result for Oando SAE 20w50

Spindle number = 3

Speed in RPM = 60

Factor = 40

Dial reading X Factor =Viscosity

S/N	Temperature (^{0}C)	Dial Reading	Viscosity (cSt)
1	24.8	5.00	290
2	40	3.53	141
3	50	2.65	106

4	60	1.90	76
5	70	1.26	50.50
6	80	0.81	32.40
7	90	0.51	20.20
8	100	0.45	18.00

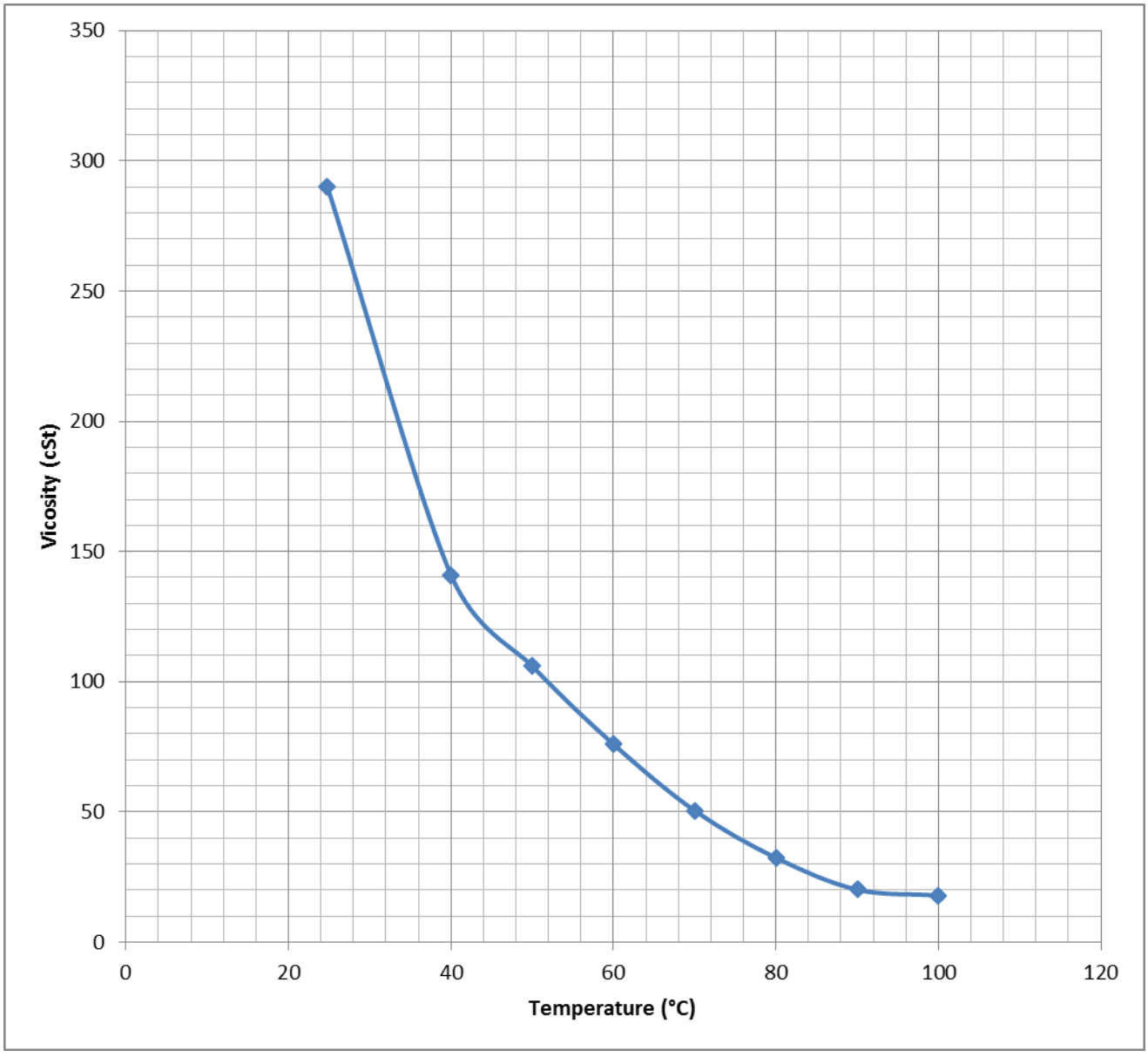


Fig 4.1 Variation of viscosity with temperature for Oando SAE 20W50

Table 4.2 Viscosity Determination Result for Total SAE 20W50

Spindle number 3

Speed in RPM 60

Factor 40

Dial reading X Factor =Viscosity

S/N	Temperature (^{0}C)	Dial Reading	Viscosity (cSt)
1	24.8	7.26	290.50
2	40	3.50	140.00
3	50	2.55	102.00
4	60	2.11	84.20
5	70	1.75	70.00
6	80	1.04	41.50
7	90	0.73	29.30
8	100	0.50	20.00

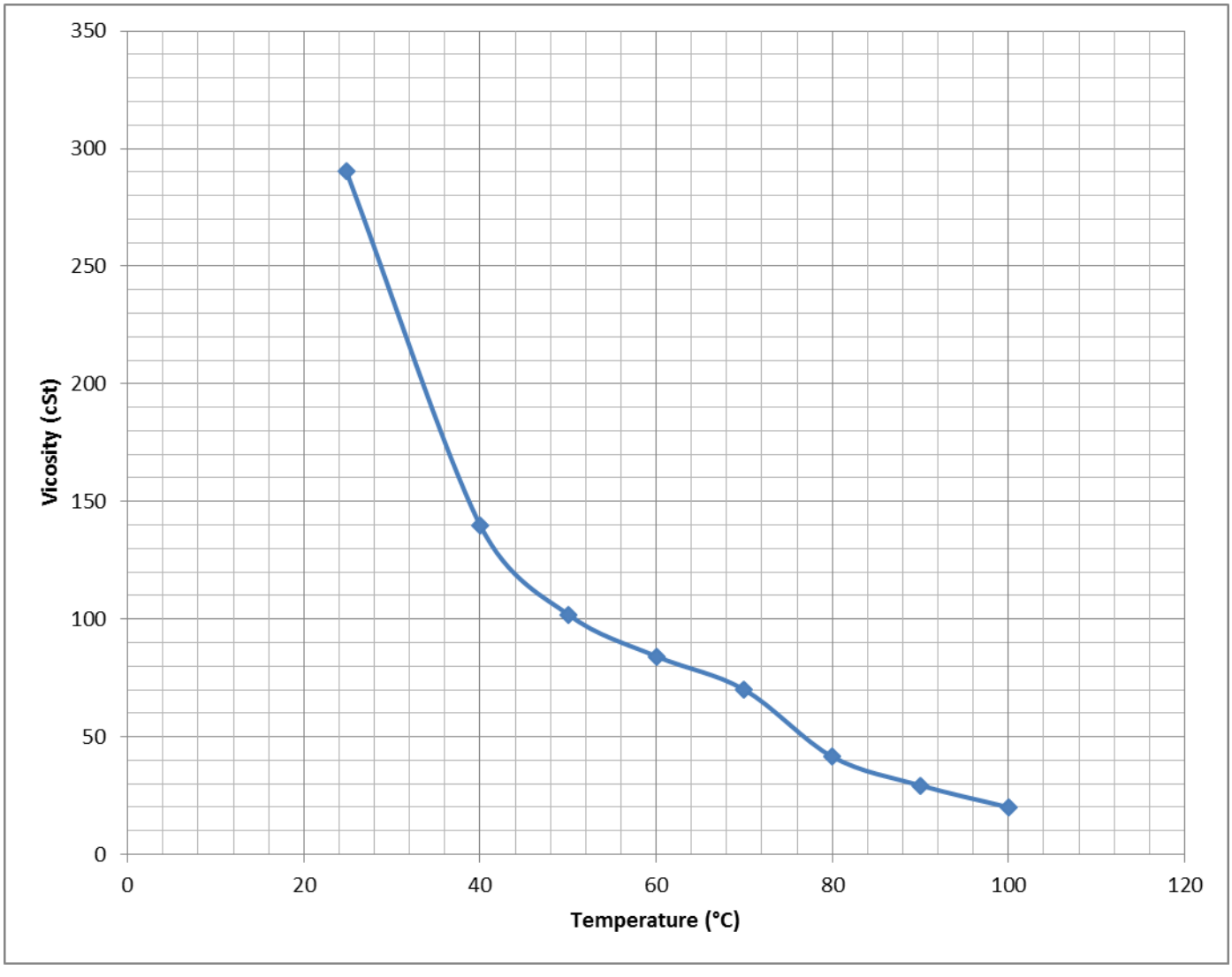


Fig 4.2 Graph of viscosity against temperature for Total SAE 20W50

Table 4.3 Viscosity Determination Result for Mobil 1 SAE 0W40

Spindle number 3

Speed in RPM 60

Factor 40

Dial reading X Factor =Viscosity

S/N	Temperature (^{0}C)	Dial Reading	Viscosity (cSt)
1	24.8	7.16	286.40
2	40	3.55	142.00
3	50	2.65	106.00
4	60	1.82	72.80
5	70	1.36	54.40
6	80	0.89	35.60
7	90	0.63	25.20
8	100	0.53	21.20

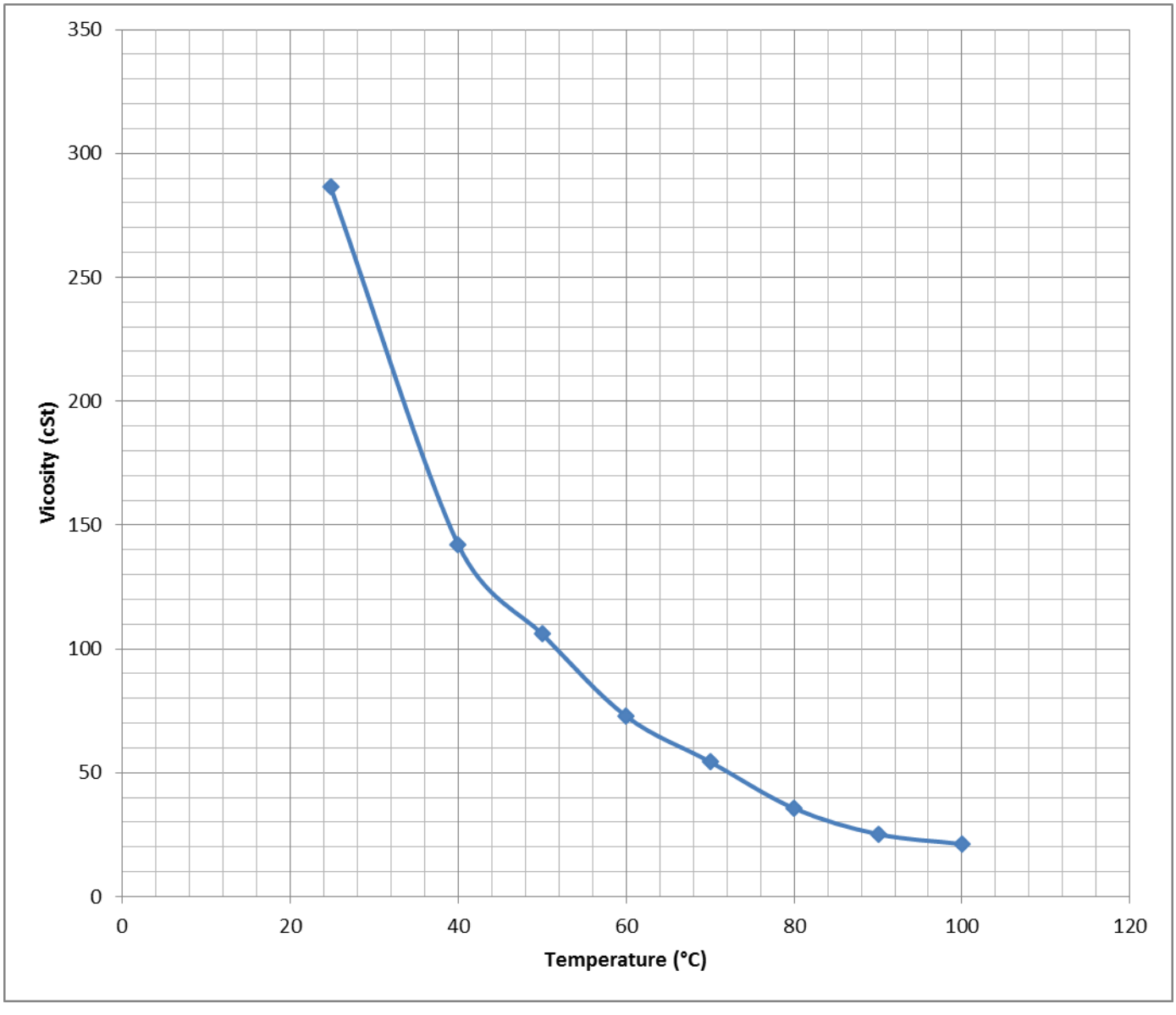


Fig 4.3 Variation of viscosity with temperature for Mobil 1 SAE 0W40

Table 4.4 Viscosity Determination Result for Total SAE 40

Spindle number 3

Speed in RPM 60

Factor 40

Dial Reading X Factor =Viscosity

S/N	Temperature (^{0}C)	Dial Reading	Viscosity (cSt)
1	24.8	7.38	295.20
2	40	3.50	140.00
3	50	2.63	105.20
4	60	1.95	78.00
5	70	1.25	50.00
6	80	0.77	30.80
7	90	0.49	19.60
8	100	0.39	15.60

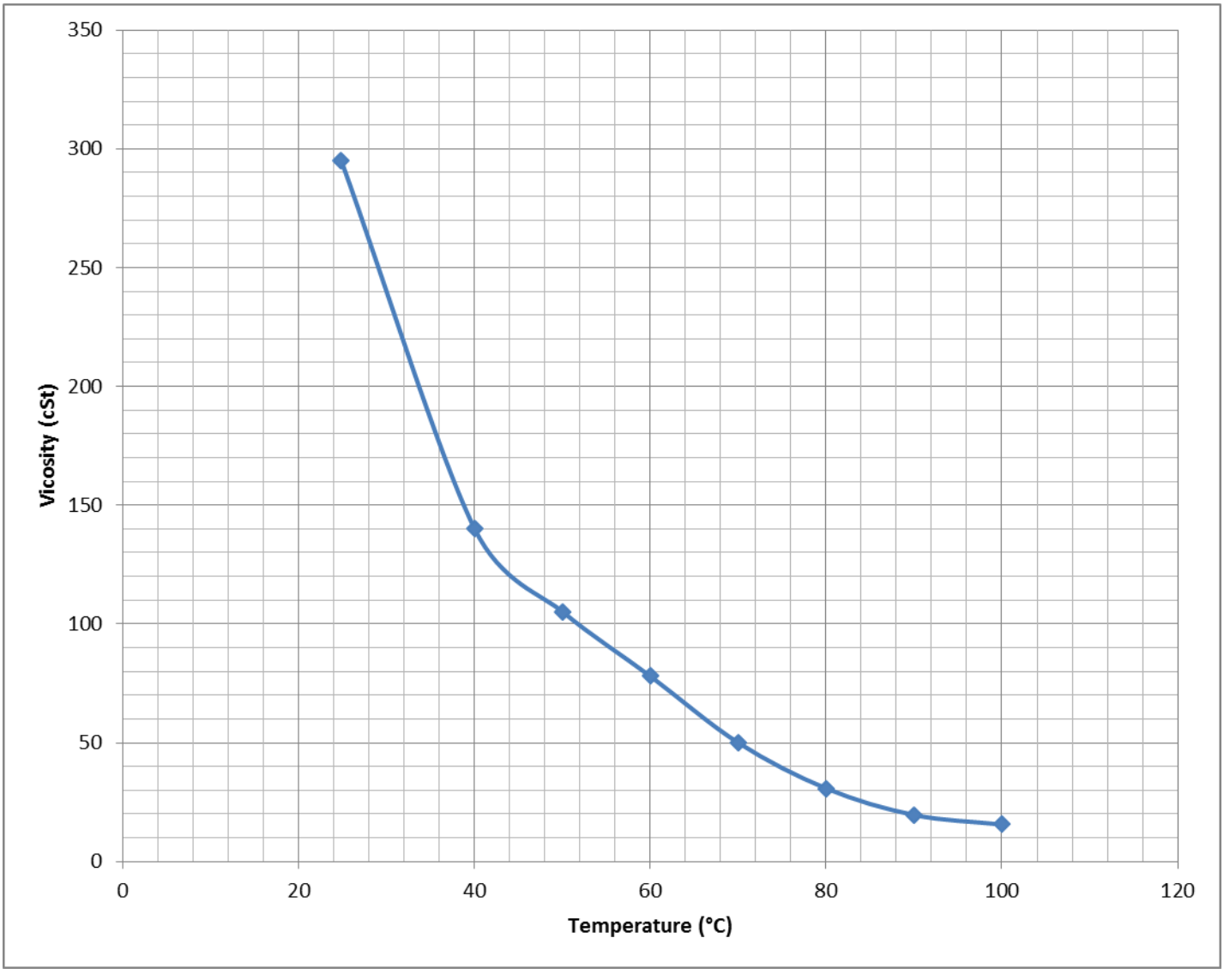


Fig 4.4 Variation of viscosity with temperature for Total SAE 40

Table 4.5 Viscosity Determination Result for AZ SAE 20W50

Spindle number = 3

Speed in RPM = 60

Factor = 40

Dial reading X Factor =Viscosity

S/N	Temperature (^{0}C)	Dial Reading	Viscosity (cSt)
1	24.8	7.42	296.8
2	40	2.55	102.00
3	50	2.12	84.80
4	60	1.79	71.60
5	70	1.26	50.40
6	80	1.02	40.80
7	90	0.70	28.00
8	100	0.49	19.60

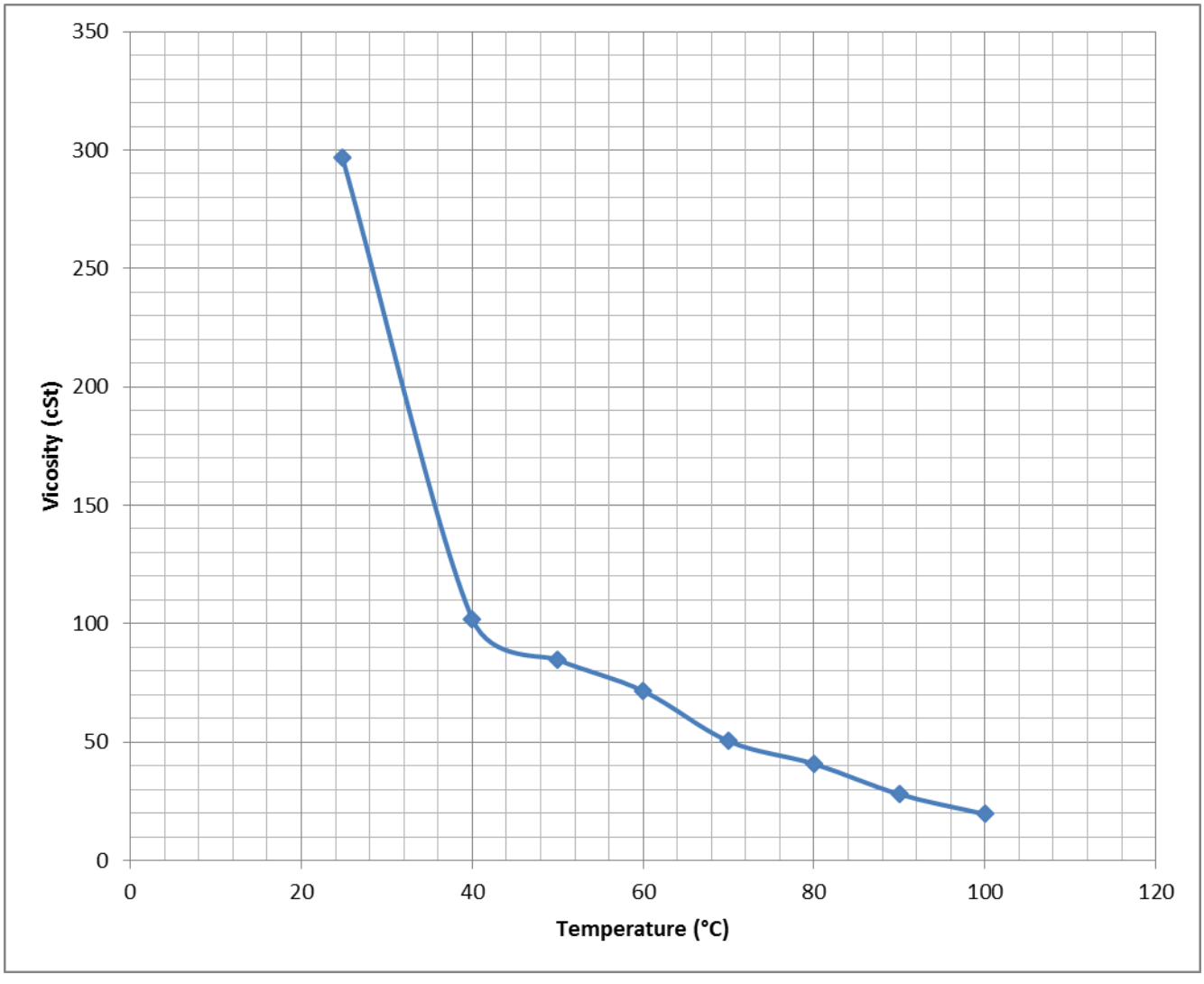


Fig 4.5 Variation of viscosity with temperature for AZ SAE 20W50

Table 4.6 Viscosities of the 5 samples at various temperatures

S/N	Temperature (^{0}C)	Viscosity (cSt) OANDO SAE 20W50	Viscosity (cSt) TOTAL SAE 20W50	Viscosity (cSt) MOBIL 1 SAE 0W40	Viscosity (cSt) TOTAL SAE 40	Viscosity (cSt) AZ SAE 20W50
1	24.8	290	290.50	286.40	295.20	296.8
2	40	141	140.00	142.00	140.00	102.00
3	50	106	102.00	106.00	105.20	84.80
4	60	76	84.20	72.80	78.00	71.60
5	70	50.50	70.00	54.40	50.00	50.40
6	80	32.40	41.50	35.60	30.80	40.80
7	90	20.20	29.30	25.20	19.60	28.00
8	100	18.00	20.00	21.20	15.60	19.60

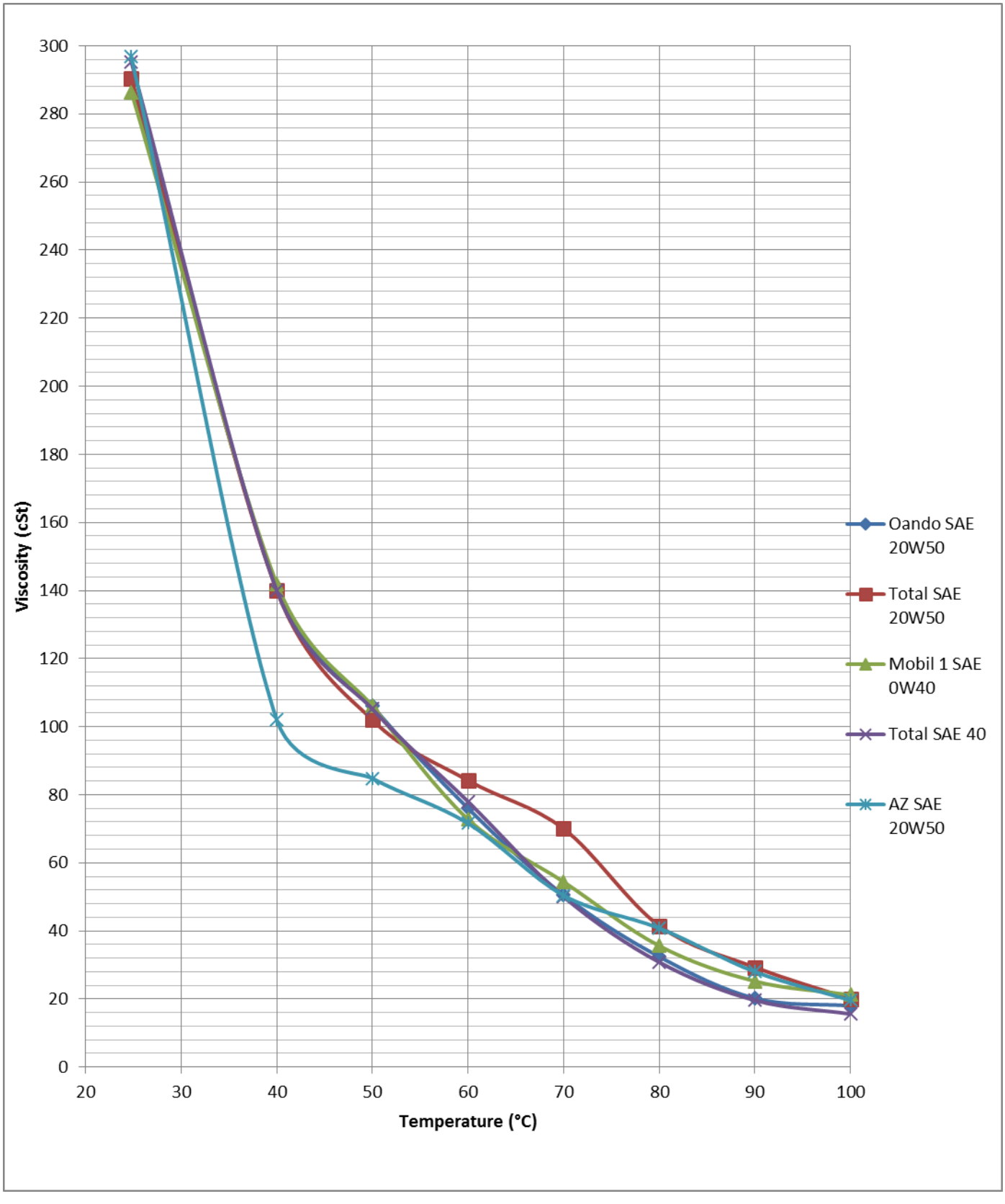


Fig 4.6 Comparing the variation of viscosity with temperature for the 5 samples

Table 4.7 Pour Point Determination Result

S/N	Samples	Pour point (^{0}F)	Pour Point (^{0}C)
1	MOBIL 1 SAE 0W40	-14.8	-28
2	TOTAL SAE20W50	-7.60	-22
3	Oando SAE 20W50	-11.20	-24
4	AZ SAE 20W50	-7.60	-22
5	TOTAL SAE40	5.00	-15

Table 4.8 Flash Point Determination Result

S/NO	SAMPLE	FLASH POINT (°C)
1	TOTAL, SAE 40	102
2	MOBIL1, SAE 0W40	160
3	OANDO, 20W50	175
4	TOTAL, SAE 20W50	160
5	A-Z, 20W50	170

Table 4.9 Carbon Residue Experiment Result

S/N	Samples	Empty crucible (g)	Crucible + Sample (g)	Crucible + Residue (g)	Sample (g)	Residue (g)	Carbon residue (%)
1	MOBIL 1 20W50	20.00	22.0	20.012	2.00	0.0120	0.60
2	TOTAL SAE20W50	20.00	22.0	20.012	2.00	0.0180	0.90
3	OANDO SAE 20W50	20.00	22.0	20.012	2.00	0.0190	0.95
4	AZ SAE 20W50	20.00	22.0	20.012	2.00	0.0194	0.95
5	TOTAL SAE40	20.00	22.0	20.012	2.00	0.020	1.00

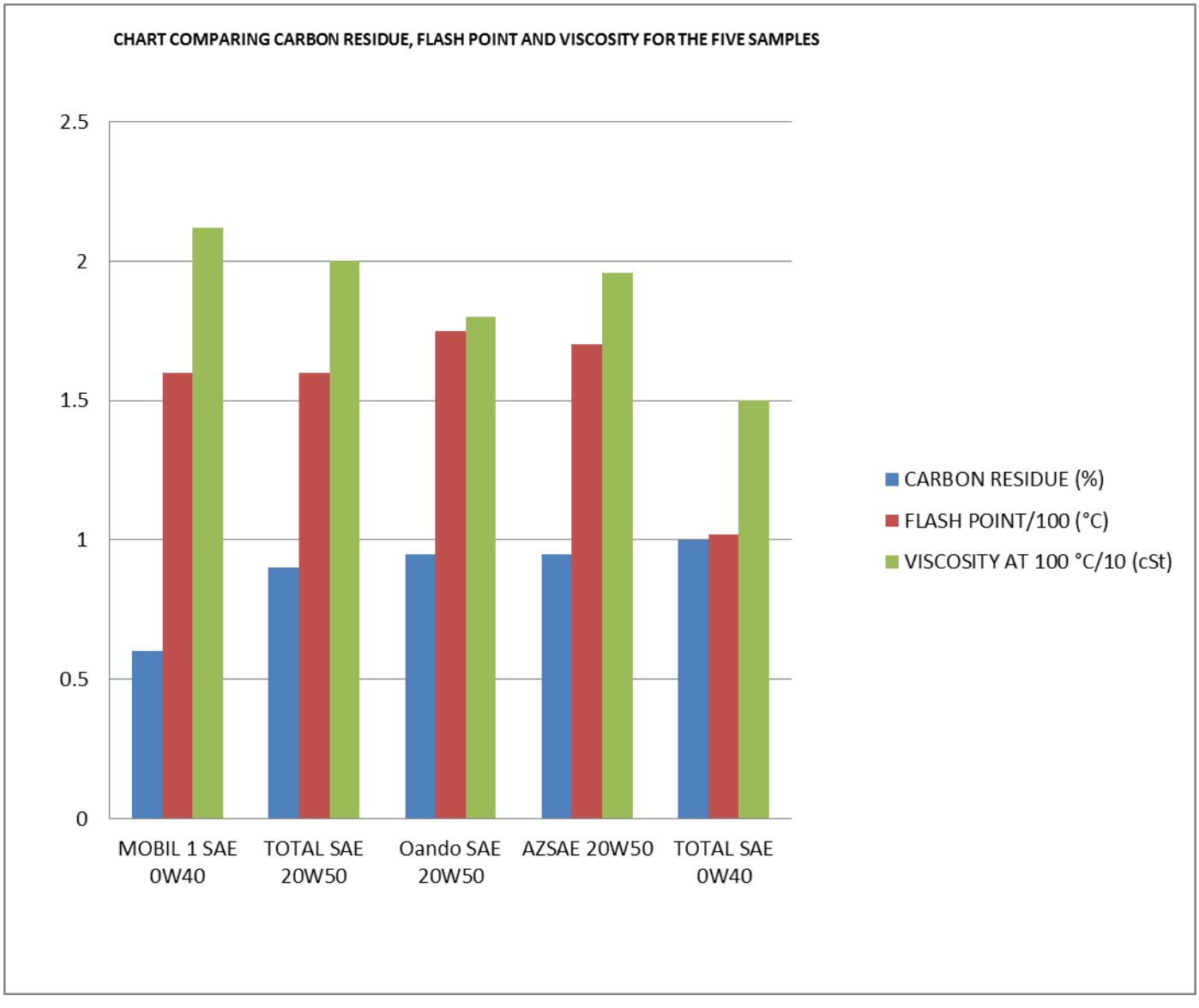


Fig 4.9 Chart comparing carbon residue, flash point and viscosity for the 5 samples

1. SAMPLE NAME : AZ SAE 20W50

Idle Speed : 1000 rpm

Idle Press : 2.00 bar

Max Speed : 4000 rpm

Max Press : 2.90 bar

Temperature : 60 °C

Table 4.10 Pressure Mapping Experiment Result

S/NO	ENGINE SPEED (rpm)	OIL PRESSURE (bar)	OIL TEMPERATURE (°C)
1	1250	2.2	60
2	1500	2.3	60
3	1750	2.4	62
4	2000	2.4	62
5	2250	2.6	62
6	2500	2.6	63
7	2750	2.7	63
8	3000	2.7	64
9	3250	2.8	64
10	3500	3	64

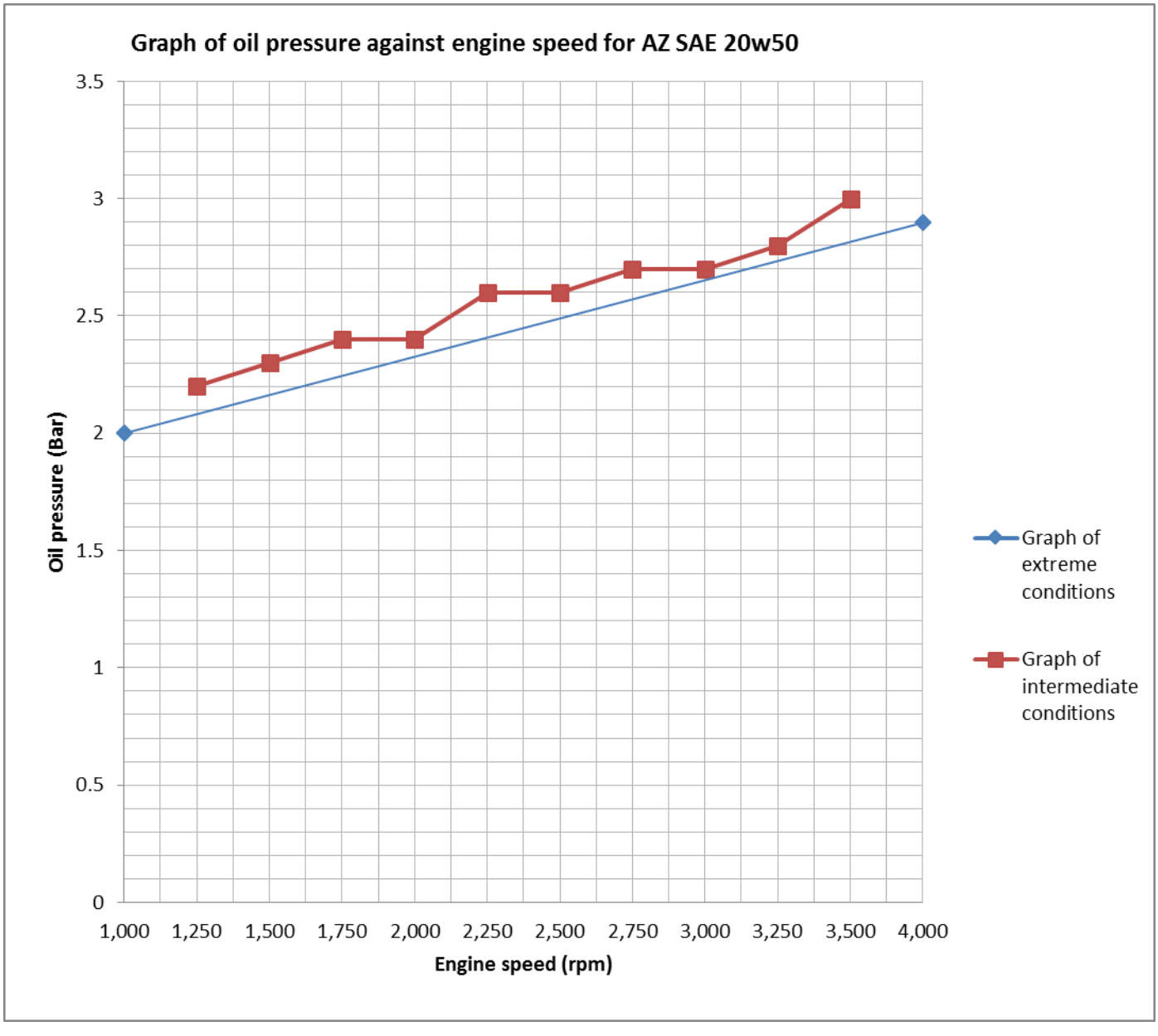


Fig 4.10 Graph of oil pressure against engine speed for AZ SAE 20W50

2. SAMPLE NAME : Total SAE 20W50

Idle Speed : 1000 rpm

Idle Press : 1.80 bar

Max Speed : 4000 rpm

Max Press : 2.90 bar

Temperature : 58 °C

Table 4.11 Pressure Mapping Experiment Result

S/NO	ENGINE SPEED (rpm)	OIL PRESSURE (bar)	OIL TEMPERATURE (°C)
1	1250	2.1	59
2	1500	2.2	60
3	1750	2.3	60
4	2000	2.4	60
5	2250	2.4	61
6	2500	2.5	61
7	2750	2.6	61
8	3000	2.6	61
9	3250	2.8	62
10	3500	3	62

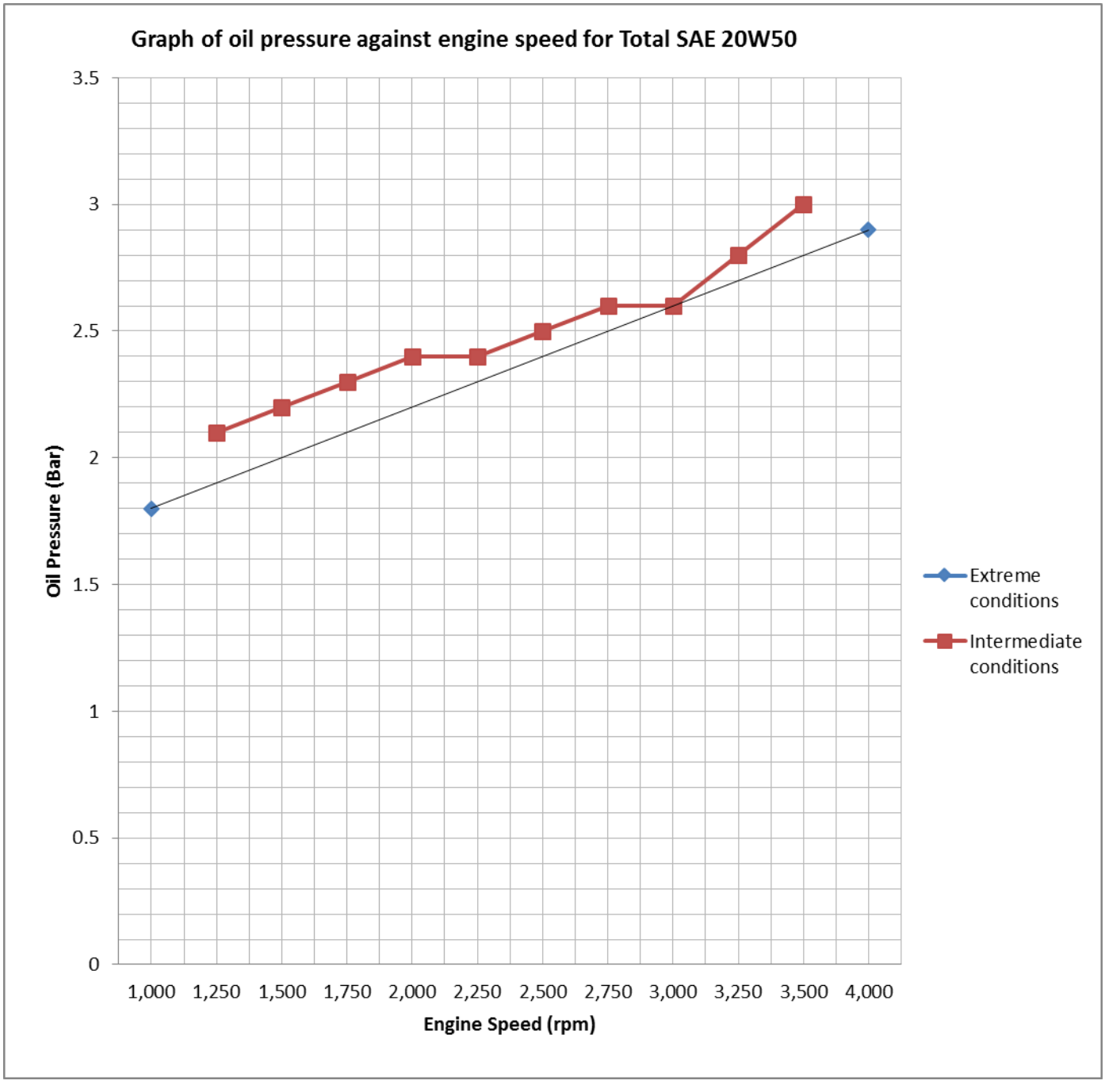


Fig 4.11 Graph of oil pressure against engine speed for Total SAE 20W50

3. SAMPLE NAME : Oando SAE 20W50

IDLE SPEED : 1000 rpm

IDLE PRESS : 1.90 bar

MAX SPEED : 4000 rpm

MAX PRESS : 2.90 bar

TEMPERATURE : 60 °C

Table 4.12 Pressure Mapping Experiment Result

S/NO	ENGINE SPEED (rpm)	OIL PRESSURE (bar)	OIL TEMPERATURE (°C)
1	1250	2.1	60
2	1500	2.2	60
3	1750	2.3	60
4	2000	2.3	60
5	2250	2.4	61
6	2500	2.5	61
7	2750	2.6	61
8	3000	2.7	62
9	3250	2.8	62
10	3500	3	63



Fig 4.12 Graph of oil pressure against engine speed for Total SAE 20W50

4. SAMPLE NAME : Total SAE 40

IDLE SPEED : 1000 rpm

IDLE PRESS : 1.8 bar

MAX SPEED : 4000 rpm

MAX PRESS : 2.8 bar

TEMPERATURE : 55 °C

Table 4.13 Pressure Mapping Experiment Result

S/NO	ENGINE SPEED (rpm)	OIL PRESSURE (bar)	OIL TEMPERATURE (°C)
1	1250	2.1	60
2	1500	2.2	60
3	1750	2.3	60
4	2000	2.5	61
5	2250	2.4	61
6	2500	2.5	61
7	2750	2.6	61
8	3000	2.7	62
9	3250	2.8	62
10	3500	3	62

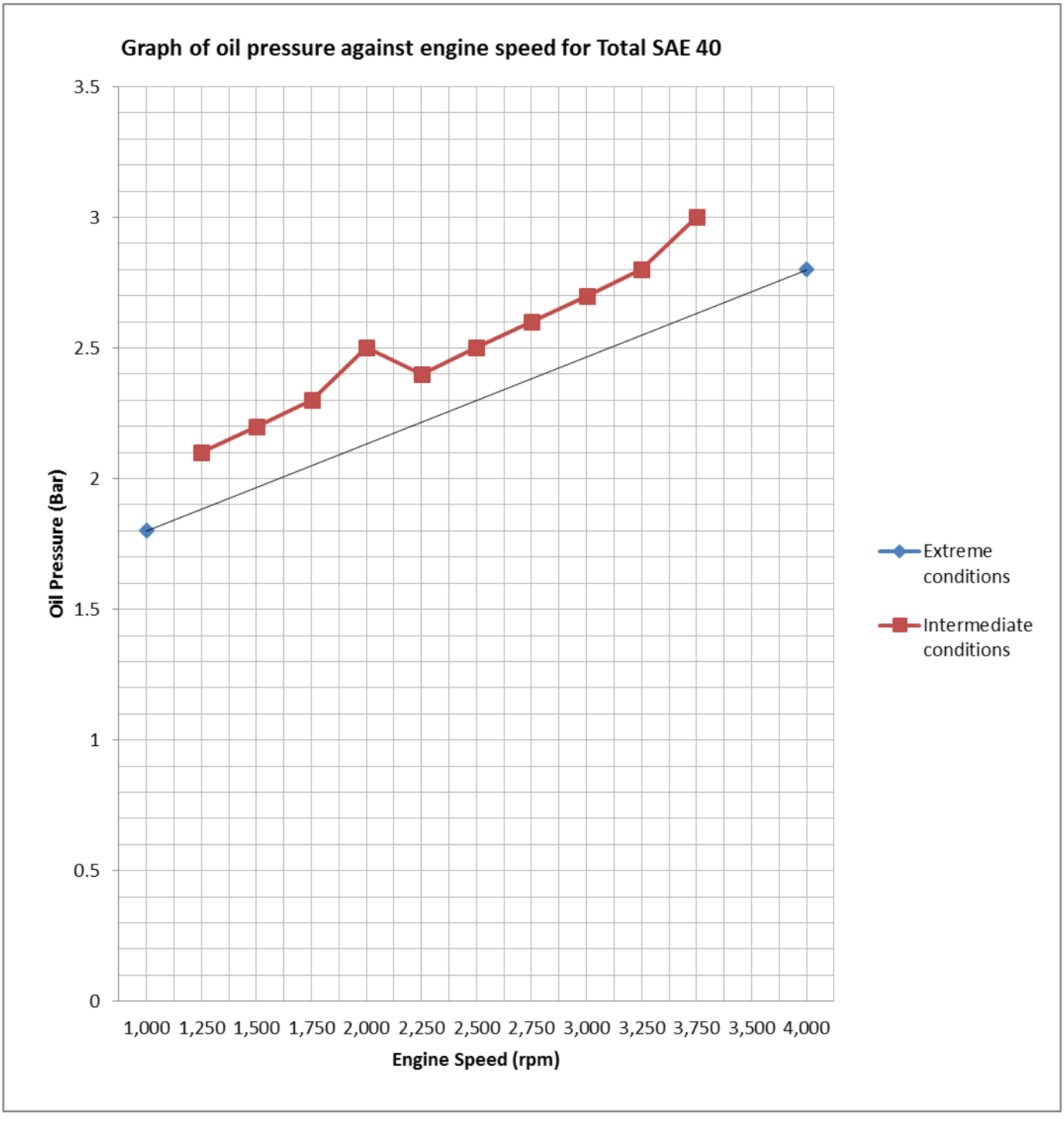


Fig 4.13 Graph of oil pressure against engine speed for Total SAE 40

5. SAMPLE NAME : MOBIL 1, SAE 0W40

IDLE SPEED : 1000 rpm

IDLE PRESS : 1.8 bar

MAX SPEED : 4000 rpm

MAX PRESS : 3.00 bar

TEMPERATURE : 60 °C

Table 4.14 Pressure Mapping Experiment Result

S/NO	ENGINE SPEED (rpm)	OIL PRESSURE (bar)	OIL TEMPERATURE (°C)
1	1250	2.1	60
2	1500	2.2	60
3	1750	2.3	60
4	2000	2.4	61
5	2250	2.5	61
6	2500	2.6	62
7	2750	2.7	62
8	3000	2.8	62
9	3250	2.9	63
10	3500	3	63

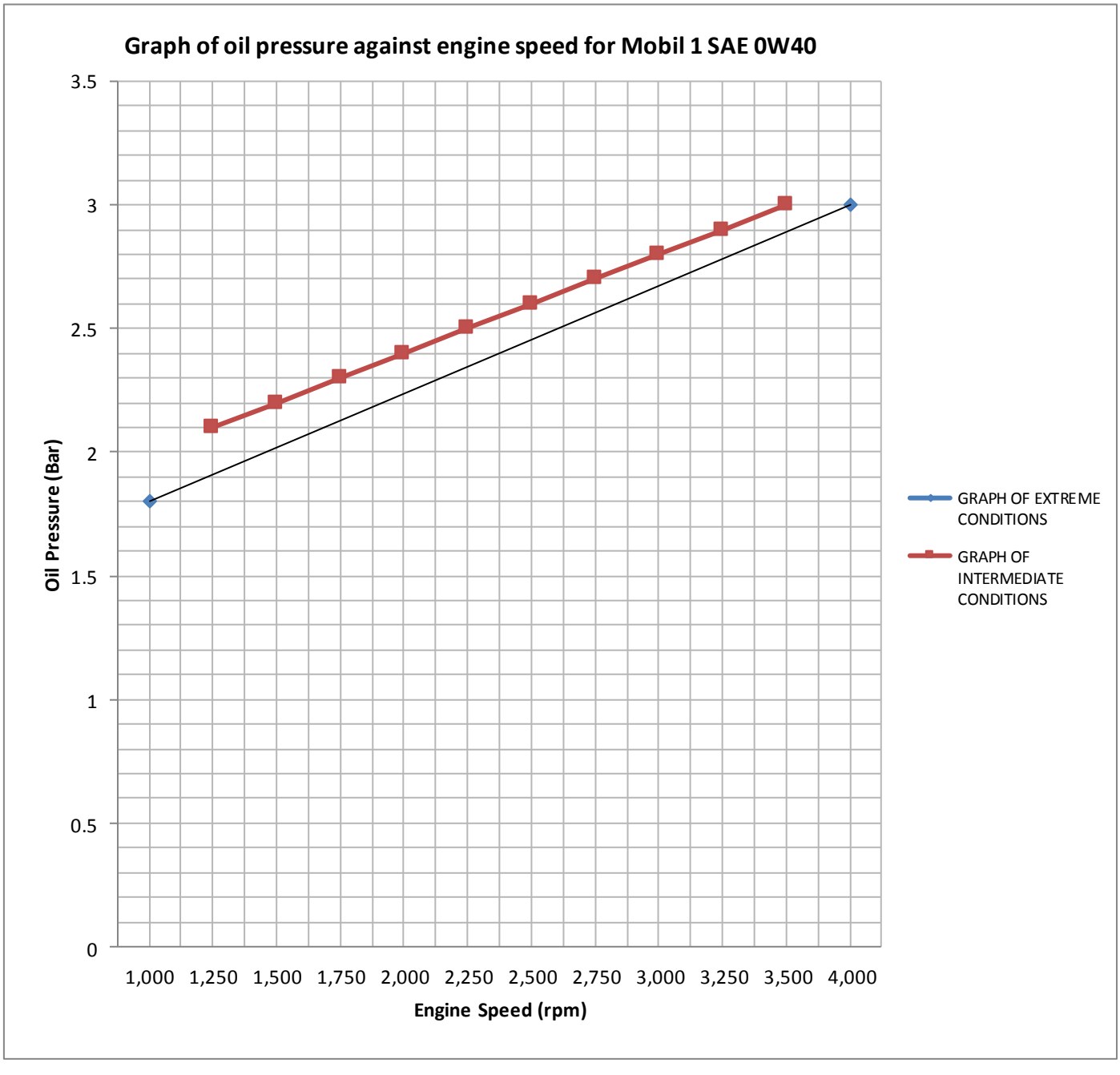


Fig 4.14 Graph of oil pressure against engine speed for Mobil 1 SAE OW40

Table 4.15 Oil pressure at various engine speeds for the 5 samples

S/NO	ENGINE SPEED (rpm)	Mobil 1 SAE 0W40 oil pre (bar)	Total SAE 40 oil pre (bar)	Oando SAE 20W50 oil pre (bar)	Total SAE 20W50 oil pre (bar)	AZ SAE 20W50 oil pre (bar)
1	1250	2.1	2.1	2.1	2.1	2.2
2	1500	2.2	2.2	2.2	2.2	2.3
3	1750	2.3	2.3	2.3	2.3	2.4
4	2000	2.4	2.5	2.3	2.4	2.4
5	2250	2.5	2.4	2.4	2.4	2.6
6	2500	2.6	2.5	2.5	2.5	2.6
7	2750	2.7	2.6	2.6	2.6	2.7
8	3000	2.8	2.7	2.7	2.6	2.7
9	3250	2.9	2.8	2.8	2.8	2.8
10	3500	3	3	3	3	3

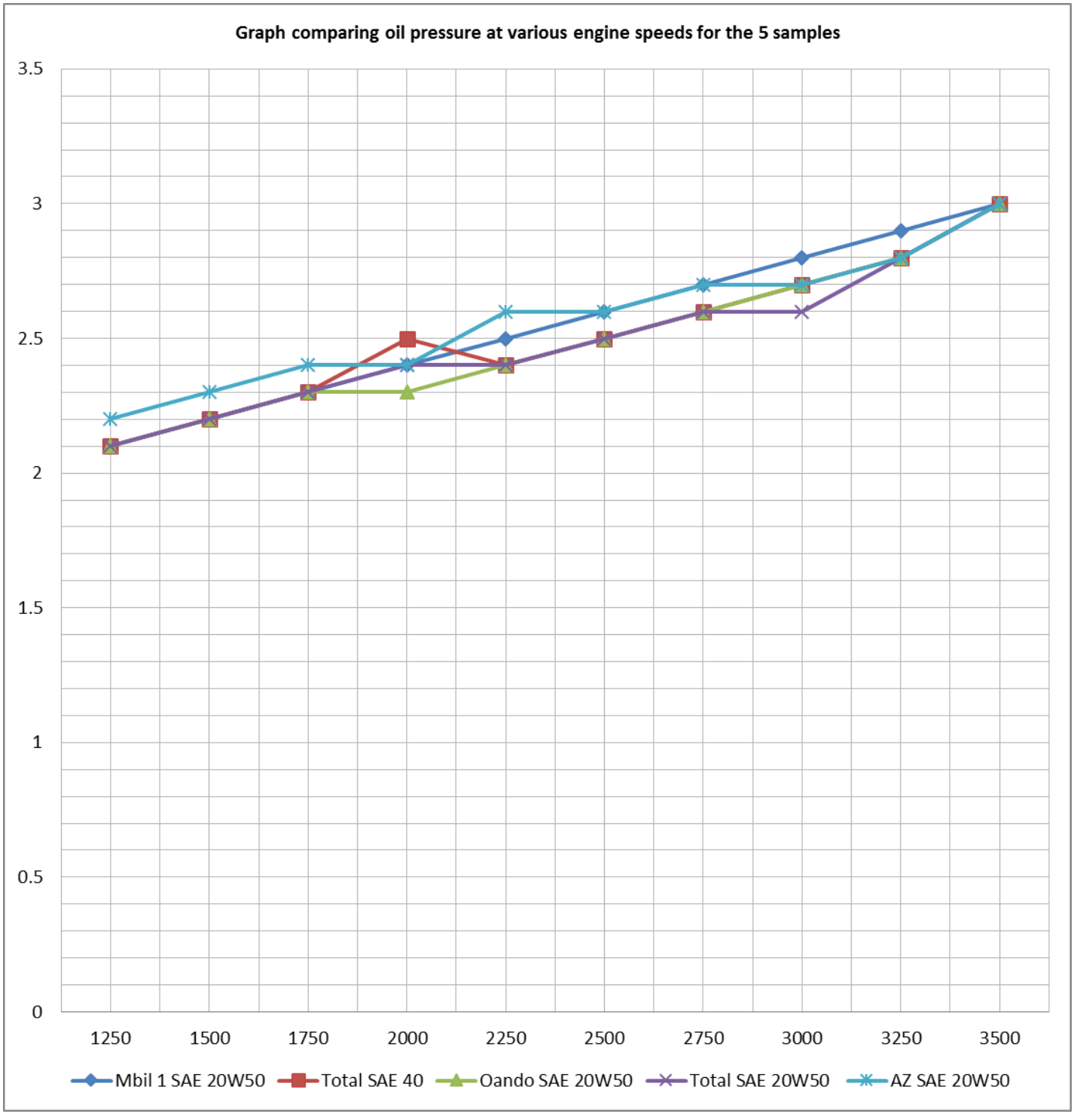


Fig 4.15 Graph comparing oil pressure at various engine speeds for the 5 samples

Table 4.16 Results Comparing Viscosities (cSt) OF Fresh And Spent Oils at 100°C

SAMPLES	VISCOSITY (cSt)	VISCOSITY (cSt)
	FRESH OIL	SPENT OIL
OANDO SAE 20W50	18.00	17.00
TOTAL SAE 20W50	20.00	18.00
MOBIL 1 SAE 0W40	21.20	21.00
TOTAL SAE 40	15.60	12.50
AZ SAE 20W50	19.60	17.50

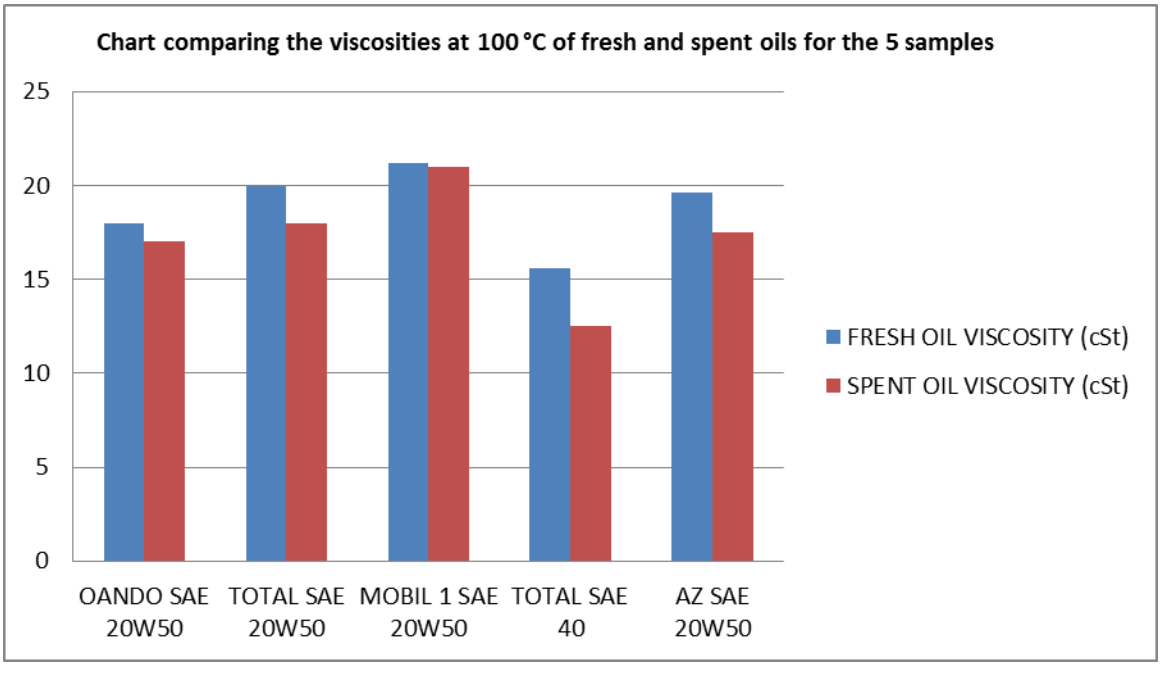


Fig 4.16 Chart comparing viscosities (cSt) of fresh and spent oils at 100°C

Table 4.17 Results Comparing the Carbon Residue of Fresh and Spent Oil.

SAMPLES	FRESH OIL (%)	SPENT OIL (%)
OANDO SAE 20W50	0.95	1.05

TOTAL SAE 20W50	0.90	1.00
MOBIL 1 SAE 0W40	0.60	0.61
TOTAL SAE 40	1.00	1.20
AZ SAE 20W50	0.95	1.00

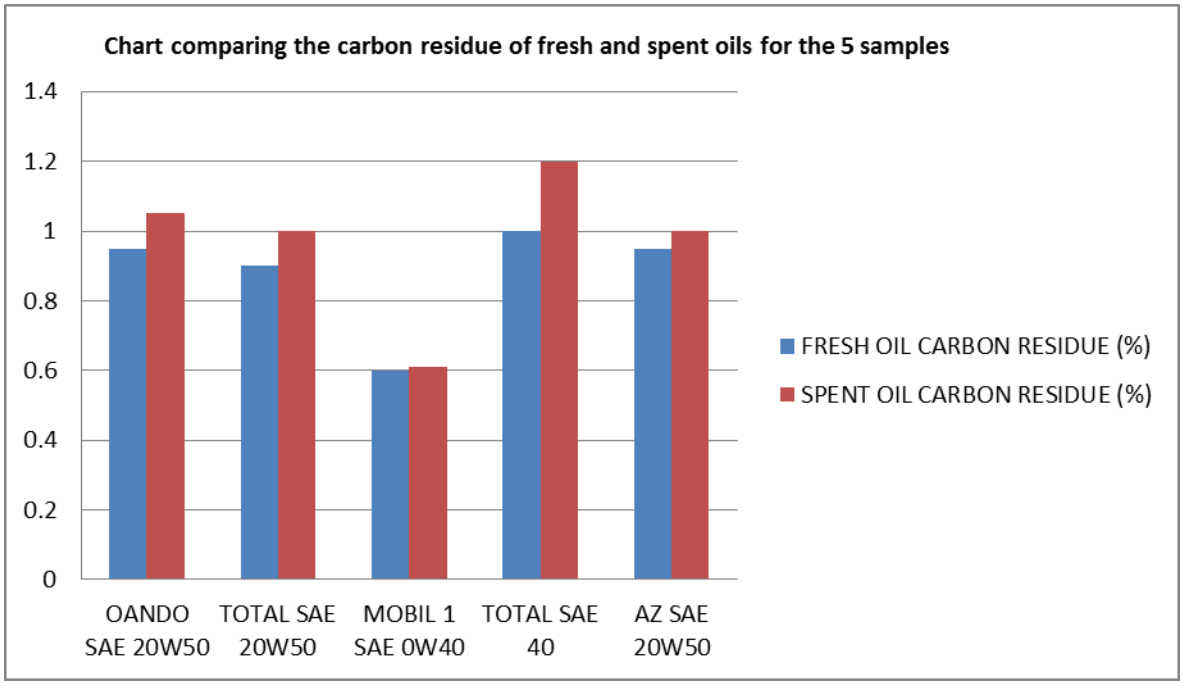


Fig 4.17 Chart comparing the carbon residue of fresh and spent oil

4.2 Discussion

Viscosity:

The viscosity of the lubricants was seen to decrease with increase in temperature but to different extents. The science of viscosity temperature relationship reveals that a molecular view of liquids can give a qualitative picture of the process of decrease in the shear viscosity of a simple fluid with temperature. As the temperature increases, the time of interaction between neighboring molecules decreases as a result of the increased average kinetic energy of the molecules.

The resulting effect is that the intermolecular forces decrease and so does the viscosity.

The phenomenon has mathematical or empirical model representation as below:

The exponential model for the temperature dependence of shear viscosity (μ) was first proposed by Reynold in 1886.

The model $\mu(T) = \mu_0 \exp(-bT)$

Where T is temperature and μo and b are coefficients.

The Arrhenius model $\mu(T) = \mu_0 \exp(E/RT)$ where T is temperature , μ_0 is a coefficient, E is the activation energy and R is the universal gas constant is based on the assumption that the fluid obeys the equation for molecular kinetics.

This remained true in all the experiments carried out during this research.

Mobil 1, synthetic oil was seen to have the lowest viscosity at room temperature of 24.8^0C and highest viscosity at the highest temperature of 100^0C.

Total SAE 40 has the highest viscosity at the lowest temperature and the lowest viscosity at the highest temperature.

Low viscosity at low temperature is an advantage at engine start up where the oil is required to be pumped to the necessary locations for the engine to start. Very high viscosity at room temperature will be a disadvantage in a situation where external heating will be required for the oil to be light enough to flow.

In Nigeria and Africa both oil will flow at room temperature and so are suitable for use in internal combustion engine.

At the high temperature of 100^0C, viscosity of the monograde oil 1s 15 cSt and of the synthetic oil is 21 cSt. Both oils are suitable in internal combustion engine where a temperature of 70 ^{0}C is too high for a normal operation. However in an environment where very high temperature is expected, the synthetic oil is preferred

The other oils: Oando , Total and Az all of 20W50 are multi grade oils whose highest and lowest viscosity at lowest and highest temperature respectively of this experiment fall within the range of those of the monograde and synthetic oils. They are all suitable for use in internal combustion engine.

Pour Point:

The pour point of the oil is the minimum temperature at which the oil can flow or the minimum temperature below which the oil stops flowing.

The synthetic oil was seen to have the lowest pour point of -28^0c and the monograde oil has the highest pour point of -15^0c. The multigrade have -22 ^{0}C and -24 ^{0}C.

In a very cold environment where -10 ^{0}C can be recorded at room temperature, the synthetic oil is preferred. However in Nigeria both oils are suitable for use in internal combustion engine based on the Pour Point Test results.

Flash Point:

The highest flash point noticed was for Oando 20W50 at 175 ^{0}C and the lowest was for Total SAE 40 at 102 ^{0}C .The others are 160 ^{0}C and 170 ^{0}C.

The flash point of 102 ^{0}C is not advisable in a service environment where a high temperature is expected.

In an internal combustion engine where over 90 ^{0}C is expected during abnormal condition of engine overheating, this is not suitable. Under normal working condition, the oils are suitable for use in internal combustion engine.

Carbon Residue:

The carbon residue test carried out revealed that the synthetic oil has the lowest carbon residue of 0.60 % and the monograde has the higher of 1.00%.

High amount of carbon residue is a disadvantage as it amounts to more of sludge formation. This can get the filters easily clogged up thereby increasing the cost of operation. It can also affect the lubricity of the lubricant.

The synthetic oil will serve longer in service followed by multigrade and the least performing oil is the monograde oil.

Pressure Mapping:

The results obtained from the pressure mapping experiment confirm those obtained from the laboratories; that the oils tested in this work are suitable for use in internal combustion engine.

From the procedure, it is appropriate that after noting the pressures at idle and maximum engine speed, oil pressure should then be measured at 10 or more speed intervals equally spaced between idle and maximum engine speed. It is helpful to draw a straight line from the first

reading taken at idle to the last reading taken at maximum engine speed. All the intermediate points on the curve should lie above this line. (Gray and Dan, 2008)

It is seen here that there is a rapid increase in output pressure as engine speed increases until at some critical point where the output drops off again.

The graph of the oil pressure against engine speed agrees with the theory of pressure mapping with the best graph of the pressure mapping as that of the synthetic oil.

All the oils under the stated condition with which the pressure mapping equipment operated are suitable for use in internal combustion engine.

With the help of this pressure mapping equipment so developed in the cause of this research work, the oils have been tested in a way similar to their service environment. Having given a good output /result in this condition is a proof that these oils are good for lubrication in internal combustion engine within the conditions of this experiment.

In all the cases as seen in the results, the synthetic oil is most preferred but putting into consideration the cost of oils as shown on table 1 above, Synthetic oil is less economical as compared to the others followed by the multigrade oils and the most economical is the monograde oil. In any service environment where both oils can serve the desired purpose, the monograde oil is preferred. For instance considering pour point, In Nigeria and Africa all oils flow at room temperature and so the monograde oil is preferred. However in an internal combustion engine where sludge formation, carbon residue, viscosity, corrosion control e.t.c are very important issues, the synthetic oil is still recommended.

4.3 Limitations

1. Inability to integrate sensors on the equipment to sense the properties and quantities measured to convert them to digital values using a transducer for higher experimental accuracy.

2. The inability to test the performance properties or mapping the oil pressure at very high pressure as the engine is fitted with a pressure relief valve. The oils listed here are for internal combustion engines lubrication only.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The experiments undergone in this work have brought about the following conclusions:

1. Pressure mapping Technology has a positive impact on the evaluation of the performance properties of lubricating oils.

2. As stated in the objective of this research that a main method for evaluating lubricants performance properties will be provided, this pressure mapping using this equipment is a fast method for evaluating the performance properties of lubricants in our local market.

3. The results obtained from the pressure mapping experiment confirmed those obtained from the laboratory, concluding that this method is good to be used for the evaluation.

4. That Pressure Mapping Experiment can be used to monitor the lubricants in our local markets.

5. The oils investigated here are all good for use in internal combustion engine with the best performing oil as the synthetic oil and followed by the multigrade and then the monograde.

5.2 Recommendations

1. The synthetic lubricating oils are recommended for use in internal combustion engines because of their outstanding performance properties as compared to the other lubricants. This is followed by the multi-grade oils (TOTAL SAE 20 W 50, Oando 20 W 50, AZ 20 W 50).
2. The pressure mapping equipment developed in this work is recommended for use in the evaluation of the performance properties of lubricating oils in our local market.
3. Pressure sensor should be integrated into the system and a transducer used for digital output display to avoid error due to parallax in taking readings.
4. For quality assurance and monitoring, evaluation of the performance properties of lubricating oils should be regularly carried out.

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