

Research article

Effect of Additives on the Performance of Engine Oil

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Abstract.

This research work was based on the effect of additives on the performance of engine oil. This performance which is a function of the properties include viscosity, density, flash point, colour as well as foaming ability/stability. The additives whose effects were investigated in this research work were B023233 (comprising of anti-oxidant, detergent, dispersant, pour point depressant, anti-corrosion and anti-rust additives) and B23333 which is the viscosity modifier additive. All the laboratory tests carried out were in accordance with the specification of the American Society for testing and materials (ASTM).

The results of the tests obtained from the blend show that the properties- viscosity, density, flash point, increases with increase in additive concentration, while that of the foaming ability decreases as the concentration of the additive increases. **Copyright © IJEATR, all rights reserved.**

Key words: Engine oil, additive, Density, Foaming, Flash point.

Introduction.

Historical Background of Engine Oil.

Engine oil is a basically selected petroleum oil fraction that has been suitably refined and compounded with various types of additive agents to obtain a finished product with the optimum properties for the specific service condition to be encountered. The engine oil is basically classified as the diesel engine oil which is normally marked "C" denoting compression ignition and the gasoline engine oil marked "S" denoting spark ignition¹. The major difference between the two classes is the detergent and the dispersive property of the engine oil. To the diesel engine, the detergent property is of utmost important while in gasoline engine the dispersive property is of much importance.

The primary assignment of engine oil is to lubricate the metal parts of the engine just as the joints of human- the ankle, the knees and the most intricate parts of the body like the spinal cord are been lubricated by the body fluids. Fluids in the human body within the bones lubricate them thereby making them fit and operational and prevent eroding². These fluids do to the joints what engine oil does to the automobile engines. As a result, lubrication was present at the beginning of creation and therefore it is not a product of industrial age².

The use of animal fats, vegetable and olive oils as lubricants in the rolling wheels of carts was developed in the Middle East. This has since advance from the use of animal fat, vegetable and olive oils to refined mineral oil free from unstable compounds which have negative effect on the service life of the bearings. However, in 1947 the inter-industry needs for the system which would include other factors for improved engine oil performance other than viscosity was adopted by the American Petroleum Institute (API), hence the introduction of API classification systems which established three types of crank engine oils as Regular containing no additive, Premium containing oxidation inhibitors and Heavy duty type containing oxidation inhibitors and detergents/dispersant additives⁴.

Consequently, in 1969, the tripartite of the American Petroleum Institute (API), American Society for Testing and Materials (ASTM), and the Society for Automotive Engineers (SAE) cooperated in establishing an entirely new classification system¹⁰. The new classification system was based on engine design and construction, fuel type, operating conditions and the base oil stock. Based oil stock selected became important because the characteristics and performance of the finished oil depends on the crude oil source, the refining method used and the additive incorporated. This new classification enables engine oils to more precisely defined and selected according to their performance characteristics and easily related to the type of service for which each is intended. The system uses letter designations for each category to enable automobile engines manufacturers use the letter to indicate the class or classes of engine oil suitable for the engine¹³.

As at today, there are fifteen classes of API engine service classification systems, eight of which are spark ignition (petrol or gasoline) engines while seven other classes are the compression ignition (Diesel) engines¹³. They are normally identified with presiding letters "S" and "C" meaning spark and compression respectively. Unlike the 1885 ancestors, the challenges for the design of modern car engines were meeting the emission requirements, increased speeding, engine weight reduction, production cost reduction, operating cost and fuel economy, then oils are not oil, just as the modern automobiles have advanced from raw base oil to pre – 1947 to those containing additives to help achieve the performance advantage required by the modern automobile⁵.

Principle of Manufacturing of Base Oil.

The base oil used for the production of engine oils are obtained as distillate from the vaccum distillation. The raw material for this vaccum distillation is the atmospheric residue obtained at temperatures above 380⁰C³. The

products of vacuum distillation include the diesel fuel, the distillate of base oil, asphalt and bitumen. The distillates of the base oil are further treated in the three stages below:

a) **Deasphalting:** This is the process of treating the vacuum residue to eliminate resins and asphaltic substances. These asphaltic substances are extracted from the vacuum residue by treating with propane. The removal of sulphur and oxygen containing compounds improves the colour and quality of the base oil. The extracted asphalt is used in manufacturing bitumen.

b) **Furfural treatment:** The objective of this treatment is to do away with the aromatic substances whose viscosity indexes are low. Furfural is a hydrocyclic aldehyde, which is a by-product of processing cereal wastes in paper-pulp production. Furfural preferentially dissolves hydrocarbons not needed. The base oil obtained has a high viscosity index but this index is also dependent on the type of crude oil processed.

c) **Dewaxing:** The objective of dewaxing is to eliminate the long straight chain paraffinic hydrocarbons called petroleum waxes; These waxes are responsible for the high pour-point when present. The principle of dewaxing is simple; the raffinate is cooled so that the wax in the form of crystal crystallizes which is separated by filtration. However, doing this is difficult because wax and raffinate form a spongy mass that is hard to filter. Solvent dewaxing is preferred since it can dewax stocks from light distillate to heavy residues. The solvent used is a blend of methyl-ethyl ketone and toluene.

d) **Hydro-finishing:** The final treatment is hydro finishing. It means getting rid of the least impurities not yet eliminated in the form of volatile products. These impurities include sulphur, nitrogen and oxygen products. The oil is hydrogenated in the presence of a catalyst at a temperature of 25⁰C and a pressure of 40 bars after which a good quality mineral base oil is obtained. The grade of the base oil obtained include 85, 100, 150, 330, 600NS (neutral solvent) and BSS (bright stock solvent). The NS 85 is of a lower viscosity while BSS is the most viscous of the base stocks. However, 500 NS is a base oil blended of NS 330 and NS 600. This is because this blend is important due to its range of viscosity which its use is important more than the 300 and 600 Neutral Solvents.

Additives.

Additive are materials which are not normally present in an oil and which when added in it, improves its physical and chemical properties. They are used to obtain results not attainable by refining methods alone or to partially replace refining methods; the use of additives gives a desired result in a cheaper and economical way. The primary objectives of additives in the base oil are:

- a) To prevent undesirable changes taking place during services.
- b) To improve the original properties of the product.

Origin of Engine Oil Additives.

The manufacturing of engine oil by conventional refining methods is almost entirely subtractive in its effect. The process is all about removal of certain components thereby concentrating the more desirable hydrocarbons. The method of improving the properties of a substance by adding a small quantity of a foreign material is an old art in many industries. Therefore, it is natural that almost as soon as petroleum oils were used as lubricants, attempts were made to improve their properties by the addition of various other materials.

In 1855 English patent 2668 were issued covering, the addition of small amount of rubber to petroleum oils to improve the lubricating properties⁵. This was followed by a number of other patents taken out in different countries and covering the mixture of various types of material to petroleum products to improve their properties in

one way or the other. However, it has only been in the last five to six decades that any systematic study has been made on this subject.

In 1922 Mourea and Dufraisse published the first of a series of papers describing the study of oxidation of organic compounds and its inhibition. During the course of the study of the properties of acrolein, they discovered that adding traces of certain other materials could inhibit the oxidation of this very unstable compound⁶. This made them to extend their investigation to petroleum oils and discovered that it could be stabilized against oxidation by addition of small amount of other compounds.

Between 1930 to 1940, there was at least one stabilized turbine oil in the market, additives for depressing the pour point of lubricating oil was also introduced commercially at this time. This was also followed by special additive for prevention of bearing corrosion by motor oils. Since 1935, there has been progressive development in the use of chemical additives to enhance engine oil performance⁷.

Types of Additives.

a) Anti-oxidants: It would be highly desirable if the engine oil could maintain its original physical properties without a change for an infinite period of time. However, the hydrocarbon nature of petroleum oil makes it readily susceptible to oxidation, particularly when subjected to high temperature in the presence of certain oxidation catalysts which are usually associated with its use. Oxidation of petroleum oil results in marked changes taking place in both its physical and chemical properties. The oil becomes more viscous in nature; it develops corrosive acid and deposit insoluble sludge and lacquer-like material. Anti-oxidants are meant to inhibit the deterioration of oils by oxidation during service. Some anti-oxidants are meant to stabilize the oil under relatively mild conditions while some are meant to stabilize the oil that will encounter high temperature and severe conditions. This work is based on the later since the lubricants used in the internal combustion engines encounter temperatures of the order of 150 – 250⁰C in the piston zone and much higher than this in the combustion chamber itself. Examples of this anti-oxidants are dithiophosphate, 2,3- tert-butyl para cresol etc.

b) Detergents: The rapid development of the small high-speed diesel engine during the past decade has been accompanied by the evolution of the so called “detergent” or “heavy duty” type lubricating oil designed to prevent excessive piston and ring zone deposits which were found to be prevalent in this type of engine. Materials of this type are generally molecules having a large hydrocarbon tail and a polar head group. The tail section, an olephilic group serves as a stabilizer in the base fluid, while the polar group is attracted to contaminants in the lubricant. Although these compounds are commonly called detergents, their functions appear to be dispersing of the particulate matter rather than cleaning up existing dirt and debris. Therefore, it is more appropriate to classify them as dispersants. Examples are sulphates, salicylates, phenates and phenol sulphide salts.

c) Dispersants. A major development in the additive field was the discovering and the use of ashless dispersants. These materials may be categorized into two broad types; high molecular weight polymetric dispersants used to formulate multigrade engine oils and lower molecular weight additives for use where viscosity modification is not necessary. Examples of these dispersants are high molecular weight esters, high molecular weight alkylated phenols, polymetric dispersants etc.

d) Anti-wear additives. Wear is the loss of metals with subsequent change in clearance between surfaces moving relative to each other. If continued, it will result in equipment malfunction. Among the principal factors causing wears are metal to metal contact, presence of abrasive particulate matters, and attack of corrosive acids. Example of material used here to prevent wear is dithiophosphates.

e) Viscosity modifiers. Viscosity modifiers or viscosity index improvers as they were formally known, comprises a class of materials that improves the viscosity/temperature characteristics of the lubricant. This modification of rheological properties result in increased viscosity index of the engine oil. Viscosity modifiers are generally oil soluble organic polymers with molecular weight ranging from about 10,000 to 1 million.

f) Antifoam agents. Oil foaming was not formally considered a problem, but with the use certain additives which seems to stabilize form, and with changes in engine design it has become serious in recent years. Excessive foaming of engine oil may cause failure of feeding mixtures of oil and air to the pressure pumps, or by displacement and loss of oil from the lubricating system, or by giving erroneous reading of oil level in the oil and air pressure pumps, or by giving erroneous reading to the oil level in the supply system. Anti-foam agents prevent foaming by destroying bubbles when they reach a free surface almost as rapidly as they are formed. Many materials have some anti-foaming ability, the most effective product so far found are the silicon polymers (polymethylsiloxanes) and these have found extensive use in engine oils.

Materials and Methods.

Determination of the kinematic viscosity of blended base oil.

Base oils, NS 150 with lighter viscosity (60.68%wt), NS 500 with heavier viscosity (21.32%wt) were blended with some additives B023232 (14.2%wt) comprising anti oxidant, detergent, pour point depressant, anti-foam agent) as well as a viscosity modifier B23333 (3.8%wt). The blended oil was pour into a viscometer and placed in a bath and allowed for some time to ensure bath equilibrium temperature was attained. The bath could be maintained at 40⁰C or 100⁰C. When the temperature was attained, the head level of the test sample was adjusted using a suction pump to the capillary of the viscometer above the first timing mark. The stop watch was started when the meniscus of the sample was at the upper timing mark, and when the meniscus got to the lower timing mark, the stop watch was stopped and the timing was recorded. The test was repeated and two values of time that did not differ by 0.4% were obtained and the average kinematic viscosity was calculated and recorded.

Note: NS – Neutral solvent, BSS – Bright stock solvent

Determination of the density (specific gravity) of the blended base oil.

The sample was poured into a clean measuring cylinder and the accompanying air bubbles were got rid of. The sample was stirred continuously with a thermometer and the temperature was recorded to the nearest 0.25⁰C immediately the sample stabilized. Once the thermometer was removed, the hydrometer was depressed about two scale division into the oil and it was released. Sufficient time was allowed for the hydrometer to remain stationary and at this point the reading was taken. The actual value of the specific gravity was read at 15⁰C from the petroleum measurement table using the value obtained from the experiment at the observed temperature.

Determination of the flash point of the blended base oil.

At room temperature, a Cleveland cup was filled with the oil sample up to the specified filling point. The bulb of the thermometer was immersed in the sample. The oil was then heated at a temperature of 9⁰C to 11⁰C. At every rise in temperature, a small flame was passed over the sample. When a flash occurs, the temperature reading is taken as the flash point of the sample.

Determination of the colour of the blended oil sample.

The sample container was filled to about 50mm with distilled water and placed in one of the two compartment of the Lavibond colour comparator. The oil sample was placed in the second container and placed in the remaining compartment. The containers were locked to keep away from external light. The light source was switched on and the colour of the sample was compared with that of a standard sample by varying the knob of the comparator. When the standard and the sample assumed a uniform colour, the reading on the knob was taken as the colour of the blend.

Determination of the foaming ability/stability of the bended oil sample.

About 190 ml of the oil sample was poured into 1000ml graduated cylinder with the aid of a glass rod or a thermometer to avoid air bubbles or mess on the side of the cylinder. The oil sample was heated to a temperature of $46^{\circ}\text{C} - 52^{\circ}\text{C}$ after which the cylinder was placed in thermostatic bath and allowed to cool at a temperature of 24°C . The water level in the bath was maintained at about 900ml. Air was bubbled through the oil for 5 minutes and the foam height was recorded, also the height after 10 minutes foam collapse period was also recorded. The height was the foaming ability whereas its height after the 10 minutes foam collapse was the foaming stability.

Results and Discussions

This section has the results of the experimental works reported above. For ease of understanding, the results were tabulated and graphically presented below.

The effect of the additive on the engine oil properties is presented below. These properties include physical properties – colour, viscosity; physiochemical properties – dispersant power, reduction of friction and wear, antirust and resistance to foaming; chemical properties - resistance to oxidation and corrosion.

Viscosity is the measure of the flow of fluid at a definite temperature. Table 1.1 below shows the result of the experimental work obtained on the effect of additive concentration on the kinematic viscosity at 100°C . From the table, it was observed that the viscosity of the blend at 100°C increases as the additive concentration increases. These viscosity cannot be neglected, it has to be taken into account so as to keep the engine oil blend within the chosen SAE range of 16.5 – 17.5. The result presented in table 1.1 below conforms to this range.

Fig 1.1 below shows the plot of table 1.1. The plot is almost a curve showing that the higher the concentration of the additive in the oil blend, the higher the viscosity until at a particular point on the graph, 15.58 cst, the increase in viscosity dropped. It means that after this point, no matter the quantity of additive added into the oil blend, no appreciate amount of viscosity increase will be recorded.

Density could be defined as the mass per unit volume of a substance. Density is of paramount importance in engine oil to ensure effective and efficient working of the engine oil. Table 1.2 shows the experimental result of the effect of additive on the density of the oil blend at a particular temperature. The table expressed that the more the additive concentration on the oil blend, the higher the density of oil. The test temperature for the density is 15°C and the ASTM specification for the density of multigrade engine oil falls within the range of 0.886 – 0.906. The result in table 1.2 conforms to this range.

Fig 1.2 below is a plot of the density against the additive concentration, the plot is linear showing that the more the additive concentration in the oil, the higher the density. From the plot, it was observed that at the density of 0.8870, further increase in the additive concentration does not produce further increase in density.

Flash point is the lowest temperature of the engine oil at which the application of a test flame causes the vapour of the oil to ignite under a specified condition of test. Flash point is just a specific value for safe guard. Table 1.3 below shows the experimental result of additive concentration on the flash point of the blended engine oil. According to the table, increase in additive concentration increases the flash point of the oil.

Fig 1.3 below which is a plot of flash point against additive concentration confirms the increment. The plot is a linear graph showing that the more the additive concentration in the blended oil, the higher the value of this flash point temperature. Much additive should be avoided to maintain a safe flash point when blending oil wit additive. .

In automobile and aircraft engines, the foaming phenomenon brings about lubrication problems since the presence of gas (air bubbles) in the oil makes it impossible to know the actual quantity and quality of the oil in the engine, and this can lead to inefficiency of the engine. Table 1.4 below shows the experimental result of the effect of additive on the foaming property of engine oil. The table shows a decrease in foaming ability of the oil as the additive concentration increases. This is also confirmed by the plot of the foaming ability against the additive concentration (Fig 1.4 below). The graph is a negative one showing that no matter the volume of the foam, increase in additive concentration will gradually die down the foam.

On the stability of the foam formed, the engine oil blend after 10 minutes of disconnecting the source of air into the diffuser, there was no foam present in it since the sample decreased to its original value. Any increase in the volume of the test sample would have been as a result of the foam present in the engine oil.

Fig 1.1: Plot of additive concentration vs viscosity at 100⁰C. Additive is B023232 (composed of anti oxidant, detergent, pour point depressant, anti-foam agent).

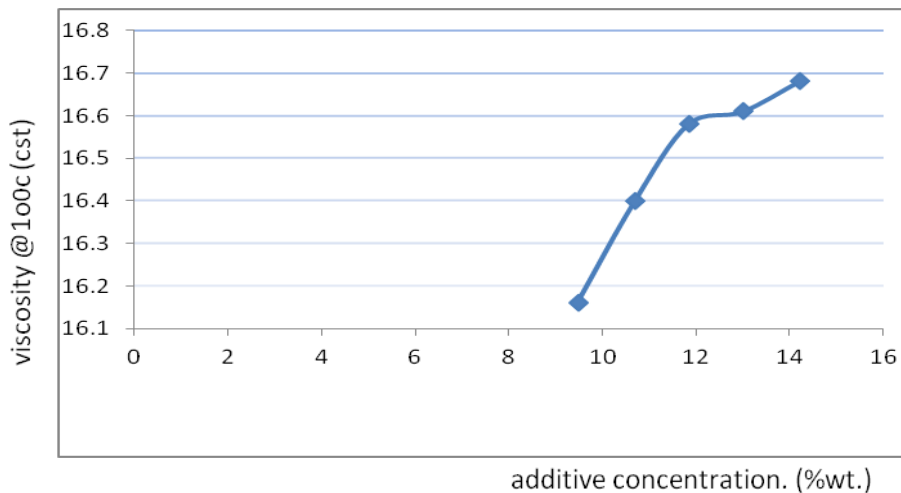


Fig 1.2: plot of density at 15⁰C against additive concentration (% wt)

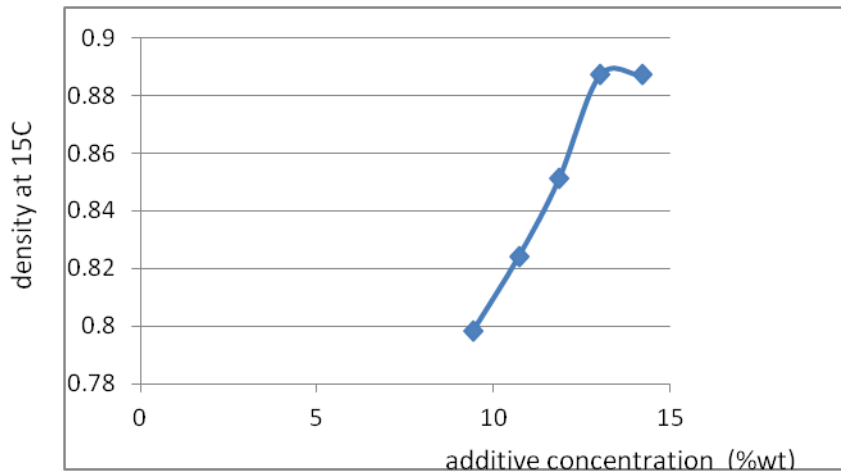


Fig 1.3: Plot of flash point (⁰C) against additive concentration (% wt)

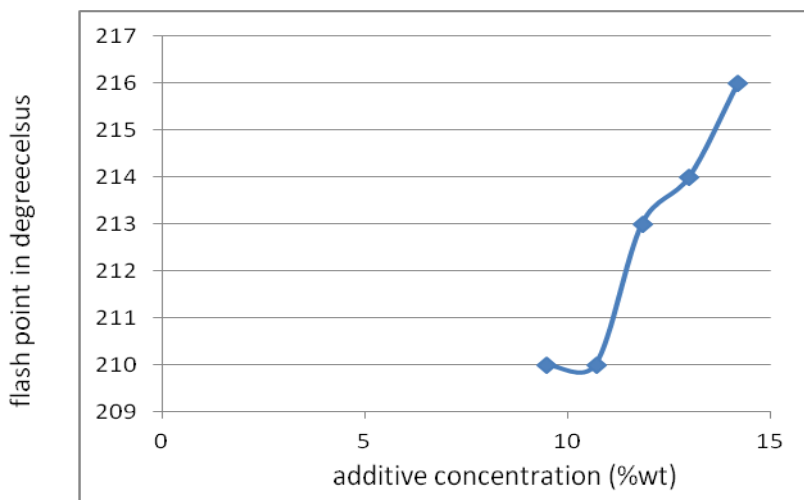


Fig 1.4: plot of foaming ability against additive concentration (ppm)

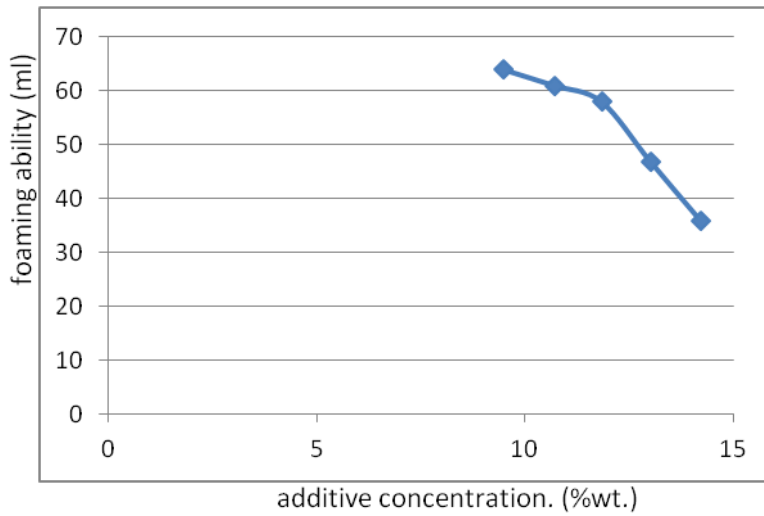


Table 1.1: Effect of additive concentration on the kinematic viscosity at 100⁰C. Additive is B023232 (composed of anti oxidant, detergent, pour point depressant, anti foam agent).

Additive concentration (% wt)	Viscosity@100 ⁰ C (Cst)
9.47	16.16
10.70	16.40
11.84	16.58
13.00	16.61
14.20	16.68

Table 1.2: effect of additive concentration on the density at observed temperature and their corresponding values at 15⁰C.

Additive conc. (% wt)	Density at observed temp. (kg/l)	Density at 15 ⁰ C
9.47	0.790 @27.5 ⁰ C	0.7980
10.70	0.817 @26 ⁰ C	0.8240
11.84	0.840 @32 ⁰ C	0.8509

13.00	0.861 @28.2 ⁰ C	0.8870
14.20	0.880 @26 ⁰ C	0.8870

Table 1.3: Effect of additive conc. On the flash point.

Additive concentration (% wt)	Flash point (⁰ c)
9.47	210
10.70	210
11.84	213
13.00	214
14.20	216

Table 1.4: Effect of additive conc. On the foaming ability/stability.

Additive conc. (% wt)	Foaming ability (ml)	Foaming stability (ml)
9.47	64	0
10.70	61	0
11.84	58	0
13.00	47	0
14.20	36	0

Conclusion.

Having carried out this research work, it is imperative to state that additives used in this research work proved compatible when blended with the two neutral solvents (base oils). It is recommended that additives should be used to achieve the desired properties of the engine oil for enhanced engine performance.

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References.

- [1] Wikins, A. J., Hannington, N. A, 1990, “The Effect of Fuel Oil Additives on Automobile Catalyst Performance”, Johnson Matchey Catalytic Systems Division, Royston, 34(1), Pp 16-24
- [2] Vandiray, A., Manivasagam, k., Sreenivasan, S. V, 2012, “Effect of Nano Oil Additive Proportions on Friction and Wear Performance of Automobile”, Tribology in Industry, No I, Vol 34, pp 3-10.
- [3] Soveran, D. W., Sulatisky, M., Ribson, K. W, “The Effect of Diesel Engine Emissions with High Cetane Additive from Biomass Oils”, ORTECH International, 2395 Speakman Drive Mississauga, Ontario, Canada.
- [4] Lin, C.J., Huagg, J.C., 2003, “An Oxygenating Additive for Improving the Performance and Emission Characteristics of Marine Diesel Engines”, Ocean Engineering, 30, 1699-1715.
- [5] Elliot, A, Evans. 1963, “Lubricating and Allied Oils”, Chanpmans and Wall Ltd London, 4th Edition.
- [6] Kishore, R. A., Nadkarni, 2000, “Guide to ASTM Test Methods for the Analysis of Petroleum Products”, E Lubrizol.
- [7] Raymones C., Guather, 1972, “Lubrication”, Bailey Brother and System Ltd, UK.
- [8] Alphore,S, 1968, “Motor Oil Engine Lubricants”, Scientific Publications (GB), UK.
- [9] Samuel, D. L, 1997, “Lubricants”, Review for Petroleum Technology, 5th Edition.
- [10] ASTM, 1937, “Standards on Petroleum Products and Lubricants’.
- [11] ASTM, 1999, “Research Report PR-D02 Cold Starting and Pumpability Studies in Modern Engines”.
- [12] Proceedings of the 7th World Petroleum Congress, 1967, Elsevier Publishers Co. Ltd, Vol 4.
- [13] AP News, 2000, “Magazine of African Petroleum Plc”, No 2, Vol 21.
- [14] Total News, 2000, “Magazine of Total (Nig) Plc”, No 74.
- [15] Lubrizol, “Lubrication Theory and Practice’, Http// www.lubrizol.com.
- [16] ASTM, 2000, “Publication on Product and services”.