

VARIATION IN RHEOLOGICAL PROPERTIES OF ENGINE OIL WITH USAGE

J. C. OFODU and C. ANOSIKE

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ABSTRACT

The variation in the rheological properties of engine oil with usage was examined in this study. The parameters considered include: the kinematics viscosity, viscosity index and specific gravity. These properties of lubricating oil tend to degrade in quality with usage. This study gives a relationship between the stated properties and distance covered for a commonly used car in Nigeria (fairly used Honda Accord of 1988 model). The relationship so obtained is represented in the form of a linearized model to enhance prediction.

KEYWORDS: Rheology, viscosity, friction and lubrication.

NOMENCLATURE

σ	specific gravity
ν	kinematics viscosity (cSt)
ν_{40}	kinematics viscosity at 40 °C
ν_{100}	kinematics viscosity at 100 °C
VI	viscosity Index

viscous oil to 1000 molecular weight for very viscous fluid. The main rheological property of engine oil is its viscosity. This is so because it's the only property among others like density, elasticity, shear rate, stress and strain, viscosity index etc, that determines to a large extent, the flow characteristic of the engine oil. These properties are highly important for transportation, lubrication and other plant related processes. The engine oil viscosity is the capability of the engine oil to resist flow. It should be noted that all other rheological parameters are tied to the viscosity, hence, the determination of its value for engine oil with usage, other parameters mentioned above can be numerically worked out.

INTRODUCTION

In engineering practice, the relative motion of two or more metal surfaces in contact with each other often results to friction, heat generation and wear of the rubbing parts or surfaces. These problems have long been solved simply by applying a known property fluid between the two or more rubbing surfaces, known as lubricant. The art of doing this, that is, application of lubricant between the concerned surfaces is called lubrication. Due to the special properties (viscosity, density, etc.) of this lubricant it tends to prevent friction, wear and adhesion. At the same time it aid in load distribution, prevent corrosion and in some cases cool the moving elements.

Lubricating oils are of varied types ranging from, petroleum fluid, synthetic fluids, greases, solid films; working fluids, animal fat, metallic and mineral films, vegetable oils etc. In Nigerian, most vehicles where designed to be lubricated with petroleum fluids because chemically, they are more stable and simpler than their other counterparts. Petroleum fluid consists essentially of complex mixtures of hydrocarbon molecules of different sizes and types. The carbon molecule content varies approximately from 20 to 70. The molecular weights ranges from, 250 for low

LITERATURE

A number of studies have been carried out with respect to characterization, ageing etc of rheological property of some selected crankcase oils, and their effects on the wear patterns on engine components. Umesi (1995), carried out a research on recycling used oil of an internal combustion engine. From his analysis, the viscosity of three samples of an automobile crank case lubricant decreased with increase in the distance at which the samples were taken.

Ofunne et al (1991), studied the effects of temperature on the chemical characteristics of automotive crankcase oils and their base oils. This was achieved by simulating the hot spot temperatures of parts of the engine which ranges from 90 °C at the connecting rod and cylinder head to 426 °C at the piston crown. It was noticed that at temperature above 260 °C polumerisation results, which plays a significant role in the variation of the rheological property. Their result

showed that both the engine oils and their based oils is sensitive to temperature increase. It was concluded that the temperature of the surface of internal combustion engines plays a leading role in the deterioration of the lubricating oil.

Rashid (1996), investigated the effects of a number of process variables (shear rate, temperature, pressure) on heavy oil and heavy oil emulsions. Other parameters studied include the influence of pre-treatment and the role of variable amounts of water on the rheological property of oils. Kokal et al (1992), carried out a research on the rheological behaviour of emulsions at different percentage of oil in water by altering the shear stress, temperature and pressure. The result indicated that emulsions containing up to 50% oil are Newtonian in behaviour while emulsions with larger amounts of oil are non-Newtonian. Najji et al (1992), developed a mixed model to predict frictional forces in thermo-hydrodynamic lubricated contacts with non-Newtonian fluids. This model takes into account the implicit rheological laws and has shear stress field as one of its vital parameters.

Oxidation of engine oils give rise to distortion of rheological and chemical characteristics of oils under high temperature conditions. Korcek et al (1986), found that, to obtain high performance of lubricants under severe operating conditions of high temperature and engine speed, anti-oxidants and other additives are added to their base oils to

reduce the rate of deterioration of these oils. They also warned that these additives and anti-oxidants have a negative effect on the oils because they break down and form volatile acids and sludge.

Ofunne et al (1989), studied the aging characteristics of two competing engine lubricants, mono-grade and multi-grade oils. It was found that the rheological ageing of these oils was mainly by oxidation, decomposition and polymerization. The multi-grade oils ages faster than the mono-grade oils and it was also noticed that the final acidity of the oxidant and the volatiles were also higher for the multi-grade which polymerizes to form deposits. Gonsel et al (1988), reported the mechanism of degradation in mineral based engine lubricants. It was found that the degradation of lubricant is a stage wise act that continues till the last stage of its degradation, which is deposit on the engine surfaces.

Maduako et al (1996), recently carried out an extensive research on the role of metals in the oxidative degradation of automotive crankcase oils. Metals usually find their way into the oil either as wear or through additives. It was concluded that the presence of these metals catalysis the hydrocarbon auto-oxidation. In this present study, the degradation in the rheological properties such as viscosity, with usage (distance covered) in a commonly used vehicle (1988 fairly used Honda Accord) in Nigeria is investigated.

Table 1: Kinematics Viscosity Values with Distance covered

Samples	Date	Distance covered (km)	Average kinematics Viscosity @ 40 °C (cSt)	Average kinematics Viscosity @ 100 °C (cSt)
1	04 - 09 - 2001	00000	158.4	15.0
2	04 - 09 - 2001	01500	149.5	13.6
3	12 - 09 - 2001	03000	140.2	12.9
4	29 - 10 - 2001	04500	128.1	11.1
5	25 - 11 - 2001	06000	118.9	9.2
6	30 - 01 - 2002	07500	112.9	8.3
7	18 - 02 - 2002	09000	105.1	6.4
8	30 - 03 - 2002	10500	94.2	5.9

Table 2: Specific Gravity and Density with Distance covered

Samples	Date	Distance covered (km)	Specific Gravity	Density (kg/m ³)
1	04 - 09 - 2001	00000	0.8964	0.8956
2	04 - 09 - 2001	01500	0.8974	0.8966
3	12 - 09 - 2001	03000	0.8983	0.8975
4	29 - 10 - 2001	04500	0.8995	0.8987
5	25 - 11 - 2001	06000	0.8998	0.8990
6	30 - 01 - 2002	07500	0.9014	0.9005
7	18 - 02 - 2002	09000	0.9163	0.9155
8	30 - 03 - 2002	10500	0.9325	0.9317

Table 3: Viscosity Index with Distance covered

Samples	Date	Distance covered (km)	Viscosity Index (100%)
1	04 - 09 - 2001	00000	94
2	04 - 09 - 2001	01500	83
3	12 - 09 - 2001	03000	88
4	29 - 10 - 2001	04500	58
5	25 - 11 - 2001	06000	17
6	30 - 01 - 2002	07500	-13
7	18 - 02 - 2002	09000	-175
8	30 - 03 - 2002	10500	-350

This important property of lubricating oil, which is known to degrade in quality with usage, is better predicted to aid proper replacement.

EXPERIMENTAL

A vehicle was serviced; hence the old oil was changed with a new lubricant (AP Super-V SAE 20). The remainder of this lubricant was taken as the first sample, that is, the servicing of the vehicle formed a datum point from which all other sample collections followed at intervals of 1500 km. The proceeding samples were collected by draining some quantity of the oil from the oil sump drain point, located on the underside of the oil sump. After the sample was collected, the sump was tightly shut to prevent leakage of engine oil. These samples were taken to the Research and Development (R&D) department of the Nigerian National Petroleum Corporation (NNPC) for analysis. A total of eight samples were analyzed.

MATERIALS

The viscosity values of lubricant (samples taking at different kilometers covered) were determined using viscometer. This equipment has the capability to measure the viscosity at different temperature ranges (40 °C and 100 °C). Why a hydrometer was used to measure the specific

gravity of the lubricant sample. Note that, the viscosity of the sample at 40 °C is a measure of the lubricants ability to resist shear flow under gravity at 40 °C. This was measured by means of a viscometer in combination with a 40 °C bath of water. The viscometer consists of a glass capillary with a bulb at one end. This bulb is calibrated at two points, so that the volumes between these two points are known. Other instruments used include; a suction device, thermometer, electronic stopwatch, and viscometer holder.

PROCEDURE FOR VISCOSITY DETERMINATION

The viscosity was determined by using the Standard American Society for Testing and Materials (ASTM) 445 method. It was determined by measuring the time required for a fixed volume of the lubricant to flow under gravity through a capillary of the calibrated glass viscometer at 40 °C. The time of flow in seconds is multiplied by the viscometer calibration factor c (0.2178), to obtain the kinematics viscosity ν .

Performing a similar experiment at temperature bath of 100 °C gives the lubricants ability to resist shear flow under gravity at 100 °C.

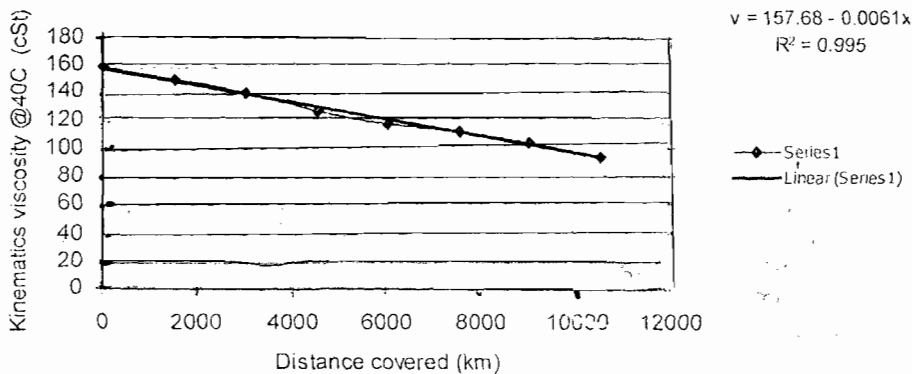


Figure 1: Plots of Average Kinematics viscosity @40 C against Distance covered (km)

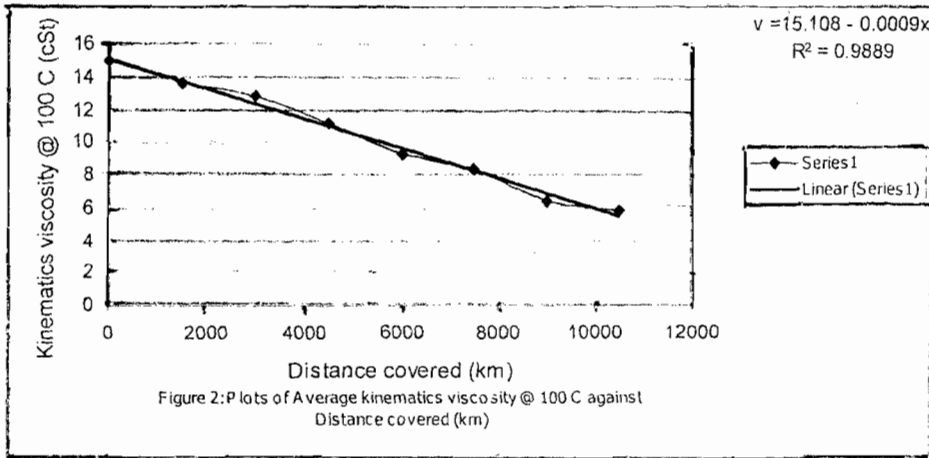


Figure 2: Plots of Average kinematics viscosity @ 100 C against Distance covered (km)

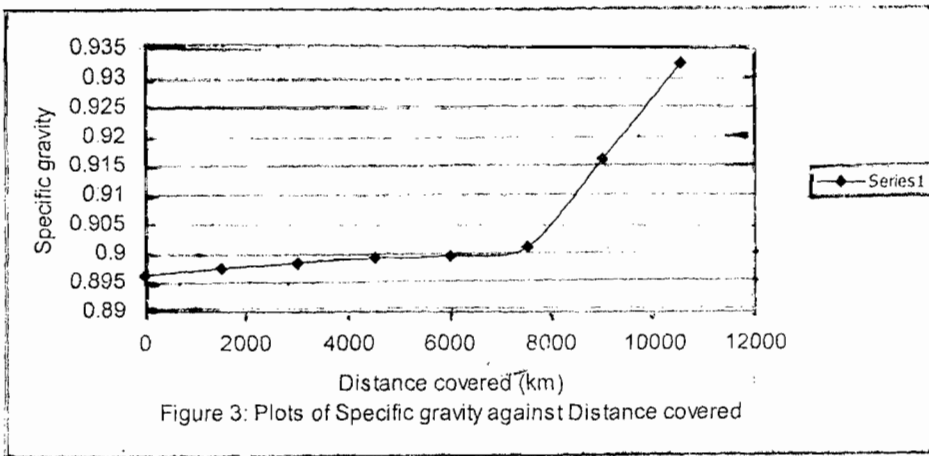


Figure 3: Plots of Specific gravity against Distance covered

SPECIFIC GRAVITY

The specific gravity w of a lubricant is the ratio of the mass density of a lubricant at 15 °C to the mass density of equal volume of pure water at the same temperature.

$$\sigma = \left[\frac{\text{Density of lubricant}}{\text{Density of equal volume of water}} \right]_{at 15^\circ C}$$

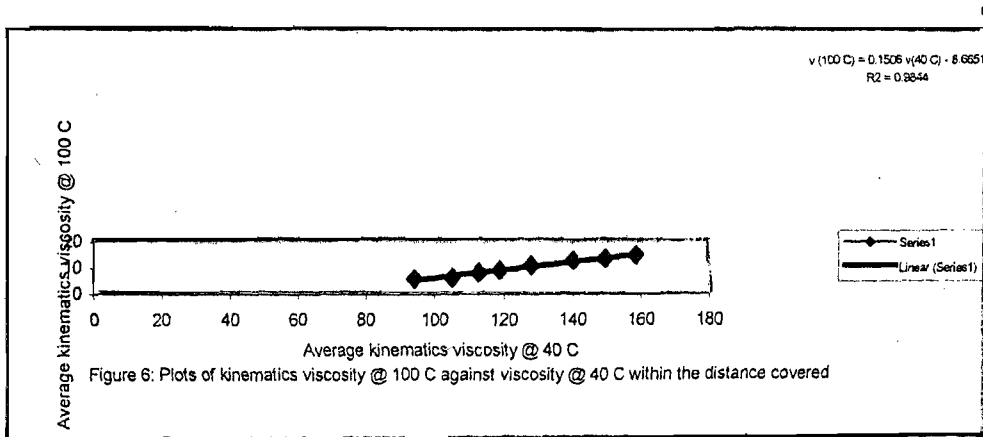
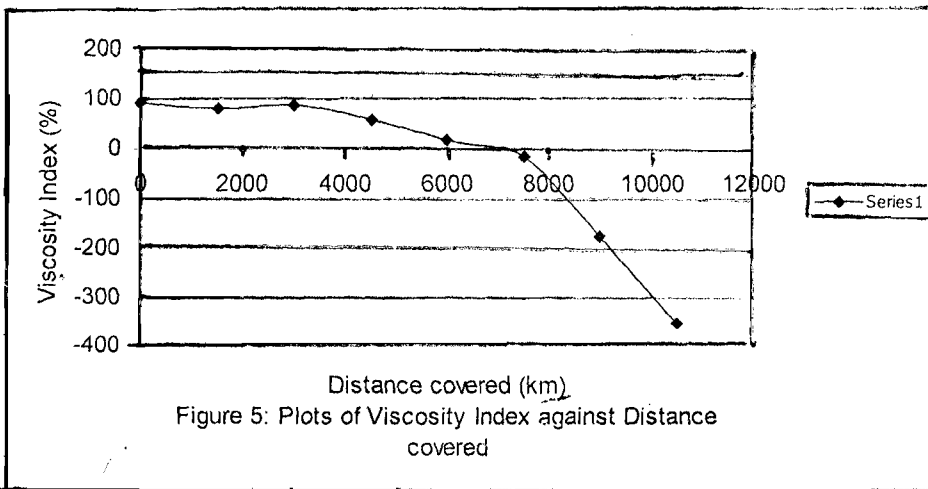
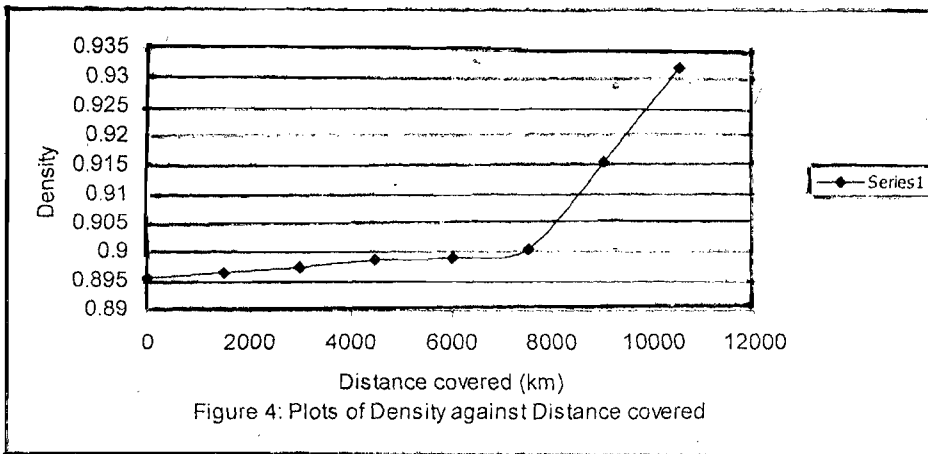
The specific gravity was determined using the standard ASTM 1298 method (the hydrometer method). This was determined by lowering a hydrometer into the lubricant sample in a hydrometer cylinder allowing it to settle before taking the reading.

RESULT AND DISCUSSION

The result of this study confirms that there exist a gradual decrease in the value of both the kinematics viscosity and the viscosity index with usage (kilometer covered).

Result from sample 1 (unused AP SAE 20 lubricating oil) indicates that at temperature of 40 °C and with viscosity size of 300 and constant c of 0.2178, the viscosity is 159.36208 (that is, 731.69×0.2178) for first run and 157.40188 (that is, 722.69×0.2178) for the second run. Resulting to an average kinematics viscosity of 158.4 cSt. For same sample at temperature of 100 °C and with same viscosity size and constant c , the first run gave a value of 15.059114 (that is, 69.05×0.2178) and 14.902098 (that is, 68.33×0.2178) for the second test run. Resulting to an average kinematics viscosity of 15.0 cSt. The complete results of this for the entire eight samples taken at different kilometer covered were shown in table 1. Shown in figures 1 and 2 are plots of average kinematics viscosity' at 40 and 100 °C against distance covered respectively.

The result of the experiment with the specific gravity and density of the lubricant shows a gradual increase in value with usage. The results for the eight samples are shown in table 2, while plots of these values with distance covered are shown in figures 3 and 4. Table 3 shows the



result of the viscosity index as evaluated from the kinematics viscosity of the lubricant at 40 °C and 100 °C according to ASTM 2770 standard. The viscosity index (VI) is given as;

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

where L is the kinematics viscosity at 40 °C of a lubricant of zero viscosity index having the same viscosity at 100 °C as the lubricant whose

viscosity index is sort. U is the kinematics viscosity at 40 °C of the lubricating oil whose viscosity index is to be estimated. H is the kinematics viscosity at 40 °C of a lubricant of viscosity index 100, having the same viscosity at 100 °C as the lubricant whose viscosity index is to be estimated. The viscosity index is an index representing the temperature stability of the lubricant (high viscosity index means that an increase in temperature brings about a small change in viscosity, while a low viscosity index signifies that an increase in temperature results to a high change in the viscosity). Plots of viscosity

index with usage are shown in figure 5.

From this study, the life span of lubricant (AP Super-V SAE 20) can be estimated to be at approximate kilometer of 6,000, which gives the permissible minimum viscosity value in centi-Stoke at 100 °C as specified by the SAE Automotive Lubricant Viscosity Classifications, Anosike (2002). This value is given as a range of 5.6 (minimum) to 9.3 (maximum). Above this range, the lubricant may start undergoing chemical degradation depending on the state of the engine.

A linearized model (data fitting) of the kinematics viscosity value at 40 °C with respect to distance covered is given by;

$$\nu_{40} = 157.68 - 0.0061x$$

That of the kinematics viscosity value at 100 °C with respect to distance covered is given by;

$$\nu_{100} = 15.108 - 0.0009x$$

The mathematical relationship between the two is given as;

$$\nu_{100} = 0.1506\nu_{40} - 8.6651$$

The plots are shown in figure 6.

CONCLUSION

This work-study presents the experimental result determining the degradation in the rheological properties with usage. The coefficients considered include: kinematics viscosity, viscosity index, and specific gravity. These properties of lubricating oil tend to degrade in quality with usage. The result of this work gives an accurate relationship between the stated properties and distance covered for a commonly used vehicle (Honda Accord 1988 model) in Nigeria. It is also applicable to other Japanese cars within the same engine design and conditions. The relationship so obtained is represented in the form of a linearized model to enhance prediction.

RECOMMENDATION

It is of great importance to consumers to monitor any product (especially vehicle) that has been purchased for efficient usage and long lasting. Consumers should estimate the life span of the lubricant corresponding to the type of engine just by simple manipulation of the linearized model presented in this work. Such that at any point, be it that the viscosity falls below the recommended level as a result of engine usage, the user may be

alerted to this problem and some thing better can be done before hand.

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