THE EFFECT OF ADDITIVE ON THE VISCOSITY INDEX OF LUBRICATING OIL (ENGINE OIL)

ONYEJI, LAWRENCE IBE; ABOJE, A. AUDU

Chemical Engineering Department,
Federal University of Technology FUT, P. M. B. 65, Minna, Nigeria.

1.0 Abstract

The effects of four different additive formulations namely 5748, 801, 264 and 261 on the viscosity index of two lubricating oils (base oils) namely 150N and 500N at two temperatures 40^0C and 100^0C were investigated. The base oils were blended with the additives in three different proportions of 100/4. 100/8 and 100/12. The results gave a viscosity index of 96 and 98 respectively for 150N and 500N without additives. On the other hand, the addition of 12g of 261 additive formulations to $100cm^3$ of both base oils gave about 180% increase in kinematic viscosity at 40^0C, about 161% increase and 146% increase at 1000C for 150N and 500N respectively. About 60% in viscosity index was achieved by 100/12 blend of 261 additives in 150N. The results revealed that 261 additive formulations gave the highest increase in viscosity in all proportions increasing as the weight of the additive increases. Generally, all the four additive formulations used improved the viscosities of all the blends in all the proportions and at both temperatures. The blends can be classified as very high viscosity index being above 110. This means that they will undergo very little change in viscosity with temperature extremes and so can be considered to have stable viscosity.

KEY Words: Lubricant (Base Oil), Kinematic, Viscosity, Additives, Viscosity Index, Temperatures

2.0 Introduction

A lubricant (also referred to as lube) is defined as a substance introduced between two surfaces in relative motion to prevent friction, improve efficiency and reduce wear. They can be in the form of gas, liquid or solid. A lubricant prevents the direct contact of rubbing surfaces and thus reduces wear. It keeps the surface of metals clean and also prevents failure due to seizure. Lubricants can also act as coolants by removing heat effects and also prevent rusting and deposition of solids on close fitting parts. One of the single largest applications for lubricants, in the form of motor oil, is to protect the internal combustion engines in motor vehicles and powered equipment [API, (2002)].

There are three major types of lubricants: Gaseous lubricants e.g. air, helium, Liquid lubricants e.g. oils, water and Solid lubricants e.g. graphite, grease, teflon, molybdenum disulphide etc. Liquid lubricant is the most commonly used lubricant because of its wide range of possible applications while gaseous and solid lubricants are recommended in special applications [Boughton, (2003)]. Based on its origin, lubricating oil can be two basic categories: mineral and synthetic. Mineral oils are refined from naturally occurring petroleum, or crude oil. Synthetic oils are manufactured polyalphaolefins which are hydrocarbon-based polyglycols or ester oils and are often “tailor made” for specific application. Of all these, mineral oils are the most commonly used because the supply of crude oil has rendered them inexpensive. Also a large body of data on their properties and use already exists. Another advantage of mineral-based lubricating oils is that they can be produced in a wide range of viscosities for diverse applications. They range from low-viscosity oils (light lube oil), which consist of hydrogen-carbon chains with molecular weights of around 200 atomic mass units (amu), to highly viscous lubricants with molecular weights as high as 1000 amu. Mineral-based oils with different viscosities can even be blended together to improve their performance in a given application. [Bienkowski, (1993)].

Viscosity is a measure of the oil’s resistance to shear. It is more commonly known as resistance to flow. If lubricating oil is considered as a series of fluid layers superimposed on each other, the viscosity of the oil is a measure of the resistance to flow between the individual layers. A high viscosity implies high resistances to flow while a low viscosity indicates a low resistance to flow. Viscosity varies inversely with temperature. It is also affected by pressure; higher pressure causes the viscosity to increase and subsequently, the load-carrying capacity of the oil also increases. This property enables the use of thin oils to lubricate heavy machinery. The viscosity of a lubricant is closely related to its ability to reduce friction. Generally, we want the thinnest oil which still forces the two moving surfaces apart. If the lubricant is too thick, it will require a lot of energy to move the surfaces (such as in honey); if it is too thin, the surfaces will rub on each other and friction will increase. [en.wikipedia.org/wiki/**Viscosity_index**].

Two common methods for measuring viscosity are shear and time methods. When viscosity is determined by directly measuring shear stress and shear rate, it is expressed in centipoise (cP) and is referred to as the absolute or dynamic viscosity. It is more common to use kinematic viscosity, which is the absolute viscosity divided by the density of the oil being tested. Kinematic viscosity is expressed in centistokes (cSt). Viscosity in centistokes is conventionally given at two standard temperatures: 40 ^{0}C and 100 ^{0}C (104 ^{0}F and 212 ^{0}F). Another method used to determine oil viscosity measures the time required for an oil sample to flow through a standard orifice at a standard temperature. Viscosity is then expressed in SUS (Saybolt Universal Seconds). SUS viscosities are also conventionally given at two standard temperatures: 37 ^{0}C and 98 ^{0}C (100 ^{0}F and 210 ^{0}F). [dictionary.reference.com/browse/**viscosity**]

Viscosity index, commonly designated VI, is an arbitrary numbering scale that indicates the changes in oil viscosity with changes in temperature. It is a lubricating oil quality indicator, an arbitrary measure for the change of kinematic viscosity with temperature. Viscosity index can be classified as follows: low VI - below 35; medium VI - 35 to 80; high VI - 80 to 110; very high VI - above 110. A high viscosity index indicates small oil viscosity changes with temperature. A low viscosity index indicates high viscosity changes with temperature. Therefore, a fluid that has a high viscosity index can be expected to undergo very little change in viscosity with temperature extremes and is considered to have a stable viscosity. A fluid with a low viscosity index can be expected to undergo a significant change in viscosity as the temperature fluctuates. [www.engineersedge.com/lubrication/**viscosity_index**.htm]. Many applications require a lubricant to perform across a wide range of conditions. Automotive lubricants must reduce friction between engine components when it is started from cold (relative to engine operating temperatures) as well as when it is running (up to 200 °C). The best oils (with the highest VI) will not vary much in viscosity over such a temperature range and therefore will perform well throughout. [dictionary.reference.com/browse/**viscosity]**. Thus an ideal oil for most purposes is one that maintains a constant viscosity throughout temperature changes. [www.tpub.com/content/engine/14105/css/14105_37.htm].

Additives are chemical compounds added to refined base oils to impart some specific properties to the lubricating oil either by enhancing inherent properties or adding new, desired ones to the finished product. A lot of unfortified base oils are being used as engine oils in our country. These base oils have to an extent some of the properties required for lubrication. However, these by themselves are not sufficient to meet the lubrication requirement of today's modern highly rated engines. Thus, it is often desired to add various chemicals to improve the physical properties of these oils. Due to the advancement in technology, varieties of machines, instruments and appliances have been developed which have to be operated at extreme new temperature, pressure and speed thus, this demands some specific characteristics from the lubricants. Base oil alone is unable to meet the demands of these modern engines; hence additive(s) that enhances the performance of such lubricant is/are needed. Various compounds have been discovered to possess operating characteristics such as oxidation stability, viscosity index, pour point, rust inhibition etc [Bienkowski, (1993)]. Thus this work is aimed at studying the effect of four additive formulations on the viscosities of two base oils with regards to enhancing their performance in service.

3.0 Methodology

The viscosity index via kinematic viscosity and fire points of two base oils: 150N use for producing lubricating oil (Engine oil) for cars, buses, vans etc and 500N used for production of heavy lubricating oil for trucks, trailers, tractors, lorries etc were investigated using four different additive formulations namely 5748; 801, 264 and 261. Three masses 4g, 8g and 12g of these additives were added to 100g of each of the base oils.

3.1 Experiment 1: Test of Kinematic Viscosity

The test was carried out on two different base oils (150N; used for light lube oil production and 500N; used in producing heavy lube oil) using four different additive formulations (5748, 801, 264 and 261). Each base oil/additive mixture, known as a pilot blend, was presented in three proportions: 100/4, 100/8, and 100/12 for the 150N and 500N base oils. The time, T was recorded for a sample of the pilot blend to flow from the upper meniscus of the viscometer tube to the lower meniscus, after the meniscus is sucked up to the upper mark by a compressed air pressure of 6 bar. Each of the base oil/additive mixture proportions is placed in two kinematic viscometers maintained at a temperature of 40^{0}C and 100^{0}C respectively. The kinematic viscosity (KV) of the oil is a product of the measured time, T and the viscometer tube constant, k, which designates the friction factor incorporated into the individual tube during manufacture. Therefore kinematic Viscosity (KV) = K*T

3.2 Experiment 2: TestfFor Fire Point:

The base oil/additive mixture was poured into a flash cup and placed on the hot stove of the open-cup flash point electric tester device. A thermometer was dipped into the mixture to record the temperature rise until the thermometer reading is at 180^{0}C. At this temperature, a flame stick was lit and the naked flame was slowly passed continuously over the open surface of the heated mixture until the mixture reached a temperature at which it inflamed. This temperature is known as the flash point and the flame at this point was bluish in colour. The mixture was further heated with the flame stick still moving over the surface until the mixture ignites into a fire and burns. The temperature at which this occurs is called the fire point and the flame at this point is yellowish in colour.

4.0 Discussion of Result:

Lubricating oils with good viscosities index values are usually obtained by the introduction of additives. The effects of these additives on the viscosity index of two base oil samples (150N and 500N) blended with different proportions of additives at 40 ^{0}C, 100 ^{0}C and at the fire points were investigated.

Table 1: Results of Kinematic viscosity and Viscosity Index Tests at 40^{0}C and 100^{0}C of two base oils containing four Additives in three different proportions (Mixtures).

Table 1: Results of Kinematic Viscosity and Viscosity Index Tests of the 2 Base Oils for the 3 proportions(Mixtures) with the 4 Additives													
	Sample	Tube Type	K	Tav (s)	KV40 (Cst)	% increase in KV	Tube Type	K	Tav (s)	KV100 (Cst)	% Increase in KV	VI	% Increase in VI
150N	100	16194	0.2371	143.63	34.07	0	1522	0.0238	231.40	5.51	0	96	0
500N	100	17599	0.9989	84.63	84.56	0	18403	0.0348	284.75	9.88	0	95	0
ADDITIVE 1: 5748 (150)	100/4	400 (441)	1.3083	35.46	46.39	36.16	200 (698)	0.1041	71.75	7.47	35.57	133	37
	100/8	400 (E36)	1.2019	54.22	65.17	91.28	200(19185)	0.1056	92.74	9.79	77.68	133	37
	100/12	400 (441)	1.3083	65.28	85.41	150.69	200 (698)	0.1041	120.1	12.5	126.86	144	48
ADDITIVE 1: 5748 (500)	100/4	400 (441)	1.3083	89.66	117.3	38.72	200 (698)	0.1041	129.13	13.44	36.03	111	16
	100/8	400 (E36)	1.2019	122,30	146.99	73.83	200(19185)	0.1056	163.27	17.24	74.49	128	33
	100/12	400 (441)	1.3083	142.63	186.59	120.66	200 (698)	0.1041	116.94	12.17	23.18	151	56
ADDITIVE 2: 801 (150)	100/4	400 (441)	1.2019	37.16	48.61	42.68	200 (698)	0.1041	70.54	7.34	33.21	113	17
	100/8	400 (E36)	1.3083	55.33	60.5	77.58	200(19185)	0.1056	92.22	9.74	76.77	129	33
	100/12	400 (441)	1.2019	60.35	78.95	131.73	200 (698)	0.1041	116.94	12.17	120.87	151	55
ADDITIVE 2: 801 (500)	100/4	400 (E36)	1.2019	108.02	129.82	53.52	200 (698)	0.1041	136.57	14.22	43.93	108	13
	100/8	400 (441)	1.3083	116.72	152.7	80.58	200(19185)	0.1056	158.5	16.74	69.43	117	22
	100/12	400 (E36)	1.2019	147.69	177.51	109.92	200 (698)	0.1041	183.8	19.41	96.46	125	30
ADDITIVE 3: 264 (150)	100/4	400 (E36)	1.2019	35.62	42.81	25.65	200(19185)	0.1056	67.24	7.1	28.86	131	35
	100/8	400 (441)	1.3083	43.94	57.49	68.74	200 (698)	0.1041	87.82	9.14	65.88	139	43

	100/12	400 (E36)	1.2019	61.27	73.64	116.14	200(19185)	0.1056	106.89	11.29	104.90	145	49
ADDITIVE 3: 264 (500)	100/4	400 (441)	1.3083	86.94	113.74	34.51	200 (698)	0.1041	125.93	13.11	32.69	111	16
	100/8	400 (E36)	1.2019	113.44	136.34	61.23	200(19185)	0.1056	144.01	15.21	53.95	114	19
	100/12	400 (441)	1.3083	129.61	169.56	100.52	200 (698)	0.1041	177.99	18.53	87.55	123	28
ADDITIVE 4: 261 (150)	100/4	400 (441)	1.3083	37.19	48.65	42.79	200 (698)	0.1041	73.7	7.67	39.20	124	28
	100/8	400 (441)	1.3083	52.11	68.18	100.12	200 (698)	0.1041	104.61	10.89	97.64	150	54
	100/12	400 (E36)	1.2019	79.33	95.34	179.84	200(19185)	0.1056	136.05	14.37	160.80	156	60
ADDITIVE 4: 261 (500)	100/4	400 (E36)	1.2019	102.41	123.08	45.55	200(19185)	0.1056	138.13	14.38	45.55	117	22
	100/8	400 (441)	1.3083	131.34	171.83	103.20	200 (698)	0.1041	180.22	19.03	92.61	126	31
	100/12	400 (441)	1.3083	181.47	237.41	180.76	200 (698)	0.1041	233.67	24.33	146.26	129	34
Tav (s) = Average Time in Sec., K = Viscometer tube constant,													

Table 1: Shows the results of Kinematic Viscosity (KV) and Viscosity Index (VI) Tests at 40^0C and 100^0C of two base oils containing four Additives in three different proportions (Mixtures). From the table, the Kinematic Viscosities of the untreated base Oils are 34.07cst and 84.56cst for 150N and 500N respectively at 40^0C. While at 100^0C, the KV obtained were 5.51cst and 9.88cst for 150N and 500N respectively. The viscosity index was calculated using the KV at 40^0C and 100^0C from the ASTM (American Standards for Testing Material) D2270 table the values obtained for the two base oils **were** 96 and 95 respectively. When the 150N base oil sample was treated with the 5748 additive at 40^0C, the kinematic viscosities, KV, obtained increased to 46.39cst, 65.17cst and 85.41cst respectively for the three proportions of base oil/additive blends (i.e 100/4,100/8,100/12) while at 100^0C, the KV obtained were 7.47cst, 9.79cst and 12.50cst respectively. The calculated viscosity index from the ASTM D2270 table gave the values as 133, 133 and 144. These mean that the addition of additives resulted to an increase in KV to about 36.2 % at 40^0C and 35.6 % at 100^0C. A 38.5 % increase was also observed in the values of the viscosity index. For the 500N base oil, the values for the KV at 40^0C obtained were 117.30cst, 146.99cst and 186.59cst; giving an increase of about 38.7 % and for the KV at 100^0C, 13.44cst, 17.24cst and 21.18cst were obtained indicating a 36 % increase. Increase in the viscosity index value from 95 to 111, 128 and 134 for the three proportion were also recorded.

When the 150N base oil sample was treated with 801 additive formulation, the kinematic viscosities recorded were 48.61cst, 66.50cst and 78.95cst for the three proportions 100/4, 100/8, 100/12 respectively at 40^0C. For KV at 100^0C, the values obtained were 7.34cst, 9.74cst and 12.17cst respectively. The values of the viscosity index obtained were 133, 129 and 151. For the 500N, the KV at 40^0C were 129.82cst, 152.70cst and 177.51cst while at 100^0C, the KV recorded were 14.22cst, 16.74cst and 19.41cst. The viscosity index values obtained were 108, 117 and 125 respectively. The other two additives 264 and 261 also gave similar increase in the KVs and VIs of the blends as observed with 5748 and 801 additives

Generally, it can be seen from table 1 that the addition of additives greatly improved the kinematic viscosity from 36% for 4g of 5748 additive formulation in 100g of 150N at 40^0C to about 181% for 12g of 261 additives in 100g of 500N at 40^0C. At 100^0C, the Kinematic Viscosity increases from 36% for 4g of 5748 additive formulation in 100g of 150N to about 161% for 12g of 261 additives in 100g of 500N. This also shows that the improvement in the Kinematic Viscosity increases with increase in the mass of the additives. It is equally evidence from table 1 that the effect of the additives is more at 40^0C than at 100^0C. This is in agreement with literatures that viscosity varies inversely with temperature. Of the four additive formulations investigated, 261 gave the highest increase in kinematic viscosity for the three proportions in both base oils and at both temperatures. This was followed by 5748, then 801 while 264 additives gave the least effect.

The Viscosity Index of the base oils also improved by the addition of these additives. Table 1 shows an increase of 13% when 4g of 801additive formulation was blended with 100g of 500N to as high as 60% when 12g of 261 additives formulation was blended with 100g of 150N. All the blends (mixtures) can be classified as very high viscosity index being above 110. This means that they will undergo very little change in viscosity with temperature extremes and so can be considered to have stable viscosity. The blends can be termed ideal oils since they maintain almost constant viscosity throughout temperature changes. Just as is with kinematic viscosity, the viscosity index increases with increase in the mass of additives and 261 additives in 150N base oil recorded the highest increase in viscosity index.

Table 2: Results of the Kinematic Viscosity at Fire Points.

Table 2: KINEMATIC VISCOSITY RESULTS AT FIRE POINT									
Base Oil	Additive Type	Fire Pt Temp OC	Sample	Tube Type	K	T1	T2	Tav	KV
150	5748	226	100/4	200 (698)	0.1041	71	70.97	70.99	7.39
150	5748	242	100/12	200(19185)	0.1056	117	116.72	116.86	12.34
150	801	244	100/4	200(19185)	0.1056	69.19	69.22	69.21	7.31
150	801	244	100/12	200 (698)	0.1041	115.75	115.75	115.75	12.05
150	264	246	100/4	200 (698)	0.1041	68.62	68.88	68.64	7.15
150	264	238	100/12	200(19185)	0.1056	102.82	102.65	102.73	10.85
150	261	270	100/4	200 (698)	0.1041	73.49	73.49	73.49	7.65
150	261	276	100/12	200(19185)	0.1056	134.85	134.85	134.85	14.24
500	5748	286	100/4	200(19185)	0.1056	129	129.06	129.03	13.63
500	5748	282	100/12	200 (698)	0.1041	201.22	201.19	201.21	20.95
500	801	268	100/4	200 (698)	0.1041	130.38	130.9	130.64	13.6
500	801	280	100/12	200(19185)	0.1056	186.19	185.59	185.89	19.63
500	264	280	100/4	200 (698)	0.1041	122.87	122.56	122.75	12.77
500	264	280	100/12	200(19185)	0.1056	175.18	175.75	175.47	18.53
500	261	282	100/4	200(19185)	0.1056	132.86	132.86	132.86	14.03
500	261	286	100/12	200 (698)	0.1041	229.2	229.2	229.2	23.86

Table 2 shows the results of the Kinematic Viscosity at Fire Points for 100/4 and 100/12 blends. These results show that there were no significant changes in the KV of the blends at 100^0C and at the Fire Point Temperatures. This means that both oils were stable at about 286^0C as observed for 500N base oil in 100/12 blend.

5.0 Conclusion

The most important consideration in selecting a lubricant is its ability to reduce friction and hence control wear between two moving parts. Thus viscosity is the primary factor in performance. However, viscosity decreases with increase in temperature. So, achieving the right viscosity depends on selecting the right base oil and blending it with additives to obtain desired characteristics for a better functional performance. This work has improved the viscosity of two base oils, 150N and 500N, by blending them in different proportions with four additives formulations; 5748, 801, 264 and 261. All the four additives improved both base oils to very high viscosity index since viscosity index values higher than 110 were achieved in all the base oil/additives mixtures investigated. This is why the viscosity of the blends did not show much variation with temperature change and so giving very stable lubrications. This means that the blends will resist excessive thickening when the engine is cold and, consequently, promotes rapid starting and prompt circulation; it resists excessive thinning when the motor is hot and thus provides full lubrication and prevents excessive oil consumption.

6.0 Recommendation

- This work shows that the effect of additives on viscosity of lubricating oil increases as the mass/weight of the additives increases. It is therefore recommended that further work to determine the mass of the additives that will give maximum/ ultimate effect be carried out.

- Film strength is the capability of a lubricant to resist being wiped or squeezed out from between the surfaces when spread out in an extremely thin layer. There further work to determine at what temperature and the thinnest layer the oil resist being wiped or squeezed out be investigated.

- An investigation into the combined effect two or more additives on the base oil is recommended for more studies.

Reference

[1] API 1509, Engine Oil Licensing and Certification System, 15th Edition, 2002. Appendix E, API Base Oil Interchangeability Guidelines for Passenger Car Motor Oils and Diesel Engine Oils (revised) http://www.en.wikipedia.org/wiki/lubricant

[2] ASTM (American Standards for Testing Material) D2270 table for Celsius temperature.

[3] Boughton and Horvath (2003); Environmental Assessment of used Oil Management method, Environmental Science and Technolgy, Volume 38. (http://en.wikipedia.org/wiki/lubricant)

[4] Bienkowski, Keith (1993); "Coolants and Lubricants: The Truth." Manufacturing Engineering. http://www.answers.com/topic/lubricating oil

[5] en.wikipedia.org/wiki/**Viscosity_index**

[6] dictionary.reference.com/browse/**viscosity**

[7] www.engineersedge.com/lubrication/**viscosity_index**.htm

[8] www.tpub.com/content/engine/14105/css/14105_37.htm