Comparative Assessment of Viscothermal Stability between Jatropha oil and SAE 40 Motor oil.

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Abstract- **The viscosity of lubricating oils (lubricants) is a very essential component of lubricity in any tribology, regardless of the type of lubrication function and system in question. The lubricants' viscosity is always needed to be at an optimal level, not too high that it could not be able to penetrate through the contact surface that require lubrication, and not too low that it will easily be squeezed out of the surfaces. In most often than not, lubrication of contact surfaces is carried out at temperatures above the room temperature. However, the temperature at which these lubricants are subjected to greatly affect the viscosity of the lubricants. Before thinking of substituting a non-degradable mineral/petroleum-based lubricant with an environmentally friendly vegetable-based lubricants, it is essential to ensure that at least they can perform the same way if not better than the existing conventionally used oils in all aspects, in which, viscothermal stability is one of the functional requirements. This is what this study tends to investigate. The aim of this study is to determine and compare the viscothermal stability of Jatropha oil and SAE 40 motor oil. In this study, the viscosities of SAE 40 motor oil and that of Jatropha oil were determined at different temperatures (21, 40, 60, 80, and 100ºC) to study the viscosity variation with temperature using a Brookfield Viscometer as per ASTM D 445-79. The viscosity index for the two oil samples was eventually evaluated. The two oil samples showed a down ward trend in the viscosity with increased temperature from 21°C to 100°C, but SAE 40 motor oil shows higher viscosity values especially at lower temperatures but with Jatropha oil displaying a better Viscothermal stability, having a viscosity index of 391, which is higher than that of SAE 40 motor oil which has a value of 245 as calculated according to ASTM D 2270-40**

*Keywords***: Jatropha oil, SAE 40 Motor oil, Viscosity, Viscothermal stability.**

INTRODUCTION

Viscosity is an important property that is used in the characterization of oils generally. In the case of lubricating oils, the viscosity tells a lot about its ability to hydrodynamically lubricate contact surfaces. It is defined as resistance offered to fluids' flow. The 'Hydrodynamic Theory of lubrication', clearly explains that; this property (viscosity), plays a central/key role in the lubrication system the machine elements encounter in service. The viscosity of lubricating oils is directly related to its ability to separate contact surfaces from contacting each other, thereby reducing wear. It is, however, a known fact, that the viscosity of oils is greatly affected by temperature (Tribonet, 2019).

Visco-thermal behaviors of greases and lubricating oils is one of the significant determinants for lubricants' performance in mechanical systems. Due to the high sensitive nature of lubricants' visco-thermal relationship, the sustainability of lubricating film, in-between bodies in contact in mechanical systems, becomes critical. Oils' viscosity usually decreases rapidly when its temperature rises. This rapid decline in lubricants viscosity may result in to a severe performance consequences in most mechanical systems for both transportation and industrial applications. Friction induced heat in tribological systems such as bearings, gears, engines etc., which eventually translates into a temperature rise is inevitable. In some applications, another thing that is considered to be a major source of heat, is the environment (that with high operating temperature), such as; turbines (steam or gas). Similarly, just as it has been established that the viscosity of lubricants is affected by temperature, it is worth noting that, the viscosity is not only impacted by the temperature when it is on the rise. The sub-zero temperatures equally impacts on the lubricants' viscosity, by way of thickening the oil so much so that it is made to develop much resistance to its flow, such that it adds up to the overall resistance to the movement of the machine elements. Hence, neither thin nor a thick lubricant is desirable. An optimum value will always be a better choice an engineer should make for various applications. (Tribonet, 2019).

Viscosity affects heat generation in bearings, cylinders and gear sets related to oil's internal friction. It governs the sealing effect of oils and the rate of oil consumption, as well as determines the ease with which machines may be started or operated under varying temperature conditions, particularly in cold climates. Viscosity, it has earlier been defined, is a measure of oil's resistance to flow. Its value declines (thins) when the temperature is on the increase and increases (or thickens) when the temperature decreases. These conditions clearly explain the reason why oils flow much more easily in the summer at a temperature of 25°C (78°F), than it will when it is winter at -25°C (-13°F). Oils' viscosities are most commonly measured by 'kinematic viscosity' and reported in centistoke (cSt). Kinematic viscosity is measure defines the the time it takes for a given (specific) volume of an oil to flow through a special device called a capillary tube. Not all oils respond in the same way to a given change in temperature. Many oils contain an ability to resist changes in viscosity due to a change in temperature. This property is referred to as the oil's viscosity index or VI. The higher the VI of oil, the less its viscosity is altered by temperature changes (Noria Corporation, 2021).

The benefits of oils with a higher VI are:

1. A general increase in viscosity at higher temperatures, which results in lower oil consumption and less wear.
2. A reduced viscosity at lower temperatures, which will improve starting and lower fuel consumption (Noria Corporation, 2021).

Jatropha plant is a non-edible plant. It is one of its kinds being singled out for large scale plantation on deserts. Jatropha plant is capable of growing under unfavorable weather conditions. It is characterized as being a perennial plant capable of living up to fifty years, drought resistant capable of surviving up to five successive years of drought, it can also grow virtually on any type of soil. The yield of the Jatropha plant is good, up to 0.8 kg can be achieved per square hectare. The seed has relatively high oil content of about 30 – 40% by weight. Research findings shows that; fresh Jatropha oil is odorless and colorless, slow-drying, but the color turns yellowish when it ages (Sarin and Sharma, 2007).
The viscosity of lubricating oils (lubricants) is a very essential component of lubricity in any tribology, regardless of the type of lubrication function and system in question. The lubricants' viscosity is always needed to be at an optimal level, not too high that it could not be able to penetrate through the contact surface that require lubrication, and not too low that it will easily be squeezed out of the surfaces. In most often than not, lubrication of contact surfaces is carried out at temperatures above the room temperature. However, the temperature at which these lubricants are subjected to greatly affect the viscosity of the lubricants. Before thinking of substituting a non-degradable mineral/petroleum based lubricants with an environmentally friendly vegetable based lubricants, it is essential to ensure that at least they can perform the same way if not better than the existing conventionally used oils in all aspects, in which, viscothermal stability is one of the functional requirements. This is what this study tends to investigate.

Ahmed & Yassin, (2019) reported a study on the extraction of Jatriopha bio-based oil for Two stroke engines. The work was aimed at improving the environmental pollutant control that are usually generated from two stroke engines. In the work, jatropha oil was extracted and characterised as per ASTM standards. The experimental findings of the work showed that; Jatropha oil as bio-lubricant has high flash point (266°C), viscosity index (354), American Petroleum Institute of 17, an acid number of 0.457 mg KOH/mg, carbon residue (0.001 w/w%), and low pour point of -13°C.
Almutairi et. al., (2017) reported a study on two stroke engine performance using waste cooking oil (WCO) as a lubricant substitute. The viscosities of the pure WCO and that of the synthetic (Mobil) oil, as well as that of the semi-synthetic oil which is a blend of WCO and the synthetic oil (75/25%, 50/50% and 25/75% Synthetic oil to WCO respectively) were determined at 25°C and 40°C. The test result showed that WCO has viscosity values less than that of the Synthetic oil, and for the semi-synthetic oil; increase in the amount of WCO in the blend resulted in a corresponding increase in the air – fuel ratio (AFR), decrease in O_2, HC, CO and CO_2.

Gunam et. al. (2015) reported a research work on synthesis of biodegradable lube oil obtained from jatropha oil having a high free fatty acid content. The work was aimed at probbing the feasibilty of producing esters of Trimethylopropane (TMP) using Jatropha oil as the source of the free fatty acids. The process of transesterification was used to synthesize the evaluated esters, lubricity of the biolubricant was investigated. It was found that more than 80 percent yield of the biolubricant was achieved, lubricity properties obtained were found to be comparable the other vegetable oil based lubricants. A summary of their finding is shown in Table 2.1.

Table 2.1. Physical characteristics of the different lubricant bases (Gunam et. al., 2015)

Fluid		Standard Requirement by ISO VG46	Mineral Oil	Synthetic*		Bio-based Synthetic	
				Olefin Oligomers	Propane Alkylated Aromatics	Oil Palm	Jatropha
Kinematic Viscosity (cSt)	40°C	>41.4	568	399	109	52.4	43.9
	100°C	>4.1	27.8	40	12.4	10.2	8.71
Viscosity Index (VI)		>90	62	147	105	186	180
Pour point (°C)		-10	-4	-36	-36	-5	-6

MATERIALS AND METHODS

A. Materials Used

Materials used include;

a) Jatropha oil: This was acquired from NARICT Zaria and the properties of the Jatropha oil as obtained are as follows:

b) Motor oil (SAE 40): A brand of 'Oando' SAE 40 oil was used as one of the most commonly used commercial motor oils.

Table 3.1 Properties of Jatropha oil as obtained from NARICT Zaria

S/N	Properties	Value
1	Density (g/cc) @ 30°C	0.93292

2	Kinematic Viscosity (Cst) @ 30°C	52.76
3	Cetane number	38
4	Flash point (°C)	210
5	Calorific Value (MJ/kg)	38.20
6	Saponification Value	198
7	Iodine no.	94

B. Methods

The viscosities of the two oil samples (SAE 40 & Jatropha oil) were tested at different temperatures (21, 40, 60, 80, and 100°C) to study the viscosity variation with temperature using a Brookfield Viscometer. The absolute viscosities were converted into kinematic viscosity by using the density of the oil samples; according to ASTM D 445-79. The operating conditions used were spindle number 02, 50rpm and factor of 8. After each measurement, viscometer dial reading was converted to a viscosity value in units of centipoise (cp), using the following equation;

Absolute viscosity (cp) = dial reading × factor (3.1)

Kinematic viscosity (m^2/s) = $\frac{\text{Absolute viscosity (Pa*s)}}{\text{Density (kg/m3)}}$ (3.2)

And the Viscosity Index (VI) was calculated according to ASTM D2270 – 04, using the equation;

VI = ______ + 100 (3.3)

Where;

N = $\frac{Log\,H - Log\,U}{Log\,Y}$ (3.4)

Y = Kine (An oil whose viscosity index is to be calculated (cSt)

U = Kine il whose viscosity index is to be calculated (cSt)

(ASTM International D 2270 – 04, 2009)

This analysis was carried out at the Department of Chemical Engineering, Ahmadu Bello University Zaria.

Results and Discussion

The results of viscosity variation with temperature for the two oil samples are presented in Table 2. From the table, the chart in Figure 1 was plotted.

Table 2: Viscosity test results for SAE 40 motor oil and Jatropha oil

Temp. (°C)	SAE 40 Motor Oil			Jatropha oil		
	Dial reading	Absolute viscosity (cp)	Kinematic Viscosity (cSt)	Dial reading	Absolute viscosity (cp)	Kinematic Viscosity (cSt)
21	60.0	480	534.5	11.5	92	98.7
40	23.5	188	209.4	8.0	64	68.7
60	9.5	76	84.6	5.0	40	42.9
80	6.0	48	53.5	4.0	32	34.3
100	4.5	36	40.1	3.0	24	25.8

Table 2: Viscosity Index (VI) calculation

	H (cSt)	**U** (cSt)	**Y** (cSt)	**N** $= \frac{\text{Log H} - \text{Log U}}{\text{Log Y}}$	**VI** $= \frac{(\text{Antilog N}) - 1}{0.00715} + 100$
Jatropha Oil	336.7	68.7	25.8	$\frac{\text{Log } 336.7 - \text{Log } 68.7}{\text{Log } 25.8}$ = 0.4890	$\frac{(\text{Antilog } 0.489) - 1}{0.00715} + 100$ = **391**
SAE 40 Motor oil	651.8	209.4	40.1	$\frac{\text{Log } 651.8 - \text{Log } 209.4}{\text{Log } 40.1}$ = 0.3076	$\frac{(\text{Antilog } 0.3076) - 1}{0.00715} + 100$ = **245**

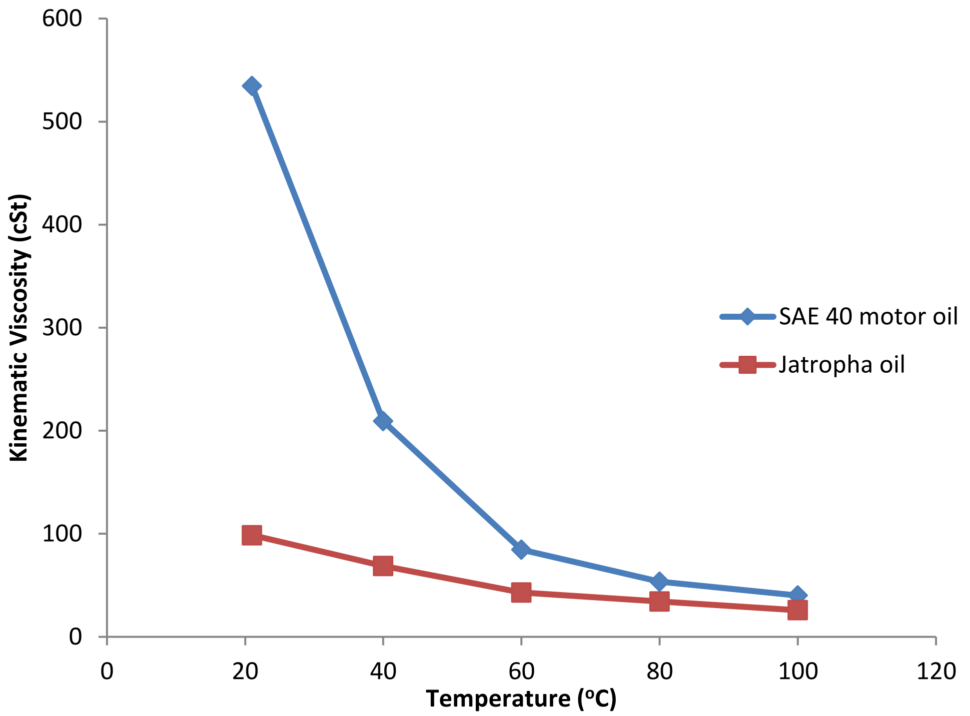

Figure 4.1: Viscosity variation with temperature for both the oil samples

Figure 4.5 shows the variation of viscosity with temperature for both Jatropha oil and SAE 40 motor oil. The figure reveals a decreasing trend in the viscosity values as the temperatures increases for both the two oil samples from 21ºC – 100ºC. SAE 40 motor oil shows higher viscosity values especially at lower temperatures (534.5Cst at 21ºC). The difference in viscosity values decreases significantly at higher temperatures. However, Jatropha oil can be seen to have a better viscosity index value of 391 than that of SAE 40 motor oil which has V.I of 245 as calculated and presented in Table 2, according the ASTM D 2270 – 40. That means the viscothermal stability of Jatropha oil is better as compared to that of SAE 40 motor oil. This result is found to be in concurrence with the findings of the work conducted by Ahmed & Yassen (2019); which showed a kinematic viscosity of 79.06Cst and 26.13Cst for Jatropha oil at 40°C and 100°C respectively, with a VI value of 354.

Conclusion

The study is comparative in nature. The findings of the study revealed that; Jatropha oil (in its crude form) shows a reduced viscosity values especially at low temperatures compared to SAE 40 motor oil (a fully formulated petroleum based oil). The difference tends to vanish as the temperature increases. However, the viscosity index (VI) for Jatropha oil appears to be better (391), which translates in to higher viscothermal stability. This result is expected to be much better with the addition of some oil additives such as the viscosity modifiers.

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