ISSN 2229-5518

POSSIBILITIES OF VEGETABLE OILS AS BASE OILS FOR AUTOMOBILE SHOCK ABSORBER FLUIDS

[1]Binfa Bongfa*, [2]Abolarin, M. S., [1]Aboh, A. M., [3]Anekunu A. Y., [4]Barnabas Atuci, [1]Abdul Musa

Abstract - Mineral - based damper oils predominantly in use are of good performance, but non-regenerative, environmentally unfriendly and often scarce or expensive as a result of difficulties and cost of exploration and processing. Chemo-physical properties (acidity level, specific gravity, viscosity at 40^{0}C and at 100^{0}C, viscosity index, pour point, and flash point) of groundnut oil, palm kernel oil, coconut oil, and soybeans oil as damping fluids were experimentally investigated to see their suitability as alternative shock absorber fluids. The acidity levels of the oils were suitable, being below 10mgKOH/g - the maximum for lubricant, although coconut oil has total acid number as 6.70mgKOH/g. They have suitable viscosities for light and medium duty dampers; flash points, all above 145^{0}C-the minimum from standard; viscosity indices well above 170; and pour points suitable at least for tropical region when treated with pour point depressant.

Index Terms: automobile, shock absorber fluids, mineral oils, vegetable oils, viscosity, viscosity index, acidity, pour/flash points.

1 Introduction

Dampers or Shock absorbers, are mechanical devices normally mounted on another mechanical system, to neutralize vibration generated due to motion of unbalance masses or perturbation from external sources. So-called shock absorbers in an automobile prevents it from jarring, jolting, jouncing, swaying, pitching, and leaning when the wheels move over a rough surface [1]. One of the most effective and economical way of vibration damping is provided by fluid resistance known as viscous damping. The damping force is controlled by the viscosity of the liquid (called the damping or shock absorber fluid) and by the size of the orifice in the piston [2]. Shock absorber fluids are foam free oils with good oxidation stability. They possess good compatibility with sealing elements and excellent damping characteristics. Their formulation chemistry, include anti-wear additives, usually phosphorus containing compound for protection against wear [3]. The main requirements for any hydraulic fluid (for braking, transmission or suspension systems) are good oxidation resistance, high thermal stability, powerful corrosion protection, a low tendency to foam and entrain air, rapid separation from water, suitable viscosity characteristics covering low ambient (pour point) to high operating temperatures, and compatibility with the chosen construction materials and seals employed in the system. Shock absorber oils have extreme requirements - they must be fluid down to all conceivable ambient temperatures to avoid damper or vehicle damage but they must retain sufficient viscosity (high viscosity index) at operating temperatures above 100^{0}C [4]. The oils must be resistant to oxidation and thermal breakdown, have low foaming properties, and be capable of protecting the pistons and seals from wear and degradation over long service period [5]. No single oil may provide all the properties and characteristics required for optimum lubrication operation (engine and non-engine). Oils are therefore blended with additives either to enhance their properties or to impact new properties. Efficiency of additive utilization depends on the chemical composition of the additive, and the concentration, type and operating environment of the oil usage [6]. The damping oils commonly used in automobile shock absorbers are hydrocarbon mineral base oils and some selected synthetic oils [7]. Shock absorbers oils are usually made from naphthenic base stocks [8]. With the declining availability of naphthenic stocks and more realistic performance tests, paraffinic stocks are now favoured [9].

The exploration and exploitation of hydrocarbon mineral oils and fuels have contributed immensely to the building, operating and maintenance of engineering mechanisms. But they are expensive and often scarce due to difficulties in processing. Moreover, the global inclination toward synthetic oils, natural oils as engine lubricants; bio-fuel and bio-diesel for fuelling of automobiles makes it uneconomical to process crude oil just for the purpose of utilising them for damping oils. Petroleum is finite non-renewable natural resources which its feedstock is not readily available in all parts of the world and as such requires potential substitute. Moreover shock absorbers are normally not high lubricant consumption mechanism, so the

- ***Main/corresponding Author**: Binfa Bongfa, is currently pursuing dectorate degree program in mechanical engineering at Universiti Teknologi, Malaysia, PH-+60167059590. E-mail: engrbinfabongfa@gmail.com*
- ***Other Authors**:*
  [1]Mechanical Engineering Department Federal Polytechnic, Idah, Nigeria
  [2]Department of Mechanical Engineering, School of Engineering & Engineering Technology, Federal University of Technology, Minna, Nigeria
  [3]Electrical Engineering Department Federal Polytechnic, Idah Nigeria
  [4] Mubeco Petroleum Company, Kaduna, Nigeria

use of natural vegetable oils cannot be jeopardised by availability considerations.

There is need to shift from mineral based damper oils to natural oil based types, since the raw materials are abundantly available and regenerative through improved agricultural activities. Natural oils are biodegradable and their usage does not leave any environmental pollution concerns. According to Dawn and Terry [10], while 80 percent of hydraulic oil formulated using vegetable oil, as base oil biodegrades in 28 days, only nearly 30 percent of the mineral oil-based type biodegrades within this duration. Natural oil are low in toxicity, and of course harmless to terrestrial and aquatic inhabitants, low volatility, good boundary lubrication properties, excellent viscosity-temperature characteristics (due to narrow range of viscosity change with temperature), good solvency, miscibility, and compatibility with additives compounds and mineral oil.

Although vegetable oils generally have weak resistance against oxidative and hydrolytic degradation, and also poor fluidity at low temperatures, these deficiencies can be taken care of through chemical and genetic modifications, use of antioxidants, pour point depressants, etc. [11]. Blending of vegetable oils with mineral or synthetic oil can also aid them to meet service requirements.

In this work, the authors focused on investigating some selected locally processed vegetable oils, as automobile shock absorber fluids. The vegetable oils of interest were from groundnut (GNT), soybeans (SYB), coconut (CCN), and palm kernel (PKN) seeds. The choice was informed by the availability of GNT and SYB all over Nigeria and abundance of PKN and CCN plantations, all over the southern part and also the middle belt of the country, and the indubitable possibility of growing them in abundance to cover other usage together with this application, if found suitable [6]. Moreover, SYB and PKN covers 56% and 2% respectively of world oilseed producers [12] At present, the market value of some of these oils, in Nigeria are comparable to mineral base stock. While the mineral base oil is going for NGN400 per litre, PKN, SYB, and GNT oils are respectively going for NGN350, NGN600, and NGN400 per litre. Once the broad based suitability can be established in this study, ways of enhancing the performance characteristics can then become the subject of any further studies in this area.

Specifically, the study concentrates on the following:

(i) determination of the acid value of the studied oils,
(ii) determination of some of the relevant physical properties, including specific gravity and viscosity, both at 40^{0}C and at 100^{0}C, viscosity indices, pour points, and flash points of the studied oils, and
(iii) Comparative analysis between standard data of conventional mineral oils used in cars shock absorbers and the properties of the studied oils.

2 Materials and Methods

Samples of locally produced coconut, palm kernel and soy beans oils were purchased from local markets within Nigeria, while groundnut oil was locally extracted from the seeds purchased from the local market, still within Nigeria. The following physio-chemical properties of the oil samples were investigated.

2.1 Acidity test

The apparatus/ reagents used for this test were 250 cc conical vessel, phenolphthalein solution, alcohol, potassium hydroxide (KOH) solution, Bunsen burner, Thermometer, 10g each of GNT oil, SYB oil, CCN oil, and PKN oil.

10g of an oil sample was poured in a 250cc conical vessel, 1cc of phenolphthalein solution was added to 50cc of alcohol in a beaker, and heated to 40-50°C and neutralized with a solution of potassium hydroxide (KOH), the neutralized alcohol was added to the oil sample and the sample was then heated to boiling point and boiled for 5 minutes. Again 1cc of phenolphthalein was added and cool to 40- 50°C and then titrated against solution of KOH. The milligrams of KOH which neutralized the acid content of a gram of each of the oil sample was computed from,

$$AV = \frac{56.1NV}{W} \quad (1)$$

AV is Acid value of oil sample in mgKOH/g, N is known as the normality of KOH solution, V is the volume of KOH solution in ml and W is the weight of the oil sample in grams. The result of acidity test is tabulated as shown in Table 1.

2.2 Specific Gravities of the Studied Oils

The apparatus/reagents used for this test were a 200ml plastic container, chemical balance and the oil samples. The specific gravity of each of the oils were determined thus:

(i) 200 ml empty density bottle was weighed using a chemical balance and recorded as W

(ii) The density bottle filled with water was weighed and recorded as W_w.
(iii) The density bottle filled with one oil sample was weighed and recorded as W_o

(iv) Step (iii) was repeated for the remaining oil samples.
(v) The weight of each oil $= W_o - W$
(vi) The weight of equal quantity of water

$= W_w - W$

Specific gravity, $\rho_r = \frac{W_o - W}{W_w - W}$ (2)

The measurements were carried out for the various oil samples and the results recorded in Tables 2 and 3.

2.3 Viscosities of the Studied Oils at 40^{0}C and at 100^{0}C

The apparatus/reagents used for this test were, Ostwald viscometer, thermometer, distilled water, stopwatch, conical flasks, pipette, heating mantle and the vegetable oil samples. In the viscosity determination, the viscometer was properly cleaned and some volume of a particular oil sample (heated to required temperature i.e. 40°C and later 100°C) was added into the bulb. The liquid oil sample was sucked up by the capillary arm until the meniscus crossed the upper mark. The mouth of the viscometer was covered immediately and later released to allow the liquid to flow down. The stopwatch was started as soon as the oil was released to flow down from the upper mark and stopped as soon as it touched the lower mark.

The flow time for the oil was noted and recorded as (T), and the procedure was repeated for all the other oil samples.

From the experimental results, Viscosity, $\eta = \frac{\eta_w \rho_L T}{\rho_w t}$

Or $\eta = \frac{\eta_w \rho_r T}{t}$ (3)

Where $\rho_r = \frac{\rho_L}{\rho_w}$ = specific gravity

ρ_L = density of oil

ρ_w = density of water

T = time taken for the oil to flow

t = time taken for the water to flow

The result of the viscosity test for the various oils at 40°C and 100°C are tabulated in Tables 4 and 5 while their viscosity indices are in Table 6.

2.4 Pour points of the Studied Oils

The apparatus used were, six beakers, cellophane of nylon material, refrigerator, container, retort stand and thermometer. The pour point can be determined by simulating cold environment condition for the oil. For this experiment, each of the six beakers was filled completely with a sample of the vegetable oils. The beakers were sealed with cellophane or nylon material to protect the oil from being contaminated by moisture. The oils were then placed inside a refrigerator and allowed to freeze. After it has frozen, one beaker after the other was brought out and mounted on retort stand and tilted at angle 45° to the horizontal in order for the oil to pour when it started melting. The thermometer was placed on the surface of the solid oil where it can pour when the temperature was reached. The nylon material was removed from the surface before the beaker was placed on the retort stand. The temperature at which each of the oils started to pour was noted and recorded as shown in Table 8.

2.5 Flash points of the Studied Oils

The apparatus used for this test were retort stand, Bunsen burner, thermometer and test-tube. 15 ml of sample of one of the studied oils was poured into the test-tube and clamped on a retort stand, and then heated slowly using the Bunsen burner. Flame was set on the mouth of the test-tube as soon as the oil started boiling. The thermocouple of the multimeter tester was inserted into the boiling oil and the temperature taken. At certain temperature, the vapour coming out of the boiling oil was ignited. This temperature was noted and recorded as the flashpoint. The flash points of each of the vegetable oil were tabulated as shown in Appendix A.

3 Results Analysis and Presentation

3.1The Analysis of Acidity Test

The acid values were computed from the experimental results, using equation (1).

Table 1: Results of acid values of the studied oils

Oil	NM	V (ml)	W (mg)	Acid value (mgKOH/g)
GNT oil	0.1	2.0	10	1.12
CCN oil	0.1	12	10	6.70
PKN oil	0.1	3.6	10	2.12
SYB oil	0.1	1.0	10	0.56

3.2 Result of Specific Gravity

Table 2: Specific gravity of the studied oils at 40^0C/40^0C.

Oil	W_1 (g)	W_2 (g)	W_3 (g)	ρ_r
GNT oil	25.2	49.6	45.7	0.84
CCN oil	25.2	49.6	47.8	0.93
PKN oil	25.2	49.6	47.4	0.91
SYB oil	25.2	49.6	47.2	0.90

Table 3: Values of specific gravity of oil at 100^0C/100^0C

Oil	W_1 (g)	W_2 (g)	W_3 (g)	ρ_R
GNT oil	25.2	50.3	46.9	0.87
CCN oil	25.2	50.3	47.5	0.89
PKN oil	25.2	50.3	46.8	0.86
SYB oil	25.2	50.3	47.0	0.87

3.3 Result of Viscosity Measurement

Table 4 gives the values of viscosities of oils measured at 40^0C; Table 5 gives the values of viscosities of oils measured at 100^0C and Table 7 contents the viscosity index of each of the oil samples.

Table 4: Viscosities of studied oils at 40^0C (using Ostwald viscometer)

Oil	ρ_r	$T_{(s)}$	$t_{(s)}$	η @ 40^0C (mPa.s)
GNT oil	0.84	4825.9	79.2	33.45
CCN oil	0.93	3396.1	79.2	25.95
PKN oil	0.91	3395.5	79.2	25.50
SYB oil	0.90	3218.4	79.2	23.95

Table 5: Viscosities of studied oils at 100^0C (Ostwald viscometer)

Oil	ρ_R	$T_{(s)}$	$t_{(s)}$	η@ 100^0C (mPa.s)
GNT oil	0.865	3332.7	56.7	14.35
CCN oil	0.888	2159.2	56.7	9.54
PKN oil	0.861	1990.8	56.7	8.53
SYB oil	0.869	1591.2	56.7	6.88

The viscosity of water, vegetable oil and many other fluids varies with temperature and much cervical stress. There are some fluids whose viscosity does not depend on any variable. Such fluids are known as Newtonian fluids. For those that depend on variables such as mechanical stress, temperature etc they are known as non-Newtonian fluids. Viscosity basically entails the fluid's natural resistance to flow. The viscosity of non-Newtonian fluids decreases with increase in temperature. These values of the viscosity recorded on Tables 4 and 5 show the dynamic viscosity or absolute viscosity

.

Table 6: Viscosity Indices of the studied oils

Oil	η@40^0C (cSt)	η@100^0C (cSt)	V I
GNT oil	39.82	16.59	174.31
CCN oil	28.62	10.74	184.38
PKN oil	28.02	9.91	184.45
SYB oil	26.56	7.92	181.21

Looking at the viscosity at 100°C of the oil of interest, the corresponding values of the reference oils, 'L' and 'H' are read from the Standard Data Tables for the evaluation of viscosity index [13].

$$\text{Viscosity Index} = \frac{100(L-U)}{L-H} \quad (4)$$

U is the viscosity (cSt) at 40^{0}C of the oil whose viscosity index is being determined.

3.4 Results of the Pour Point Test

Table 7: Pour points of the studied oils

Oil	Test Method	Pour Point,^{0}C
GNT oil	ASTM D97	7.40
CCN oil		19.10
PKN oil		24.10
SYB oil		-7.00

3.5 Results of the Flash Point Test

Table 8: Flash points of the studied oils

Oil Sample	Flash Point (^{o}C)
GNT	330
CCN	261
PKN	287
SYB	345

4 Discussion

The absolute viscosities, viscosity indices, and flash points of the oils placed them within the range of standard shock absorber fluids mostly for none racing cars shocks from collected manufacturers' data in Table 9, which ranges from 5.0 cSt to 46.7 cSt, viscosity at 40^{0}C; from 1.9 cSt to 13.8 cSt, viscosity at 100^{0}C; 45 to 400 VI; 145^{0}C to 200^{0}C flash point.

The flash points of all the oils considered place them at a comfortable level to be utilized as shock absorber oil; but this parameter is not a sole determinant. The flash points measured fell between 260 and 350 °C.

Although their pour points are high, SYB oil with pour point well below zero can be used even in the temperate region; but will need to be treated with pour-point depressant(s) for it to meet ASTM standards for shock absorber oils. CCN oil, GNT oil and PKN oil with pour point of 7.4, 19.1, and 24.1 respectively may not be suitable even in the tropical region unless properly refined and/or treated with pour point depressant(s). Where the equipment are sedentary and/or localized to the tropical environment, GNT oil could be used as an exceptional case, considering that in the tropics environmental temperatures do not fall as low as 7.0 °C even in tropical winters.

It is also noteworthy from Appendix A that the range of the viscosity values and the viscosity indices cover such a wide range because of the diversities of designs of shock absorbers available in the market. However the most predominant viscosity is the ISO-VG 46 value which is between 44.0 cSt to 48.0 cSt at 40 °C. The common trucks and most automobiles on our roads fall into this value, which may need to be raised by one ISO-VG value to 68 for the tropical conditions. To achieve this, certain amount of VI Improvers could then be introduced to improve the viscosity characteristics.

Apart from CCN oil which has high acidity value of 6.7 mg KOH/g, though not alarming, being less than 10mgKOH/g the maximum requirement for biolubricant, all other samples have quite lower acidity which placed them on a platform of not really harmful to other shock components except for properties improvers.

5 Conclusion

Analysis of some selected vegetable oils as alternative shock absorber fluids for motor cars have been carried out. Their individual, chemical and physical properties suggest them as suitable candidates for further and more thorough examination towards adopting and developing all of them by shock absorber fluid manufacturing industries as excellent alternatives or expansion mechanisms to mineral oil which is non-regenerative and environmentally unfriendly, and synthetic oils which are costlier.

Appendix

Appendix A: Properties of commercially available Shock Absorber Fluids

Description	Viscosity (cSt) @40°C	@100°C	Viscosity Index	Flash Point (° C)	Pour Point (°C)	Aniline point (°C)	Saponification No. (mgKOH/g)
Golden shock fluid, very light (spectro product)	26.4	9.9	400	-	-	-	-
Honda Showa SS7 5W shock oil	16.49	3.77	130	-	-	-	-
Mak Shock Absorber Fluid – 2R	17.2	-	110	175	-24	83	-
Hydraunycoil FH 371 fluids SAE 7.5 ISO VG 32 shock fluid	34.3	7.0	173	-	-42	-	-
Hydraunycoil FH 392 fluids ISO VG 46 racing cars shock fluid	46.7	13.8	309	-	-57	-	-
Reliance lube oil Shock oils	35 - 40	5.75min	100	200		95 min.	5.0 - 6.0
HP shock absorber oils Light	11-12.5	2.85	45min.	145	-40	71 - 82	5.5 – 7.0
HP shock absorber oil heavy	18.1 -21.3	3.3min.	45 min.	160	-37	71 - 82	5.5 -7.0
HP shock absorber oils AW	11.5 - 13.1	2.8 min.	45 min.	149	-45	74-82	3.5 – 7.0
HP shock absorber oils CB(Commercial vehicles)	11.5 -13.1	2.8 min.	45	149	-36	74 - 82	3.5 -7.0
HP shock absorber oils E-modern vehicles	10 -13	-	125 min	150	-39	79	-

Sources (ShockOilComparo.pdf, 2010) and (http://www.peterverdonedesigns.com/files/suspension%20oils.pdf, 2010

References

[1] De Espíndola, J. J., Bavastri C. A., & Eduardo M. D. L. (2008). Design of Optimum Systems of Viscoelastic Vibration Absorbers for a Given Material Based on the Fractional Calculus Model, Journal of Vibration and Control, vol. 14 no. 9-10, 1607-1630.

[2] Leeming, D. J. and Smith, M. E. (1985). Basics of Automotive Technology. London, Pitman Publishing Ltd.

[3] Ahuja Oil. (2009). Ahuja Oil Complete Lubricant Solution. Available at: ahujaoil.com/products.html

[4] Caines, A. J. & Haycock R. F. (1996). Automotive Lubricants Reference Book. London & Bury St Edmunds: Mechanical Engineering Publication Limited, ISBN 1-86058049-1.

[5] Roger, F. H., Arthur, J. C., & John, E. H. (2004). Automotive Lubricants Reference Book, Society of Automotive Engineers, Inc, Warren dale, USA.

[6] Oseni, M. I., Nnuka, E. E. & Ette, A. O. (2006). Evaluation of Chemo-Physical Properties of Selected Natural Oils Relevant to Lubrication, *Nigerian Journal of Engineering Research and Development, vol. 2*, pp1-9.

[7] Stachowiak, G.W, & Batchelor, A. W. (2005). Engineering Tribology. Butterworth Heinmann Publications, United States.

[8] Bamiro, O. A., & Osibanjo, O. (2004). Pilot study of used oils in Nigeria. In Report of Study sponsored by the Secretariat of the Basel Convention.

[9] Haycock, R F., & Hillier, J. E. (2004). Automotive Lubricants Reference Book, Inc, Warrendale, USA, SAE International, ISBN 0-7680-1251-1.

[10] Dawn, L. J., & Terry, A. I. (1998). Biodegradable Plant-Based Hydraulic Fluid. Agricultural Research Magazine, Vol. 46, No. 11.

[11] Gwarilow, I. (2003). Palm Oil Usage in Lubricants, Presented at 3rd Global Oils and Fats Business Forum U S A "Interfacing with the Global Oils and Fats Business"

[12] Erhan, S. Z. (2003). The Use of Vegetable Oils Biobased Products, National Center for Agricultural Utilization Research USDA/ARS, Peorca, IL.

ISSN 2229-5518

[13] ASTM D2270. 1986. Standard Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 and 100°C.