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Investigation on the Possibility of Using Natural Rubber Seed Oil as Brake Fluid

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Authors' contributions

This work was carried out in collaboration between all authors. Author WAA designed the study, wrote the protocol, performed live test of the brake fluids performance and part of the laboratory test and wrote the first draft of the manuscript. Author WAA also managed literature searches. Authors EGI and PA managed the extraction process of the rubber seed oil and a substantial part of the laboratory test of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This paper studies the possibility of using natural rubber seed oil as brake fluid. The laboratory properties of both standard brake fluid (SBF) and natural rubber fluid (NRF) obtained from seed oil were determined. The actual test of the braking efficiencies of the brake fluids were carried out with a Mercedes 190 model within the speed range of 20[km/hr] to 90[km/hr] at the permanent campus of University of Uyo and the braking efficiency of 93.45% for SBF and 90.24% for NRF were obtained. This result shows that NRF is suitable for use as brake fluid.

Keywords: Brake fluid; natural rubber seed; brake properties; braking efficiency.

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1. INTRODUCTION

In fluids, deformation takes place and the particles continuously change their positions relative to one another [1,2]. It offers no lasting resistance to displacement. Deformation of the fluid takes place continuously so long as a shear force is applied. But if this force is removed the shearing movement subsides and as there are no forces tending to return the particles of the fluid to their original relative positions, the fluid keeps its new shape (Bernard, 2001). Fluids may be divided into liquids and gases. Under ordinary conditions liquids are so difficult to compress and for most purposes may be regarded as incompressible, however gases may be much more easily compressed [3]. Fluids have unique and distinct properties that enable its application in Engineering. The brake fluid is a very important component of a braking system. It assists the braking system to bring a moving mass to rest. Most of the brake fluids that are in use are glycol-ether based though mineral oil and silicone-based fluids also exist. Silicone-based fluids must meet the standard spelt out by various organizations. Brake fluids are classified according to their physical properties. The standards in the US come from the Department of Transportation (DOT) [4]. Thus, we have DOT 3, DOT 5 and DOT 5.1. The Society of Automotive Engineers SAE has similar standards of SAE JI703, JI704 and JI7O5 [5]. The international organization for standardization (ISO) 4925 Specifications exist for non-petroleum based brake fluids for hydraulic system.

The two commonly available types of brake fluids are glycol and ester blends. These glycol-based fluids normally have low compressibility but are hygroscopic in nature. The dry boiling point of glycol based fluid seldom exceeds $304[^{\circ}C]$. The second classification which is ester-based has higher dry and wet boiling points. It is not hygroscopic but it is more expensive than the glycol-based fluids. These types of brake fluids are expensive and the petroleum based brake fluids have serious effect on the environment. There are numerous properties which a fluid must possess for it to be considered as a brake fluid. These properties are: dry and wet equilibrium boiling point, viscosity, pH value, fluid stability, corrosion resistance, fluidity and appearance at low temperature, water tolerance, resistance to oxidation, swellness, compressibility, chemical stability, compatibility. The brake fluid must possess a high boiling point to avoid it vaporizing and becoming spongy. It must not boil after accepting a certain amount of moisture. The brake fluid must also possess high viscosity and should not change under a wide range of temperatures. The pH value should not be less than 7.0 or more than 11.5. Brake fluids should not be corrosive. Brake fluids must maintain low compression despite variance of operating temperature. The braking efficiency is said to be 100% when the braking force is equal to the weight of the vehicle, or when deceleration is $9.81[m/s^2]$ [6]. An efficiency of 100% is not desirable because of the rapid wear of the brake linings and tyres, discomfort to passengers and the risk of losing control of the vehicle. It is generally accepted that brake efficiency of 80% to 85% should be aimed at [6]. Natural rubber tree, contains valuable oil which has potential application in the production of soap, cosmetics, paints, glazing pottery as well as brake fluids. Large quantities of rubber seeds abound in Nigeria. About 42, 980 metric tons of the seeds could be produced annually in the country. However, the amount of the seed that could be produced in any year is influenced by factors such as powder mildews disease, abnormal leaf disease, *Phytophthora* disease, genetics and weather. There is need to explore other viable economic use of rubber seed in the country and this calls for this research study.

The rubber seeds usually mature and dehisces from the seed pods during the short dry period between August and September in the rubber belt in Southern Nigeria. The oil content in dry Kernel varies from 35 to 45%. Two products are obtainable from rubber seeds and they are the oil and the cake. The oil is semi-drying, yellowish and consists of 17 – 82% unsaturated fatty acids and 17-22% saturated fatty acids.

The main objective of this paper is to determine the possibility of using natural rubber seed oil as brake fluid.

2. MODELS AND THEORIES

The braking force is derived from the applied pressure in a confined fluid and if the fluid is incompressible that pressure is transmitted equally in all directions throughout the fluid. Work is done by the applied force which pushes a friction plate onto the rotating brake drum. When rotating members of a machine are caused to stop by means of a brake, the kinetic energy is absorbed. The energy absorbed by the brake depends on the type of motion. Such motion could be translational, pure rotational or both [7,8].

From Newton's second law of motion,

$$v^2 = u^2 + 2as \quad (1)$$

Where v and u are final and initial velocities, a and s are deceleration and distance covered.

Equation 1 was used to compute the deceleration when the vehicle was brought to rest as shown in Table 1.

For a moving mass, the retarding force is given as:

$$F = ma \quad (2)$$

With m given as 3000 [kg], the applied force to bring the vehicle to rest is calculated using equation 2 as shown in Table 1.

The energy absorbed is:

$$E_1 = 1/2m(v^2 - u^2) \quad (3)$$

Where E_1 is the energy absorbed, if the moving mass is brought to rest after braking, then v is zero.

Thus,

$$E_1 = 1/2m(v^2) \quad (4)$$

Equation 4 was used to calculate the energy absorbed as shown in Table 1.

3. MATERIALS AND METHODS

Rubber seeds (*Hevea brasiliensis*) were obtained at PAMOL Nigeria Limited, a rubber plantation at Calabar Municipal Local Government Area, Cross River State, Nigeria. The seeds were dehulled, cleaned and dried under the sun for three days to ensure that water moisture was removed. It was then ground into paste using a mortar and pestle in order to weaken and rupture the cell. The paste was stored in a labeled airtight container for oil extraction. All chemicals and reagents used were of analytical grade. In all cases, distilled water was used. For each specimen, oil was extracted from the paste with n-hexane solvent for three hours, using the Soxhlet apparatus. The viscosity, the dry boiling point, wet boiling point, pH value, fluid stability, corrosion test of the oil were all determined and the values compared with the standard commercial DOT 3 brake fluid.

Before running the live test, the brake fluid line of the car was emptied and flushed before the inclusion of the natural rubber seed oil fluid in the brake reservoir system. The fluid line was bled to remove any entrapped air. The live test was conducted using a Mercedes 190 model car of about 3000 [kg]. Before conducting the test the brake system and the tyres were checked to be in good conditions. A point was marked on a tarred road for an experienced driver to start to apply his brake. When the car finally came to rest that point was also noted. The distance between the points when the brake was applied and when the car stopped was measured too. The time interval of each activity was measured. For each speed limit six values were obtained and the mean data recorded as shown in table. The speed range used was between 20 [km/hr] and [90 km/hr].

4. RESULTS AND DISCUSSION

The measured physical properties of the DOT 3 standard brake fluid and natural rubber seed oil brake fluid are presented in Table 1. The physical properties of natural rubber seed oil match closely with the DOT 3 brake fluid. The boiling point natural rubber seed oil brake fluid is within the range stipulated and is close to that of the commercial DOT 3 brake fluid used for the case study. Natural rubber seed oil has a higher wet equilibrium boiling point of $172.5[°C]$ compared to $162.5[°C]$ of the DOT 3 brake fluid which shows that is less hygroscopic. The natural rubber seed oil also possesses a higher viscosity of 48.0 x 10^{-6} $[m^2/s]$ than that of DOT 3 of 43.90 x 10^{-6} $[m^2/s]$ and, this may have hindered the flow characteristics of the natural rubber seed oil and account for the reduction in braking efficiency compared to the DOT 3 brake fluid used for this study. The natural rubber seed oil is also chemically stable as shown in Table 1.

The chemical stability ensures that the fluid does not decompose at the stipulated operating temperature. The pH value of 6.5 requires chemical treatment to make the fluid more basic like the SBF which has a pH value 9.5 at the measured temperature as shown in Table 1.

The performance data of the standard and the natural rubber seed oil brake fluids are presented in Table 2.

Table 3 shows the corrosive test results for the two brake fluids. Like all oils, either plant or mineral-based, it is naturally expected that rubber seed oil is non-corrosive.

Table 4 shows the braking efficiency of the two brake fluids. The natural rubber seed oil brake fluid gives an average braking efficiency of 90.24% which is more than the minimum required-80% (Doland, 1991) and close to 93.45% obtained from DOT 3 used in this case study. The braking efficiency of the natural rubber seed oil is higher than that of soya bean oil -89%, cotton seed oil- 90.4% and formulated water based brake fluid of 88% [9,10,11].

Table 1. Physical properties of a standard brake fluid and natural rubber seed oil

S/N	Fluid properties	Standard dot 3 brake fluid	Natural rubber seed oil
1.	Equilibrium reflux boiling point ERRP	245[ºC]	235[ºC]
2.	Wet ERBP	162.5[ºC]	158[ºC]
3.	pH value	9.5 at 32[ºC]	6.5 at 32[ºC]
4.	Dynamic viscosity	402.39 x 10^{-10} [Ns/m^{2}]	455.5 x 10^{-10} [Ns/m^{2}]
5.	Kinematic viscosity	43.90 x 10^{-6} [m^2/s]	48.0 x 10^{-6} [m^2/s]
6.	High temperature stability	Stable (243.75[ºC])	Stable (234[ºC])
7.	Chemical stability	Stable (181.25[ºC])	Stable (185[ºC])
8.	Fluidity and appearance (colour)	Amber	Dark brown
9.	Water tolerance	Tolerant	Tolerant
10.	Compatibility	Compatible	compatible

Table 2. Performance test data of SBF and NRF on metal trips

S/N	Speed [m/s]	Braking Distance [m]	Braking Time[s] (SBF)	Deceleration [m/s^2] (SBF)	Braking Time[s] (NRF)	Deceleration [m/s^2] (NRF)	Applied force (N) (SBF)	Applied force [N] (NRF)	Energy Absorbed [J]
1	5.56	3.50	2,4	4.42	3.01	3.82	13,260	11,460	46,370.40
2	11.11	8.00	4,01	7.71	3.48	7.71	23,130	23,130	185,148.15
3	16.67	14.00	4.25	9.92	4.13	8.66	29,760	25,980	416,833.35
4	22.22	25.50	5.00	9.87	5.12	9.83	29,610	29,490	740,593.60

**SBF – Standard brake fluid * NRF -Natural rubber oil brake fluid*

Table 3. SBF and NRF corrosion test data on metal trips

S/N	Material	Original mass [g] in SBF	Mass after 4 days in A closed system [g] in SBF	Mass after another 6 days in an open system [g] in SBF	Original mass [g] in NRF	Mass after 4 days in a closed system [g] in NRF	Mass after another 6 days in an open system [g] in NRF
1	Brass	10.12	10.12	10.12	10.14	10.14	10.14
2	Copper	10.18	10.18	10.18	10.18	10.18	10.18
3	Aluminum	15.47	15.47	15.47	16.26	16.26	16.26
4	Steel	25.38	25.38	25.38	46.78	46.78	46.78
5	Cast iron	50.05	50.05	54.05	78.87	78.87	78.87

Table 4. Braking efficiency of the two brake fluids

Speed [m/s]	Deceleration [m/s^2] (SBF)	Deceleration [m/s^2] (NRF)	Braking efficiency of SBF %	Braking efficiency of NRF %
5.56	4.42	3.82	70.20	60.9
11.11	7.71	7.71	78.9	78.9
16.67	9.92	8.66	99.8	90.8
22.22	9.87	9.83	99.2	99.8
Average braking efficiency			93.45	90.24

5. CONCLUSION

From the laboratory and live test results presented, natural rubber seed oil is effective for use as brake fluid. The natural rubber seed oil possesses good hydraulic properties which can be used in other areas of hydraulics and fluid machinery. The natural seed oil brake fluid is not corrosive and other desired fluid properties can be enhanced by the addition of additives.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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