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# Determination of the Density and Viscosity of Engine Oil with Grade 20w-50 in Nigeria

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## ABSTRACT

*Oil plays a role in the moving parts of an engine. It reduces friction and minimizes the wear and tear of the engine parts. The thermo-physical properties considered are the density and viscosity of the oil samples. . Viscosity is thick, sticky, and semi-fluid due to internal friction. Viscosity is a measure of a fluid's resistance to flow. Oil samples from five companies with a grade of 20w-50 were tested for viscosity between 20℃ and 100℃ , which indicate the maximum temperature rating according to manufacturers' specification. The results obtained for the given temperature range were Mobil engine oil (2.56 to 0.67)Pa.s, Total engine oil (0.54 to 0.22)Pa.s, A-Z engine oil (1.55 to 0.41)Pa.s, Sea Horse engine oil (1.35 to 0.35)Pa.s, and Oando engine oil (1.21 to 0.35)Pa.s. These results show that the viscosity decreases as temperature increases. Similarly, the density of each oil sample subjected to the same temperature check range had the following: Mobil engine oil (0.856 to 0.799)$kgm^{-3}$, Total engine oil (0.826 to 0.765)$kgm^{-3}$, A-Z engine oil (0.865 to 0.784)$kgm^{-3}$, Sea Horse engine oil (0.872 to 0.774)$kgm^{-3}$, Oando engine oil (0.879 to 0.799)$kgm.^{-3}$ Having seen that at high temperature only Mobil oil has the maximum value of viscosity, it can therefore be considered the most preferred amongst the five oil samples.*

***Keywords:*** *Engine oil, Density, Viscosity and Temperature*

## 1. INTRODUCTION

Engine oil plays a vital role in the parts of an engine, just like blood in the human system. It is produced from compounds such as base oil and additives. Crude oil from the refinery is first sent to the extraction unit as the raw material of the lubrication unit, where the substances that contain gasoline compounds are removed (ASTM, 2016). Raffinate (refining material) comprising the oil is then sent to the dewaxing unit to separate paraffin and wax, and finally to the furfural unit to produce the petroleum-based oil.

Engine oil has two main functions in car engines: Lubrication and Cleaning. Depending on the type of engine in terms of power and production speed, as well as alloys used in parts such as pistons, cylinders, valves, or unique rubber parts such as radial shaft seals, washers, bearings, etc., suitable engine oil can lubricate and clean as correctly as possible. This engine oil requirement is always specified by the car manufacturer in the car manual but not every car user especially the named second-hand car users bother to check the manufacturer's oil specification for their cars (Smolenski and Schwartz 1994).

Engine oil has many other applications, such as minimizing friction and wear between car engine parts and absorbing pollution and sediment sludge from the operation and combustion of the engine (Nagy *et al.,* 2019). It also keeps parts inside the engine clean, reducing the heat generated by the engine function and cooling the engine, and smoothing the movement of the pieces by sealing their parts. The advantage of engine oil inside a machine is a symphony of moving metal parts that work in concert to produce power. Pistons move up and down in their cylinders as they respond to bursts of energy during combustion. A series of lifters, rockers, and pushrods move with the camshaft to open and close up to three dozen valves to let air and fuel into the cylinders and exhaust out. The pistons pedal a heavy crankshaft that transmits torque to the transmission so that car can move. The benefits of quality motor oil are many - reduced friction, excellent cold weather, extreme temperature protection, reduced deposits, smoother startup, and (most conspicuously) improved fuel economy are all made possible through routine oil and filter changes with quality engine oil. As a result, an engine will work more effectively and work longer. Car engines are provided with fans to maintain a steady-state temperature when at work (Owen and Coley 1995). This steady-state temperature is to be $100^oC$. One could keenly observe that as soon as the fan belt of a car cuts, there would be an indication on the dashboard showing overheating and possible danger to the engine. The temperature of the engine may have risen above $100^oC$ which could degrade the performance of the engine oil in such an engine. Manufacturers of the oil conditioned the maximum temperature of the oils at $100^oC$ for optimal performance. The ability to identify engine oil that withstands a certain level of viscosity despite some temperature changes sparked the purpose of this work.

## 2. THEORY

In the very viscous liquid under test, the small balls fall with a constant (terminal) velocity (Ette, 1994). According to Stoke's law, such a sphere of radius ® falling in a viscous liquid of viscosity coefficient with a terminal velocity (V) is acted on by a viscous drag force (F) given by: F = $6\pi\eta v r$ 1.

In a steady state, F will equal the net downward force;

$6\pi\eta v r = \frac{2}{9} g r^2 \frac{(\rho-\sigma)}{\eta}$ (Ette, 1994) 2.

The equation of motion is therefore;

$Mg - V - U = Ma = F$ 3.

Also, $6\pi\eta v r = M\frac{(V-U)}{t} = F$ 4.

Therefore, $F = 6\pi\eta v r = Mg$ 5a.

But, $v = \frac{L}{t}$ 5b.

By making η the subject of formula, we have

$\eta = \frac{Mg}{6\pi v r} = \frac{Mg}{6\pi L/tr} = \frac{Mg}{\frac{6\pi L r}{t}} = \frac{Mg*t}{6\pi L r}$ 6a.

$\eta = \frac{Mgt}{6\pi L r}$ (Ebong *et al*.., 2014) 6b.

where η is the viscosity, M is the mass of the oil sample, g is the gravitational force, L is the distance between points A and B, r is the radius of each of the ball bearings, and t is the mean time taken for each of the balls to fall and $v = \frac{L}{t}$ is the average terminal velocity of the bearing in the liquid. But, at a certain stage, the ball ceases to accelerate but moves with uniform velocity, called terminal speed. The viscous force $V$ is proportional to a velocity $v$; $V = kv$ where $k$ is constant (Bowden and Tabor, 1956). As the ball bearing accelerates, the speed increases, and so does the viscous force 'V', reaching a point where the viscous drag equals the downward force. At this stage, acceleration 'a' = 0. Hence the above equation becomes; $Mg - V - U = 0$ or 7.

$V = Mg - U$ (Ebong *et al*.., 2014) 8.

Engine oils, the most effective lubricant in automobiles have attracted researchers' interest. Motor oil is important to the engine and necessary to replace regularly with a quality product. Most drivers have the vague sense that it is important to change engine oil often. Cook (2018) determined some properties of engine oils and recommended methods of determining the performance properties of lubricating oils. Cook (2018) presented an article titled: "Conformity to standards of Engine oils manufactured in Nigeria" at the Nigeria Institute of Mechanical Engineers Conference. Hasan-Zadeh and Poshtiban (2001) determined the service specifications of Nigerian produced-engine oils using their hydrodynamic, thermal, and chemical properties. They recommended regular investigation of these properties to monitor the oils in the local markets. Many scholars and researchers have investigated the performance of the local oils in the Nigerian market but failed to focus on the viscosity of the same grade of different oils.

## 3. MATERIALS AND METHOD

According to (Ebong *et al*.., 2014), since detection in edible oil products is negligible, the consumers should prefer branded edible oil in the belief that its manufacturers would not resort to adulteration. Hence, sealed or branded engine oils were used for this study such as Mobil super oil, Total Quartz oil, A-Z oil, Sea Horse oil and Oando oils of Grade 20W-50. These five branded oil products were obtained from different oil shops in Mkpat Enin Local Government Area of Akwa Ibom State.


Figure1: *Samples of different oil Grade 20W-50 used for the study*

**Determination of Viscosity Using Stoke's Law:**

This involves the steps in determination and measurement of viscosity of pure and adulterated oil sample by Stoke's law (Ebong *et al*.., 2014). To use this method, five balls bearing of the same size of radius 0.245cm were carefully dropped, and the terminal velocity was observed between 45cm-50cm, 40cm-50cm, 35cm-50cm, 30cm-50cm, 25cm-50cm.

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**Figure 2:** Experimental setup for the determination of viscosity

**Determination of Density for different *oil Grade 20W-50 used for the study***

Each of the oil samples was conditioned by the use of a plastic container containing ice with water; the oil samples were gently poured into 5 different calorimeter cups of the same size. Each oil sample was immersed in a container that contained ice, and the thermometer was inserted into it and stirred using a non-metallic stirrer for temperature uniformity. At 20°C, the density was recorded, and the depth of the calorimeter cup that contained the oil sample was determined and transferred to a borosilicate glass tube that was graduated at a 1cm interval diameter. Moreover, the oil sample was placed on a Hotplate for the temperature to rise from 20°C to 40°C while using a non-metallic stirrer for uniform temperature, and then pour it into a graduated tube which was conditioned. The ball bearing of radius 0.245cm was dropped gently, and position for terminal velocity was observed as the time it took to reach was recorded using a digital stopwatch. The experiment was carried out at five different temperatures in each of the oil samples. All measurements were made at room temperature.

**Figure 3:** Experimental setup for the determination of density

## 4. RESULTS AND DISCUSSION

As clearly stated in theory above, viscosity decreases with increase in temperature but with temperature above 100$^o$c, the degrading viscosity may cause damage to the car engine. This is also dependent on the brand of oil which one can say that some oils are better than others.

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**Table 1:** Density, Inverse velocity and Viscosity values at various temperatures of the oil samples.

| Oil Grade and Name | Temperature, T(°C) | Density, $\rho(10^3kgm^{-3})$ | $\rho_0-\rho$ $(10^3kgm^{-3})$ | Slope of t vs d plot, $(sm^{-1})$ | Dynamic viscosity, $\eta(p_a.s)$ |
|---|---|---|---|---|---|
| 20W-50(Mobil Super | 20.0 | 0.856 | 7.061 | 27.18 | 2.56 |
| | 40.0 | 0.848 | 7.069 | 21.80 | 2.06 |
| | 60.0 | 0.835 | 7.082 | 10.92 | 1.03 |
| | 80.0 | 0.826 | 7.091 | 8.76 | 0.83 |
| | 100.0 | 0.799 | 7.118 | 7.07 | 0.67 |
| 20W-50(Total Quartz) | 20.0 | 0.863 | 7.054 | 5.72 | 0.54 |
| | 40.0 | 0.826 | 7.091 | 4.29 | 0.41 |
| | 60.0 | 0.795 | 7.122 | 3.47 | 0.33 |
| | 80.0 | 0.779 | 7.138 | 2.74 | 0.26 |
| | 100.0 | 0.765 | 7.152 | 2.31 | 0.22 |
| 20W-50(A-Z Crown) | 20.0 | 0.865 | 7.052 | 16.43 | 1.55 |
| | 40.0 | 0.862 | 7.055 | 11.25 | 1.06 |
| | 60.0 | 0.825 | 7.092 | 10.16 | 0.96 |
| | 80.0 | 0.793 | 7.124 | 5.66 | 0.54 |
| | 100.0 | 0.784 | 7.133 | 4.32 | 0.41 |
| 20W-50(Sea Horse) | 20.0 | 0.872 | 7.045 | 14.37 | 1.35 |
| | 40.0 | 0.833 | 7.084 | 10.92 | 1.03 |
| | 60.0 | 0.822 | 7.095 | 8.96 | 0.85 |
| | 80.0 | 0.860 | 7.111 | 5.42 | 0.51 |
| | 100.0 | 0.774 | 7.143 | 4.12 | 0.39 |
| SAE40(Oando) | 20.0 | 0.879 | 7.038 | 12.91 | 1.21 |
| | 40.0 | 0.842 | 7.075 | 12.91 | 0.69 |
| | 60.0 | 0.834 | 7.083 | 7.27 | 0.57 |
| | 80.0 | 0.824 | 7.092 | 6.07 | 0.49 |
| | 100.0 | 0.799 | 7.118 | 5.13 | 0.35 |

## Determination of Inverse velocity

The inverse velocity measures the change in time for displacement (distance). Table 1 shows the variation of slope in a time versus distance graph as the steel ball moves through each oil sample at specified distances with a corresponding temperature change. It also shows the variation in density and dynamic viscosity with temperature change. These indicate the time increase as the temperature increases. Generally, Figures 4 to 8 indicate the variation of time with distance having slopes that are inverse velocities. For Mobil super at the tube distance of 0.05m, the sphere ball travels 1.30secs at $20^0c$, but at $100^0c$ the ball travels 0.24sec. For Total Quartz at 0.05m, the ball travels 0.33secs at$20^0c$, but at 100°C the ball travels 0.08secs. For A-Z Crown at 0.05m the ball travels 0.80secs at $20^0c$ but at 100°C the ball travels 0.19secs. For Sea Horse, at 0.05m the ball travels 0.78secs at $20^0$C but at 100°Cthe ball travels 0.16secs. For Oando at 0.05m the ball travels 0.60secs at

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$20^0c$, but at $100^0c$ the ball travels 0.12secs. It can be seen that at increasing temperatures, the velocities of the ball also increase, thereby decreasing the falling time at those specific distances. Consequently, the velocity of the falling ball increases with decreasing viscosity.

**Figure 4:** Inverse velocity of steel ball in Mobil super oil

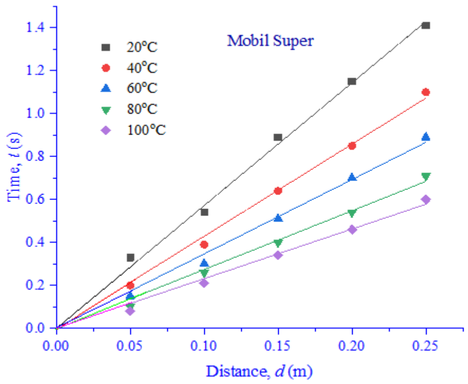
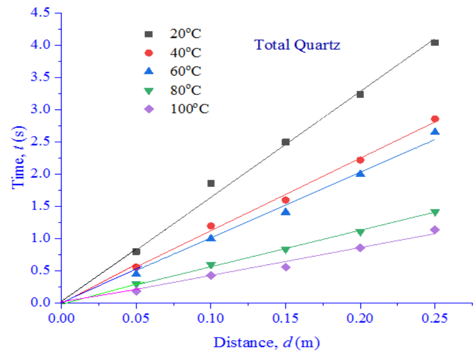



**Figure 5:** Inverse velocity of steel ball through Total Quartz



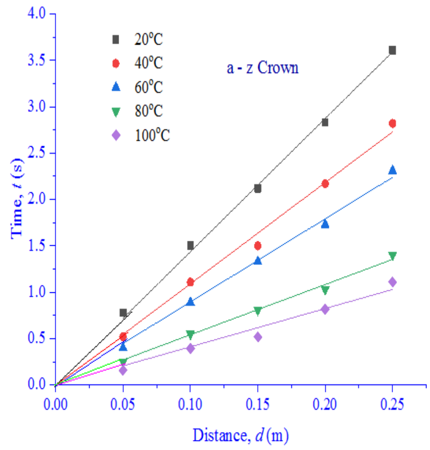




Figure 6: Inverse velocity of steel ball in A-Z Crown oil

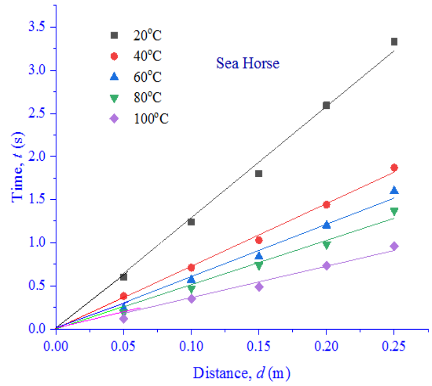



Figure 7: Inverse velocity of steel ball in Sea Horse

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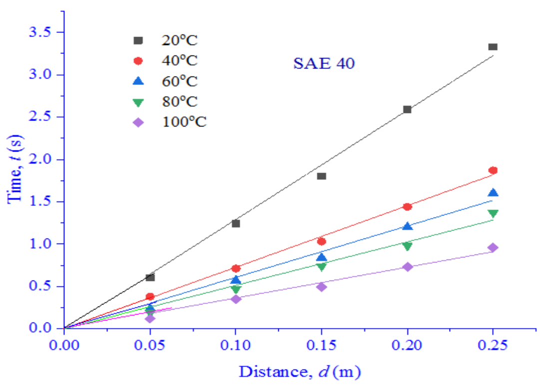


**Figure 8:** Inverse velocity of steel ball through SAE 40 Oando

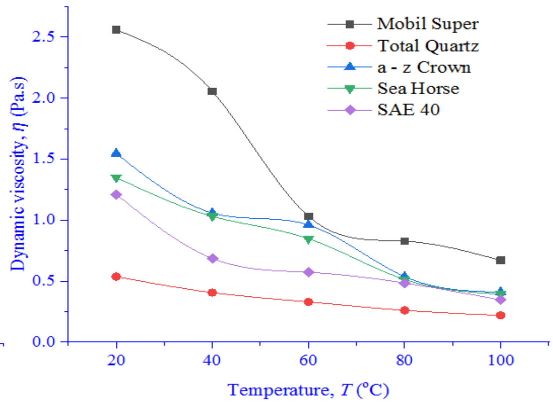


Figure 9: Dynamic viscosity($\eta$) Against Temperature,T(°C)

## Determination of Density

The density is a measure of the amount of matter contained by a given volume. The mass $M_o$ of an empty calorimeter was measured and the mass M was measured for the calorimeter and oil. The volume of the oil sample in the calorimeter was also measured. Thereafter the ratio of mass to volume was used to determine the density of the oil sample as $\rho$in kilogram per cubic meter. The density of Mobil at 20°C was $0.856kgm^{-3}$and at 100°C was$0.799\,kgm^{-3}$.For Total Quartz at 20°Cwas $0.863\,kgm^{-3}$and at 100°C was 0.765kg$m^{-3}$. *For* A-Z at 20°Cwas $0.865kgm^{-3}$and at 100°Cwas $0.784kgm^{-3}$.For Sea Horseat 20°Cwas $0.872kgm^{-3}$and at 100°Cwas $0.774kgm^{-3}$. For Oando at 20°C was $0.879kgm^{-3}$ and at 100°C was $0.799kgm^{-3}$. These imply that as the temperature rises the density falls, meaning that the density of each oil would increase with viscosity increases.

## Determination of Dynamic Viscosity

The viscosity of the lubricants was seen to decrease with an increase in temperature but to differently with each sample. The viscosity-temperature relationship reveals that a molecular view of liquid can give a qualitative picture of the process of decrease in the shear viscosity of a simple fluid with temperature (Massey 1989). As the temperature increases, the time of interaction between neighbouring molecules decreases as a result of the increased average kinetic energy of the molecules. As can be seen from the dynamic viscosity-temperature graph (figure 9), Mobil sample at $20^0c$ (room temperature) has a viscosity of 2.56Pa.s and 0.67Pa.s when the Temperature is at $100^0c$. We now observed that the viscosity of the lubricants decreases when the temperature is raised. A similar trend occurs for other oils. Total Quartz at $20^0c$ has a viscosity of 0.54Pa.s, and 0.22Pa.s when the temperature was at $100^0c$. A-Z at $20^0c$ has a viscosity of 1.55Pa.s at 20°C and at $100^0c$ the viscosity is reduced to 0.41Pa.s. Sea Horse at $20^0c$ has a viscosity of 1.35Pa.s and at $100^0c$ the viscosity is reduced to 0.39Pa.s.SAE 40 at $20^0C$ has a viscosity of 1.21Pa.s at 20°C and at $100^0C$ the viscosity of the SAE 40 was decreased to 0.35Pa.s. Now from the graph, we observed that the Viscosity of the Mobil oil was reduced gradually as the temperature was increased while the viscosity of Total Quartz was rapidly reduced with an increase in temperature. Mobil super synthetic oil was seen to have the highest viscosity at room temperature of 20°Cand highest viscosity at the highest temperature of $100^0C$.Total Quartz has the lowest viscosity at both the highest and the lowest temperatures (Total Enegies 2021).

Low viscosity at low temperatures is an advantage at engine start-up where the oil is required to be pumped to the necessary locations for the engine to start. Very high viscosity at room temperature will be a disadvantage in a situation where external heating will be required for the oil to be light enough to flow. Based on the Society of Automotive Engineers (SAE) recommended standard of oil-grade good for regions like Nigeria is 20W – 50. This grade was used for all samples under investigation. Therefore, Mobil oil is most preferred for use in the Nigerian setting.

## 5. CONCLUSION AND RECOMMENDATIONS

The study shows that not all engine oils are suitable for engines. It is because the viscosity of some oils is very low at higher temperatures. Thereby, such oil becomes a poor lubricant at that temperature. The viscosities of oil samples at higher temperatures are parameters for appropriate engine oil that can enhance the lifespan of car engines. The results show that Mobil oil is the most appropriate for engines, closely followed by A-Z oil and Sea oil. However, the results reveal that Oando oil and Total oil are not very suitable for car engines due to their low viscosities at higher temperatures. It can easily result in the fuming of the oils at higher temperatures which sacrifice their viscosities. Therefore, car users and mechanics should note the order of preference of the oil samples accordingly.

This work is limited to a maximum temperature of 100°C according to oil manufacturers' specifications. It therefore recommended further studies into what happens to the oil and engine if the temperature of the oil is raised above the maximum limit.

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