American Journal of Physics and Applications
2022; 10(4): 57-61
http://www.sciencepublishinggroup.com/j/ajpa
doi: 10.11648/j.ajpa.20221004.11
ISSN: 2330-4286 (Print); ISSN: 2330-4308 (Online)

Simulation of the Effect of Temperature on the Viscosity of Some Selected Engine Oils

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To cite this article:
Kehinde Abdulsemiu Busari, Alhaji Abubakar, Taiwo Abduljelil Busari, Suleiman Modu Ngaram, Adam Tijjani Jakada, Musbaudeen Alaba Afolabi, Abdulhamid Mohammed Ribadu, Hassan Adamu. Simulation of the Effect of Temperature on the Viscosity of Some Selected Engine Oils. *American Journal of Physics and Applications*. Vol. 10, No. 4, 2022, pp. 57-61. doi: 10.11648/j.ajpa.20221004.11

Received: June 24, 2022; **Accepted**: July 20, 2022; **Published**: October 21, 2022

Abstract: Viscosity is the resistance of a fluid to flow due to internal friction on the layers of the fluid. An example of such fluid is engine oil which happens to be viscous and thus serves as a lubricant for the moving parts of automobile engines to work efficiently. However, this lubrication is only possible because automobile engines generate heat that reduces viscosity and allows the smooth flow of oil through engine parts. So, we conducted an experiment to determine the effect of temperature on the viscosity of engine oil A, B, C, D and E. Thereafter, we used MATLAB programming to analyze and optimize the viscosity of these fluids. Results show that at the temperature range of (35 – 95)°C, the viscosity of SAE20W-50W (A, B, C, D and E) engine oil is maximum at (0.5079, 0.4848, 0.4971, 0.4980, and 0.4846) kg/ms respectively and minimum at (0.2793, 0.2934, 0.2804, 0.2682 and 0.2806) kg/ms respectively. Therefore, increase in temperature decreases the viscosity and cooling rate of engine oils to provide a favorable lubrication. Conclusively, we established that engine oils B, C and E are more preferable for automobile users in both industries and households.

Keywords: Viscosity, Simulation, Temperature, Engine Oil

1. Introduction

Motor oil or engine oil is formed from petrochemicals. Origin of oil in general is established from animal, vegetable, or petrochemical [2]. The purpose of using oil in engines and rotating machineries is lubrication, which means adding a layer of oil or film between the surfaces to prevent metal to metal contact also with cooling and heat transfer processes [5]. Multi-grades engine oil is used today for all seasons. In the past car owners used engine oil in winter and summer season [5]. One example of multi-grade engine oil is 10W-40, the letter W means winter, not weight or watt or anything else and the other numbers show that the oil has maximum viscosity at low temperature, the lower W number, the better oil cold starting performance for example 5W is better than 10W [1]. Viscosity is the most important parameter of engine oil, viscosity shows shear force or resistance to motion, and it depends on temperature and speed (basic engine oil report). Engine oil should be capable of flowing at low temperatures. Oil rotates under the oil pump action around the engine in a fraction of a second at start-up and must protect engine components at high temperatures without evaporating or carbonizing by maintaining adequate oil pressure [1]. The effect of mixing new and old engine oils is presented the study shows the effect of adding old oil to new oil and adding new oil to old oil, with temperature range of -10°C to +60°C, the results shows engine oil viscosity with temperature for different mixing percentages [12]. Engine oil is made from petrochemicals with different grades, the most important specification of engine oil specifications list is viscosity, and mathematical models of different grades engine oil (10W-40, 5W-30, and 20W-50) are used based on pervious paper. The optimization technique is used to show the minimum value of viscosity of engine oil at minimum temperature. Study shows that the temperature of minimum viscosity for all engine oil grades (10W-40, 5W-30, and 20W-50) is approximately around 40°C [1]. So, plenty of researches on the variation of viscosity have been performed to solve the problem of temperature-varying properties of the fluid [13]. A paper was presented to study the effect of viscosity on the heat transfer mechanism in thermal treatment of canned liquid product by considering Carboxyl Methyl Cellulose (CMC) solution as a viscous agent using Computational Fluid Dynamics (CMD) analysis [11]. The consequences of varying viscosity and varying Prandtl number on Falkner–Skan flow of Williamson nano-fluid over a wedge, plate and stagnation point were explored [10]. A study on viscosity-temperature dependence using some parameters such as energy (Ea), pre-exponential factor (A), Arrhenius Temperature (T) and Arrhenius Activation Temperature (T^*) was presented to show the viability of soya bean and palm oil as feed stock for biodiesel production and relevance in electric voltage transformers [4].

2. Background Theory

Viscosity is a property of a liquid which defines the resistance of liquid to flow [7]. More specifically, it determines the fluid strain rate that is generated by a given applied shear stress. In most cases, lower viscosity is beneficial to air pollution control applications. Viscosity relates directly to pump performance to a system connected to a pump. Prior to designing a pump, it is important to determine the viscosity of the fluid at the expected operating condition. An increase in the liquid viscosity generally increases the required net inlet pressure and the require pump input power. Furthermore, an increase in the viscosity generally corresponds to a decrease in the maximum allowable pump speed. Viscosity affects the size of liquid particles. Liquid droplets can be formed by vapor condensation in the stack gas or by spraying liquid into the gas stream (i.e. air pollution control equipment).

Viscosity is measured with various types of viscometers and rheometers. A rheometer is used for those fluids which cannot be defined by a single value of viscosity and therefore requires more parameters to be set and measured than it's the case for a viscometer. Close temperature control of the fluid is essential to accurate measurements, particularly in materials like lubricants, whose viscosity can double with a change of only 5°C. For some fluids, viscosity is constant over a wide range of shear rates (Newtonian fluids). Viscosity can also be calculated using the equation below

$$\eta = \frac{[2(\rho_s - \rho_l)gr^2]}{9v} \quad (1)$$

where, ρ_s is the density of the sphere, ρ_l is the density of the liquid, g is the acceleration due to gravity, r is the radius of the sphere and v is the kinematic viscosity of the sphere [3, 6].

DENSITY (ρ)

Density of the substance is defined as the mass of the substance per unit volume.

And it can be defined mathematically as

$$\rho = \frac{M}{V} \quad (2)$$

Where M is the mass of the object and V is the volume of the object [8].

Mass is the quantity or aggregate of matter usually of considerable size.

$$M_l = M_{l+B} - M_B. \quad (3)$$

where M_s, M_l, M_B, M_{l+B} is the mass of the solid iron, mass of liquid, mass of the empty beaker and mass of liquid and the beaker respectively.

VOLUME (V)

Volume is the amount of space occupied by a three-dimensional object as measured in cubic unit such as liters or quarts, it's definite for any specific temperature and pressure [9]. Volume of the liquid is measured using measuring scale on the Beaker.

Volume of iron sphere is obtained using the relation.

$$V_s = V_2 - V_l \quad (4)$$

Where V_s is the volume of iron sphere, V_l is the initial volume of the liquid, and V_2 is the final volume of the liquid with the iron sphere.

Substituting equation 3 and 4 into equation 1 we have,

$$\rho_l = \frac{M_l}{V_l} \quad (5)$$

$$\rho_s = \frac{M_s}{V_s} \quad (6)$$

RADIUS OF THE SPHERE (r)

The radius of the sphere is obtained using the relation below

$$V_s = \frac{4}{3}\pi r^3 \quad (7)$$

$$r = \left(\frac{3V_s}{4\pi}\right)^{1/3} \quad (8)$$

Velocity is the rate of changes of distances with time. It can be written mathematically as

$$v = \frac{d}{t}, \quad (9)$$

where v is the Velocity, d is the distance covered by the object and t is the time taken by the object [3].

3. Methodology

In this work, we have used both experimental and simulation procedures for the analysis of the results as follow:

Experimental Procedure

In this work we have analyzed the viscosities of different engine oil (20W − 50W Engine Oil), By Using analogs apparatus (Graduated cylinder, Liquid in question: A, B, C, D, E SEA20W−50W Engine Oil, Beam balance, Meter ruler, Thermometer 0-100°C, Small metal ball i.e sphere and Stopwatch) in the laboratory.

We obtained the density of the iron sphere ρ_S using equation 6 by measuring its mass with beam balance and the volume using equation 4.

We obtained the density of the engine oil (A, B, C, D and E), ρ_l as (916kg/m^3, 886 kg/m^3, 880 kg/m^3, 892 kg/m^3, 888 kg/m^3) respectively using equation 3 and 5.

We obtained the velocities of the sphere for each case with the equation 9 using the height of the liquid and the times taken to drop (for all the seventh times of the experiment of each liquid).

We obtain the radius of the sphere using equation 8, as r = 0.0129m.

We obtained temperatures (T) of the liquids to show cooling rates, by heating the liquids up to 110°C and recording the temperatures after thirty-thirty seconds as A [108.50, 106.75, 106.00, 105.25, 104.50, 104.00, 103.00,], B [108.00, 106.00, 105.00, 104.25, 103.75, 103.25, 102.75,], C [108.25, 106.50, 105.75, 105.00, 104.25, 103.75, 103.00,], D [108.25, 106.75, 105.75, 104.75, 104.25, 103.75, 103.00,], E [18.00, 106.00, 105.00, 103.75, 102.75, 102.00, 101.50,] and the values of times as [30, 60, 90, 120, 150, 180, 210].

Simulation Procedure

In this work we have analyzed the viscosities (η) of different engine oil 20w-50w (A, B, C, D, E) Using equation 2.1 as polynomial function using MATLAB in order to optimize their performances with temperature (T).

We utilize output functions for the viscosities of all the liquids (as mention above) such as $\eta_1, \eta_2, \eta_3, \eta_4, \eta_5$ respectively, and input parameters such as (ρ_s, ρ_l, g, r, v).

We generated a script for the output functions in the editor script environment of the MATLAB by defining a poly functions for the input parameter, as[$\eta_1, \eta_2, \eta_3, \eta_4, \eta_5$]= poly ($\rho_s, \rho_l$, g, r, v).

In the first case, we set $\rho_s, = 7222.2\ kg/m^3, \rho_l = 916\ kg/m^3$, g = 9.8 m/s^2, r = 0.0129 m, v = [4.5000, 4.8649, 5.4545, 5.8065, 6.4285, 7.2000, 8.1818], for engine oil A. A script is then generated to run a poly function defined on the command window for a reasonable optimization.

In the second case, we set $\rho_s, = 7222.2\ kg/m^3, \rho_l = 886 kg/m^3$, g = 9.8m/s^2, r = 0.0129m, v = [4.7368, 5.1429, 5.4545, 6.0000, 6.2069, 6.9231, 7.8261] m/s, for engine oil B. A script is then generated to run a poly function defined on the command window for a reasonable optimization.

In the third case, we set $\rho_s, = 7222.2kg/m^3, \rho_l = 880\ kg/m^3$, g = 9.8 m/s^2, r = 0.0129m, v = [4.6154, 5.0000, 5.4545, 5.8065, 6.6667, 7.5000, 8.1818] m/s, for engine oil C. A script is then generated to run a poly function defined on the command window for a reasonable optimization.

In the fourth case, we set $\rho_s, = 7222.2\ kg/m^3, \rho_l = 892\ kg/m^3$, g = 9.8 m/s^2, r = 0.0129m, v = [4.6154, 5.1429, 5.4545, 6.0000, 6.6667, 8.1818, 8.5714] m/s, for engine oil D. A script is then generated to run a poly function defined on the command window for a reasonable optimization.

In the fifth case, we set $\rho_s, = 7222.2kg/m^3, \rho_l = 888\ kg/m^3$, g = 9.8 m/s^2, r = 0.0129m, v = [4.7368, 5.0000, 5.4500, 5.8065, 6.4286, 6.9231, 8.1818] m/s, for engine oil E. A script is then generated to run a poly function defined on the command window for a reasonable optimization.

We obtained the output values of viscosities of all the liquids with the given value of the input parameters in the command window due to the generated scripts.

We plotted a 2-D graphs of viscosities of the liquids (as mention above), against the temperatures value for each case using command window which contain grid, legend of the strings and colors with X and Y label for temperature (T) and output functions viscosities (η) respectively, as plot (T,n1,'b-*',T,n2,'k-*',T,n3,'r-*',T,n4,'m-*',T,n5,'g-*').

Finally, the display of 2-D graphics plot shows the performances of the viscosities for all the liquids against the sequential temperatures.

We adopted similar procedures to plot a graph of Temperatures (T) against time (t) to show the rate of cooling of the liquids (A, B, C, D, E) with times, by inserting the value of temperatures and the times as above (as in 3.22).

Finally, the display of 2-D graphics plot shows the variation of the temperatures with times (as the liquid is not getting heats, the temperatures dropping with times.

4. Results

The result obtained for all the engine oil A, B, C, D and E are graphically displayed to show the variation of viscosity with temperature as in figures 1, 2, 3, 4, 5, 6 and 7 respectively.

In figure 1, the viscosity of A engine oil is maximum at 0.5079 kg/ms and minimum at 0.2793kg/ms, with temperature range of (35 – 95)°C.

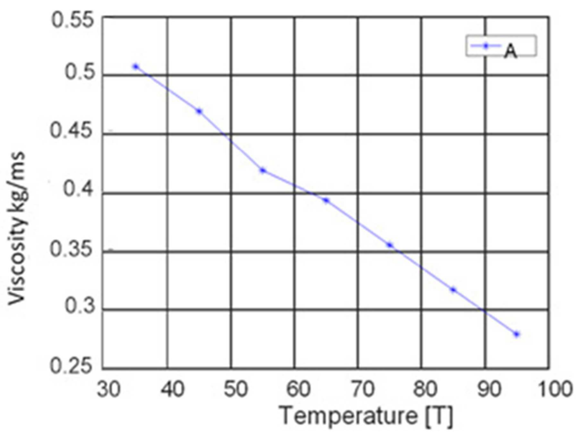

Figure 1. *Viscosity of A (Engine oil SAE20w-50w) at different temperature.*

In figure 2, the viscosity of B engine oil is maximum at 0.4848 kg/ms and minimum at 0.2934kg/ms, with temperature range of (35 – 95)°C.

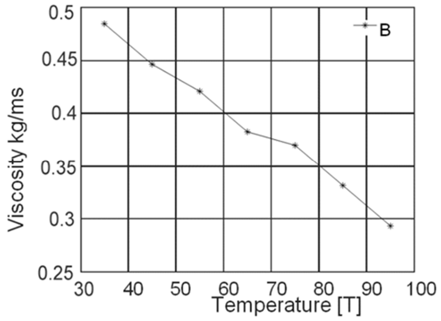

Figure 2. *Viscosity of B (Engine oil SAE20w-50w) at different temperature.*

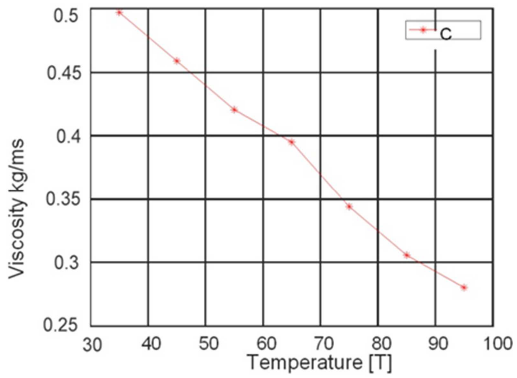

Figure 3. *Viscosity of C (Engine oil SAE20w-50w) at different temperature.*

In figure 3, the viscosity of C engine oil is maximum at 0.4971 kg/ms and minimum at 0.2804 kg/ms, with temperature range of (35 – 95)°C.

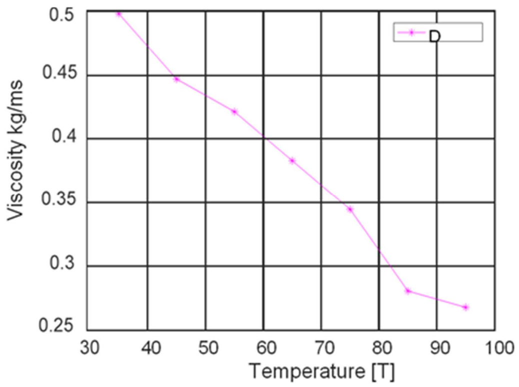

Figure 4. *Viscosity of D (Engine oil SAE20w-50w) at different temperature.*

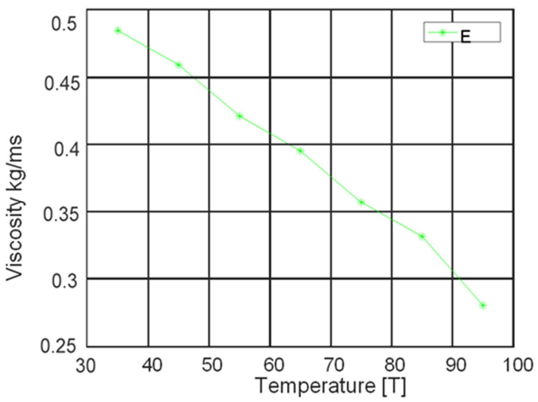

Figure 5. *Viscosity of E (Engine oil SAE20w-50w) at different temperature.*

In figure 4, the viscosity of D engine oil is maximum at 0.4980 kg/ms and minimum at 0.2682 kg/ms, with temperature range of (35 – 95)°C.

In figure 5, the viscosity of E engine oil is maximum at 0.4846 kg/ms and minimum at 0.2806 kg/ms, with temperature range of (35 – 95)°C.

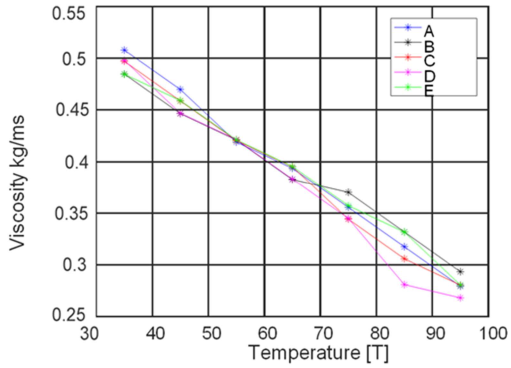

Figure 6. *Viscosities of A, B, C, D, E (Engine oil SAE20w-50w) at different temperature.*

In figure 6 at high temperature of 95°C, B has the high viscosity of 0.2934kg/ms, while D has the lowest viscosity of 0.2682 kg/ms. The result shows that there is a common pattern throughout as the temperature of fluids increase, its viscosities decrease with decrease in the average time of fall of the mass. This is seen visually in the generally decreasing gradient of the trend line which represents how each liquid gets hotter, the viscosity level decreases and the mass travelling through moves faster.

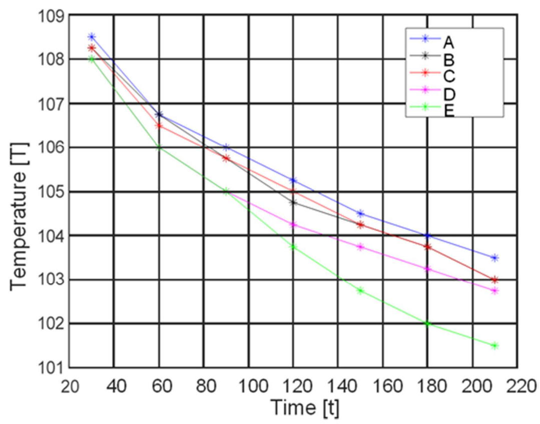

Figure 7. *Temperatures of A, B, C, D, E (Engine oil SAE20w-50w) at different time.*

In figure 7, the temperature of all the liquids A, B, C, D, E (Engine oil SAE20w-50w) decreases with increase in time. Generally, this shows that there is a common pattern throughout as the time increases, the temperature of the fluids decreases.

5. Discussion

Generally, the result shows that there is a common pattern throughout as the temperature of a fluids increase, its viscosities decreases as the average time of fall of the mass decreases. The viscosity of SAE20W-50W (A, B, C, D and E) engine oil is maximum at (0.5079, 0.4848, 0.4971, 0.4980, and 0.4846) kg/ms respectively and minimum at (0.2793, 0.2934, 0.2804, 0.2682 and 0.2806) kg/ms respectively, with temperature range of (35 – 95)°C. It can be observed that the viscosity decreases with the increase in temperatures. This is seen in the generally decreasing gradient of the trend lines which represents how each liquid gets hotter as the viscosities level decreases and the mass travelling through moves faster.

6. Conclusion

In this study we have computationally analyzed and demonstrated that at a temperature of 95°C, B engine oil has the highest viscosity of 0.2934kg/ms while D engine oil has the lowest viscosity of 0.2682 kg/ms. This implies that engine oil with higher viscosity at higher temperature has a good performance for automobile engines. This prevents wear and tear of engine parts through reduction of friction and improves the durability of engine as the engine oil combustion increases with temperature.

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