International Journal of Research in Engineering, Science and Management
Volume-3, Issue-3, March-2020
www.ijresm.com | ISSN (Online): 2581-5792

Lubricating Capacities of Different Engine Oil Samples Using Specific Heat Capacity and Newton's Law of Cooling

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***Abstract*: Many engine oil users switch from one type of oil to another without actually knowing the difference between them. In this research work the lubricating capacity of different engine oil samples (SAE20W-50) was investigated by using specific heat capacity and Newton's law of cooling method. The different engine oil samples were for economic reasons labeled A, B, C, D and E respectively. The result obtained showed that sample B has the highest specific heat capacity, which is suggestive of the high internal energy stored in the lubricating system and sample E(unbranded oil) has the least specific heat capacity. It was also observed that oil sample D cools faster than A, B, C and E respectively. The multigrade oil with higher cooling rate is the best coolant and lubricator and the oil sample with highest specific heat capacity has high internal energy that is inversely proportional to viscosity. High energy and less viscous sample (B) lubricates better and starts engines faster than other samples which may have low internal energies and high viscosities when compared with sample(B).**

***Keywords*: Lubricating Capacity, Specific heat capacity, Multigrade, Viscosity.**

1. Introduction

Lubricating oils are viscous liquid and are used for lubricating moving parts of engines and machines. Grease, which is a semi-solid, also belongs to this group. There are three major classes of lubricating oils, namely: lubricating greases, automotive oils and industrial lubricating oil. When lubricating oils are used in service, they help to protect rubbing surfaces and promote easier motion of connected parts. In the process, they serve as a medium to remove high buildup of temperature on the moving surfaces. Further buildup of temperature degrade the lubricating oils, thus leading to reduction in properties such as: viscosity, specific gravity, etc. (Udonne, 2010). Specific heat capacity of motor oils refers to the heat required to raise the temperature of 1 kilogram of motor oil through 1 degree Celsius. Experimentally, heat received by motor oil is proportional to the mass of oil and the thermodynamic temperature of the engine in which the motor oil is enclosed. Engine oils are useful derivative of crude oil or petroleum obtained through fractional distillation (George et al., 2010). Denser petroleum products are the major lubricants in our engines and machines. Besides lubrication, engine oils also serve as coolants. The high rate of cooling in an engine system is a function of the specific heat capacity of the fluid used and its viscosity. A substance with high specific heat capacity does not lose its internal energy completely even at unusual frozen temperature (George et al., 2010). In motor engine oil, the internal energy enables the engine to start faster because the heat lost by the engine is stored as an internal energy in the lubricating systems (Corsico et al.,1999; George et al., 2010). Modern lubricants, with high performance can do much more than simply reducing attrition and wear. Lubricant oil are really important, presenting different functions, as refrigeration, cleaning, fencing off and protection against corrosive agents (souza, 2000; Santos et al., 2006). Variations in heat capacities serve as a sensitive indicator of phase transitions and are an important tool for understanding changes in the structure of liquid solutions (Santos et al, 2005; Ugochuku et al, 2016). Oil thermal conductivity and specific heat are also important parameters for engine cooling system design, and are a function of temperature. Oils with a larger thermal conductivity value will transfer heat energy more efficiently. In any mechanical device using engine oil, the internal energy enables the engine to start faster because the heat lost by the engine is stored as an internal energy in the lubricating systems. (Corsico et al., 1999; Ugochuku et al., 2016). Water has thermal conductivity and specific heat values approximately twice those of typical glycols. High-temperature heat transfer fluids and petroleum engine oils have lower values for thermal properties than glycols. Many types of oils are used as heat transfer fluids, which leads to a fairly wide band of typical thermal conductivity and specific heat values. (Wrenick et al., 2005; Ugochuku et al., 2016). In simpler terms, viscosity can also be identified as fluid friction. Like friction between moving solids, viscosity transforms the kinetic energy of (macroscopic) motion into heat energy (Fowler, 2007; Roslan et al., 2016). Viscosity is significantly affected by temperature whereby as the operating temperature increases, the viscosity of liquids decreases which in turn causes the lubricating oil to become thinner. The viscosity of a good lubricating oil should not vary much with respect to temperature changes, so that it can be used at all times under varying conditions of temperature (Roslan et. al., 2016). The viscosity of motor oil is graded in terms of the SAE (Society of Automotive Engineers) index number. This number depends on the viscosity of the oil. For instance, SAE 10 motor oil is less viscous than SAE 30 motor oil (George et al., 2010) . However, viscosity depends on the temperature of the engine. At very low temperature, SAE 30 motor oil will be too thick as lubricant while at very high temperature, SAE 10 motor oil will be too light to be used as lubricant. This effect is due to the specific heat capacities of engine oils (Woydt 2007; George et al, 2010). In the early days of the integrated circuit engine, there were only mono-grade oil such as SAE 20, SAE 30 and SAE 50. However, putting additives called viscosity index improver into these oils, generated multi-grade oils. The viscosity index improver is flexible molecule which rolls up like a ball at low temperature and stretches out like string at higher temperature (ALTAD, 2006; George et al., 2010). This allows the oil to remain viscous at high temperatures. Multi-grade oils are represented by two parts. The first part goes with ‘W’ which stands for the viscosity glass at low temperature – the winter rating of the oil (George et al, 2010). The second part is SAE glass at working temperature. For example, SAE 20W – 50 means that the viscosities of the oil at lower temperature corresponds to SAE 20W oil and the viscosity at high temperature corresponds to SAE 50 oils. Conventional monograde motor oils tend to “boil off” in high temperatures, losing up to 25 percent of their original weight (Corsico et al., 1999; ALTAD, 2006; George et al., 2010). These vaporized oils circulate poorly, reduce fuel efficiency and contribute to excessive emissions and engine wear. High performance synthetic 20W –50 motor oils resist vaporization (George et al., 2010).

2. Materials and Methods

The popularly use SAE 20W-50 and unbranded engine oils were for economic reason coded as A, B, C, D and E respectively. The oil samples were collected from different standard engine oil dealers in Offa L.G.A of Kwara State, all in North Central Nigeria where the average ambient temperature is 30oC. The collected samples in their labeled containers were taken to the laboratory for determination of their specific heat capacities and cooling rates. Again, Copper Calorimeter, thermometer, Bunsen burner, stirrer, tripod stands, stop watch, solid block of brass material, beam balance, thread and lagging materials were used in the experiment as materials for determining specific heat capacity and cooling rates of the engine oil samples.

3. Determination of specific heat capacity

The method of mixture was used to determine the specific heat capacities of the different SAE 20W–50 engine oil samples. The brass block was weighed and its mass recorded as M1. It was then placed by means of a thread tied to it in a beaker of water and heated until the water boiled and began to evaporate. Before this, the calorimeter together with the stirrer was first pre-weighed empty and recorded as M2 and reweighed after being half filled with an oil sample and recorded as M3. The initial temperature of the oil sample was read with the thermometer and recorded as θ1. The solid brass block whose temperature was recorded as θ2 in boiling water beaker was quickly transferred to a lagged calorimeter containing the oil sample. The calorimeter was covered with a lid and the mixture was gently stirred to ensure uniform distribution of temperature. The highest steady temperature was read and recorded as θ3. The experiment was repeated for all the other oil samples and in each case the measurable parameters measured above were also recorded with the necessary precautions observed. The specific heat capacity of the oil samples were calculated from many readings as average value for each of the samples by assuming that the law of conservation of energy is held.

Heat lost by brass block equals heat gained by engine oil and calorimeter

$$M_1C_1(\theta 2 - \theta 3) = M_2C_2(\theta 3- \theta 1)+(M_3-M_2)C_3(\theta 3- \theta 1) \tag{1}$$

Where,
C1 = specific heat capacity of brass block
C2 = Specific heat capacity of calorimeter (copper)
C3 = Specific heat capacity of oil to be found which is given from (1) as in (2)

$$C3 = \frac{M1C1(\theta 2-\theta 3)-M2C2(\theta 3-\theta 1)}{(M3-M2)(\theta 3-\theta 1)} \tag{2}$$

4. Cooling rates of oil samples

The temperature of the surrounding was measured at 30^0C and recorded, then the beaker was filled with oil and heated to 60^0C. The oil in the beaker was then quickly transferred into the calorimeter containing thermometer and begin to stirred for some time. The temperature for every two-minute degree fall in temperature were noted and recorded. The experiment was repeated for equal volume of different oil samples used, and each time the degree fall in temperature for every two minute were recorded.

Theoretically, the time rate of decrease of temperature is proportional to the difference in initial temperature before cooling and the surrounding. This is illustrated in (3) below:

$$\frac{d\theta}{dt}\ \alpha(\theta-\theta_R) \tag{3}$$

$$\frac{d\theta}{dt} = -k(\theta-\theta_R) \tag{4}$$

Where k in (4) is a positive constant known as cooling constant and the negative sign indicates that the temperature is decreasing (Nelkon et al., 1987; George et al., 2010). Separating variables in (4) and integrating from θ_0 to θ and 0 to t, we have equation (5).

$$\theta = \theta_0\, e^{-kt} \qquad (5)$$

$$\text{Where } \theta_o = (\theta\text{-}\theta_R) \qquad (6)$$

and θ_R is the ambient temperature while θ is the falling temperature. A graph of falling temperature θ against time, t will give moderate exponential model curve that can be fitted in to a line and the slope of the curve fitted into a line at any point on the line will give the rate of cooling, k which is a determining factor for the time it takes for the multigrade oils to adjust between their high and low operating temperature ranges. This experiment was based on Newton's law of cooling which states that the rate of loss of heat is proportional to the excess temperature over the surroundings.

5. Results and discussion

Using equation (2) and substituting the measured values of M1, C1, θ2, θ3, C2, θ1 and M3, the average specific heat capacity for each of the different oil samples was obtained as shown in table 1. The table below shows that sample B has the highest specific heat capacity and this is followed by C, D, A and E respectively.

Table 1
Specific heat capacities for different SAE20W-50 oil samples

SAE 20W- 50 Oil sample code	Specific heat capacity (j/kg/k
A	1953.94
B	3151.48
C	2860.33
D	2081.35
E (Unbranded oil)	1552.22

This suggest that the quantity of heat required to raise the temperature of a unit mass of the oil sample is highest in oil sample B and least in oil sample E of all the five oil samples considered.

Table 2
Cooling curve table for the different oil samples

	Falling temperature of coded oil samples in (^0C)				
Time (min)	A	B	C	D	E
0	60	60	60	60	60
2	58	57	59	58	57
4	56	55	56	55	57
6	55	53	55	53	56
8	54	52	53	52	55
10	52	51	50	50	54
12	51	50	49	49	53
14	50	49	47	46	52
16	49	48	45	44	50
18	49	47	43	43	49
20	48	46	42	40	47
22	47	45	40	38	45
24	46	44	38	36	44

The plotting of the falling temperature θ, against time t, gives the cooling exponential curves which were fitted into straight lines (Figs. 2 – 6). The resulted curves which were linearly fitted are governed by Newton's law of cooling.

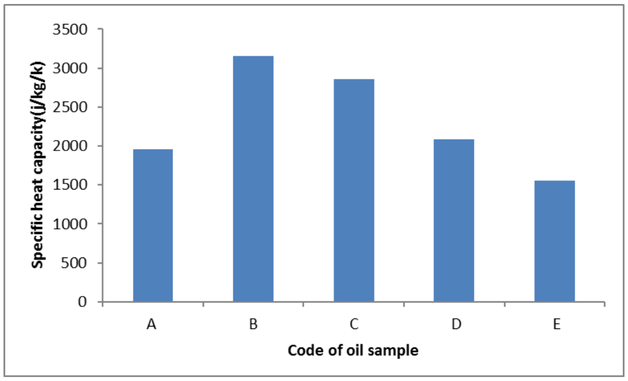

Fig. 1. A graph of comparison of specific heat capacities of oil samples A, B, C, D and D

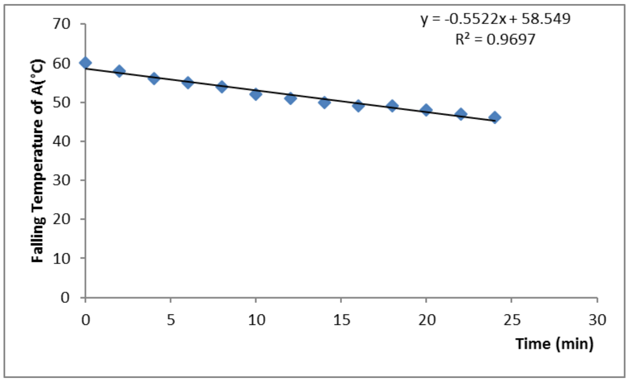

Fig. 2. A graph of temperature of oil sample A against time

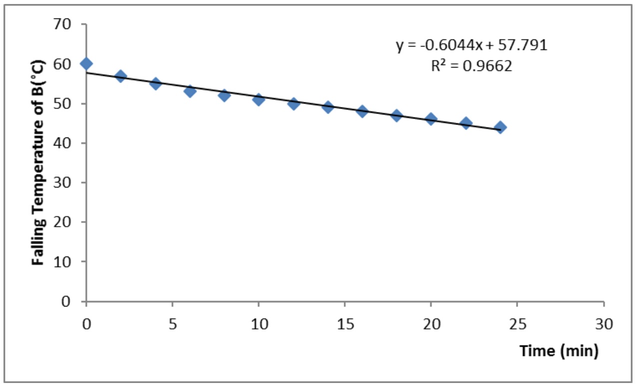

Fig. 3. A graph of temperature of oil sample B against time

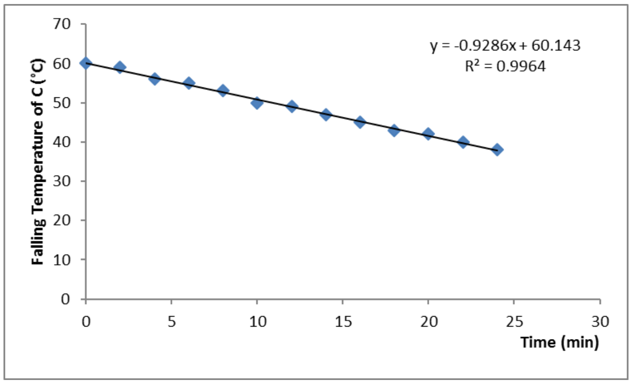

Fig. 4. A graph of temperature of oil sample C against time

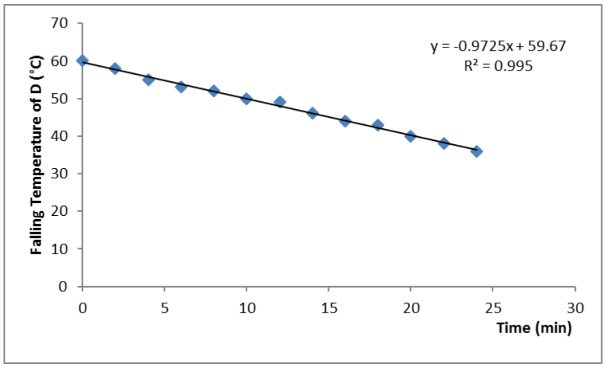

Fig. 5. A graph of temperature of oil sample D against time

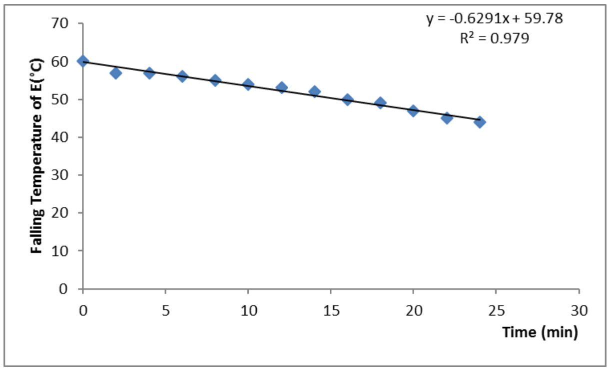

Fig. 6. A graph of temperature of oil sample E against time

By comparing the specific heat capacity of the oil samples from the bar chart fig. 1, it shows that sample B has the highest specific heat capacity than the other oil samples. This suggest that the quantity of heat required to raise the temperature of a unit mass of the oil sample is highest in oil sample B and least in oil sample E of all the five oil sample, this indicate that oil sample coded W will contain more heat than other sample when the same quantity is used at the same temperature. This high heat content does not allow internal energy to be lost completely even at the unusual frozen temperature.

The slope of each of the curves (fig. 2-6) stands for the constant k in degree Celsius per minute. This is called the cooling rate for engine oil sample which in this case was considered among lower engines that generate heat within the range: 30 > θ< 100^{o}C. The lower temperature in this case represents the ambient environmental temperature while the upper temperature represents the maximum temperature that the engine has when it is heated up. This also corresponds to the winter rating of the engine oil and the working temperature of the oil respectively. For most of the engine oils, the caprices of the viscosities are dependent on the rate of cooling which is a function of the winter rating temperature, the working temperature and the specific heat capacities of the oil samples (George et al., 2010). For the coded oil samples used in this study, sample D has the highest value of k (0.972^{o}C/min from Fig. 5). Samples A, B, C and E have closely related values which lie between 0.500 and 0.930 ^{o}C/min as the regression equations show in the relevant figures of the samples. In all the relevant graphs, the correlation coefficient shows strong relationship between temperature and time. The intercept in each of the graphs shows on the average, the working (maximum) temperature before the sample oil begins to cool.

6. Conclusion

The specific heat capacity are strongly connected with the lubrication and cooling of the internal engines operating at higher and lower temperature. Engine oils with higher cooling rates and higher specific heat capacities readily become less viscous and lubricate better. The lubricating and cooling effects jointly prevent wear, tear and difficulty in starting the engine even when the environmental temperature is extremely low. The ambient temperature does not really affect the oil because of the synergistic effect between the two tractable temperature extremes. The results of cooling rates and the specific heat capacities of the different SAE20W-50 oil samples show the behavior's of each of the samples coded as A, B, C, D, and E at operating temperature of some lower engines. Based on the result obtained within the limit of experimental error, sample D has the highest cooling rate of 0.972^{o}C/min while sample coded as B has the highest specific heat capacity of 3151.48Jkg^{-1}k^{-1}. This shows that these two samples D and B respectively have good physical properties to maintain the longevity of engines. This vital information about the properties of the engine oil, frequently used in our engines is a repository of knowledge tailored to the desired selection of efficient engine lubricators and coolants.

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