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Lubricating and cooling capacities of different SAE 20W – 50 engine oil samples using specific heat capacity and cooling rate

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Abstract

The lubricating and cooling capacities of different SAE 20W-50 multigrade engine oil samples were examined in terms of specific heat capacities and cooling rates. Out of the five samples of oil coded as A, B, C, D and E, four of them have very close related values of cooling rates while only B, has a bright-line distinction with a characteristically high cooling rate. Sample E of the multigrade oil samples examined also has the highest specific heat capacity which is suggestive of the high internal energy stored in the lubricating system. 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 (E) lubricates better and starts engines faster than other samples which may have low internal energies and high viscosities when compared with sample E.

Keywords: SAE 20W-50, cooling, lubrication, cooling rates, specific heat capacity and viscosity of oil samples.

INTRODUCTION

Engine oils are useful derivatives of crude oil or petroleum obtained through fractional distillation. 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 [1]

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. [2]

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 [3]. 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 [4].

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 [5]. This allows the oil to remain viscous at high temperatures. Multi-grade oils are represented by two parts [6]. The first part goes with ‘W’ which stands for the viscosity glass at low temperature – the winter rating of the oil [7]. 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 [2, 5]. These vaporized oils circulate poorly, reduce fuel efficiency and contribute to excessive emissions and engine wear [8]. High performance synthetic 20W –50 motor oils resist vaporization [6, 8].

Heat is a concept that deals with the study of the relative motion of fluid from one body to another due to the temperature differences between the two bodies. Hence, heat is a property that depends directly on the measure of the kinetic energy of the particles making up a thermodynamic system [9].

Specific heat capacity of motor oils refers to the heat required to raise the temperature of 1 kilogram of motor oils through 1 degree Celsius. It is the heat capacity per kilogram of the oil. 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.

Cooling is the process of loosing heat by a hot body to its surrounding or another body of lower temperature. Cooling leads to a fall in temperature. The rate at which a liquid cools depends on its mass, temperature, ambient air and the surface area of the liquid exposed. Engine oils are used as lubricants because of its viscosity - the internal friction which exists between layers of fluid in motion. Viscosity of fluid is temperature dependant. It decreases with temperature as its molecules become loose and less tightly bound to one another [10]. Engine oil becomes less viscous as it gets hotter and lubricates better [11]. If the weather is cold, the engine may be difficult to start because the oil becomes thickened. SAE 20W-50 multigrade oils unlike the monograde oils are made to operate over a wide range of temperatures; so that the ambient conditions may not prominently influence the oil thermal states. Cooling rate broadly depends on the specific heat capacity of the fluid and its viscosity. The higher the cooling rate, the shorter the time it takes for the oil to readjust its temperature between the upper and the lower ranges of thermal states [12]. Depending on which problem that one has to solve in the engine, one has to consider the specific heat capacity and the rate of cooling to see if they really fit the external and internal conditions of the engine used.

MATERIALS AND METHODS

The frequently use SAE 20W-50 engine oils were for economic reason coded as A, B, C, D and E. The oil samples were collected from different standard engine oil dealers in Akwa Ibom, Cross River and Rivers States, all in Southern Nigeria where the average ambient temperature is 30°C. 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 Copper material, beam balance, thread and lagging materials were used in the experiment as materials for determining specific heat capacity of the engine oil samples.

Determination of specific heat capacity

Mixture method was used to determine the specific heat capacities of the different SAE 20W – 50 engine oil samples. The Copper block was weighed and its mass recorded as M_1. 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 M_2 and reweighed after being half filled with an oil sample and recorded as M_3. The initial temperature of the oil sample was read with the thermometer and recorded as θ_1. The solid Copper block whose temperature was recorded as θ_2 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 θ_3. 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 copper block equals heat gained by engine oil and calorimeter

$$M_1C_1(\theta_2-\theta_3) = M_2C_2(\theta_3-\theta_1) + (M_3-M_2)C_3(\theta_3-\theta_1) \quad (1)$$

Where C_1 = specific heat capacity of copper block
C_2 = Specific heat capacity of calorimeter (copper)
C_3 = Specific heat capacity of oil to be found which is given from (1) as in (2)

$$C_3 = \frac{M_1C_1(\theta_2-\theta_3) - M_2C_2(\theta_3-\theta_1)}{(M_3-M_2)(\theta_3-\theta_1)} \quad (2)$$

Cooling rates of oil samples

For cooling rates, the oil samples were heated to a temperature of about 80°C. It was then placed near an open window and allowed to cool. The temperature of the oil as it was cooling was then recorded every two minutes until the temperature fell to 50°C. This was repeated for all the five oil samples.

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:

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

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

Where K in (4) is a positive constant known as cooling constant and the negative sign indicates that the temperature is decreasing [12]. Separating variables in (4) and integrating from θ_o to θ and 0 to t, we have equation (5)

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

where $\theta_0 = (\theta - \theta_R)$ (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.

RESULTS AND DISCUSSION

Using equation (2) and substituting the measured values of M_1, C_1, θ_2, θ_3, C_2, θ_1 and M_3, 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 E has the highest specific heat capacity and this is followed by D, C, B and A respectively.

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

SAE20W-50 oil sample code	Specific heat capacity ($Jkg^{-1o}C^{-1}$
A	19252.96
B	19282.99
C	20033.06
D	20430.41
E	22473.45

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 E and least in oil sample A of all the five oil samples considered.

For the cooling table, the results shown in table 2 were obtained for A, B, C, D, and E as average value of each of the oil samples. The plotting of the falling temperature θ, against time t, gives the cooling exponential curves which were fitted into straight lines (Figs. 1 – 5). The resulted curves which were linearly fitted are governed by Newton's law of cooling.

A system generated graph, slope, intercept and correlation coefficient for data of each oil samples are shown in (Fig. 1 -5). Figure 6 also compares the cooling curves of all the oil samples and sample B seems to be departed in cooling rate from the other four samples that show high synergy in terms of cooling rates.

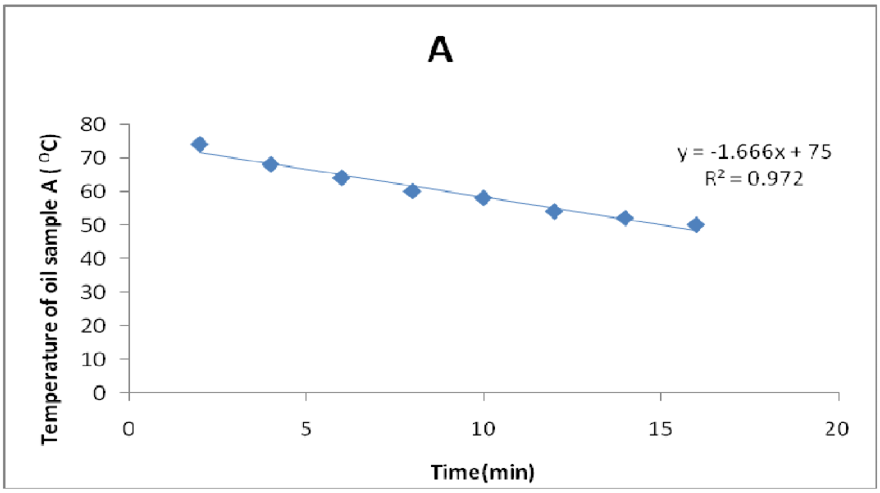

Fig. 1: A graph of temperature of oil sample A against time

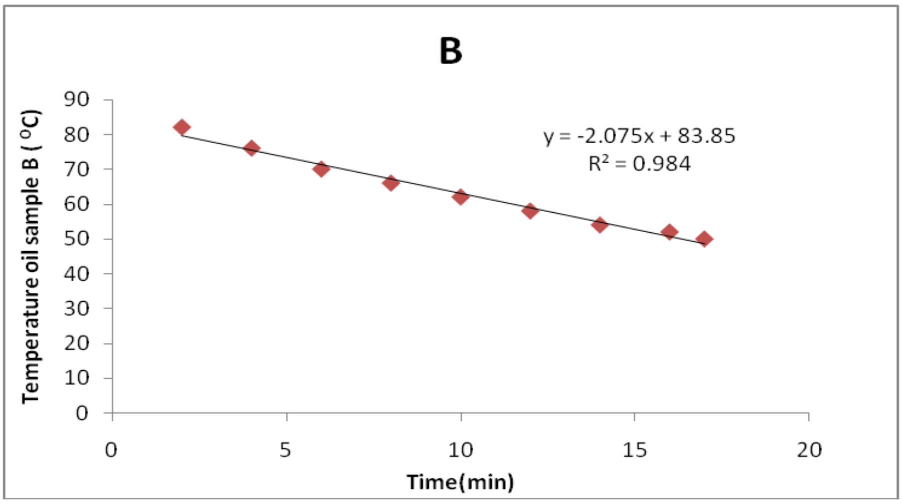

Fig. 2: A graph of temperature of oil sample B against time

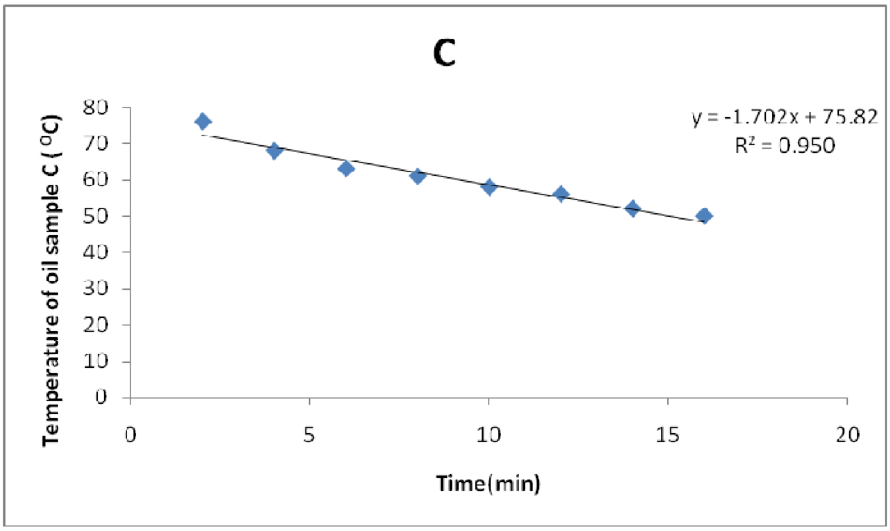

Fig. 3: A graph of temperature of oil sample C against time

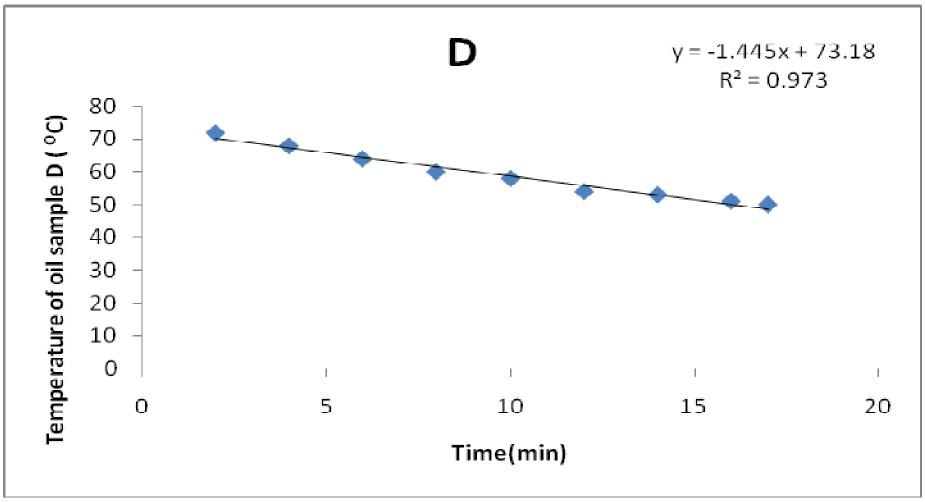

Fig. 4: A graph of temperature of oil sample D against time

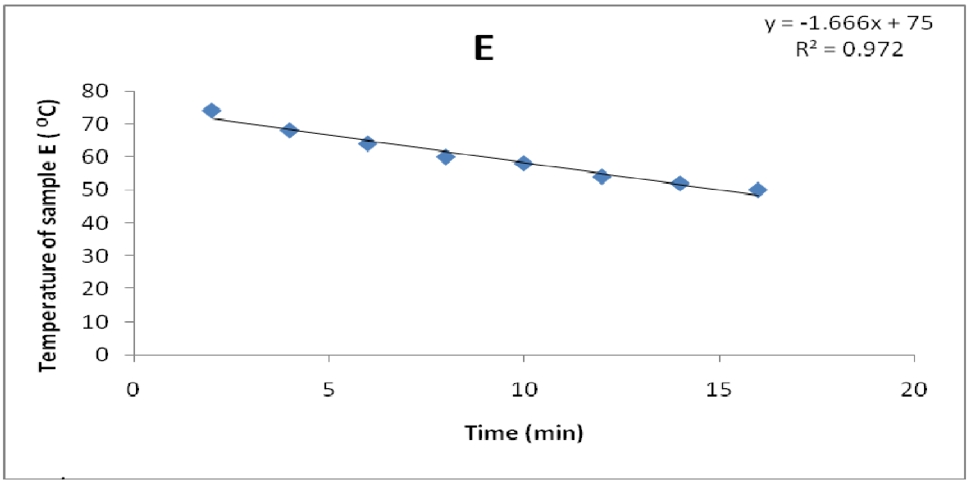

Fig. 5: A graph of temperature of oil sample E against time

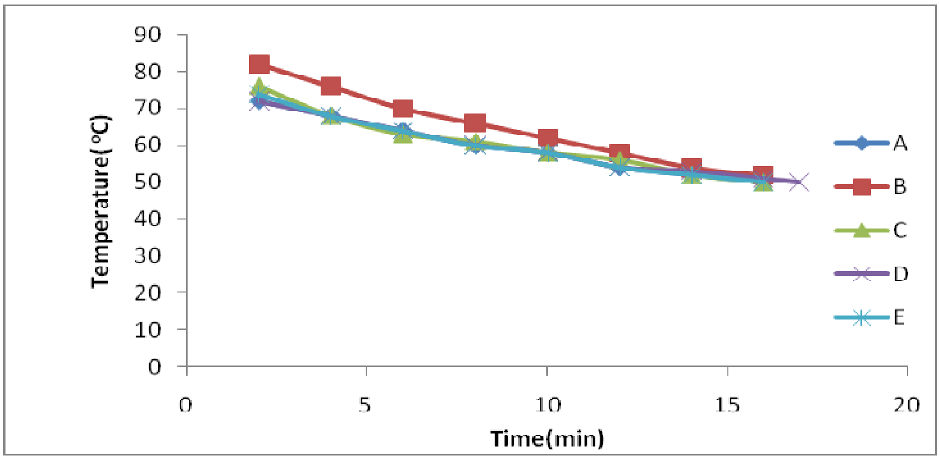

Fig. 6: A graph of comparison of cooling curves of samples A, B, C, D and E

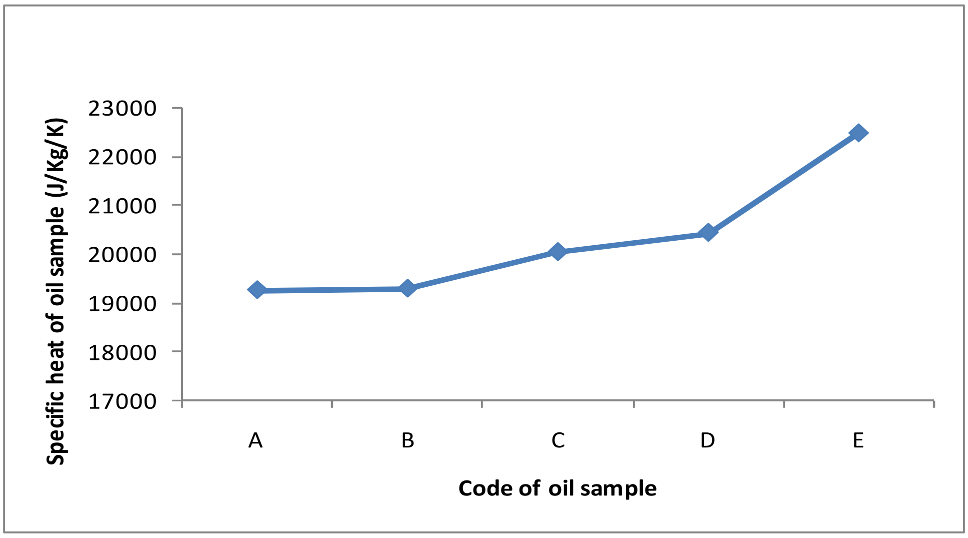

Fig. 7: A graph of comparison of specific heat capacities of oil samples A, B, C, D and E

Table 2: Cooling curve table for the different oil samples

	Falling temperature of coded oil samples in (^{o}C)				
Time (min)	A	B	C	D	E
2	72	82	76	72	74
4	68	76	68	68	68
6	64	70	63	64	64
8	60	66	61	60	60
10	58	62	58	58	58
12	54	58	56	54	54
14	52	54	52	53	52
16	50	52	50	51	50
17	-	50	-	50	-

Figure 7 compares the specific heat capacities of the different engine oil samples and by observations, the increasing order is given as E > D > C > B > A.

The slope of each of the curves 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: $30 \geq \theta < 100^{o}$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.

For the coded oil samples used in this study, sample B has the highest value of K (2.142^{o}C/min from Fig. 2). Samples A, C, D, and E have closely related values which lie between 1.445 and 1.70^{o}C/min as the regression equations show in the relevant figures of the samples. In all the relevant graphs, the correlation coefficient show 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.

The cooling rate reflects the degree of fall of temperature with time. This hinges on the viscosity and of course, the specific heat capacity. However, substances with high cooling rates are good coolants and lubricants [11].

It is interesting to note that when the specific heat capacity increases, the quantity of heat present in the oil sample also increases per unit mass and per degree rise in temperature. The values in table 1 and the corresponding graph of specific heat capacities for samples A, B, C, D and E in Fig 7, show that sample of oil coded as E, has the highest specific heat capacity while A has the least. This suggests that in comparison of sample oil coded as E with others, sample E will contain more heat than other samples 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. 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. By determining the cooling rates and the specific heat capacities of different SAE20W-50 multigrade engine oil samples coded as A, B, C, D and E, comparisons are made to see which of the multigrade oil samples is best for cooling. It is also relevant to identify the multigrade oil that is associated with high heat content usually stored in the lubricating system as internal energy that quickens the starting of engines at both lower and higher temperature extremities.

CONCLUSION

The efficacy of the SAE20W-50 is really dependent upon the cooling rates, specific heat capacities and the viscosity of the oil samples. These properties are strongly connected with lubrication and cooling of the internal engines operating at higher and lower temperatures. 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 behaviours 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 B has the highest cooling rate of 2.075^{o}C/min while sample coded as E has the highest specific heat capacity of 22473.45Jkg^{-1}k^{-1}. This shows that these two samples B and E respectively have good physical properties to maintain the longevity of engines. From the similarity and closeness of cooling rates of A, C, D and E, it is practicable and effortless to conclude that of all the samples investigated, sample B lubricates and cools engines better than other oil samples used in these study (Fig. 6). Although sample coded as E shows a synergy with A, C, and D in terms of cooling rates as graph in Fig. 6 shows, it has the highest specific heat capacity. This reflects that the oil sample has high heat content per kilogram per degree rise in temperature and hence could have more internal energy stored in the lubricating system for starting of engines even in the unusual frozen environmental condition. These 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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